PERFORMANCE RESULTS:

Assessing the Impacts of Implemented Transportation Projects

Final Report

Prepared by:
Cambridge Systematics, Inc.

In association with:
Fitzgerald and Halliday
Dewberry

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The preparation of this report has been financed in part by the U.S. Department of Transportation, North Jersey Transportation Planning Authority, Inc., Federal Transit Administration and the Federal Highway Administration. This document is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or its use thereof.

PERFORMANCE RESULTS
FINAL REPORT
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1.0 Executive Summary

Constrained resources must be used wisely and cost-effectively for transportation improvements, as with any public investments. Taking into account the actual outcomes of implemented transportation projects allows decision-makers to learn from experience and continue to advance the most prudent actions. For transportation, intertwined in so many facets of a region's vitality, measuring outcomes of projects requires understanding a wide range of impacts over potential large areas, even for transportation projects confined to a single locale. With this in mind, the North Jersey Transportation Planning Authority (NJTPA) has expanded its performance-based planning capabilities with an innovative study of how to assess the impacts of transportation projects.

The NJTPA undertook the *Performance Results: Assessing the Impacts of Implemented Projects* study to help the region make better decisions about managing and investing in the transportation system. The Performance Results study is intended to help planners answer everyday questions about transportation investments, like these:

- *"What effect did a new transit station have on transit ridership?"*
- *"Did a new rail intermodal terminal shift freight from truck to rail?"*
- *"Did a new left turn lane help improve intersection safety and level of service?"*
- *"What impacts did countdown timers at an intersection have on pedestrian safety?"*

…and most importantly:

- *"How can we learn from past investments and policies and do even better next time?"*

The study was supported by a consultant team of Cambridge Systematics, Fitzgerald and Halliday, and Dewberry. A range of NJTPA staff and representatives from NJTPA subregions and implementing agencies including the New Jersey Department of Transportation (NJDOT), New Jersey Transit (NJ Transit), Port Authority of New York and New Jersey (PANYNJ), and New Jersey Turnpike Authority (NJTA) contributed to the effort.

This final report provides an overview of the study and its major findings and recommendations. It underscores both the challenge of discerning project impacts and the importance of doing so.

1.1 Overview of the Performance Results Study

The Performance Results study has its origins in Federal requirements that Metropolitan Planning Organizations (MPOs) like the NJTPA monitor the results of federally-funded projects implemented through the region's Congestion Management Process (CMP). Since the CMP requirements were developed, the Federal Highway Administration, Federal Transit Administration and others have required MPOs and state Departments of Transportation to incorporate performance-based planning and management into all aspects of the statewide and

metropolitan planning process. This includes assessing performance related to environmental, economic, safety, maintenance, and operations-factors in addition to congestion management. As performance-based planning and programming gains traction as the state-of-the-practice for DOTs and MPOs across the country, forthcoming Federal surface transportation legislation may codify these practices and require US DOT to develop formal policies and procedures that would apply to the NJTPA and other MPOs.

Why Evaluate the

- *Learn from the results and outcomes of previous policies and investments*
- *Apply these lessons to the development of future projects and policies*
- *Inject project-level data and analysis into regional decision making*
- *Help NJTPA meet Federal Congestion Management Process requirements and anticipate possible new requirements in the upcoming federal transportation authorization bill.*

The NJTPA's existing approach to planning and programming is already holistic. *Plan 2035* lays out a policy framework across six broad goal areas and a Regional Capital Investment Strategy (RCIS) calls for sustainable growth, increasing overall accessibility, making travel safer, maintaining existing infrastructure, slowing the growth of roadway congestion, accommodating increased freight traffic, and enhancing system efficiency. The addition of a Performance Results process would enhance and strengthen the NJTPA's existing planning process by feeding back performance results to previous steps thereby improving the region's ability to move towards its goals.

The NJTPA undertook the Performance Results study in coordination with its member and partner agencies. The study looked at a wide range of project types—roadway, public transit, pedestrian/bicycle, freight, travel demand management, and others—and a host of performance measures relevant to regional transportation, social, economic and environmental goals. Examples of previously implemented projects were utilized in order to develop analytical methods, with research into the availability of historical data, the validity of performance measure formulations, the precision to which background trends could be tracked, and the potential for extracting the specific effects of projects themselves.

From this research, a set of detailed methods was developed to advance the practice of measuring project results, and to learn from and apply those results in future planning. The goal of the study was to help provide information about the impacts of completed projects to improve decisions about how future transportation policies and investments are planned and implemented.

Performance Results builds on the performance-oriented activities already taking place at the NJTPA, including monitoring trends, identifying needs and potential improvements in the region's Strategy Evaluation/congestion management process, scenarios, and prioritizing projects for the transportation improvement program (TIP). Each of these activities is, of course, ultimately aimed at generating and implementing beneficial projects and programs. Feedback on the performance of those projects and programs that get implemented completes the cycle and should be able to inform all planning steps along the way.

In addition to this Final Report, the study resulted in the development of a *Guidebook for Project Performance Measurement*. The Guidebook, which is organized like a cookbook, contains detailed

step-by-step instructions for conducting project-level performance evaluation. It contains data "ingredients", detailed calculation steps, a list of analytical tools needed to conduct the evaluation, and real-world examples of results to provide context to the user.

1.2 Findings and Recommendations

The overall findings of the study include the following:

- **This is a first-of-its kind study for an MPO, particularly given the breadth of project types and performance goals examined.** Thus, the *Guidebook for Project Performance Evaluation* is intended to be a living document, to be revised over time as the state of the practice in project evaluation evolves.

- **There is rarely a "one-size-fits-all" approach to analysis of performance results.** Every project has unique circumstances and context. Some projects are truly "one of a kind" and require a tailored approach or additional resources to conduct a more thorough, rigorous analysis. In every case, the evaluation of a project will require a great deal of judgment by the evaluator(s), and the NJTPA will have to work with its partners to train evaluators and update the training as the process evolves. As an example, the scale of an evaluation will vary by project type and by measure.

- **Quality and availability of data is a key constraint on the ability to perform comprehensive project evaluations.** Some data that would be helpful are simply not available and therefore proxies must be identified. The spatial and temporal granularity of data also presented a challenge where more fine-grained data would have been ideal. Some data sets proved to be unreliable due to data entry errors. Finally, some data are maintained by multiple jurisdictions, and the various databases or paper records must be reconciled through a time-intensive process in order to conduct even a basic project evaluation.

- **NJTPA can begin a data management and monitoring effort to improve data availability for future evaluation efforts**. "Before" data on travel speeds, volumes, costs, and existing land uses can be recorded for evaluation of future projects and even for recently completed projects, recognizing that some project impacts accrue gradually over time (e.g., property value impacts) and others diminish over time (e.g., congestion relief).

- **Isolating project-specific impacts is a major challenge in conducting project performance evaluations.** In order to isolate a project's net impacts, most cases necessitate a "control" case for comparative purposes. Selecting this "control" case is challenging in a region as complex as the NJTPA region because so many variables need to be assessed. Although this project began to answer important questions about calculating a project's net impact, NJTPA and others need to conduct more research into which variables are correlated, significant, and relevant to each project type, and to what extent external factors (e.g., gas prices and economic factors) affect each measure.

Although there are differences by project type, performance measures can be divided into four general categories:

- Those that are ready to evaluate today or in the short term given available data and analysis tools;
- Those for which data availability is likely to be a challenge, but if data are available the evaluation is straightforward;
- Those that will require significant data collection or evaluation effort; and
- Those that will require proxies until the state-of-the-practice in project-level performance evaluation evolves.

Ready to Evaluate with Minor Effort Using Existing Data and Analysis Tools	• Crashes/crash rate • System condition (highway pavement and bridges) • Travel time reliability • Person-hours of delay (projects with local impact) • Network connectivity and continuity
Ready to Evaluate, but Data Availability a Challenge	• System condition (transit and freight rail) • Transportation resiliency (protection, prevention, redundancy, and recovery) • Quality of wetlands, surface water, and drinking water • Impacts on protected lands
Data Available, but Significant Effort Required to Compile or Evaluate Data	• Accessibility measures (need analysis tools/models) • Person-hours and ton-hours of delay (projects with regional impact) • Transportation-related noise and vibrations (need sound measurements) • Customer satisfaction measures (need surveys) • Population and employment density (Census data not at fine-grained enough scale) • Land use and land value changes (data not consistent across municipalities)
Requires Use of Data Proxies or Estimates Pending Further Data Research and/or Development	• VMT, mode share, and net transit ridership: Need O-D data and other detailed survey data. For now can use "triangulation" process based on "control" cases and regional trends. • Emissions: Multiply estimated net change in VMT by an average emissions per vehicle

1.3 Possible Further Research and Next Steps

There are several key areas that the NJTPA may consider for possible next steps towards advancing a performance results process.

As an initial step toward implementing a performance measurement program, the NJTPA can move forward with a manageable number of measures and processes and consider adding new evaluation capabilities over time as the state-of-the practice in data collection, data management, and analysis tools evolves. Based on the work completed in this project, the most promising areas appear to be system preservation (pavement and bridge maintenance), safety, and measures of congestion that could make use of recently-acquired INRIX data by the NJDOT. INRIX is a traffic services and mobile app company providing historical and real-time traffic information to businesses and individuals in the United States and Europe through the collection of information about roadway speeds from over 5 million trucks, delivery vans and other fleet vehicles equipped with GPS satellite locator devices as well as consumer cellular GPS-based devices including the iPhone, Android (operating system), BlackBerry and Windows Phone phones, Ford SYNC and Toyota Entune.

To obtain data needed to support a performance measurement program, the NJTPA and its partners should start to identify and compile data now that will become the "before" data in future project-level analyses. The NJTPA and its partners should develop a data management plan for the Performance Results process and seek to incorporate considerations of the needs of the Performance Results process into other ongoing database development projects. Paramount among the data concerns is the need to implement data consistency and quality control procedures statewide or at least throughout the NJTPA region to facilitate future analyses. This will be especially important for INRIX, safety, and system condition data where its increasing availability and volume present a significant challenge in both managing and producing useful information from it. The *Guidebook for Project Performance Measurement* can be a useful tool to start identifying what data are needed now.

In areas requiring advancement of the state-of-the-practice, the NJTPA and its partners should seek to identify and prioritize topic areas that need further research and development. However, the NJTPA should recognize that the need to strike a balance between academic rigor and resources available to conduct evaluations. Research should help determine which measures are correlated and which are statistically significant (and therefore applicable to various project types). The Association of Metropolitan Planning Organizations (AMPO), the Transportation Research Board (TRB), the National Cooperative Highway Research Program (NCHRP), the Transit Cooperative Research Program (TCRP), and the National Cooperative Freight Research Program (NCFRP) are all forums that the NJTPA and its partners can use to advance the state-of-the-practice in project-level performance evaluations.

Finally, the NJTPA should seek to promote the value of the Performance Results approach to its stakeholders and to decision makers around the region at all levels of government.

Specific recommendations for implementation of the Performance Results process are included in Section 3 of this report.

2.0 Study Development and Analysis

2.1 Goals and Objectives

The NJTPA's Performance Results study developed methods for compiling information about the impacts of completed projects to inform how future transportation policies and investments are planned and implemented. For this effort, the NJTPA engaged the consultant team of Cambridge Systematics, Fitzgerald and Halliday, and Dewberry to work with its staff and representatives from NJTPA subregions and implementing agencies including the New Jersey Department of Transportation, New Jersey Transit, Port Authority of New York and New Jersey, and New Jersey Turnpike Authority. The primary objectives of the study were to select appropriate performance measures for assessing the results of completed projects and to develop a methodology for conducting evaluations of the results of discrete projects, as well as groups of related projects and policy initiatives.

The lessons learned in conducting the Performance Results study were compiled as a *Guidebook for Project Performance Measurement*, which represents national and international best practices adapted to the unique characteristics of the NJTPA region and constraints imposed by available data and analysis tools.

2.2 Study Participants and Committees

The NJTPA and its consultant team (a.k.a. the "project team") developed a Stakeholder Involvement Plan, consistent with the NJTPA's overall approach to stakeholder participation. A project Technical Advisory Committee was formed consisting of the following representative agencies:

- New Jersey Department of Transportation (NJDOT),
- New Jersey Transit (NJ Transit),
- The Port Authority of New York & New Jersey (PANYNJ),
- The New Jersey Turnpike Authority (NJTA), and
- The City of Jersey City

The role of the Technical Advisory Committee was to provide input and overall direction at key points throughout the study. In a first round of meetings conducted in the Summer of 2009, the project team met with TAC representatives to provide an introduction to the project and gather input from each agency regarding how they might use the products of the study to improve their own planning and programming processes. The initial conversations also dealt with the types of projects that could be evaluated and the data sources that might be useful in conducting the evaluations.

The project team held a workshop with the NJTPA Regional Transportation Advisory Committee (RTAC) during October 2009. Based upon RTAC input as well as that obtained from the project TAC, a recommended list of performance measures and example projects was developed for the

study. Throughout the course of the study, NJTPA staff and the consultant team delivered presentations and regular status updates on the projects to various NJTPA committees and stakeholders.

During 2010, the project team worked with the TAC and RTAC members to gather information about projects in the various project categories for which evaluation methodologies were to be developed. The information ranged from planning documents for individual implemented projects to traffic or ridership counts for an entire roadway or transit corridor. In the study's final stages in 2011, a range of NJTPA staff, TAC and RTAC members provided comments and insight on the study's data sources, evaluation methodologies and other potential next steps needed to finalize the Performance Results study products.

2.3 Research into Best Practices in Performance Evaluation

The consultant team reviewed existing federal and national research, as well as efforts by states and MPOs, to develop performance management and project evaluation methodologies. The team also reviewed project evaluation processes and critical decision-making elements of the NJTPA and its partner agencies, notably NJDOT, the NJTA, and the PANYNJ.

Many state DOTs and some MPOs have established performance measurement practices or are beginning to track performance measures on the condition and operation of their systems, though there is wide variability in agency resource-allocation capabilities and practices nationwide. Although performance measures are used by many agencies to help make better planning and programming decisions, the literature review did not reveal any examples of an agency in the United States that has performed a post-evaluation of a group of completed transportation projects.

Though post construction reviews are not commonly conducted in the United States, some international transportation agencies do use such reviews to help improve their project planning and development practices. An international scan of performance evaluation processes noted that both Australia and Japan reviewed projects after completion.

The state of New South Wales, Australia, in particular, has a fairly rigorous process known as "Total Asset Management", which includes ten assessment and decision-making tools, one of which is called Post-Implementation Review (PIR). PIR is required for all state-funded projects over $10M AUS, and is intended to match actual results with "needed" results in order to improve general service delivery. A subcomponent of PIR, known as "Post Construction Review" or PCR, compares actual results with "what was asked," which then feeds back directly into the procurement/project development process.

Of primary interest to the NJTPA Performance Results project is the process and methodology that New South Wales uses to select which projects should be evaluated using PIR/PCR. The generic PCR Guidelines recommend choosing "significant projects," stating that "a project may be significant if it seems to be performing exceptionally, effectively or poorly, or it is a key service delivery resource. Formal evaluation of any asset may provide information that could be the basis for improving the economical operation and maintenance of all asset types." Further, the Treasury recommends that agencies "aim to review between one in five and one in ten of all

completed projects. All pilot projects or projects involving innovative procurement systems should be evaluated."

The New South Wales Treasury lists the following challenges associated with the PIR/PCR process, all of which reflect important considerations and issues that NJTPA may face in the future:

- **Institutional knowledge**. At the end of each phase of a project the assembled team disbands and moves quickly to the next project. The people most familiar with the project may not have availability to assist in the PIR.

- **Long project timeframes.** Some asset based projects can have long timeframes between funding and completion (up to 3-5 years). In the meantime, the agency goals and objectives, political factors, the economy, best practices in project evaluation, and many other factors may change.

- **Political sensitivity.** Where projects exhibit shortcomings there is an unwillingness to expose participants to perceived "criticism."

- **Staff and resource limitations.** There are rarely funds available for effective and continuous PIRs, and PIR itself is vulnerable to criticism as an ineffective use of scarce resources.

- **Culture of performance management.** The transportation industry has not developed a culture of critical examination and evaluation, and therefore without adequate training and internal marketing, PIR can be perceived as a top-down mandate with little benefit to the implementing agency.

- **Data management and information sharing.** In Australia, there is no effective mechanism for developing a "collective" reference system for performance results evaluations (compared, for example, to the legal and medical professions with their extensive case histories).

2.4 Identifying Project Categories

With guidance from the TAC and RTAC, the project team developed a list of project categories based on those of the NJTPA Regional Capital Investment Strategy. The following were used in the Performance Results evaluation:

Project Category	Definition
Bridge and Roadway Preservation	**Bridge Preservation**: Programs and projects that seek to ensure long-term continuation of viability and availability of bridges. These include bridge maintenance, rehabilitation, replacement, and other similar initiatives. **Road Preservation**: Programs and projects that seek to ensure long-term continuation of viability and availability of roadways. These include repaving, signage, lighting, replacement, drainage repairs, and other similar initiatives.
Roadway Enhancement, Safety, and ITS	**Roadway Enhancement:** Programs and projects that seek to improve the operation, and accessibility of a roadway. These include signalization improvements, intersection geometry improvements, new turning lanes, and other similar initiatives. **Safety Improvements**: Programs and projects that seek to improve the safety of a roadway. These include traffic calming (e.g., roundabouts), median and shoulder treatments, safety enhancements at railroad crossings, and other similar initiatives. **Intelligent Transportation System (ITS)**: Programs and projects that seek to provide improved traveler information and traffic operation for existing and future roadway facilities. These include variable message signs, integrated signal control system, and other similar initiatives.
Roadway Expansion	Programs and projects that seek to improve the connectivity and accessibility of the existing transportation network by adding capacity to existing roadway and by building new roadway. These include new grade separations, new travel lanes, new interchanges, new roads, and other similar initiatives.
Transit Preservation	Programs and projects that seek to ensure long-term continuation of the viability and availability of transit facilities and services. These include ensuring operation of existing services, maintenance of facilities and equipment, acquisition of new rolling stock for existing routes and other similar initiatives.
Transit Enhancement and Transit-Oriented Development	**Transit Enhancement**: Programs and projects that seek to improve the quality, availability, accessibility and reliability of existing transit service and facilities. These include station improvements (e.g., parking, amenities), operational efficiency improvements, increased service on existing routes, new stations on existing lines, and other similar initiatives. **Transit-Oriented Development:** Programs and projects that seek to promote TOD. These include applying mixed-land use policy around a transit station to encourage ridership, public –private partnership in housing and commercial development near a transit station, improving bicycle/pedestrian access to a transit station, and other similar initiatives.
Transit Expansion	Programs and projects that seek to significantly expand the availability and accessibility of existing transit service and facilities. These include new bus routes, fixed facilities for new "bus rapid transit" services, new rail lines or extensions, major rail infrastructure capacity, and other similar initiatives.

Project Category	Definition
Freight Rail	Programs and projects that seek to enhance the quality, availability, accessibility and reliability of existing freight rail service and facilities. These include improvements to ROW and rail line components related to operation. *The techniques presented here would not necessarily be applicable to other freight-rail facilities improvements such as terminal and intermodal freight transfer facilities.*
Freight Roadway	Programs and projects that seek to enhance the availability, accessibility and safety of existing roadway facilities for truck traffic. These include improvements to existing roadways turning radii, bridge or tunnel clearance, dedicated freight roads (e.g. Portway) and other similar initiatives.
Transportation Demand Management	Programs and projects that help to adjust demand level on the transportation network by applying strategies and policies to reduce travel demand (specifically that of single-occupancy private vehicles). These include value pricing, high-occupancy vehicle lanes, and other similar initiatives. The techniques presented would be applicable to TDM programs such as carpooling, vanpooling and teleworking often administered by Transportation Management Association.
Bicycle and Pedestrian	Programs and projects that seek to improve safety, quality, accessibility and availability of bicycle and pedestrian programs. These include new sidewalks, new bike lanes or bike paths, improvements at pedestrian crossings, and other similar initiatives.

2.5 Identifying Performance Measures

Performance measures are metrics used by organizations to monitor progress toward achieving a goal or objective. The process for selecting measures should consider the following:

- Performance measures should be **policy-driven**, tied to the goals and objectives of NJTPA's Regional Transportation Plan and other relevant policy documents;
- A **mix of qualitative and quantitative measures** are appropriate to convey the full range of a project's impacts;
- The measures should provide a **consistent** way of comparing a range of projects, whether large or small; urban, suburban, or rural; or passenger or freight;
- Measures and presentations of their results should be as **transparent** as possible, and be both **easy to explain** and comprehensible by NJTPA's stakeholders;
- Measures should have **realistic and feasible data requirements**. This principle includes current, project-specific data availability, when known, as well as national practices in data collection (i.e., data collected and/or derived elsewhere in the nation), possible future trends

in collection, and the potential use of qualitative measures where quantitative data is currently unavailable or difficult to assemble; and

- A **reasonable level of effort** should be required to evaluate the measures.

The consultant team worked closely with the NJTPA and its stakeholders to select potential performance measures to support this study and NJTPA's ongoing performance management objectives.

The procedure for deriving recommended performance measures consisted of two primary phases: collection of potential measures and a subsequent multi-layered screening process. The comprehensive list of performance measures, included in a Technical Memorandum ("State of the Practice in Performance Evaluation"), was compiled through a review of New Jersey-specific planning and performance measurement documents authored by the NJTPA and NJDOT, as well as transportation stakeholders. This effort was supplemented by a national and international review of best practices in performance measurement. At final tally, nearly 300 distinct (but often closely related) potential performance measures were identified and grouped into the NJTPA's six fundamental goal categories, highlighted in the 2035 Regional Transportation Plan, and cross-categorized by the NJTPA RCIS categories (aggregated into six groups).

While it was important to ensure that a broad range of possible measures was available for initial evaluation, the subsequent step required paring the list down to a compact, implementable set of measures. The first step in this process involved eliminating redundancies—several performance measures were fundamentally similar, with only minor differences in emphasis, methodology, and/or terminology. This step removed approximately one-third of the comprehensive list. Next, each goal was evaluated by the project team, in coordination with the TAC, to determine which remaining measures bore sufficient relevance to NJTPA's goal categories. Through this effort, the list of potential performance measures was reduced by another two-thirds, leaving around 100 measures. The remaining performance measures were then evaluated, first at an RTAC workshop for correlation to NJTPA RCIS categories, and later using additional screening criteria including data availability, the relative ease of data collection, and the effort and complexity associated with deriving the measures. The final roster of proposed performance measures, shown in the table below, is built around a core of existing NJTPA and NJDOT measures supplemented by others identified through national best practices and input from RTAC members. More information about the selection process can be found in the Technical Memorandum "Recommended Performance Indicators and Measures."

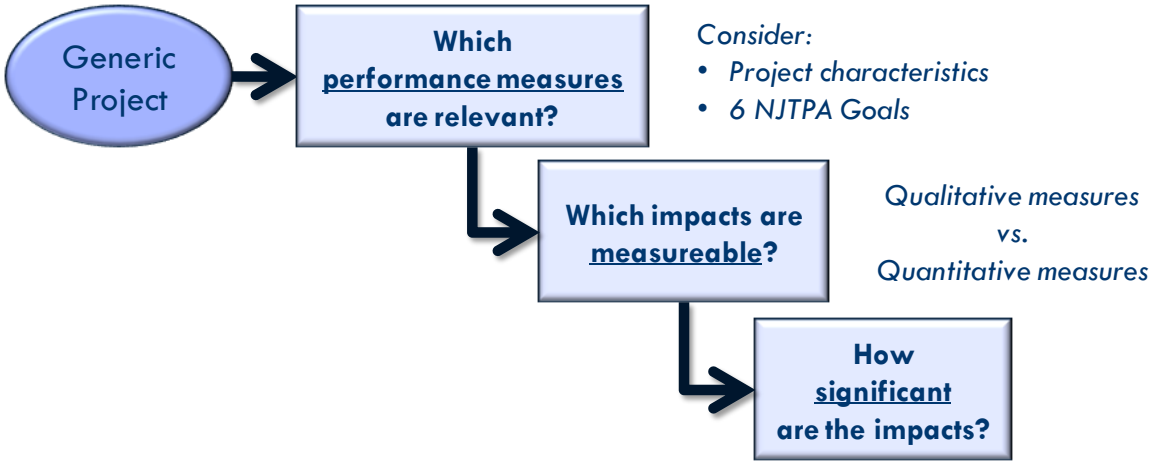
Table 1. Performance Measures Assigned to Each NJTPA Goal Area

Goal Area	Measures
Environment	• Emissions of Clean Air Act criteria air pollutants and greenhouse gases • Transportation-related noise and vibrations • Impacts on wetlands, streams, and water quality • Impacts on Section 4(f) lands, including publicly owned parks, recreational areas, wildlife and waterfowl refuges, or public and private historical sites. • Visual aesthetics and context sensitivity
User Responsiveness	• Access to jobs and/or labor force • Access to trading partners • Access to regional amenities • Access to community amenities • Person-miles of travel by mode • Ton/TEU-miles traveled by mode • Net new transit riders • Customer satisfaction
Economy	• User benefits (Vehicle operating costs, accident costs, monetized travel time) • Regional market share of imports/exports • Return on investment/cost effectiveness
System Coordination	• Travel time reliability (Ratio of peak to non-peak travel time and On-time performance) • Person hours and ton/TEU-hours of delay • Ratio of non-recurring delay to total delay • Percent of person-hours-traveled under congested conditions • Percent of ton-miles traveled under congested conditions • Network connectivity and continuity by mode
Repair/Maintenance/ Safety/Security	• Crashes/crash rate • Percent of roadway pavement in good/fair/poor condition • Percent of bridges in good/fair/poor condition • Percent of train track in good/fair/poor condition • Hours of service disruptions per year • Mean time between equipment failure • Number of riders impacted by service disruptions per year • Perception of Security • Transportation resiliency (protection, prevention, redundancy, and recovery measures)
Land Use/ Transportation Coordination	• Population/employment density • VMT per capita

2.6 Assigning Measures to Project Categories

The project team worked with the TAC to assign measures to project categories. Figure 1 illustrates the process used to determine the application of measures to projects

Figure 1. Considerations When Assigning Measures to Projects



The first step in the assignment process was to determine the relevance of different performance measures to specific projects. The characteristics and original purpose of the project relative to the six goal areas in NJTPA's regional transportation plan were key factors used in making this determination. It should be noted that for transit projects, measures of freight impacts are not relevant.

The second step in the process was to identify whether these performance measures would need to be evaluated quantitatively (i.e. impacts could be mathematically quantified), or qualitatively (e.g. impacts would need to be assessed using ordinal measures or ranges, such as "high/medium/low" or "yes/no"). As an example of the evaluation process, where it was not possible to quantitatively determine exactly how much energy consumption increased as a result of a project, an order-of-magnitude estimate was considered to be an appropriate measurement approach. Similarly, for a measure such as "visual aesthetics and context sensitivity" that cannot be quantified, certain yes/no criteria could be used to help determine the extent to which a project was designed to fit into the built environment.

Third, for those measures that could be quantified, a determination was made of how significant the impacts might be and the scale at which such measurements should be made. As an example, while the emissions impact of a bicycle/pedestrian project would be almost immeasurably small at the individual project scale and may not warrant project level evaluation, several small projects of this type, when put together could have modest measurable emission impacts, especially across multiple years.

The following table shows which measures were applied to each project category based on the recommended projects. Please refer to the Technical Memorandum: "*Recommended Projects for Evaluation"* for more information.

PERFORMANCE MEASURES BY NJTPA REGIONAL GOAL	ROADWAY AND BRIDGE PRESERVATION PROJECTS	ROADWAY ENHANCEMENT, ITS AND SAFETY IMPROVEMENT PROJECTS	ROADWAY EXPANSION PROJECTS	TRANSIT PRESERVATION PROJECTS	TRANSIT ENHANCEMENT AND TRANSIT ORIENTED DEVELOPMENT PROJECTS	TRANSIT EXPANSION PROJECTS	FREIGHT RAIL PROJECTS	FREIGHT ROADWAY PROJECTS	TRANSPORTATION DEMAND MANAGEMENT PROJECTS	BICYCLE AND PEDESTRIAN PROJECTS
ENVIRONMENT										
Emissions of Clean Air Act criteria air pollutants and greenhouse gases (May use Vehicle Miles Traveled - VMT as an intermediate measure)		•	•	•	•	•	•	•	•	
Transportation-related noise and vibrations at sensitive receptors			•	•	•	•	•	•		
Quality of wetlands, surface water, and drinking water			•			•	•	•		
Impacts on Section 4(f) protected land			•		•	•	•	•		
Visual aesthetics of the built environment		•	•		•	•	•	•		•
USER RESPONSIVENESS										
ACCESSIBILITY MEASURES:										
Access to jobs and/or labor force			•		•	•			•	•
Access to trading partners			•				•	•		
Access to regional amenities		•	•		•	•			•	•
Access to community amenities		•	•		•	•			•	•
MODE SHARE MEASURES:										
Person-miles of travel by mode			•		•	•			•	•
Ton-miles of travel by mode			•				•	•		
Person-trips by mode			•		•	•			•	•
Tons and TEUs by mode			•				•	•		
Net transit ridership (Use as an intermediate measure)					•	•				
Customer Satisfaction	•	•	•	•	•	•	•	•	•	•

PERFORMANCE MEASURES BY NJTPA REGIONAL GOAL	ROADWAY AND BRIDGE PRESERVATION PROJECTS	ROADWAY ENHANCEMENT, ITS AND SAFETY IMPROVEMENT PROJECTS	ROADWAY EXPANSION PROJECTS	TRANSIT PRESERVATION PROJECTS	TRANSIT ENHANCEMENT AND TRANSIT ORIENTED DEVELOPMENT PROJECTS	TRANSIT EXPANSION PROJECTS	FREIGHT RAIL PROJECTS	FREIGHT ROADWAY PROJECTS	TRANSPORTATION DEMAND MANAGEMENT PROJECTS	BICYCLE AND PEDESTRIAN PROJECTS
ECONOMY										
Operating Costs	•		•		•	•		•		
Accident Reduction		•	•		•	•		•		
Travel Time Savings		•	•		•	•		•		
Regional Market Share of Imports and Exports							•			
Return on Investment		•	•					•		
Cost Effectiveness		•	•		•		•	•	•	•
SYSTEM COORDINATION										
Travel Time Reliability		•	•	•	•	•	•	•		
Person hours of delay and/or Ton hours of delay		•	•	•	•	•	•	•		
Ratio of non-recurring delay to total delay		•	•					•		
Percent of person-hours-traveled under congested conditions		•	•							
Percent of ton-hours traveled under congested conditions		•	•					•		
Network connectivity and continuity by mode		•	•		•	•	•	•		•

PERFORMANCE MEASURES BY NJTPA REGIONAL GOAL	ROADWAY AND BRIDGE PRESERVATION PROJECTS	ROADWAY ENHANCEMENT, ITS AND SAFETY IMPROVEMENT PROJECTS	ROADWAY EXPANSION PROJECTS	TRANSIT PRESERVATION PROJECTS	TRANSIT ENHANCEMENT AND TRANSIT ORIENTED DEVELOPMENT PROJECTS	TRANSIT EXPANSION PROJECTS	FREIGHT RAIL PROJECTS	FREIGHT ROADWAY PROJECTS	TRANSPORTATION DEMAND MANAGEMENT PROJECTS	BICYCLE AND PEDESTRIAN PROJECTS
REPAIR/MAINTENANCE/SAFETY/SECURITY										
Crashes/Crash rates		•	•	•	•	•	•	•		•
Percent of roadway pavement in good/fair/poor condition	•			•						
Percent of bridges in good/fair/poor condition	•			•						
Percent of train track in good/fair/poor condition				•						
Hours of service disruptions per year				•						
Mean time between failure				•						
Number of riders impacted by service disruptions per year				•						
Perception of Security										•
Transportation resiliency (protection, prevention, redundancy, and recovery measures)		•	•	•	•	•	•	•	•	
LAND USE/TRANSPORTATION COORDINATION										
Population and Employment Density		•	•		•	•		•	•	•
Vehicle Miles of Travel per capita					•	•			•	

2.7 Research and Data Collection

Throughout the study, the consultant team continued research into best practices for project evaluation tools and techniques and consulted with NJTPA and members of the TAC to determine the most appropriate methodologies and data sources to use in the Performance Results evaluation process.

One of the biggest challenges during the study was compiling data to use in the evaluation process. The consultant team relied largely on staff at the participating agencies to provide data or allow access to existing databases. In some cases, such as with detailed safety information, data was identified but could not be incorporated into the study due to privacy or sensitivity concerns. In other cases, data were freely available online, but not in a format that could easily be downloaded or inserted into a database or spreadsheet. For example, although some roadway traffic data on NJDOT's website stored in PDF formats could not be easily transferred to a spreadsheet for analysis, it is likely that the raw source data used internally by the agency could be obtained through further coordination. In still other cases, there is variability in the format and management practices for information. For example, while some land use data are readily available on county property assessor websites, similar data in other counties are stored in paper format within file cabinets and must be searched manually. Environmental data are usually well-documented in planning documents such as Environmental Impact Statements, but the data collected in various studies around the region are not compiled in one central database for use in studies like this.

To better understand the state-of-practice, the consultant team conducted a review of performance results focusing on the types of measures used in planning, programming and operational monitoring. The consultant team found that while many state DOTs and some MPOs use performance measures to help make better planning and programming decisions, there is wide variability in resource allocation capabilities and practices by these agencies. While it was found that many agencies use formal data collection programs and applications of decision-support systems, such as those designed to support the congestion management process or asset management, such measures were typically limited to those directly under that agency's control and to tracking individual routes or selected areas where data are easier to collect and analyze. As noted earlier, the literature review did not identify any examples of an agency in the United States that has performed a post-evaluation of a group of completed transportation projects.

Given a recent emerging federal emphasis on accountability, however, DOTs and MPOs across the U.S. have begun to recognize the need to monitor performance on a consistent and ongoing basis, and to consider use of before-and-after performance case studies to identify the results of specific actions taken by an agency. The literature review found that agencies have begun to respond by initiating new approaches to managing their assets. These include strategic visioning, use of performance measures and targets based on stated policy objectives and input from public outreach, performance-based management, use of economic methods (e.g., minimization of life-cycle costs and benefit/cost analysis), consideration of tradeoffs in program resource allocation.

2.8 Developing and Applying Methodologies for Performance Measurement

The literature review included investigations into methodologies that could be used to conduct performance results evaluations. However, given that no comparable process exists, the methodologies developed for the study (compiled in the *Guidebook for Project Performance Measurement)* were culled from a variety of sources.

The detailed guidance for applying evaluation methodologies takes into account the unique circumstances and context surrounding each project to be evaluated. To the greatest extent possible, the methodologies for conducting project-level performance assessments were developed to be replicable and consistent across project types, and to reflect existing practices that NJTPA and its members employ in the NJTPA region. For example, the *Guidebook* recommends relying on existing NJDOT measures and evaluation methodologies for determining the effectiveness of bridge and pavement management investments and on existing NJ Transit and PATH methodologies for estimating the benefits of rail and transit-related maintenance and state-of-good-repair investments.

Evaluation tools made available to states, MPOs, and other agencies by FHWA, FTA, and other Federal agencies were also incorporated or adapted to provide reliable methods, approaches and software platforms that could support performance analysis. For example, FHWA's Noise Model was incorporated into the methodology developed to estimate the noise impacts of transportation investments, and the Highway Economic Requirements System (HERS) was similarly applied to help estimate net change in delay on roadway segments and direct user benefits associated with travel time savings, vehicle operating cost savings, and accident cost savings.

Nevertheless, many measures cannot be easily evaluated using existing data and analysis techniques. In many cases, and significantly for vital measures like net impacts on vehicle miles traveled or net impacts on person-miles of travel by mode that inform other downstream measures, the consultant team adapted industry best practices to calculate proxy measures or to perform basic calculations that could help identify a potential range of net impacts.

For example, without exhaustive information on origin-destination flows before and after construction of a project, it is not possible to precisely calculate net impacts on vehicle miles traveled. Instead, the project team recommended a multi-step "triangulation" process whereby the variables that are known (how much traffic increased on the roadway in question, on parallel roadways, and in the county in which the project is located) can be used to estimate the range in possible values for what is not known (the region-wide net impact on vehicle miles of travel that the project generated).

In another example, it is difficult to estimate the net impact of a rail project on transit ridership without knowing how many riders previously used other routes (parallel rail lines and bus routes), how many switched to transit from other modes (primarily cars), and how many people didn't even attempt to make the trip before the improvement was put in place. However, as in scientific studies, the project team recommended use of a "control" case where possible to make comparisons between ridership levels at similar stations that could then lead to an assessment of how much of an impact the rail improvement may have had on net ridership. In one instance, a series of improvements and policy changes facilitated transit-oriented development in the area

around one station and made the area around the station and the station itself more aesthetically appealing to pedestrians and others who might want to use the station. Another station with similar transit service characteristics (e.g., number of trains per hour) and socio-economic characteristics (e.g., population within ½-mile of the station, property values, median income) was used as a "control" case, and changes in ridership were compared over several years at both stations.

Where data were simply not available, methods incorporating proxy measures that may suggest which direction a measure moved, even if a specific numerical range cannot be determined, were applied. For example, the net impacts of a project on freight ton-miles of travel by mode may never be known due to confidentiality of operational data maintained by private-sector rail and marine cargo operators. However, if known data points are collected (e.g., tonnage by truck and marine highway services along affected corridors) and compared with regional data on overall tonnage of freight flowing through the region, then the net impact of a rail project on freight mode share could be inferred.

Likewise, in cases when a critical input measure could not be calculated, methods were developed to use what information is known to determine the degree and direction of the impact. For example, if net vehicle-miles of travel are not known, it would be difficult to calculate net impact on mobile source emissions. However, if available data strongly suggest that the project resulted in a net decrease in vehicle-miles of travel, and travel speeds improved such that vehicles could operate more efficiently, then it can be inferred that emissions decreased due to the project.

Finally, there are some measures that can only be evaluated qualitatively. The impacts of a project on visual aesthetics and the degree to which a project was designed to be context-sensitive are subjective. These methodologies do not attempt to define the impacts in quantitative terms, but instead supply a format for a checklist or score sheet that can be used to suggest whether the project was implemented in a manner that is consistent with local and regional plans, and whether surveys of area residents and businesses indicate a high degree of satisfaction with the project as implemented.

The analytical methods developed and investigated were compiled as a large set of detailed step-by-step instructions for conducting performance assessments. They were organized into a "cookbook" format, with figures, sample calculations, directions on data processing, and observations regarding computational accuracy. Arrayed by project category and NJTPA goal area, the methods in the *Guidebook* also note caveats, provide general recommendations for conducting evaluations and present ideas for improving data availability and evaluation tools.

3.0 Study Results

3.1 Findings

The project team faced significant challenges in developing performance measurement methodologies for the projects identified. Although the project team used industry-accepted analysis tools and approaches where possible, it was often necessary to develop new and innovative methodologies where such measures were not available or validated. Key considerations in the development of methodologies included project implementation and effectiveness time frames, the geographic scale of analysis related to a project's area of influence, and the specific information "inputs" or variables needed for analysis. Although no new data was collected for the projects, in order to allow the project team to identify current data availability and quality issues, "proxy" data were identified or estimated for use in some performance measures where their outputs formed critical inputs for other measures.

After applying the performance measurement methodologies, the project team reviewed and interpreted project results based on the characteristics of the projects relating to their overall project categories. This effort yielded a number of nuanced findings supporting the development of instructions needed to properly perform analysis and identifying challenges that would need to be overcome in order to more effectively conduct project level performance measurement in the future.

As previously mentioned, the literature review conducted as part of the project did not reveal another MPO that has undertaken an effort of this breadth and scale. Being a "first-of-its kind" project, there were a number of challenges outlined below that could not be overcome within the time frame and resources allocated to this project. Thus, the product of the research, the *Guidebook for Project Performance Measurement* is designed to be a user-friendly living document – to be updated over time as data availability improves and the state of the practice in project performance evaluations evolves. Further, NJTPA anticipates conducting a second phase of research into some of these performance measurement issues..

Key findings of the study are discussed in the following sections:

1) Quality and Availability of Data

2) Time Frame of Analysis: When to Collect Data

3) Isolating Project Impacts

4) Scale of Analysis; and

5) Findings by Performance Measure.

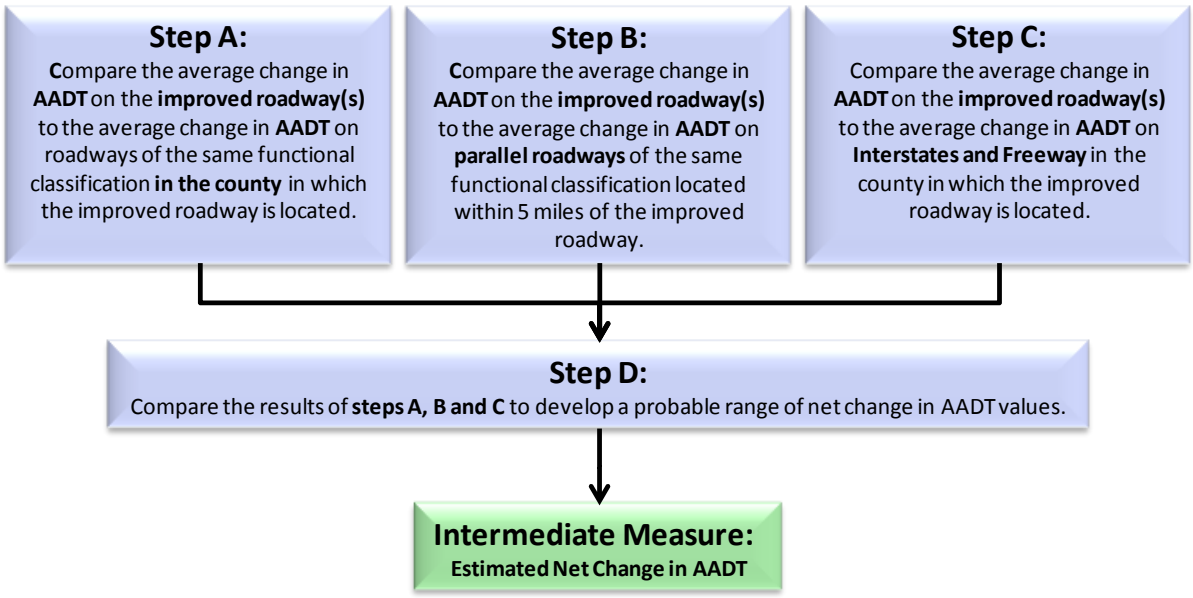
These findings represent both improvements and challenges that NJTPA faces in its ability to conduct better planning and programming.

Quality and Availability of Data

Although the project team attempted to locate and incorporate data for all measures, its availability and reliability was found to vary widely. These factors strongly impacted the ability to perform evaluations, and in some cases shaped the development of performance measure evaluation methodologies.

For example, in order to calculate net emissions impacts of a project, it would have been ideal to have origin-destination information data for every vehicle using a facility in order to calculate net VMT impacts. However, origin-destination data were not available, so the project team proposed using a "triangulation" process whereby the following were compared: (1) traffic levels in the study area to roadways of the same functional class in the county in which the project was implemented, (2) overall VMT changes in the county in which the project was located and (3) traffic levels on parallel roadways that may have been used as alternate routes before, during, and after construction. Figure 2 shows a schematic representation of this "triangulation" process.

Figure 2. Example of Process Used to "Triangulate" Net AADT in Order to Calculate Net VMT



Spatial and temporal granularity of data also was an issue. For example, although NJDOT monitors travel speeds in a limited number of locations around the region, travel speed data for every roadway segment in the region were not available. In many cases, tools such as Highway Capacity Software were used to estimate travel speeds before, during, and after construction based on what data were available: roadway geometry, capacity, and measured traffic volumes.

Data entry methods led to issues with reliability of data. An analysis of safety data recorded several years ago revealed inconsistencies and problems with coding of data. More recent data suggest that these problems have been addressed and NJTPA and its partners should have a more robust and reliable data set to conduct analyses in the future, with normal caveats surrounding project-level analysis for safety projects (e.g., randomness of incidents and incident severity)

Data consistency was also a significant issue. For example, counties and jurisdictions in New Jersey each have their own management systems for land use data. Some put information online, others provide only a hard copy in a local library. It is difficult and time intensive to sort through all the data and organize it into a format that can be used for a post-implementation analysis.

Where data were unavailable or unreliable, the project team sought creative alternatives to conduct analysis, including use of "proxy" data capable of measuring the same or similar performance issue.

Time Frame of Analysis: When to Collect Data

NJTPA can begin a data management and monitoring effort to improve data availability for future evaluation efforts. Performance evaluations often face a lack of data detail, extent, depth, time, quality, and, in all too many cases, a complete lack of data to perform analysis. A key challenge in advancing a performance results process is developing an ongoing program by which specific data needed for performance analysis would be identified, collected and maintained on an ongoing basis. Through development of an organized and systematic data collection and management effort, "before" data on travel speeds, volumes, costs, and existing land uses can be recorded. To support the evaluation of future projects, collection of this data may also be useful for evaluating recently completed projects whose full impacts may only emerge over time.

That is some project impacts increase gradually over time (e.g., property value impacts) and others diminish over time (e.g., congestion relief). Related to the appropriate time frame for data collection is the duration during which effects of a project will "mature" i.e., continue to be observed or noticeable. Although safety improvements are often most evident immediately after a project's completion, land use changes, mode choice changes and related ridership and VMT impacts may change gradually as people adjust to the new system. Conversely, the effectiveness of certain variables may lessen over time as background growth overwhelms the initial project benefits. The classic case is travel time savings due to a roadway improvement, where over time, the additional capacity will allow for economic growth, then generate new traffic that in turn fills up the available capacity.

Isolating Project Impacts

Isolating project-specific impacts is a major challenge in conducting project performance evaluations due to the many variables at play in a region as complex as northern New Jersey. It is extremely difficult separating out the effects that are truly attributable to the projects of interest,—changes in travel times, mode shares, emission of pollutants, crash rates, etc.—especially as the world around those projects continually changes and evolves in significant ways. For example, many projects may be completed in a single corridor. There is a tradeoff between isolating the impacts of any one project to determine its individual merit, and attempting to conduct an evaluation of the cumulative impact of a group of projects that may have been completed over a span of many years. Economic impacts, mode shifts, and impacts on air and water quality are three examples of performance results that cannot easily be isolated.

In order to isolate a project's net impacts, a "control" case is often needed for comparison purposes. Selecting this "control" case is challenging in a region as complex as the NJTPA region because so many variables need to be assessed.

Two questions in particular must be considered in isolating impacts:

- Which variables are correlated? If a transit station reconstruction resulted in additional parking at rail station and also improved sidewalk and bike connectivity to surrounding neighborhoods, any net increase in transit ridership will have to be carefully attributed to any of the related improvements.

- What external factors affect and are affected by the project? In the station example, did any nearby roadways that serve the same origins and destinations as the rail service undergo improvements (particularly capacity expansions) that may have affected mode choice and therefore net transit ridership?

Although this project has begun to answer important questions about calculating a project's net impact, NJTPA and others need to conduct more research into which variables are correlated, significant, and relevant to each project type, and to what extent external factors (e.g., gas prices and economic factors) affect each measure.

Scale of Analysis

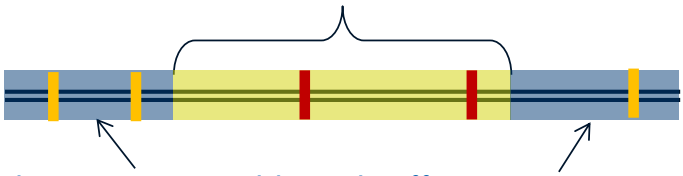
There is rarely a "one-size-fits-all" approach to analysis of performance results. Many variables may be affected both inside and outside of a project's limits. Therefore, in many cases an analysis of performance results cannot be limited to the extent of its construction. If a roadway underwent a capacity expansion, the analysis of net change in traffic and delay must take into account whether people shifted from parallel facilities or even other modes. These parallel facilities must be included in the analysis at the very least, and in some cases it may also be prudent to compare changes in traffic to overall changes in VMT at the county or regional level.

Determining the scale of the analysis will require a great deal of judgment by the evaluator. As indicated in the *Guidebook*, the appropriate scale of analysis will vary by project type, by the scale of the project, and by measure. Although the project team sought to develop orderly, replicable sets of procedures for conducting project-level performance evaluations, analysis indicated that almost every project has unique circumstances and context which require slight methodological alterations or deviations. Some projects are truly "one of a kind" and require a tailored approach or additional resources to conduct a more thorough, rigorous analysis. Figure 3 shows an example of the recommended approach to determining the geographic scale of analysis for Roadway Expansion projects.

Figure 3. Example of How to Determine Geographic Scale of Analysis

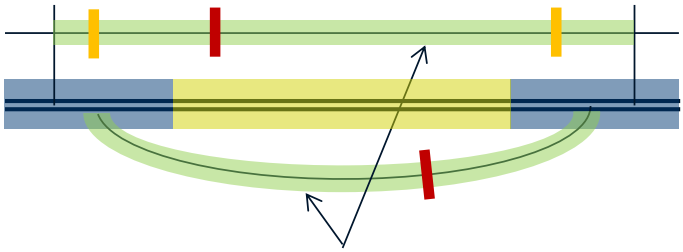
CASE 1:
CORRIDOR CAPACITY EXPANSION
with little or no traffic diversion expected

First analyze counts within project limits…



…then compare to additional traffic counts upstream and downstream of project limits, and to other roadways in the county of the same functional classification

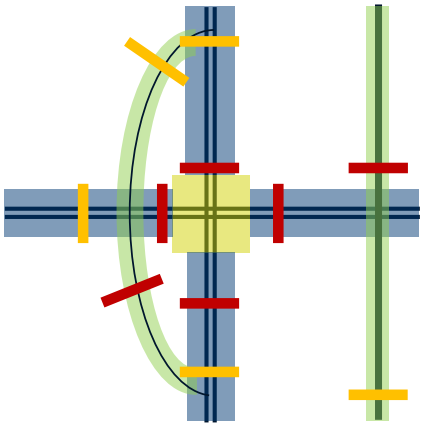
CASE 2:
CORRIDOR CAPACITY EXPANSION
with traffic diversion

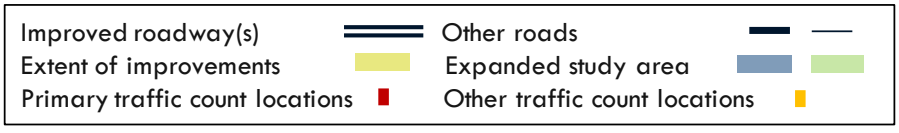


Analyze traffic counts on parallel route(s) within 5 miles that may have been used as alternate(s) or bypass(es) of bottleneck. Count stations nearest to improvement (in red) should be given greatest weight in analysis.

CASE 3:
INTERCHANGE EXPANSION
OR BOTTLENECK RELIEF

- Select count stations closest to interchange on all four legs
- Compare to AADT values on facilities that may have been used as alternate(s) or bypass(es) of bottleneck, giving precedence to counts in closest proximity to study area (in red).





Findings by Measure

Although there are differences by project type, in general the performance measures can be divided into four categories:

- Those that are ready to evaluate today or in the short term given available data and analysis tools;
- Those for which data availability is likely to be a challenge, but if data are available the evaluation is straightforward;
- Those that will require significant data collection or evaluation effort; and
- Those that will require proxies until the state of the practice in project-level performance evaluation evolves.

Ready to Evaluate Using Existing Data and Analysis Tools	• Crashes/crash rate • System condition (highway pavement and bridges) • Travel time reliability • Person-hours of delay (projects with local impact) • Network connectivity and continuity
Ready to Evaluate, but Data Availability a Challenge	• System condition (transit and freight rail) • Transportation resiliency (protection, prevention, redundancy, and recovery) • Quality of wetlands, surface water, and drinking water • Impacts on protected lands
Data Available, but Significant Effort Required to Compile or Evaluate Data	• Accessibility measures (need analysis tools/models) • Person-hours and ton-hours of delay (projects with regional impact) • Transportation-related noise and vibrations (need sound measurements) • Customer satisfaction measures (need surveys) • Population and employment density (Census data not at fine-grained enough scale) • Land use and land value changes (data not consistent across municipalities)
Requires Use of Data Proxies or Estimates Pending Further Data Research and/or Development	• VMT, mode share, and net transit ridership: Need O-D data and other detailed survey data. For now can use "triangulation" process based on "control" cases and regional trends. • Emissions: Multiply estimated net change in VMT by an average emissions per vehicle

3.2 Recommendations

The Performance Results study has its origins in Federal requirements that Metropolitan Planning Organizations (MPOs) like the NJTPA monitor the results of Federally-funded projects implemented through the region's Congestion Management Process (CMP). Since the CMP requirements were developed, the Federal Highway Administration, Federal Transit Administration and others have required MPOs and state Departments of Transportation to incorporate performance-based planning and management into all aspects of the statewide and metropolitan planning process. This includes evaluation of environmental, economic, safety, maintenance, and operations factors in addition to congestion management. As performance-based planning and programming gains traction as the state-of-the-practice for DOTs and MPOs across the country, forthcoming Federal surface transportation legislation may codify these practices and require US DOT to develop formal policies and procedures that would apply to the NJTPA and other MPOs.

The proposed addition of a Performance Results process would enhance and strengthen the NJTPA's existing planning process by feeding back performance results to previous steps thereby improving the region's ability to move towards its goals. This added process will enhance NJTPA planning and programming capabilities in the following ways: 1) learning from the results and outcomes of previous policies and investments; 2) applying these lessons to the development of future projects and policies; and 3) injecting project-level data and analysis into regional decision making.

Facing the challenges of incorporating a broad performance-based planning process in the near future and NJTPA's desire to enhance its planning and programming capabilities, the NJTPA should move forward with a manageable number of measures and processes, adding new evaluation capabilities over time as the states of the practice in data collection, data management, and analysis tools develop. The most promising areas, based on the work completed in this project, appear to be in the areas of system preservation (pavement and bridge maintenance), safety, and measures of congestion that could make use of recently-acquired INRIX data by the NJDOT. INRIX is a traffic services and mobile app company providing historical and real-time traffic information to businesses and individuals in the United States and Europe through the collection of information about roadway speeds from over 5 million trucks, delivery vans and other fleet vehicles equipped with GPS satellite locator devices as well as consumer cellular GPS-based devices including the iPhone, Android (operating system), BlackBerry and Windows Phone phones, Ford SYNC and Toyota Entune.

For example, using link-level travel speeds and link-level travel times across a broader sample of the roadway network, in turn measures like Travel Time Reliability, Delay, and Percent of Travel Under Congested Conditions can be evaluated at a fine-grained level. However, issues of isolating and attributing impacts to any given project remain a challenge even with INRIX data. It may still be valuable to assess the impacts of groups of projects in a corridor that all were intended to achieve the same goal using available system-level or corridor-level analysis tools. The corridor-level approach is consistent with the recommendations of the Guidebook for Project Performance Measurement that an analysis of performance results not stop at a project's construction limits.

With increasing availability and volume of INRIX data, safety data, and system condition data comes the challenge of managing the data and producing useful information from it. NJTPA and its

partners should develop a data management plan for the Performance Results process, or insert considerations of the needs of the Performance Results process into other ongoing database development projects. NJTPA and its partners need to start identifying and compiling data now that will become the "before" data in future project-level analyses. The *Guidebook for Project Performance Measurement* can be a useful tool to start identifying what data are needed now. Paramount among the data concerns is the need to implement data consistency and quality control procedures statewide or at least throughout the NJTPA region to facilitate future analyses.

In areas requiring advancement of the state-of-the-practice, the NJTPA and its partners should work to identify and prioritize topic areas that need further research and development. However, the NJTPA should recognize the need to strike a balance between academic rigor and resources available to conduct evaluations. Research should help determine which measures are correlated and which are statistically significant (and therefore applicable to various project types). The Association of Metropolitan Planning Organizations (AMPO), National Association of Regional Council (NARC), the Transportation Research Board (TRB) and the National Cooperative Highway Research Program (NCHRP), Transit Cooperative Research Program (TCRP), and National Cooperative Freight Research Program (NCFRP) are all forums that NJTPA and its partners can use to advance the state of the practice in project-level performance evaluations.

Finally, NJTPA should promote the value of the Performance Results approach to its stakeholders and to decision makers around the region at all levels of government.

Specific recommendations for implementation of the Performance Results process include the following six NJTPA Goal Areas:

- Environment
- User Responsiveness
- Economy
- System Coordination
- Repair/Maintenance/Safety/Security
- Land Use/Transportation Coordination

Environment

Transition to EPA's MOVES model for project-level emissions analysis. EPA's Office of Transportation and Air Quality (OTAQ) has developed the **MO**tor **V**ehicle **E**mission **S**imulator (MOVES). This new emission modeling system estimates emissions for mobile sources covering a broad range of pollutants and allows multiple scale analysis. MOVES2010 replaces the previous model for estimating on-road mobile source emission, MOBILE6.2.MOVES2010 is currently the best tool EPA has for estimating greenhouse gas (GHG) emissions from the transportation sector. It is a significant improvement over MOBILE6.2 and previous versions of MOVES for GHG estimation. MOVES also allows for project-level analysis, unlike MOBILE6.2. MOVES requires the following data inputs:

- Meteorology (can use default values)
- Source type pollution (number of vehicles in project area)
- Vehicle age distribution (from regional motor vehicle registration data)
- VMT by vehicle type (from User Responsiveness calculations)
- Average speed distribution of vehicles by roadway link (from System Coordination calculations)
- Roadway link characteristics
- Fuel formulation used in vehicle fleet
- Fuel supply available to vehicle fleet
- Characteristics of regional/state Inspection/Maintenance (I/M) program

Additional information about MOVES is available from the EPA at:

http://www.epa.gov/otaq/models/moves/

Improve extent and detail of Environmental GIS data. Many of the analysis methodologies described above rely on disaggregate and fine-grained data, for example locations and characteristics of sensitive receptors; archived data on noise levels at sensitive receptors; extent and quality of Section 4(f) protected lands (where "quality" is defined by a set of objective evaluation criteria, each of which may require its own analysis); extent and quality of wetlands; quality of surface water by body of water; and quality of drinking water by source. Sensitive receptors are people or institutions with people that are particularly susceptible to illness from environmental pollution, such as the elderly, very young children, people already weakened by illness (e.g., asthmatics), and persons engaged in strenuous exercise. While it may not be possible to collect and monitor some of these data sets at a scale that would be required to inform an estimate of net project-level impacts, project before-and-after observations and calculations may still be compared to regional and subregional data for comparison purposes.

The Council on Environmental Quality (CEQ) regulations that guide the NEPA process does not require monitoring for the purpose of determining the effectiveness of mitigation measures. CEQ regulations generally require implementation monitoring on an "as appropriate" basis (NEPA only applies to projects that involve major federal actions; if a project is wholly state, authority, or privately funded and does not require any federal permits, NEPA does not apply). Typically, it is not until the permitting stage that monitoring is started based on cost and regulatory requirements. Agencies generally do not have the funds or manpower to conduct monitoring activities and collect post implementation data. Further additional cost would be incurred if it is discovered that mitigation measures are not successful and additional mitigation actions must be undertaken. Monitoring activities, data collection, data clean up and database maintenance are also time consuming; therefore agencies may be hesitant to monitor and report performance changes. If measures are found to be ineffective, it may reflect poorly on the agencies that approved the actions. Without more thorough monitoring, enforcement, and information/data collection, it is difficult to determine project effectiveness and identify how to most effectively develop best practices.

The Tennessee Valley Authority (TVA) is an exception. The TVA has integrated NEPA into its Environmental Management System (EMS), which refers to the management of an organization's environmental programs in a comprehensive, systematic, planned, and documented manner. The EMS provides a standardized method of managing TVA's environmental impacts through an internal, web-based Environmental Information Center. This internal program features an extensive database for collecting and reporting data on the agency's environmental performance and shares organizational best practices. The NEPA process has been directly linked to EMS processes including communication and employee involvement, records management, environmental auditing, corrective action and performance monitoring and reporting. The EMS employs the NEPA adaptive management model: monitoring environmental conditions following implementation of the action with any mitigation, and adapting the action's implementation or mitigation as appropriate based on the environmental monitoring data (the "predict, mitigate, implement, monitor and adapt" model). Under this approach, actions are adjusted to further desired outcomes and reduce undesired ones. The TVA has a web-based NEPA system that stores the documentation of Categorical Exclusions and tracks mitigation commitments made in NEPA documents. Performance is measured by a NEPA Process Effectiveness Index that is calculated from surveys conducted as part of project reviews. TVA has reported increased environmental improvements that integrate environmental considerations into their business decisions.

More information is available at: http://www.tva.gov/environment/ems/index.htm

Improve wetland and water quality data and monitoring. In order to track the progress of wetland systems, a GIS database of these systems should be maintained and older versions should be archived. The archive can be used as a baseline to compare what the wetland conditions are in subsequent years to analyze how effective mitigation efforts are over time. The USACE has already started to compile this data for its own projects and would be a logical agency to organize and house this information. Stream location data should continue to be held by state DEPs and updated as needed. Water quality data is currently housed within EPA and should continue to be in the future with databases in place and the WQX framework established to share information via the internet. The EPA also has an Exchange Network agreement in place, where agencies and organizations agree to share data in standardized formats. This agreement should be extended to interested parties that collect water quality data to increase the amount of information stored and the value of the system. The Exchange Network should also include project level data from transportation-related projects. This would allow for data sharing and streamlining the NEPA planning process.

Improve monitoring of impacts on Section 4(f) properties. The Section 4(f) legislation, as established under the Department of Transportation Act of 1966 (49 USC 303, 23 USC **138)** provides protection for publicly owned parks, recreation areas, publicly and privately owned historical sites, wildlife, and or water fowl refuges from conversion to a transportation use. The Section 4 (f) information is collected during the transportation planning process and is specifically required for NEPA document preparation. There does not appear to be follow-up after NEPA process implementation to assess whether Section 4(f) properties were impacted by project activities. Assessment is not necessary for the Section 4(f) measure in all cases. Since Section 4(f) properties should be considered before the NEPA process begins, scoping potential issues and identifying and evaluating Section 4(f) properties is done at the beginning of a project. For projects where a de minimis impact or a "use" of Section 4(f) properties is determined, then developing and evaluating avoidance alternatives under the "feasible and prudent" standard

should occur. For these projects, monitoring and assessment after the activity is completed should be conducted to ensure the actions have not negatively affected the properties.

Improve methodologies and tools for linking environmental impacts of transportation to specific public health outcomes. Currently, the state of the practice in measuring transportation's impacts on public health is not advanced to the point where public health impacts can be defined quantitatively. For the most part, where health impact assessments (HIA) are performed, results are generally assessed using qualitative measures. NJTPA and its partners at the federal level and across the country should continue to seek out research that improves the understanding and correlation of pathways and quantitative links between environmental impacts and public health outcomes. Examples include the link between emissions and asthma and respiratory conditions; the link between waterborne illness and water quality; the link between mode choice, physical activity, and obesity; and the link between noise, mode choice, and human stress levels. The Centers for Disease Control (CDC) has established a toolbox of procedures, methods, and analysis tools to conduct health impacts assessments (see http://www.cdc.gov/healthyplaces/hia.htm). The University of California Los Angeles's Health Impacts Assessment Clearinghouse (http://www.hiaguide.org/) is currently under development, but already contains links to guidance and successfully-completed health impact assessments around the U.S. For example, a completed highway corridor project (outside New Jersey) was found to have the following estimated quantitative public health benefits: estimated 6.1 fewer injuries and 1.6 fewer fatalities to pedestrians; 73.8 fewer motor vehicle injuries per year; 73 minutes per week more physical activity; no change in air pollution.

User Responsiveness

Improve extent and timeliness of origin-destination data. O-D Data and travel survey data can be used to improve estimates of net VMT by providing more information on trip lengths, persons per vehicle, and modes used before and after project implementation. Research is being conducted into alternatives to travel diaries, household surveys, business surveys, and license plate surveys, all of which are extremely time-intensive and error-prone methods of estimating origin-destination patterns on a regional scale. For example, increasing market penetration of E-ZPass, GPS-enabled wireless phones and other devices, and GPS-enabled services and other automatic vehicle location (AVL) devices installed in cars and trucks all suggest methods of capturing fine-grained, real-time origin-destination and trip-chaining characteristics of travelers in the NJTPA region. Although data storage prices are rapidly declining, enormous amounts of data would be generated from even a sampling of GPS devices over a short time, and many hours of labor combined with sophisticated statistical analysis techniques would be required to clean and process the data into a usable format. Also, although E-ZPass records have successfully been entered into evidence in civil and criminal trials, privacy concerns have so far prevented the widespread collection of data from these devices for transportation planning purposes. Finally, technical issues persist: research suggests that travel diaries and/or better data processing algorithms may be necessary to distinguish congestion-related stops (e.g., a delay at rail grade crossing or a gridlocked intersection) from a quick gas station or ATM stop along a route.

Improve accessibility reporting capabilities. Develop GIS tools to interface with travel demand model inputs and outputs to automate calculations of accessibility changes due to transportation investments. Accessibility maps can be powerful public involvement and outreach tools, showing people meaningful information about the impacts of transportation investments on their daily

lives. Accessibility maps also can be used to help people and businesses make more informed location decisions, taking into account access to work and other destinations via multiple modes.

Undertake more customer satisfaction surveys for all modes on a regular basis. Agencies responsible for building, maintaining, and operating the transportation system in the region should undertake regular customer satisfaction surveys to collect a range of qualitative and quantitative data about customer perceptions about the transportation system and the implementing agencies, as well as the impacts of policy changes and investments on traveler behavior.

Economy

Develop analysis tools and methodologies to calculate macroeconomic measures. Employment, per capita income, and industrial output (expressed in dollars or regional GDP) are three easy-to-understand measures of a project's results. These measures also capture the full benefits of transportation projects, as opposed to cost-effectiveness measures that only address one specific element, or transportation costs, which only address direct user benefits. However, an assessment of macroeconomic measures requires extensive data collection, time-intensive analysis, and highly specialized expertise to produce reliable results, making these measures expensive to evaluate under the current state of the practice in economic impacts analysis. New analysis tools need to be developed to reduce the costs and time associated with estimating macroeconomic impacts of transportation projects.

System Coordination

Improve extent and detail of traffic count data. Traffic count data are currently widely available in the NJTPA region, but if traffic counts were available at more points along the roadway network, and if more count stations provided continuous counts with classification data, better information would be available to input to congestion, travel delay, and reliability estimation tools.

Collect and use travel speed data for direct observations of congested and free-flow travel speeds. With better travel speed data such as the availability of INRIX, TRANSCOM, and other sources, the NJTPA could improve estimates of link-level travel times, and in turn measurement of Travel Time Reliability, Delay, and Percent of Travel Under Congested Conditions.

Use simulation models to improve estimates of network-level congestion and delay measures. The methodology presented above assumes roadway impacts are expected to be limited to the immediate vicinity of the project plus five miles upstream and downstream of the project. When the analysis involves many links in a network of roadways, micro-simulation models can be used to calculate all of the System Coordination performance measures on a network scale. Micro- and meso-scopic network simulation models have much more extensive data requirements than HERS or HCS (for example, they require field observations of free-flow and congested travel speeds, turning movement counts at intersections, and very detailed roadway geometry data). However, network simulation models may produce more accurate estimates of travel speeds and delay when an improvement is expected to affect travel speeds and delay on many interconnected roadways, when an improvement may lead to major shifts in traffic from one roadway to another (perhaps due to improved travel times on the new route), and/or when an improvement may lead

to significant changes in trip origins and destinations (in which case a meso-scopic simulation model with a dynamic trip table may be useful).

Improve network GIS data, particularly restrictions on oversize/overweight and commercial vehicles. Network connectivity and continuity data could be enhanced with additional information on system condition, facility attributes, and restrictions on use by certain vehicle types.

Repair/Maintenance/Safety/Security

Extreme caution should be used in drawing any conclusions from before-and-after analyses of safety data, especially when evaluating projects that were completed more than 5 years ago. Many exogenous variables can affect crash statistics from year to year. This analysis revealed significant problems with crash data, especially pre-2005 data, which was found to have inaccurate reporting of crash locations and crash categorizations that could negatively affect the ultimate accuracy of project-level analysis. After 2005, this analysis found that the quality of crash data improved, and there is reason to expect further improvements with evolving technology. Both should make before-and-after comparisons of crash data more reliable going forward. In order to reduce "noise" in safety data caused by random variables, crash data should always be evaluated using rolling averages covering at least three consecutive years.

Reassess and periodically update definitions of critical transportation infrastructure and services to support analysis of system resiliency related to transportation security, climate change adaptation, and other concerns. NJDOT, NJ Transit, NJTA and other transportation agencies, in cooperation with Federal and local governments and other state agencies, have performed an assessment of critical transportation infrastructure. NJDOT, NJ Transit, NJTA, PANYNJ, and other transportation agencies should continue to work with the U.S. Departments of Transportation, Defense and Homeland Security, other relevant Federal agencies, NJTPA, and other partners to periodically reassess and improve upon definitions of critical transportation infrastructure and related systems (communications, electricity, fuel distribution, water and sewer).

Land Use/Transportation Coordination

Improve availability and archiving of parcel-level land use data. Population and employment density can provide potential proxies for actual land use changes that occur in response to transportation investments and policy changes. However, it is currently difficult to gather historical and sometimes even current land use data such as residential units and square footage of retail development that would be needed to analyze the impacts of a new highway interchange project, for example. In many New Jersey communities, some parcel-level information is available online, but key attributes such as building square footage or square footage by use (retail vs. office vs. residential) or whether the unit is even occupied may not be available. When the data are available online, often figures must be manually extracted parcel-by-parcel from an online viewer, making the analysis prohibitively labor-intensive. Several regional and national firms specializing in real estate and economic analysis have commercially-available database with parcel-level land use information, but the fee for the data sets may be cost-prohibitive. Improving the accessibility and availability of parcel-level land use data could support analysis of square footage of various types of development that would be critical to analyzing residential density or density of retail and office space near transit, or land use mix (for example, ratios of residential to retail space within ¼ mile of a transportation facility).

4.0 Conclusion

The NJTPA *Performance Results: Assessing the Impacts of Implemented Projects* study was shaped to serve the metropolitan planning process in northern New Jersey, the fifth largest MPO jurisdiction in the country. This meant incorporating a diverse set of perspectives in framing the effort, spanning urban, suburban and rural planning issues, addressing a full range of transportation modes, and tying into long-established economic, environmental and social goals. The policy foundation for the region is expressed by the NJTPA's Plan 2035 and Regional Capital Investment Strategy calling for sustainable growth, increasing overall accessibility including transit accessibility, making travel safer, maintaining existing infrastructure, slowing the growth of roadway congestion, accommodating increased freight traffic, and enhancing system efficiency.

Performance Results needed to build on performance-oriented activities already taking place at the NJTPA, including monitoring trends, identifying needs and potential improvements in the region's Strategy Evaluation/congestion management process, scenario planning, and prioritizing projects for the transportation improvement program. Each of these activities is, of course, ultimately aimed at generating and implementing beneficial projects and programs. Feedback on the performance of those projects and programs that get implemented completes the cycle and should be able to inform all planning steps.

The research aspects of the study reviewed available resources and looked at practices at other planning agencies in the U.S. and abroad. A sampling of past transportation projects was identified for testing, with historical data mined for use in designing before-after assessment techniques. Potential performance measures relating to each of the NJTPA's six Regional Planning Goals were identified and debated in staff and partner agency workshops. Technical exploration of the practicability estimating these measures followed, and methodologies were developed and refined.

The methodologies that emerged from this research were made to be as realistic as possible. They grapple with the unavailability of data as well as the limits on data—in detail, extent, depth, time, and quality.. They also deal with separating out the effects that are truly attributable to the projects of interest—changes in travel times, mode shares, emission of pollutants, crash rates, etc.— even as the world around those projects continually changes in significant ways. By necessity, the methodologies balance quantitative evaluations with qualitative, recognizing that even with the best data, some important types of impacts (such as economic or livability effects of small operational improvements) will never be measurable on an individual project basis. And finally, the methodologies were designed, where possible, to be easy to use and straightforward to apply given limitations to available planning resources faced by many agencies.

With these considerations, the study's main product — an extensive *Guidebook for Project Performance Measurement* - was developed. Using chapters spanning ten project types and applicable regional goals, the *Guidebook* is organized similar to a *"cookbook,"* with performance measurement *"recipes"* including such "*ingredients"* as detailed instructions on data (identifying data sources and appropriate coverage in time and geography), calculations (with clear illustration of typical values and units and mathematical formulas), tools needed (particularly for estimation

and processing), and examples of results. Recommendations accompany the instructions within the *Guidebook*, identifying caveats and considerations for the various measures, suggesting how to improve data collection, and noting alternative measures for further exploration.

The Performance Results effort leaves the NJTPA with a valuable resource for conducting future project performance monitoring. It is also, however, clearly still an early step in the endeavor of gauging how well our actions yield the consequences we desire. As a way forward, the NJTPA will look to build on this information, work with partners to improve data, and continue our region's dialogue on choosing actions with the best chances of success.