NJTPA
NORTH JERSEY TRANSPORTATION PLANNING AUTHORITY

PERFORMANCE RESULTS:
Assessing the Impacts of Implemented Transportation Projects

Guidebook for Project Performance Measurement

Prepared by:
Cambridge Systematics, Inc.

In association with:
Fitzgerald and Halliday
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GUIDEBOOK FOR PROJECT PERFORMANCE MEASUREMENT
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1.0 Introduction

The North Jersey Transportation Planning Authority (NJTPA) has prepared this *Guidebook for Project Performance Measurement (Guidebook)* to improve the capability of the NJTPA and its member and partner agencies in assessing the net impacts of implemented transportation projects and policies. The *Guidebook* is designed to outline a range of performance measurement methodologies and approaches developed through the study's research and analysis that can be applied to a range of transportation project types. Each contains a description of supporting data needs, detailed step-by-step instructions to apply the evaluation methodologies and guidance to help interpret the results of the analysis and appropriately use these results to improve NJTPA's planning, resource allocation, and project development processes.

While the *Guidebook* is intended to serve as a first step in supporting future evaluation and selection, a set of Performance Results procedures is developed for possible implementation by NJTPA's partners in the region who are responsible for designing, building, operating, maintaining, and regulating the region's transportation system. The study attempts to assist engineers, planners, program managers, and policy makers in answering the following questions about the implemented projects:

- What effect did a new transit station have on transit ridership?
- What impact did countdown timers at intersections have on pedestrian safety?
- Did the new left-turn bay and left-turn signal phrasing help reduce collisions and congestion at an intersection?
- Did the new rail intermodal terminal shift freight from truck to rail?

It is also intended to be a living document, to be updated as the state of the practice in transportation system performance monitoring and data management and capabilities of analysis tools improve over time.

This Guidebook, coupled with the Performance Results Final Report, is intended to be used by technical practitioners, and is organized into three Chapters:

• Chapter 1 - Introduction provides an overview of the Performance Results study: what it is, why it is important, its role in the context of the larger NJTPA performance planning process, and the challenges in developing and applying a performance evaluation methodology.

• Chapter 2 - How to Use This Guidebook explains how to understand and correctly apply the information contained herein.

• Chapter 3 –Measuring Impacts provides detailed, step-by-step instructions on how to perform Performance Results assessments across the ten categories of projects.

It should also be noted that the full study's Executive Summary, Findings, and Recommendations, documenting the technical steps of this study effort and intended for a broader audience, are contained in a companion Final Report document.

1.1 What is the Performance Results Study?

The NJTPA's Performance Results study provides recommendations on using information about the impacts of completed projects to inform how future transportation policies and investments are planned and implemented. For this study effort, the NJTPA selected Cambridge Systematics, Inc. as a consultant to work with its 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). The study focused on selecting appropriate performance measures for assessing the results of completed projects and then apply the measures in a "before-and after" evaluation of discrete projects as well as groups of related projects and policy initiatives.

The projects evaluated as part of the Performance Results study include a sample of the types of projects and initiatives that have been implemented in the past and would be expected to be implemented in the future. Projects are large and small; have impacts felt locally, regionally, or beyond the borders of the NJTPA region; and reflect the geographic diversity of the region. The measures used to evaluate each project reflect the NJTPA's regional transportation goals and objectives.

The lessons learned in conducting the Performance Results Study resulted in the development of this *Guidebook*. It represents a compilation of national and international best practices in conducting assessments of the net impacts of completed projects, adapted to the unique characteristics of the NJTPA region and the constraints imposed by limitations on available data and analysis tools.

Performance-Based Planning and Management

Performance-based planning and management is a systematic process by which agencies such as the NJTPA use analysis of performance data to enhance decision making in pursuit of a set of goals and objectives. Whether allocating existing funds or making the case for more funding, transportation agencies such as the NJTPA face increasing pressure to demonstrate accountability by measuring and reporting the impact of resource allocation decisions on system performance. Performance-based planning provides a level of transparency and objectivity that is critical for setting long-term policy priorities, determining where and how to allocate staff and capital resources, and demonstrating accountability to external stakeholders.

1.2 Why Evaluate the Impacts of Completed Projects?

Any transportation improvement and policy must be cost-effective, particularly in an era of severely constrained transportation funding. The NJTPA and its partners must make the best use of scarce transportation dollars while moving the region towards its goals and objectives. One of the primary purpose of to study the impacts of completed projects is to learn from the results and outcomes of previous policies and investments and apply these lessons to the development of future projects and policies.

Assessment of project results is a critical component of an agency's overall planning process. It attempts to inject project-level data and analysis into decision making, focusing on the anticipated and actual impacts of transportation decisions on key regional goals. The NJTPA and its partners have long since embraced this approach to planning and decision-making, and thus the Performance Results study is a natural extension and enhancement of the NJTPA's existing performance-based planning and management process.

As indicated in *Plan 2035: The Regional Transportation Plan for Northern New Jersey*, a key element of the planning process is a public dialogue about not only *where the region has been* or *where it is heading*, but also how future transportation investments can help guide it to *where it wants to be* in the future. An analysis of performance results is one element of a broader performance-based planning and management process that should help the region use performance indicators and measures to better understand how transportation investments, policies, and strategies impact our region, and how we can improve future policy and investment decisions.

In addition to the regional emphasis on performance-based planning, the U.S. Department of Transportation strongly advocates of this approach to planning. In a 2005 Federal Certification Report confirming that the NJTPA's transportation planning process meets all Federal requirements, the Federal Highway Administration (FHWA) and the Federal Transit Administration (FTA) commended the NJTPA for significant progress made in "utilizing the Congestion Management System (CMS) throughout key areas of the planning process," but also recommended that the agency "strengthen the continuous management of its congestion reduction process by developing a mechanism to monitor the system-wide impact of specific projects in the region as part of the CMS." While Federal CMS requirements have been supplanted by Congestion Management Process (CMP) requirements, the monitoring of project impacts remains a priority at the Federal level.

The NJTPA applies travel demand modeling and other techniques to anticipate impacts of plans and programs. The agency currently compiles specific information from project sponsors such as NJDOT and NJ Transit to prioritize funding for projects included in its Transportation Improvement Program (TIP). While generalized benefits are predicted for TIP projects, no region-wide study has yet been conducted to collect and compare project-specific before-and-after data to discern impacts that were in fact achieved through project implementation. Based on existing and newly compiled data, this effort serves such a function.

1.3 How Can an Assessment of Project Results Improve the NJTPA's Planning Process?

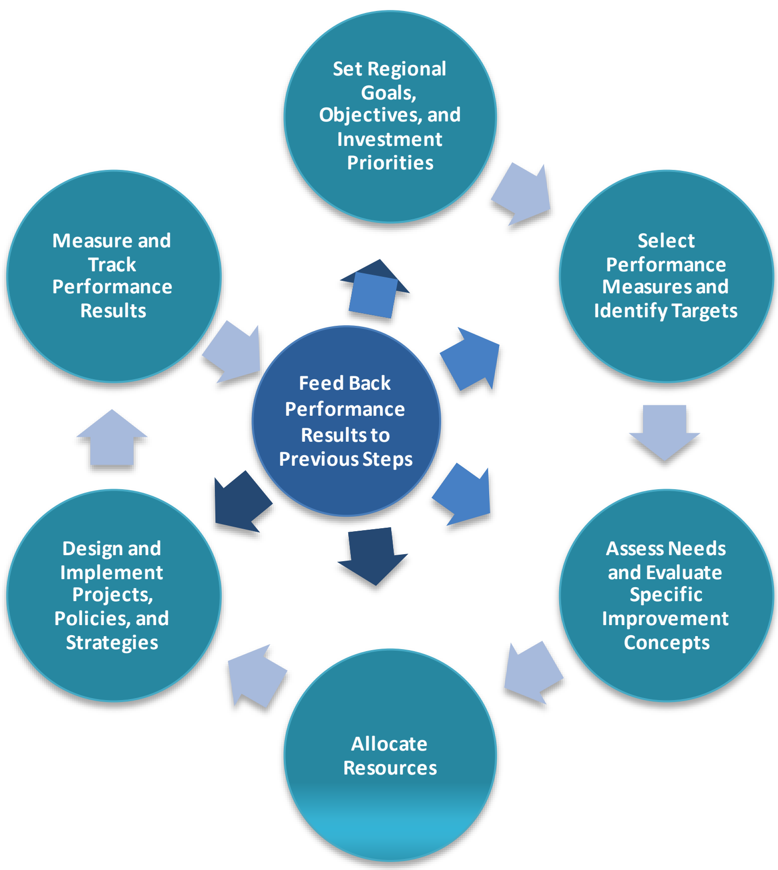
Information about project results and impacts can inform each step in the NJTPA's planning process. A basic representation of the planning process is shown in Figure 1. The relationships of Performance Results assessments to each step are discussed in the sections below.

1.3.1 Set Regional Goals, Objectives, and Investment Priorities

Performance management is anchored in strategic planning, building off of a set of policy goals and objectives that identify an organization's desired direction and reflect the environment within which its business is conducted. The results of the Performance Results process should provide information about how effective certain types of transportation investments and strategies are in moving the region towards its goals and objectives. Over time, given information about what works and what doesn't, NJTPA and its partners may make adjustments to broad policy statements and objectives, and these policy changes in turn may lead to shifts in how funding is allocated to program categories.

Plan 2035: The Regional Transportation Plan for Northern New Jersey is not only a prerequisite for Federal transportation funding, but the foundation for all of the North Jersey Transportation Planning Authority's (NJTPA) transportation planning efforts. The *Regional Transportation Plan* (RTP) identifies the region's long-term transportation needs and objectives, the planning assumptions for population, employment, land use and the economy, the trends concerning congestion, and the projects that are being supported, all for a 20-plus year planning horizon.

Figure 1. Planning Process



The six goals and related objectives laid out in *Plan 2035* are the region's foundation for performance-based planning:

Environment	Protect and improve the quality of natural ecosystems and the human environment
User Responsiveness	Provide affordable, accessible and dynamic transportation systems responsive to current and future customers
Economy	Retain and increase economic activity and competitiveness
System Coordination	Enhance system coordination, efficiency and intermodal connectivity
Repair/Maintenance/Safety/Security	Maintain a safe and reliable transportation system in a state of good repair
Land Use/Transportation Coordination	Select transportation investments that support the coordination of land use with transportation systems

In Chapter 3, these goals will be connected to the specific performance measures (see Section 1.3.2 below) to evaluate different project type categories.

Another key element of the NJTPA's regional policy framework is the Regional Capital Investment Strategy (RCIS), which currently includes eight broad investment principles and more specific investment guidelines in several categories:

- **Help The Region Grow Wisely** Transportation investments should encourage economic growth while protecting the environment and minimizing sprawl in accordance with the state's Smart Growth plan, Energy master plan, and Greenhouse Gas plan.
- **Make Travel Safer** Improving safety and security should be explicitly incorporated in the planning, design and implementation of all investments.
- **Fix it First** The existing transportation system requires large expenditures for maintenance, preservation and repair, and its stewardship should be the region's highest priority.
- **Expand Public Transit** Investment to improve the region's extensive transit network should be a high priority, including strategic expansions to serve new markets.
- **Improve Roads but Add Few** Road investments should focus on making the existing system work better, and road expansion should be very limited.
- **Move Freight More Efficiently** Investments should be made to improve the efficiency of goods movement because of its importance to the region's economy and quality of life.
- **Manage Incidents and Apply Transportation Technology** Investments should be made to improve information flow, operational coordination and other technological advances that can make the transportation system work smarter and more efficiently.
- **Support Walking and Bicycling** All transportation projects should promote walking and bicycling wherever possible.

1.3.2 *Select Performance Measures and Identify Targets*

Performance measures are a set of 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 readily **comprehensible** for 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.

Performance targets are the gauges of success that support and advance an agency's strategic plan. Without them, objectives are abstract concepts. To be useful, targets must do the following:

- Be ambitious enough to represent real accomplishments.
- Be achievable. If a target is perceived as unrealistic, the motivation to pursue it may evaporate as resources are re-directed towards more realistic goals.
- Contain specific time horizons and be short-term enough that progress can be measured monthly, quarterly, and/or yearly. Ideally, targets that support strategic planning objectives should look no more than 2 or 3 years ahead.

Guidance on target-setting for performance measurement has been developed by the National Cooperative Highway Research Program.[1] Target-setting, while valuable to translate objectives into concrete statements of what the NJTPA hopes to achieve, cannot always be developed easily in all areas. The impact of external factors like demographic and economic changes, behavioral impacts on performance (especially on areas like safety), and others can make it challenging to set achievable or reasonable targets in all areas.

The NJTPA's Performance Results process should help inform the selection of performance measures by providing information about which measures really matter in evaluating a project's

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[1] See, for example, National Cooperative Highway Research Program Report 666: *Target-Setting Methods and Data Management to Support Performance-Based Resource Allocation by Transportation Agencies.* Transportation Research Board, October 2010.

results, and which measures can realistically be evaluated given available data and analysis tools. The Performance Results process should also inform target-setting by helping the NJTPA to determine how measures interact and the extent to which external factors contribute to actual performance results. In addition, a sustained Performance Results process over several years will provide actual project results in various improvement categories, helping the region set more realistic performance targets.

1.3.3 Assess Needs and Evaluate Specific Improvement Concepts.

The NJTPA Strategy Evaluation is conducted periodically to assess how well the region's transportation system meets residents' needs. The study also generates recommendations for specific strategies and programs to benefit specific areas throughout the MPO region. As a follow-up to the Strategy Evaluation effort, the NJTPA conducts Strategy Refinement to develop concepts for future multi-modal improvement projects on the highway and transit networks. Each concept includes an assessment of specific needs and strategies, potential transportation improvements, and anticipated performance benefits across each relevant goal area. When necessary, more extensive corridor studies, alternatives analyses, and specific subregional studies are conducted as part of the NJTPA's Project Development Work Program (PDWP) to investigate the feasibility and potential impacts of various projects, strategies, and policies, in order to narrow down a long list of options.

Performance Results analysis should help to define potential benefits that might be anticipated in Strategy Evaluation or other planning studies. It might also point out contextual aspects, interactions among related actions, temporal effects, or other factors that could affect performance outcomes of particular strategies.

1.3.4 Allocate Resources.

The allocation of resources (time and money) is guided by the integration of the preceding steps into planning, programming and project development processes. The NJTPA works with its partners and implementing agencies to develop the Transportation Improvement Program (TIP) and applies Project Prioritization Criteria to prioritize projects. Like other Metropolitan Planning Organizations across the country, the NJTPA has established prioritization procedures to evaluate and score projects. The NJTPA's Project Prioritization process consists of two steps:

- Application of *Project Prioritization Criteria.* During the development of the Project Development Work Program (PDWP), projects are evaluated and scored based on technical measures of how well they fulfill the goals of the RTP. This is expressed in the Project Prioritization Criteria. All projects eligible for the TIP are ranked using these scores.
- Application of *Additional Priority Factors.* Additional factors such as feasibility of project delivery, funding availability and project timing are then considered. This is based on consultation and negotiation among the NJTPA Central Staff, professional and elected officials from the subregions, as well as staffs of the New Jersey Department of Transportation (NJDOT) and NJ Transit.

The Performance Results process is designed to provide information about the attributes of projects that produce desired results in terms of the overall regional goals and objectives. The

NJTPA can use data and qualitative information on project outcomes to improve the way in which projects are evaluated and scored in the Project Prioritization process.

1.3.5 Design and Implement Projects, Policies, and Strategies.

Detailed study and project implementation are the responsibility of the NJTPA subregional members and/or the region's implementing agencies, including NJDOT, NJ Transit, and Transportation Management Associations (TMAs). Many decisions that affect a project's performance occur during the design phase. One of the key benefits of the performance results process will be to better inform project design by providing better information about which projects have worked in the past, which have not produced desired results, and why.

1.3.6 Measure and Track Performance Results.

Effective decision-making in each element of the performance management framework requires that data be collected, cleaned, accessed, analyzed, and displayed. The analysis should indicate how close the NJTPA region is to achieving its targets and identify the actions necessary to improve results in the future.

The process for evaluating the results of completed projects is detailed in Section 3 of this Guidebook. The basic steps are to assign appropriate measures to each project type, determine the appropriate study area and time frame of the analysis, compile data to support the evaluation of performance measures for each of the projects, and finally conduct the evaluation of performance results. For more details, see Sections 2 and 3.

In addition to project-level measures, the NJTPA and its partners collect and report data that can be used to evaluate system-level or program-level performance measures. A combination of project-level and system-level measures are used to evaluate the results of transportation investments, operational strategies, and policies. Notably, different stakeholders are interested in different levels of detail about the results of a project, strategy, or policy. More information about the appropriate scale of analysis for each measure is presented in Sections 2 and 3.

1.3.7 Feed-Back Performance Results to Previous Steps.

The last step in the cycle is critical to performance management. Feedback about the results of implemented projects, policies and strategies can help the NJTPA and the region's implementing agencies reassess goals, objectives, performance measures, and targets to take into account actual outcomes; make improvements to the needs assessment process; reassess resource allocation policies and decisions; and refine the design and implementation of future projects, policies, and projects.

A variety of performance reporting and tracking tools are available today or can be easily tailored to the NJTPA's specific needs. To develop a successful system, the NJTPA need not attempt to have a complete performance management system in place on day one, but instead start with monitoring and reporting those measures that can be evaluated today, adding capabilities in the future as the state of the practice catches up with the NJTPA's needs.

The design of performance reports is a crucial step in the process. Performance reports need to be flexible enough to accommodate the needs of everyone from a high-level executive to technicians in the field. Often this means different combinations of measures will be reported to different stakeholders.

Measures and results can be reported via an online "dashboard" or electronic reporting tool, or in more traditional hard copy reports and brochures. Effective reports typically contain the following information:

- Measures organized by goal area;
- The current value of each measure in relation to a specified target;
- Trend information;
- Future projections of performance (if appropriate); and
- Background material and/or a narrative so that the audience can better understand the results.

Performance reports should highlight existing and potential problems or opportunities for improvement, and they should present findings with appropriate context. Given the significant uncertainty in estimating precise impacts or in discerning cause and effect for many measures, reports should advise appropriate caution in drawing conclusions. Reliable and accurate interpretations should be offered, and results should not be taken to mean more or less than the data can actually demonstrate. Presenting numbers and graphics alone is very often insufficient; an executive, decision-maker, or technician would need to determine the potential reasons for a trend or result, which can then be used to improve future decision-making.

1.4 What Are the Challenges in Developing and Applying a Performance-Based Planning Process at a Project-Level Analysis?

The NJTPA *Performance Results* study has underscored both the challenge of discerning project impacts and the importance of doing so. Challenges include the following:

- **Limits on data:** Evaluations are often challenged by a lack of data detail, extent, depth, time, quality, and, in too many cases, complete lack of data itself. An example is population and employment data. Although these data are available at the Census Block or Census Tract level from the U.S. Census Bureau, even these levels of analysis may be too disaggregate to accurately measure a project's net impacts, particularly when a project must be compared to one or more "control" study areas in which no improvement was made.

- **Isolating project impacts:** A significant challenge faced by this project was 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 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.

- **Balancing quantitative evaluations with qualitative:** Even with the best data, it is unlikely that some important types of impacts (such as economic or livability effects of small operational improvements) will be measurable on an individual project basis.

- **Expense and challenges in conducting project evaluations:** The methodologies proposed in this project recognize MPO planning resource constraints, erring toward ease of use rather than providing additional layers of complexity. Analysis tools in several areas (e.g., estimation of VMT or mode share impacts) are often not yet sophisticated enough to conduct a project-level performance evaluation. In other cases, tools and techniques may be available but they may require extensive training and resources to properly use for a project-level evaluation (e.g., macroeconomic analysis tools).

It is important to recognize that these challenges, even cumulatively, do not argue against pursuing a performance-based approach to decision-making at the NJTPA. Rather, such a process will by necessity be developed incrementally, using data and measures that can be readily evaluated today and adding measures in the future as challenges are addressed and overcome over time.

1.5 How Can an Assessment of Performance Results Be Useful to NJTPA Decision Makers?

Section 1.3 details how Performance Results analysis could benefit each step in NJTPA's planning process. More broadly, assessing the results of transportation investments and policy reflects responsible management and stewardship of public resources. Particularly in a time of constrained resources, it is important for public agencies to demonstrate accountability and make adjustments to policies and priorities in an effort to ensure the transportation system does in fact help move the region towards its goals.

NCHRP Report 660[2] lays out several recommendations for establishing and applying a system of performance-based planning and management, including the feedback from project results to previous steps in the planning and decision-making process. The focus of the Guidebook is the application of a performance management program to actual transportation agency decisions. According to the guidebook:

> *Performance reporting inevitably occurs as part of any performance management program, and the form and frequency of performance reports should not be an afterthought. Reporting performance is in itself a key component in developing a culture of performance management throughout the DOT. Frequent public reporting of results can produce numerous positive results, including:*
>
> - *Building credibility, accountability, and trust between the DOT and its constituencies, including the public, the legislature, and the agency's own employees;*

[2] National Cooperative Highway Research Program Report 660: *Transportation Performance Management: Insight from Practitioners.* Transportation Research Board, 2010.

- *Strengthening support for budget and program proposals;*
- *Promoting information sharing between districts and offices that experienced differing results; and*
- *Creating an expectation of continued reporting and incremental improvements which serves to solidify the performance program.*

…Agencies should employ a balance of leading indicators (signals of future performance) and lagging indicators (measures of existing or past performance) to inform the resource-allocation process. To better calibrate assumptions about the impact of future funding levels, performance measures should link system inputs, needs, and outputs. Ideally, performance measures should be sensitive and focused enough to show the impacts of allocation decisions on specific policies and programs of allocation. Time-series data also may show diminishing returns on a particular strategy or program, indicating that it has become less effective over time and that a change in strategy is needed.

Although measures should be updated periodically to ensure consistency with agency priorities and strategic plans, there are significant benefits associated with maintaining a stable collection of measures. Internally, consistently collecting and reporting the same measure for several years enables the in-depth analysis of long-term trends. Externally, consistent measures can make it easier for stakeholders to fully appreciate progress that is being made or new challenges that arise.

2.0 How to Use This Guidebook

2.1 Purpose

This Guidebook is intended to lay out methodologies for evaluating the results of completed projects and implemented policies and strategies. The Guidebook contains detailed step-by-step instructions for evaluating key project-level performance measures across ten RCIS project types and spanning all applicable regional goals.

2.2 Structure of the Guidebook

The Guidebook is fashioned as a set of performance measure “recipes” to be made available to regional planners. The Guidebook is divided into ten sections corresponding to the ten RCIS project categories:

3.1 Bridge and Roadway Preservation Projects

3.2 Roadway Enhancement, ITS, and Safety Improvement Projects

3.3 Roadway Expansion Projects

3.4 Transit Preservation Projects

3.5 Transit Enhancement Projects

3.6 Transit Expansion Projects

3.7 Freight Rail Projects

3.8 Freight Roadway Projects

3.9 Transportation Demand Management Projects

3.10 Bicycle and Pedestrian Projects

Each section begins with a summary table listing all the applicable measures for that project type, presented in order by NJTPA goal area. Each subsection is then organized in the logical order in which measures should be evaluated.

Each goal area is introduced with a discussion of the following:

- **Interdependencies** between data, analysis tools, and performance measures from other goal areas;
- **Data inputs and sources**;
- The appropriate **geographic scale** of the performance results analysis; and
- The appropriate **time frame** of the performance results analysis.

Following the introductory sections, the **analysis steps** for evaluating each applicable measure are presented in detail. Each carries detailed instructions on data ingredients (identifying data sources and appropriate coverage in time and geography), calculations (with clear illustration of typical values and units and mathematical formulas), analytical tools needed (particularly for estimation and processing), and examples of results.

Recommendations accompany the instructions within the Performance Results Guidebook, identifying caveats and considerations for the various measures, suggesting how to improve data collection, and noting alternative measures for further exploration.

The following table summarizes the list of performance measures by the six NJTPA Goals and the ten RCIS Project Categories.

Table 1: Summary List of Performance Measures by the NJTPA Goals and the ten RCIS Project Categories.

PERFORMANCE MEASURES BY NJTPA REGIONAL GOAL	ROADWAY AND BRIDGE PRESER-VATION PROJECTS	ROADWAY ENHANCE-MENT, ITS AND SAFETY IMPROVEMENT PROJECTS	ROADWAY EXPANSION PROJECTS	TRANSIT PRESER-VATION PROJECTS	TRANSIT ENHANCE-MENT AND TRANSIT ORIENTED DEVELOP-MENT PROJECTS	TRANSIT EXPANSION PROJECTS	FREIGHT RAIL PROJECTS	FREIGHT ROADWAY PROJECTS	TRANSPOR-TATION DEMAND MANAGE-MENT 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			•				•	•		

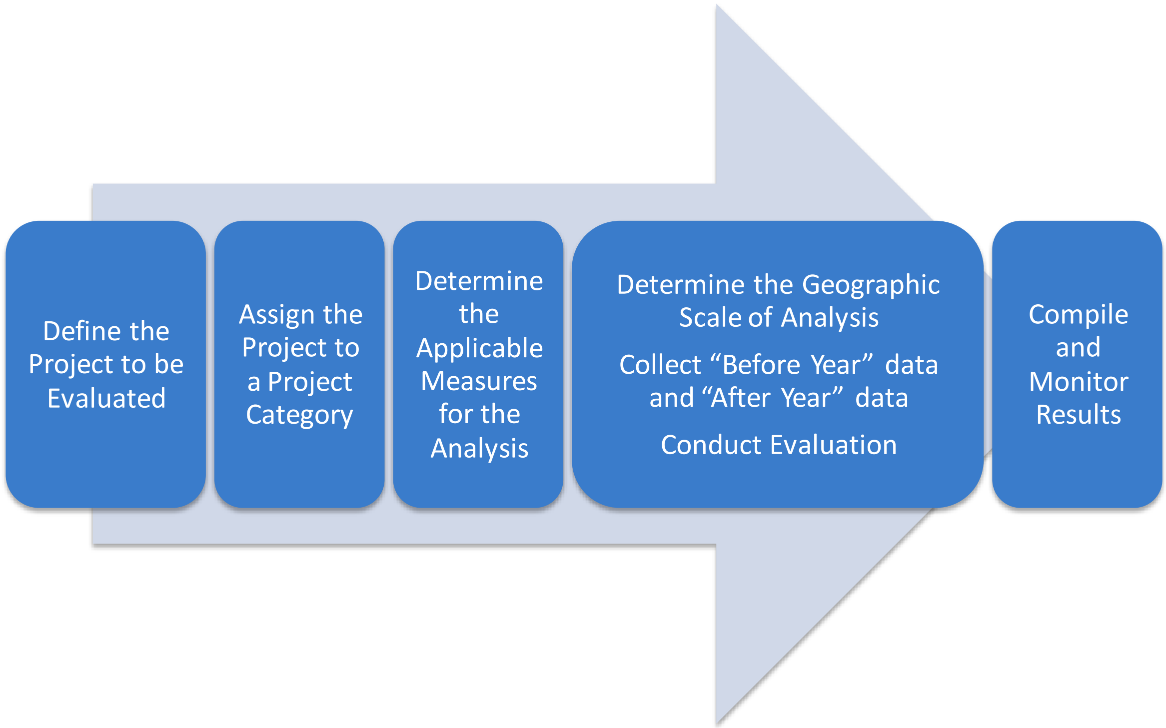
PERFORMANCE MEASURES BY NJTPA REGIONAL GOAL	ROADWAY AND BRIDGE PRESER-VATION PROJECTS	ROADWAY ENHANCE-MENT, ITS AND SAFETY IMPROVEMENT PROJECTS	ROADWAY EXPANSION PROJECTS	TRANSIT PRESER-VATION PROJECTS	TRANSIT ENHANCE-MENT AND TRANSIT ORIENTED DEVELOP-MENT PROJECTS	TRANSIT EXPANSION PROJECTS	FREIGHT RAIL PROJECTS	FREIGHT ROADWAY PROJECTS	TRANSPOR-TATION DEMAND MANAGE-MENT PROJECTS	BICYCLE AND PEDESTRIAN PROJECTS
Net transit ridership (Use as an intermediate measure)					•	•				
Customer Satisfaction	•	•	•	•	•	•	•	•	•	•
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		•	•		•	•	•	•		•
REPAIR/MAINTENANCE/SAFETY/SECURITY										
Crashes/Crash rates		•	•	•	•	•	•	•		•

PERFORMANCE MEASURES BY NJTPA REGIONAL GOAL	ROADWAY AND BRIDGE PRESER-VATION PROJECTS	ROADWAY ENHANCE-MENT, ITS AND SAFETY IMPROVEMENT PROJECTS	ROADWAY EXPANSION PROJECTS	TRANSIT PRESER-VATION PROJECTS	TRANSIT ENHANCE-MENT AND TRANSIT ORIENTED DEVELOP-MENT PROJECTS	TRANSIT EXPANSION PROJECTS	FREIGHT RAIL PROJECTS	FREIGHT ROADWAY PROJECTS	TRANSPOR-TATION DEMAND MANAGE-MENT PROJECTS	BICYCLE AND PEDESTRIAN PROJECTS
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					•	•			•	

2.3 How to Apply the Methodologies Contained in This Guidebook

The general process for evaluating the performance results of projects is shown in Figure 2.

Figure 2 Process for Evaluating Performance Results



Step 1) Define the Project to be Evaluated

The analysis of performance results begins with definition of the project to be evaluated and is an important step in the process. The performance results process was established to analyze discrete projects. However, one project often cannot be examined in a vacuum. Many projects may be implemented in close geographic proximity that all work towards the same goals and objectives, or perhaps even unintentionally work against each other. The definition of the project should be performed in close consultation with the implementing agency.

Step 2) Assign the Project to a Project Category and Select the Appropriate Guidebook Chapter

Once the project is defined, the next step is to determine which project category is most appropriate. Often, this decision will have been made during the programming process, as projects should be assigned to one of the ten RCIS categories used by the NJTPA and its partners. The chapters in this Guidebook generally reflect the ten RCIS categories and thus are intended to be used as a step-by-step guide to conducting Performance Results assessments for specific project categories. However, during Step 1, a group of projects from different RCIS categories may have been grouped together into one "project" to be evaluated as part of this process. In these cases, or when a project is a "one-of-a-kind" project that defies categorization, judgment must be used to determine how to assign it to a project category or whether to use measures and evaluation methodologies from more than one chapter to complete the analysis.

Step 3) Determine the Applicable Measures for the Project

Using the measures provided in each project category type, determine which ones are applicable to the project. This process will require technical judgment and discretion, as some measures may not easily fit all projects of that type due to nuances in the composition of the improvement design or program. For example, only projects that add a new link to the transportation system will measurably affect network connectivity. As another example, although measures used in planning and environmental studies leading up to a project's implementation can provide a good guide for which performance measures will be appropriate to include in a Performance Results evaluation, there may not be a one-to-one correlation, particularly for environmental measures. Even where projects have been granted a "Finding of No Significant Impact" (FONSI) as part of the environmental permitting and approval process, they may in fact have had significant impacts for reasons beyond the control or foresight of project planners and designers, despite their best intentions.

Another important consideration is that some projects may require the use of measures (and/or intermediate measures) abstracted from methodologies for other project types in order to properly assess their unique characteristics. Once again, the specific knowledge of the project and an understanding of its key attributes that are appropriate to measure will be an important consideration for practitioners in tailoring performance measurement processes appropriately.

Finally, all of a project's impacts should be considered as a group and assessments made based on all available data and analysis. It is likely that most projects will have a mix of positive outcomes and some negative consequences. Decisions also ultimately are made based on a combination of qualitative and quantitative information, so it would be acceptable if some measures can only be evaluated qualitatively.

Step 4) Identify Geographic Scale of Analysis; Collect "Before Year" Data and "After Year" Data; Then Conduct Evaluation as Detailed in Each Chapter of the Guidebook

The major challenge in performing this step is to determine the impacts that can be attributed to each of the selected projects. For instance, if a given area experienced growth in economic measures and transit ridership following completion of a transit improvement, to what extent was that growth attributable to the project, or simply a product of other external forces which would have had an impact regardless of the project?

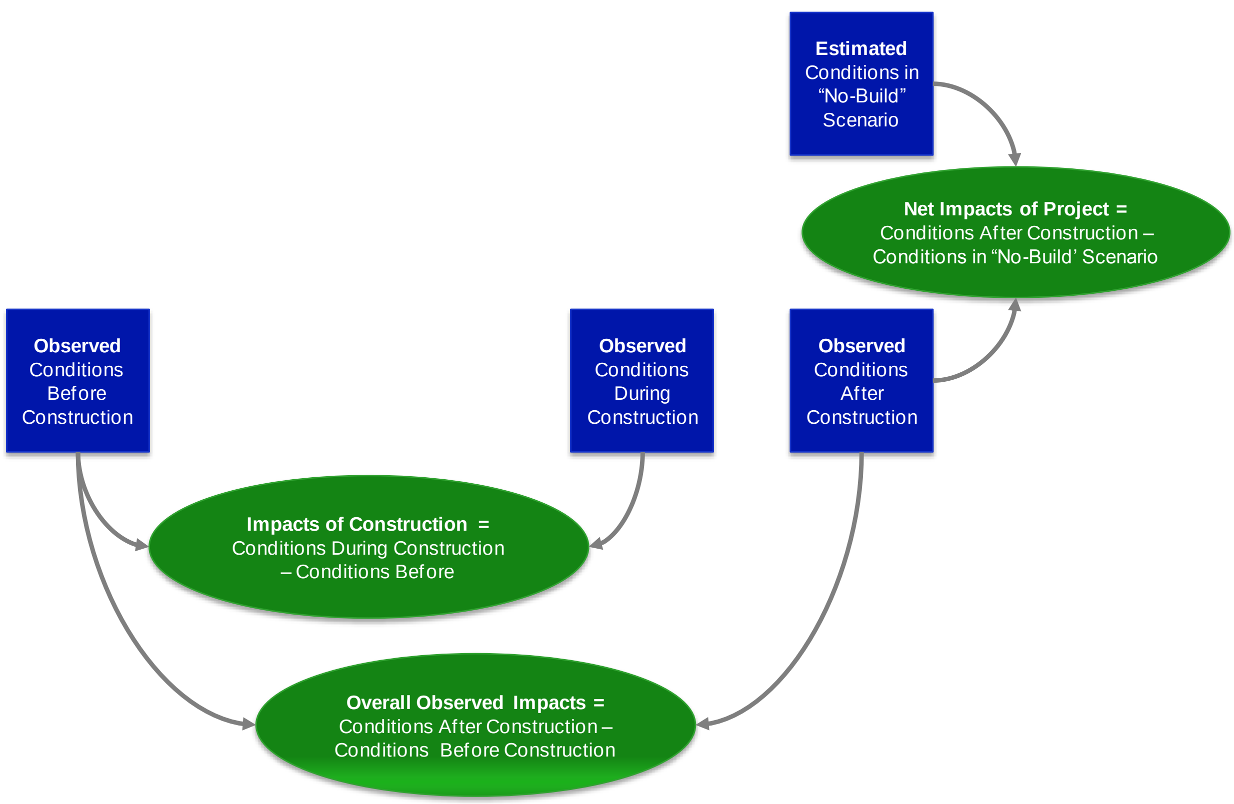
The geographic scale of an analysis is important to consider: A project may have regional benefits (job creation) but localized negative benefits (noise and emissions impacts). A project may solve a problem in one location (an intersection bottleneck) only to move the problem to another location (a lane drop downstream creates a new bottleneck).

The selection of the year(s) for the analysis may affect the outcome of the analysis (due to economic fluctuations, weather, construction, or a whole host of unknowns). Some benefits accrue over time (e.g., accessibility improvements and VMT reduction associated with a transit-oriented development), while others may diminish over time (e.g., travel time savings due to a highway capacity increase). A program of projects may be implemented over time (e.g., rail grade separations), but the benefits may not be realized until the final project is completed (e.g., increased rail travel speeds).

Figure 3 shows the various time frames for which data should be collected. Using the Transit Expansion project category and the performance measure “person-miles traveled by mode” as an example, compared to pre-construction conditions, transit usage may increase slightly during construction as capacity decreases on the roadway and delay increases. Transit ridership may then decrease after completion of the project as the roadway has less congestion and delay. Impacts can be estimated as follows:

- The overall impact of the project can be estimated by comparing person-miles traveled by mode after the project to mode share before the project.
- The net impact can be estimated by comparing person-miles traveled by mode after the project to person-miles traveled by mode in a hypothetical “no-build” scenario.
- Finally, the impacts associated with construction can be estimated by comparing person-miles traveled by mode during construction to mode shares before and after construction.

Figure 3. Time Frames for Data Collection and Calculations of Impacts



Projects also may affect multiple modes (passengers and freight, motorized and non-motorized users, rail transit and bus transit). Projects also may cause mode shifts (those that affect travel time or cost). The evaluation methodologies may be mode-specific, and therefore it may be necessary to consult the methodologies for more than one project type in order to conduct a complete, multimodal evaluation of performance results.

Each evaluation report should contain the following information about the project's results:

- A project description, including maps and photos of before-and-after conditions in the study area, as available from the project's planning documents, newspaper articles, and agencies and firms involved in the project's construction or implementation.

- A summary of the project's main attributes: the project's RCIS category; its cost; the extent of impacts (i.e., local, regional, or interregional); affected modes.

- A description of the context in which the project was implemented, before and after completion. For example, for a highway construction project: What are the characteristics of the built and natural environment in the study area? What types of passengers and freight trips are served by the facility? Were any other major projects built in the same corridor or on a parallel facility during the analysis period that may have affected flows of passenger and freight traffic? Were there any major policy changes in the analysis period (e.g., toll or transit fare changes) that may have affected how the facility is used? Were there any major economic fluctuations during the analysis period?

- A list of the performance measures to be evaluated, by goal area, and an indication of which measures can be evaluated quantitatively and which can be evaluated qualitatively.

- For each measure evaluated, tables, figures, maps, and graphics to convey what changes occurred during the analysis period as a result of the project.

- For each measure evaluated, a comparison of that project's impacts to regional or system-wide impacts.

- A summary of the project's impacts across all measures and goal areas, with an explanation of why a project may have over or underperformed in any given goal area. All of a project's impacts should be considered as a group and assessments made based on all available data and analysis. It is likely that most projects will have a mix of positive outcomes and some negative consequences. Decisions ultimately are made based on a combination of qualitative and quantitative information.

Step 5) Compile and Monitor Results

Over time, as a statistically-valid sample of project-level impacts is assessed for each project type and in each goal area, results should be assembled and compared against regional and subregional averages to determine which projects have over or underperformed. Organizing the large volumes of data that would need to be compiled would be one of the challenges for the NJTPA and its members in such an effort.

2.4 Challenges in Implementing a Performance Results Evaluation Process

The methodological application process for many of the performance measures described in this Guidebook is new and innovative. In fact, it appears that no Metropolitan Planning Organization transportation agency in the United States has developed as defined and broad-based a methodological approach for such a large array of performance measures as are presented in this document. Further, very few (if any) such agencies routinely conduct a comprehensive assessment of project results on a regular basis. For many of the reasons mentioned in earlier sections, analysis performed for this study confirms that there is rarely a "one-size-fits-all" approach in applying any single measure to a specific project, and it will be necessary to carefully consider appropriate adaptations or adjustments to methodologies and data.

Development and implementation of transportation agency-based comprehensive performance results process is still in its formative stages in the U.S. Thus, the key to advancing implementation of performance measures for the NJTPA and its partners will be to start a dialogue on the measures and methodologies contained in this Guidebook, and to seek common ground in selecting a limited set that can be evaluated today using existing data sources and current evaluation tools and techniques. Then, as the state of the practice evolves, additional measures can be added (and existing measures adjusted as necessary) to account for better data collection practices and/or analytical tools. Items to resolve include:

- **Determining who will be responsible for applying the evaluation methodologies contained in the guidebook.** The Federal government has not formally enacted performance reporting requirements, but it is likely that the responsibility for preparing periodic performance reports will reside with all recipients of Federal transportation funding, meaning NJDOT, NJ Transit, PANYNJ, and the NJTPA all will have some role in evaluating their respective Federally-funded projects. The evaluation process will require an additional dedication of staff resources, so the various agencies need to develop an implementation plan to carry out the project evaluation process.

- **Establishing lines of communication with data gatekeepers and facilitating agreements on data transfers and responsibilities.** Regardless of who is carrying out the evaluations, each agency will need to determine how to share relevant data in a timely manner so that evaluations can be conducted on a predetermined timeframe.

- **Maintaining data consistency and implementing a data quality control procedure.** In order for the evaluation process to compare project results over time, data must be consistent and of high enough quality to be credible. It is likely that each operating agency will need to maintain its own data, but as data management systems evolve and are improved over time, the needs of the Performance Results process must be considered so that evaluations can be replicable. The expectation is not that obsolete data will be maintained in perpetuity just to support the Performance Results process, but instead that all stakeholders will be involved in the evolution of data sets over time to support day-to-day operations of each agency and to support the Performance Results process.

- **Marketing and promoting the importance of the Performance Results process to key decision makers and the public.** With or without a Federal mandate to conduct Performance Results evaluations, assuming NJTPA and its partners agree on the value of this process, all parties will need to work together to promote the process as useful and beneficial to the region over the long term. Some of the messages included in Section 1 of this Guidebook could be useful, for example emphasizing accountability in the use of scarce resources, improving the design and implementation of future projects, and demonstrating the value of transportation system investments to New Jersey's economy, its environment, and its quality of life.

Finally, based on recommendations prepared based on lessons learned from the study analysis process, this Guidebook provides a good starting point to identify and prioritize performance measure areas that need further research and development. Some recurring themes include:

Improving availability of data to support evaluation of mobility and reliability performance measures. NJTPA should work closely with the FHWA and other partners who are conducting research projects related to understanding and improving measurement of travel reliability. For example, the second Strategic Highway Research Program (SHRP 2) has a variety of research activities underway in the areas of mobility and reliability.

Building more robust analysis tools to support a shift towards measures of accessibility. Improving the understanding of the impacts of transportation investments on accessibility could provide a powerful tool to decision-makers, as well as businesses and members of the general public who are making decisions about where to locate. In turn, if the impacts of transportation investments on land values were better understood, this link could one day lead to new funding streams based on capturing an increment of land value increases due to transportation investments.

Undertaking customer satisfaction surveys across a broader base of users and at a finer geographic level of detail. Transportation agencies in general need to do a better job of understanding how transportation investments are perceived by their customers. Performing customer satisfaction surveys more regularly and in connection with specific investments can provide better information to the NJTPA and its partners as future projects are designed and implemented. 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.

Organizing and archiving environmental data collected as part of regular environmental studies. State and Federal regulations require transportation and development agencies to prepare documentation of existing conditions and forecasts of environmental impacts of a wide range of investments and policies. Almost every environmental study is conducted as if there had never been another environmental study conducted in the state. Moreover, at the conclusion of each study, much of the painstakingly-collected data end up in a report on a shelf, never to be used again. There is a virtual treasure trove of data available in plans and environmental documents that could be archived for ongoing monitoring of conditions. The NJTPA should develop a consistent way of compiling and reporting information from environmental studies for ease-of-comparison and analysis over time.

Supporting improved coordination between environmental monitoring activities and transportation performance reporting, particularly in the areas of air and water quality and impacts on sensitive lands. Many of the analysis methodologies described in this guidebook 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. 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 do 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. Agencies are hesitant to encourage monitoring and reporting for political reasons as well. 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.

Improving 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 opportunities that improve 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.

Making parcel-level land-use data more accessible for purposes of monitoring land use changes over time. 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, figures must often 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 databases 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).

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.

3.1 Bridge and Roadway Preservation Projects

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 projects.

Roadway 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 projects.

Contents of This Section

Suggested Work Flow for Bridge and Roadway Preservation Projects

The following sequence of goal areas for this project category was developed specifically to enable an ordered evaluation of performance measures. This allowed calculations from earlier intermediate (and final) measures in one goal area to serve as inputs for measures in other goal areas:

1. Repair/Maintenance/Safety/Security Measures

2. Economy Measures

3. User Responsiveness Measures

The methodology for calculating each measure is presented in the following sections. Measures in **BOLD** in the table above can be calculated independently. The remaining measures rely on interdependent data, or, in some cases, depend on each other. It is not recommended that system preservation projects be evaluated independently. The state of the practice in asset management is to use a system-based approach to making investments in pavement and bridge preservation. This approach uses a least lifecycle cost analysis (LCCA) approach which focuses on how to preserve an asset at the system level over the long term at the least cost to the agency.

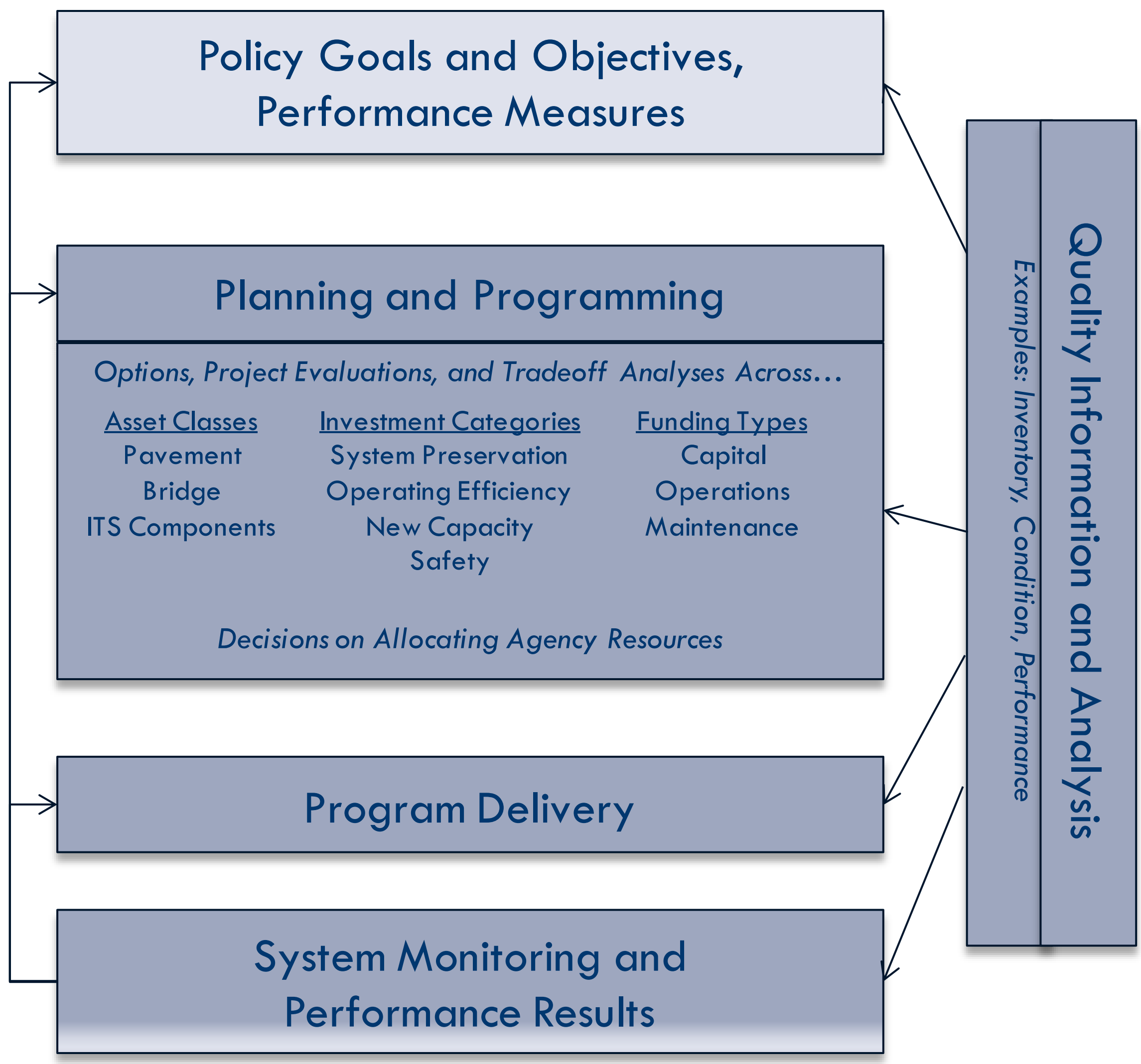
3.1.1 Evaluating Repair/Maintenance/Safety/Security Measures

NJTPA Repair/Maintenance/Safety/Security Goal - Maintain a safe and reliable transportation system in a state of good repair.

Only repair and maintenance measures are discussed in this section.

Interdependencies between Data, Analysis Tools, and Performance Measures

The following diagram provides a framework of the asset management process.



Source: AASHTO Asset Management Guide, 2002.

Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Roadway link length	Roadway GIS data, NJDOT Straight-Line Diagrams, Aerial Photos
Pavement characteristics: • Current pavement condition – summary statistics and detailed information about specific structural issues, pavement roughness, etc. • Age of pavement • Detailed data about the materials used for pavement (base, pavement lifts, etc.) • Work history	NJDOT, County and/or Municipalities' Pavement Management System
Bridge characteristics: • Condition of bridge (deck, substructure, superstructure, also potentially individual elements) • Age of bridge • Detailed data about the materials used for bridge (design characteristics, materials, etc.) • Work history	NJDOT, County and/or Municipalities' Bridge Management System
Hourly traffic volumes in each direction and directional distribution of peak hour traffic	NJDOT, county and/or municipalities' Traffic Volume Reports

Geographic Scale of Analysis

An analysis of System Condition measures are conducted at a system level, not at a project level. As such, the geographic scale of analysis is the state, though a regional or corridor analysis could be conducted as well. The reason a systemwide approach is used is because the best set of investments at a system level may not always appear to be the best investment at a project level. For example, there is often a temptation at a policy level to address the worst bridges or worst pavements first. But focusing resources on the worst case bridges and pavements can cause the overall conditions of all bridges or all pavements to decline. This is because the cost to repair an asset increases faster as the condition of the asset declines. Fixes made in the short to mid-term are relatively inexpensive and extend the life of an asset, delaying the frequency with which major investments are required. Eventually, all assets will require substantial reconstruction, but minimizing the frequency of these types of investments reduces the overall cost of maintaining assets over the long term, while enabling transportation agencies to provide a system that is in a state of good repair.

Time Frame of Analysis

Most management systems provide a short term list of investments (1 to 3 years) and a long term estimate of funding needed to maintain a specific condition level.

Analysis Steps

Percent of Pavement in Good/Fair/Poor Condition; Percent of Bridges in Good/Fair/Poor Condition

For repair/maintenance projects that may have other impacts:

- A paving project may be designed to reduce accidents. Conduct a before and after crash analysis. Please refer to the methodology for conducting crash analysis in the Roadway Enhancement, ITS and Safety section.
- Area water quality may be impacted through the implementation of a drainage project(s). Water quality assessment may be needed. Please refer to the Roadway Expansion section for the methodology for evaluating water quality.
- In replacing movable span bridges, Federal Aid Policy Guide 23 CFR 650H, Section 650.809, requires a fixed alternative be considered as a replacement option for all movable bridges. A fixed bridge shall be selected wherever practicable due to lower construction, maintenance, and operational costs. If there are social, economic, environmental or engineering reasons which favor the selection of a movable bridge, a cost benefit analysis to support the need for the movable bridge shall he prepared as a part of the preliminary plan.

Inputs: (Required for each link systemwide for the periods before construction and after construction)

- Link-level pavement characteristics for entire state roadway system in NJTPA region (from NJDOT, counties and municipalities Pavement Management System).

- Bridge inventory and condition data (from NJDOT, counties and municipalities Bridge Management System).

Analysis:

- Perform a systemwide analysis of pavement conditions and bridge conditions, calculating the percentage of all facilities in good, fair, and poor condition before construction and after construction of the project.

Recommendations for Future Performance Evaluation: Repair/Maintenance/Safety/Security Measures

Improve collection and reporting of system-wide preservation measures. NJDOT, counties and municipalities should continue to collect and report system-wide preservation measures to determine if repair and maintenance projects are achieving desired goals from a system-level perspective.

Improve data collection and reports for other repair/maintenance programs that are driven by life-cycle replacement cost. NJTPA should continue to work with NJDOT, counties, and municipalities in collecting and reporting system-wide preservation measures for traffic signs, lightings, guiderails, shoulders, drainages, ITS maintenance data (Variable Message Signs, cameras, etc.) and other items as applicable.

3.1.2 Evaluating Economy Measures

NJTPA Economy Goal - Retain and increase economic activity and competitiveness.

Interdependencies between Data, Analysis Tools, and Performance Measures

There are no interdependencies between the Economy measure "operating cost" and other measures.

Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Operating costs per passenger vehicle mile or truck mile	FHWA and NJTPA survey data
Net crashes by severity	Output measure of **Repair/Maintenance/Safety/ Security** goal area; see above
Cost per crash, by severity	NJDOT Plan4Safety and National Highway Traffic Safety Administration (NHTSA)

Geographic Scale of Analysis

All measures in the Economy goal area should be evaluated within the project limits.

Time Frame of Analysis

It is important to evaluate Economic measures on a continuous basis, using multiple data points from several years before the project and for as many years after the project as data are available.

Analysis Steps

Transportation Costs (Operating Cost and Reduced Future Maintenance Costs)

<u>Inputs:</u> (Required for each link for the periods before construction and after construction)

- Link-level pavement characteristics for entire state roadway system in NJTPA region (from NJDOT, counties and municipalities Pavement Management System).

<u>Analysis:</u>

User costs for pavement and bridge preservation projects can be estimated by examining the wear and tear on vehicles based on pavement condition, using a tool like HERS-ST.

1. Identify pavement conditions in pavement serviceability ratings (PSR) for segments before and after a project. PSR can be provided directly or calculated from other values such as the International Roughness Index (IRI).
2. Use HERS-ST or calculation methods within to estimate the average vehicle maintenance costs associated with various levels of pavement condition. Total user costs within HERS include multiple factors, but adjustments are made for tire wear, maintenance and repair, and depreciation. (See formulas below, based on PSR).

$$PCAFTW = 2.40 - 1.111 \cdot \ln(PSR) \text{ (Tire Wear)}$$
$$PCAFMR = 3.19 + 0.0967\ PSR^2 \times -0.961 \times PSR \text{ (Maintenance and Repair)}$$
$$PCAFVD = 1.136 - 0.106 \cdot \ln(PSR) \text{ (Vehicle Depreciation)}$$

3. Calculate relative difference of user cost factors before and after a project.

Recommendations for Future Performance Evaluation: Economy Measures

Estimate and track actual operating costs over time. Tools like HERS-ST are intended to predict the effectiveness of a package of investments across preservation-related measures. However, the equations and assumptions in HERS-ST or other software can be used to assess the actual operating cost impacts of a transportation investment, given actual information about traffic volumes and roadway conditions instead of predicted values. NJTPA and NJDOT can use HERS-ST as a tool or other software to help to track system performance in terms of operating costs.

3.1.3 Evaluating User Responsiveness Measures

NJTPA User Responsiveness Goal - Provide affordable, accessible and dynamic transportation systems responsive to current and future customers.

Interdependencies between Data, Analysis Tools, and Performance Measures

The User Responsiveness measure "customer satisfaction" is independently evaluated.

Geographic Scale and Time Frame of Analysis

Customer Satisfaction surveys should be performed for as broad a cross section of users of the facility as possible. Origin-destination data, if available, can be used to determine where users live and work, and therefore how to contact likely users for purposes of conducting the survey. Surveys should be conducted regularly, covering periods before and after construction.

Analysis Steps

Customer Satisfaction

Customer Satisfaction is a measure that does not depend on inputs from any other performance measure. Customer Satisfaction measures can be obtained from the results of surveys performed by NJDOT or other agencies after completion of a project.

Inputs:

- Surveys of transportation system users, ideally including information about the relative importance of each system attribute being queried.
- Typical questions on preservation-related customer satisfaction surveys include:
  - Customer perception of improvement's impacts on pavement and/or bridge condition.
  - Impacts of roadway construction: Safety, congestion and delays, access to businesses, environmental impacts during construction.

Recommendations for Future Performance Evaluation: User Responsiveness Measures

Undertake more regular customer satisfaction surveys for all modes. 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.

3.2 Roadway Enhancement, ITS and Safety Improvement Projects

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 projects.

Safety Improvement: 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 projects.

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 projects.

Contents of This Section

Goal Area	Applicable Performance Measures for This Project Type	Page
Land Use/ Transportation Coordination *See page 3.2-37*	• **Population and Employment Density**	3.2-37

Note: The measures listed here and the corresponding methodologies discussed below assume the project focuses on operational improvements and thus primarily impacts travel speeds and safety. Projects that have significant impacts on traffic volumes should be evaluated using the measures and methodologies discussed in the "Roadway Expansion" section. The performance measures that are applicable to a given project within each project type must be determined on a case-by-case basis, using information from the original Purpose and Need statement and guidance in current policy documents, such as the region's Long Range Plan, regarding the performance measures and goal areas that are important to the region.

Suggested Work Flow for Roadway Enhancement, ITS and Safety Improvement Projects

The following sequence of goal areas for this project category was developed specifically to enable an ordered evaluation of performance measures. This allowed calculations from earlier intermediate (and final) measures in one goal area to serve as inputs for measures in other goal areas:

1. System Coordination Measures.
2. User Responsiveness Measures.
3. Environment Measures.
4. Repair/Maintenance/Safety/Security Measures.
5. Economy Measures.

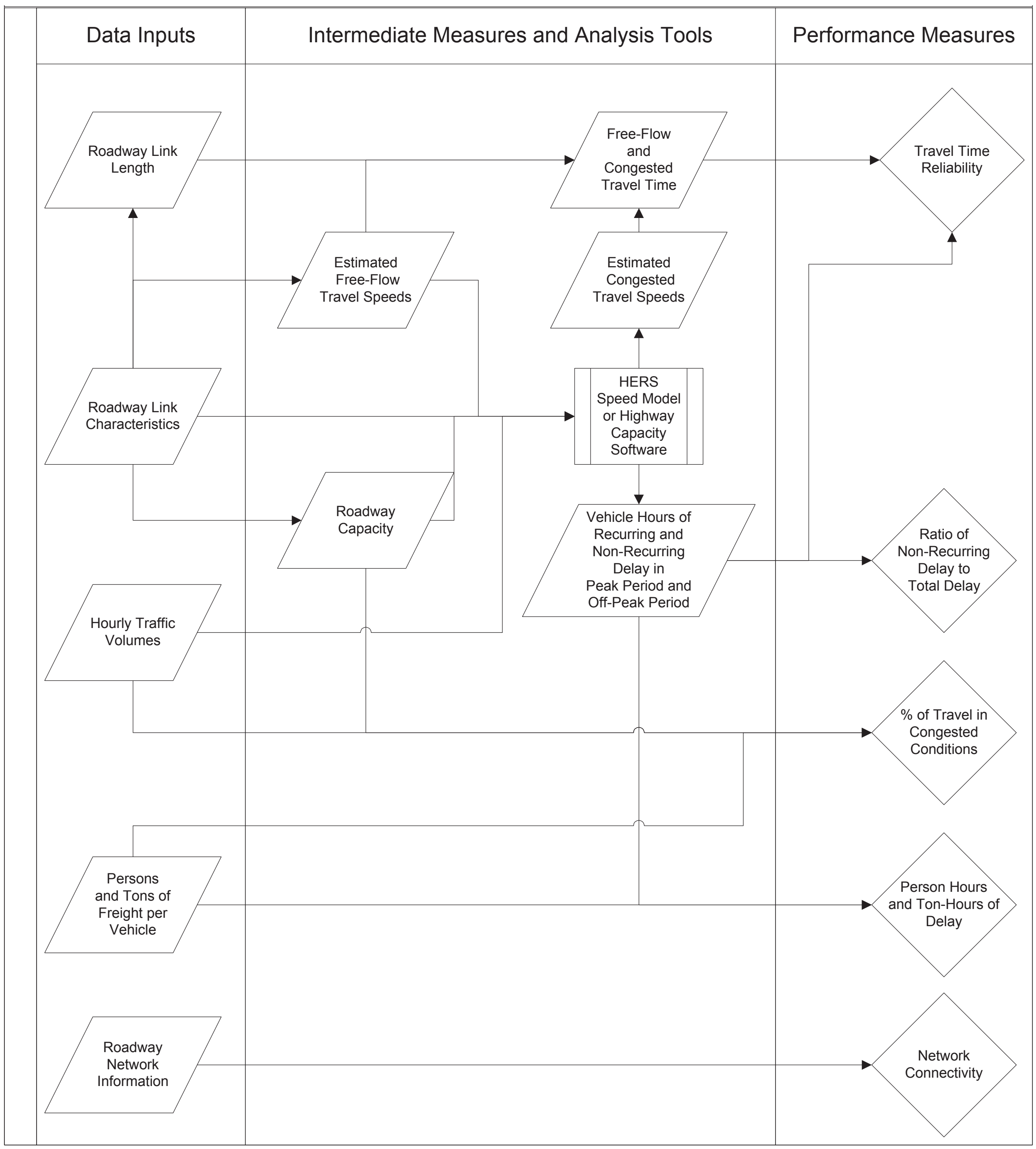
The methodology for calculating each measure is presented in the following sections. Measures in **BOLD** in the table above can be calculated independently. The remaining measures rely on interdependent data, or, in some cases, depend on each other.

3.2.1 Evaluating System Coordination Measures

NJTPA System Coordination Goal - Enhance system coordination, efficiency and intermodal connectivity.

Interdependencies between Data, Analysis Tools, and Performance Measures

The following diagram is a simplification of the interdependencies between System Coordination measures:



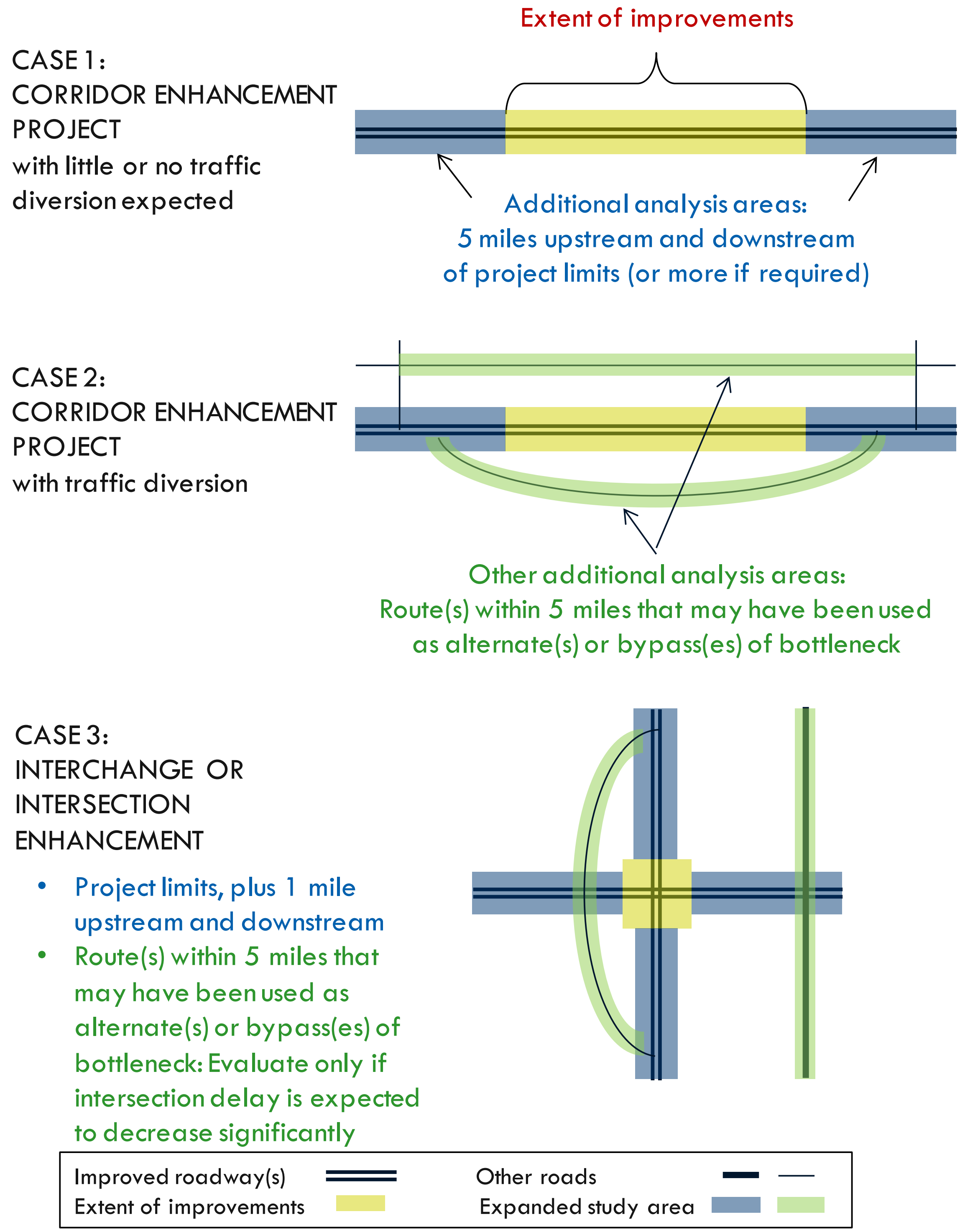
Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Roadway link length	NJDOT Roadway Network File, NJDOT Straight-Line Diagrams, Aerial Photos
Roadway link characteristics: • Roadway functional classification • Number of lanes and lane widths in each travel direction • Number of shoulders and shoulder widths in each travel direction • Terrain type, horizontal and vertical curvature[1] • Vehicle classification and composition (percent trucks and heavy vehicles in traffic flow)[2] • Median type and lateral clearance[2] • Number of access points and bottlenecks per mile[2] • Number of signals and estimated green time for primary flow as a proportion of total cycle length[2]	NJDOT Roadway Network File, NJDOT Straight-Line Diagrams, Aerial Photos [1]Can assume zero grade if terrain information is not available [2]Default value may be available in software. Also can use average values for roadways of similar functional class in same county or in NJTPA region if link-specific data are not available
Hourly traffic volumes in each direction and directional distribution of peak hour traffic	NJDOT Traffic Monitoring System
Persons per vehicle	Household travel survey data collected by NJTPA or American Community Survey 5-year average data for work/commute trips in place/county in which link is located
Tons of freight and TEUs per vehicle	Commodity flow survey data and related databases (e.g., IHS/Global Insight's Transearch database) *Note: The commodity flow data is estimated at regional system level which may not be suitable for use at local level. The use of number of trucks may be more appropriate based on data suitability*
VMT on roadways of similar functional classification as improved roadway, in the county in which the project is located	NJDOT Public Roadway Mileage and Vehicle Miles Traveled, from Highway Performance Monitoring System (HMPS) data
Block lengths and density of nodes	NJTPA GIS
Truck restrictions	NJDOT Truck Map and GIS data

Geographic Scale of Analysis

An analysis of System Coordination measures for roadway projects requires that all affected roadways be evaluated. The figure below shows the geographic extent for which data should be analyzed:



Time Frame of Analysis

The impacts of roadway enhancement projects as measured in terms of System Coordination measures are likely to be most pronounced shortly after completion of the improvement. However, as years pass and induced demand and general economic growth lead to traffic growth, many changes as measured by System Coordination measures may diminish over time. Therefore, it is important to evaluate System Coordination measures using multiple data points from several years before the project, during the construction phase, and for as many years after the project as data are available.

Using delay as an example, compared to pre-construction conditions, delay may increase slightly during construction as lanes are narrowed or closed temporarily, and then decrease as phases of construction are completed. Impacts can be estimated as follows:

- The overall impact of the project can be estimated by comparing delay after the project to delay before the project.
- The net impact can be estimated by comparing delay after the project to delay in a hypothetical "no-build" scenario.
- Finally, delay due to construction can be estimated by comparing delay during construction to delay before and after construction. Or, if enough data are available, delay during construction can be aggregated for the entire construction period and compared to the net impact on delay.

Analysis Steps

Intermediate Measures and Analysis Tools

NOTE: The following steps should be used to estimate free-flow and congested travel times on each roadway link under analysis, where travel time data do not exist. If travel time data are available for the roadway links under analysis, skip these intermediate calculations and begin with estimation of ***Travel Time Reliability*** *below.*

1. Estimate free-flow travel speeds

Inputs: (required for each link in each direction before, during, and after construction)

- Observed average overnight travel speeds or 85th percentile overnight travel speeds in miles per hour. *Use actual observed travel speed data if possible. Where data are not available, use posted speed limit as a proxy for free flow travel speed.*

Intermediate output measures:

- Actual or estimated **free-flow travel speed** in miles per hour (MPH) by link and by direction before, during and after construction. *Typical range: 25-65 MPH. Typically free-flow travel speed will not vary in the before-construction and after-construction periods, but free-flow speed may vary during construction depending on construction conditions.*
- **No-build free-flow travel speed** in miles per hour (MPH). *Typical range: 25-65 MPH. Required by link; before, during and after construction. Use pre-construction free-flow travel speed as proxy for no-build free-flow travel speed.*

2. Estimate link capacity

Inputs: (required for each link in each direction before, during, and after construction)

- Number of lanes in each direction of flow.
- Lane widths, w, in feet. *Use to calculate adjustment factor f_W. Typical range: 10-12 feet.*
- Percent heavy vehicles in traffic flow, HV. *Use to calculate adjustment factor f_{HV}. Typically 0-25 percent, but may be higher in areas with heavy freight traffic.*
- Peak hour factor, or hourly volume during the maximum-volume hour of the day divided by the peak 15-minute flow rate within the peak hour expressed as an equivalent hourly volume; a measure of traffic demand fluctuations within the peak hour. *In the absence of 15-minute traffic volume data, can assume 0.88 for rural conditions, 0.92 for urban conditions.*
- Effective ratio of green time to cycle length, or g/C ratio. *Range of 0.0-1.0; typically falls between 0.40-0.60. Can use observed values, or assume 0.55 for principal arterials, 0.45 for minor arterials, or 0.40 for collectors.*

Calculation:

- Link Capacity = 1900 *Number of lanes * f_L * f_{HV}* Peak hour factor * g/C ratio
- Lane adjustment factor $f_L = 1 + \frac{w-12}{30}$

- Heavy vehicle factor $f_{HV} = \frac{100}{[100+HV(E_T-1)]}$

  Passenger Car Equivalents for Trucks (E_T)

Two-Way Flow Rates	Type of Terrain		
(passenger cars per hour)	**Level**	**Rolling**	**Mountainous**
0-600	1.7	2.5	7.2
>600-1,200	1.2	1.9	7.2
>1,200	1.1	1.5	7.2

- Peak hour factor = hourly volume during the maximum-volume hour of the day divided by the peak 15-minute flow rate within the peak hour. *Default values are 0.92 for urban links and 0.88 for rural links.*
- Ratio of green time to total cycle length = g/C. *Use the minimum g/C ratio if there are multiple signalized intersections in the study area.*

Intermediate output measures:

- **Link capacity** in vehicles per hour by link before, during and after construction. *The maximum capacity for a single lane on a straight, level freeway is around 2,200 vehicles per hour. Calculate link capacity for each link on the study facility (or facilities) for periods before, during, and after construction.*
- **No-build link capacity** in vehicles per hour. *No-build link capacity should reflect conditions that existed before construction.*

3. Estimate congested travel speed and delay for each link in each direction before, during and after construction.

Inputs: (required for each link before, during, and after construction)

- Roadway functional classification. *Use standard NJDOT definitions, for example, "urban principal arterial" or "rural collector".*
- Number of lanes in each travel direction.
- Lane widths in each travel direction. *Typical range: 10-12 feet.*
- Number of shoulders and shoulder widths in each travel direction. *Typical range: 0-12 feet.*
- Terrain type, horizontal and vertical curvature. *Can assume zero grade if terrain information is not available.*
- Vehicle classification and composition (percent trucks and heavy vehicles in traffic flow). *Default values may be available in software. Also can use average values for roadways of similar functional class in same county or in NJTPA region if link-specific data are not available. As an example, percent trucks may range from 0 to 5 percent on suburban arterials to upwards of 20 percent on major interregional corridors and roads serving ports, rail terminals, and industrial areas.*
- Median type and lateral clearance. *Default values may be available in software. Also can use average values for roadways of similar functional class in same county or in*

NJTPA region if link-specific data are not available. For example, many design standards for freeways and expressways call for at least 6-foot left shoulders and 10-foot right shoulders, with center medians and/or median barriers. Local roads and arterials often have painted center medians or no medians or shoulders at all. HERS, HCS, and other software packages assume shoulders at least 6-feet wide provide the maximum benefit to a roadway's capacity, while shoulders less than 6 feet begin to decrease roadway capacity.

- Number of access points and bottlenecks per mile. *Default values may be available in software. Also can use average values for roadways of similar functional class in same county or in NJTPA region if link-specific data are not available. For example, in HERS and HCS, the default value for bottlenecks per mile is 0.083.*
- Number of signals and estimated green time for primary flow as a proportion of total cycle length. *Default values may be available in software. Also can use average values for roadways of similar functional class in same county or in NJTPA region if link-specific data are not available. For example, green time for the primary flow on a major arterial may be 50-60 percent of total cycle length, while the green time for the primary flow at a major intersection of two arterials may be less than 25 percent of the total cycle length, when time devoted to left turn signals, pedestrian walk cycles, and yellow and all-red phases are considered.*
- Traffic volumes in each direction, in terms of Annual Average Daily Traffic (AADT).
- Estimated free-flow travel speed, in miles per hour. *Use value from Step 1.*
- Link capacity, in vehicles per hour. *Use value from Step 2. Can use peak hour link capacity or use link capacity for various times of day (AM peak, mid-day, PM peak, and overnight).*

Analysis tools: The main analysis tool required for this analysis is a set of delay equations. These equations are automated into software such as the Speed Model of the Highway Economic Requirements System (HERS) or Highway Capacity Software (HCS). HERS is capable of modeling a single link or an entire network and is applicable for roadway that is classified as rural collector and above, while HCS can be used to analyze a multi-link corridor such as an arterial or freeway.

Intermediate output measures: The outputs of HERS, HCS, or a network simulation model should include the following:

- **Estimated congested travel speed** for determined hour of the day (or for the entire day if resources permit), by link and by direction of travel, in miles per hour. *Typical range: 0-55 MPH. Note that estimated congested travel speeds can be generated for the before, during, and after-construction time periods using data from each respective period. Congested travel speeds may be as low as 20 MPH or lower on extremely congested roadways, and it is possible that a roadway enhancement project would increase travel speeds to something approaching free flow speed (55 MPH or higher) in the best case, in the years immediately following completion of an enhancement project. Over time, congested travel speeds may begin to decrease as traffic volumes increase, so it is important to monitor speeds for many years following a project's completion.*
- **Vehicle hours of recurring and non-recurring delay** in the peak and off-peak periods, in hours per year. *Vehicle hours of delay on a congested roadway can exceed 1 million hours per year and can drop as low as 10,000 hours per year immediately after implementation of a roadway enhancement project. Over time, the vehicle hours of both recurring and non-recurring delay will gradually increase if traffic volumes increase, so it is important to monitor travel delay for many years following a project's completion.*

4. Estimate no-build congested travel speed and delay for each link.

Inputs:

- Roadway functional classification. *Use standard NJDOT definitions, for example, "urban principal arterial" or "rural collector".*
- Number of lanes in each travel direction.
- Lane widths in each travel direction. *Typical range: 10-12 feet.*
- Number of shoulders and shoulder widths in each travel direction. *Typical range: 0-12 feet.*
- Terrain type, horizontal and vertical curvature. *Can assume zero grade if terrain information is not available.*
- Vehicle classification and composition (percent trucks and heavy vehicles in traffic flow). *Default values may be available in software. Also can use average values for roadways of similar functional class in same county or in NJTPA region if link-specific data are not available. As an example, percent trucks may range from 0 to 5 percent on suburban arterials to upwards of 20 percent on major interregional corridors and roads serving ports, rail terminals, and industrial areas.*
- Median type and lateral clearance. *Default values may be available in software. Also can use average values for roadways of similar functional class in same county or in NJTPA region if link-specific data are not available. For example, many design standards for freeways and expressways call for at least 6-foot left shoulders and 10-foot right shoulders, with center medians and/or median barriers. Local roads and arterials often have painted center medians or no medians or shoulders at all. HERS, HCS, and other software packages assume shoulders at least 6-feet wide provide the*

maximum benefit to a roadway's capacity, while shoulders less than 6 feet begin to decrease roadway capacity.

- Number of access points and bottlenecks per mile. *Default values may be available in software. Also can use average values for roadways of similar functional class in same county or in NJTPA region if link-specific data are not available. For example, in HERS and HCS, the default value for bottlenecks per mile is 0.083.*
- Number of signals and estimated green time for primary flow as a proportion of total cycle length. *Default values may be available in software. Also can use average values for roadways of similar functional class in same county or in NJTPA region if link-specific data are not available. For example, green time for the primary flow on a major arterial may be 50-60 percent of total cycle length, while the green time for the primary flow at a major intersection of two arterials may be less than 25 percent of the total cycle length, when time devoted to left turn signals, pedestrian walk cycles, and yellow and all-red phases are considered.*
- Traffic volumes in each direction before construction, in terms of Average Annual Daily Traffic (AADT).
- No-build free-flow travel speed, in miles per hour. *Use value from Step 1.*
- No-build link capacity, in vehicles per hour. *Use value from Step 2.*
- Vehicle miles traveled (VMT) on roadways of similar functional classification as the improved roadway, in the county in which the improvement is located, before and after construction. For example, if the roadway is a Principal Arterial, use county-wide VMT for Principal Arterials.

Calculation:

- In order to estimate what travel speeds may have been had the improvement not been made (a **"no-build" congested travel speed**), multiply the pre-construction traffic volumes on each link by the growth rate in VMT for all roadways of a similar functional classification in the county in which the project is located, as follows:

$$\text{Volume}_{\text{Post-constr.,"No-Build"}} = \text{Volume}_{\text{Pre-constr.}} * \frac{\text{VMT}_{\text{Countywide,same func.class.,Post-Constr.}}}{\text{VMT}_{\text{Countywide,same func.class.,Pre-Constr.}}}$$

Analysis tools: The main analysis tool required for this analysis is a set of delay equations. These equations are automated into software such as the Speed Model of the Highway Economic Requirements System (HERS) or Highway Capacity Software (HCS). HERS is capable of modeling a single link or an entire network and is applicable for roadway that is classified as minor arterial and above, while HCS can be used to analyze a multi-link corridor such as an arterial or freeway.

Intermediate output measures: The outputs of HERS, HCS, or a network simulation model should include the following:

- **Estimated no-build congested travel speeds** for each hour of the day, by link and by direction of travel, in miles per hour; and
- **No-build vehicle hours of recurring and non-recurring delay** in the peak and off-peak periods, in hours.

5. Calculate congested and free flow travel times for each link, for build and no-build conditions.

Inputs: (required for each link before, during, and after construction)

- Estimated free-flow travel speed, in miles per hour. From Step 1.
- No-build free-flow travel speed, in miles per hour. *From Step 1.*
- Estimated congested travel speed, in miles per hour. *From Step 3.*
- No-build congested travel speed, in miles per hour. From Step 4.
- Length of link to which travel speed estimate applies, in miles.

Calculations: Travel time = Link length / travel speed

Intermediate output measures: (for each link, before, during, and after construction)

- **Free-flow travel time**, in minutes.
- **No-build free-flow travel time**, in minutes.
- **Congested travel time**, in minutes.
- **No-build congested travel time**, in minutes.
- *Travel time values will vary depending on the link length. For shorter links, travel times may be measured in fractions of a minute; for longer links, travel times may be several minutes. As an example, before construction, a 1-mile segment with free-flow travel speed of 60 MPH and a congested travel speed of 30 MPH will have a free-flow travel time of 1 minute and a congested travel time of 2 minutes.*
- *After construction, the free-flow travel speed may increase slightly or stay the same at 60 MPH, but the congested travel speed should increase to something above 30 MPH. Therefore, the after-construction free-flow travel time should be 1 minute or less, and the after-construction congested travel time should ideally reflect some improvement, falling between 2 minutes and 1 minute.*
- *The no-build free-flow travel time can be assumed to be 1 minute (the same as pre-construction conditions), and the no-build congested travel time would likely be greater than 2 minutes, assuming traffic volumes increased between the pre-construction and post-construction periods.*

6. Repeat steps 1-5 for each link, and then aggregate travel times across all links on the roadways being analyzed. The net impact of the project is the difference between actual conditions and "no-build" conditions.

Travel Time Reliability

Inputs:

- Congested travel times, in minutes. *Ideally, use continuous travel time monitoring data or data aggregated to 15-minute increments, or use estimated congested travel time from calculations above. Required for each roadway before, during, and after construction, ideally for 15-minute increments throughout the day. If estimated congested travel time is used, can use peak-period congested travel time.*
- Free-flow travel times, in minutes. *Ideally, use observed average overnight travel times or 85th percentile overnight travel times, based on continuous travel time monitoring data or data aggregated to 15-minute increments. The 85th percentile speed in free-flow conditions is often used as the basis for setting speed limits in engineering analyses, so the 85th percentile overnight travel time is a suitable proxy for free-flow travel time. Or use estimated free-flow travel time from calculations above. Free-flow travel times may vary throughout the day in cases when signal timing changes by time of day.*

Calculations:

- Using congested travel time data, determine the **95th percentile travel times**. *The 95th percentile travel time represents the peak hour travel time on the two worst traffic days of the month. Note that 95th percentile travel time is a guideline. For trips where reliability is not as important, for example recreational trips, a lower threshold may be used.*
- **Buffer time** = 95th percentile travel time – average travel time. *Buffer time, expressed in minutes, represents the extra time (or time cushion) that travelers must add to their average travel time when planning trips to ensure on-time arrival 95 percent of the time. Typical values for a complete trip range from as low as 5 minutes or less in light congestion to a maximum of 30 minutes or more in heavy congestion. On a shorter roadway segment in a particular study area, buffer time could be measured in seconds.*
- **Buffer index** = (95th percentile travel time – average travel time) / average travel time, expressed as a percentage. *Buffer index values closer to 0% indicate that 95th percentile travel time is close to average travel time, i.e. there is little or no variability in congestion. Buffer index values above 100% indicate severe congestion, i.e. travel time is more than twice as long on the worst traffic days than in average conditions.*
- **Planning time index** = 95th percentile travel time / free-flow travel time. *The planning time index reflects how much <u>total</u> time a traveler should allow to ensure on-time arrival 95 percent of the time (in contrast to buffer index, which represents <u>extra</u> time). For example, a planning time index of 1.60 means that for a trip that takes 15 minutes in light traffic a traveler should budget a total of 24 minutes to ensure on-time arrival 95 percent of the time.*
- For an estimate of **"no-build" reliability indices**, use estimated "no-build" congested travel times.*Continuous or 15-minute congested travel times may not be available for the no-build condition because no-build conditions must necessarily be simulated or calculated. Therefore, use peak hour travel times to estimate the improvement in travel time reliability that is attributable to the project.*

<u>Additional resources on travel time reliability include the following:</u>

- Federal Highway Administration Office of Operations Web site, www.ops.fhwa.dot.gov
- Margiotta, Richard, Taylor, Rich, 2006. "Traffic Congestion and Reliability: Making the Connection with Operations: Part 1: Measuring and Tracking Reliability." Institute of Transportation Engineers. ITE Journal, Feb 2006.
- Federal Highway Administration, 2005. "Traffic Congestion and Reliability: Trends and Advanced Strategies for Congestion Mitigation," prepared by Cambridge Systematics and Texas Transportation Institute.
- SHRP 2 Project L03, 2010. "Analytical Procedures for Determining the Impacts of Reliability Mitigation Strategies," prepared by Cambridge Systematics et al.

Ratio of Non-Recurring Delay to Total Delay

Inputs: (required for each link before, during, and after construction)

- Vehicle hours of recurring and non-recurring delay in the peak and off-peak periods. *See Step 3 in calculations of Intermediate Measures.*
- No-build vehicle hours of recurring and non-recurring delay in the peak and off-peak periods. *See Step 3 in calculations of Intermediate Measures.*

Calculations:

1) Divide non-recurring delay by total delay to determine **ratio of non-recurring delay to total delay** for each link. *The ratio should be between 0.0 and 1.0, where values closer to 0.0 indicate roads with little non-recurring delay (e.g., due to incidents) or roads with large amounts of recurring delay (e.g., congestion due to physical roadway characteristics like bottlenecks). Values closer to 1.0 indicate large amounts of non-recurring delay, and may indicate the need for safety or operational improvements to reduce incidents.*
2) Repeat for all links and calculate **average ratio of non-recurring delay to total delay**, weighted by link length or link traffic volume or both.
3) The net impact attributable to the project is the difference between after construction and no-build conditions.

Person-Hours and Ton-Hours of Delay

Inputs: (required for each link before, during, and after construction)

- Vehicle hours of recurring and non-recurring delay in the peak and off-peak periods. *See Step 3 in calculations of Intermediate Measures.*
- Vehicle classification and composition (percent trucks in traffic flow). *Can range from less than 1 percent for local roads to over 20 percent for the busiest highways.*
- Persons per vehicle. *Use 1 for single-occupant vehicles, or up to 50 or more for buses.*
- Tons per truck. *Typical values range from 1 ton for local deliveries up to 25 tons for long-distance trucks transporting ore or building materials. Note: Commodity flow data are estimated at a regional or system level, and may not be suitable for use at local level. The use of observed truck counts may be more appropriate based on data suitability and availability.*

Calculations:

1) Multiply vehicle hours of delay by percent passenger vehicles and percent heavy vehicles to determine passenger vehicle hours of delay and truck hours of delay. Then add passenger and truck hours of delay together to determine total vehicle hours of delay.
2) Multiply personal-vehicle-hours of delay by persons per vehicle to determine **person-hours of delay.**
3) Multiply no-build personal-vehicle-hours of delay by persons per vehicle to determine **no-build person hours of delay**.

4) Multiply truck hours of delay by tons per truck to determine **ton-hours of delay**. If value per ton can be assumed, multiply value per ton by ton-hours of delay to estimate impact of delay in dollars per hour of freight. *Note: Commodity flow data are estimated at a regional or system level, and may not be suitable for use at local level. The use of observed truck counts may be more appropriate based on data suitability and availability.*

5) Multiply no-build truck hours of delay by tons per truck to determine **no-build ton-hours of delay**. If value per ton can be assumed, multiply value per ton by ton-hours of delay to estimate impact of delay in dollars per hour of freight.

6) The net impact attributable to the project is the difference between actual delay and no-build estimates of delay.

Table 3.2-A: Sample of Outputs of Person-hours and Ton-hours of Delay Calculations for One Direction of Flow
(NOTE: Contains fictional data for illustration purposes only)

	Before Construction	During Construction	After Construction	No-Build
Link delay (hours per year)	**390,000**	**420,000**	**150,000**	**500,000**
Percent passenger vehicles	92%	92%	92%	92%
Persons per vehicle	2.1	2.1	2.1	2.1
Annual person-hours of delay	**753,480**	**811,440**	**289,800**	**966,000**
Estimated net project impact ("After Construction"- "No Build") Annual person-hours of delay				**-676,200**
Percent heavy vehicles	8%	8%	8%	8%
Tons per truck	16	16	16	16
Annual ton-hours of delay	**499,200**	**537,600**	**192,000**	**640,000**
Estimated net project impact ("After Construction"-"No Build") Annual ton-hours of delay				**-448,000**

Percent of Travel under Congested Conditions

Inputs: (required for each link before, during, and after construction)

- Hourly traffic volumes, vehicles per hour.
- Roadway capacity, vehicles per hour.
- Persons per vehicle. *Use 1 for single-occupant vehicles, or up to 50 or more for buses.*
- Tons per truck. *Typical values range from 1 ton for local deliveries up to 25 tons for long-distance trucks transporting ore or building materials.*

Calculations:

- Volume/capacity ratio per hour = Hourly traffic volumes / capacity. *If 15-minute traffic counts or continuous traffic counts are available, calculate V/C ratio at finer level of detail. V/C ratio for the "no-build" condition can be estimated using pre-construction capacity and post-construction traffic volume data.*
- The definition of "congested conditions" must be determined by policy. *A V/C ratio between 0.75 and 1.0 typically indicates a roadway is becoming congested, and a V/C ratio above 1.0 indicates severe congestion.*
- **Percent of person-hours-traveled under congested conditions** = Hourly traffic volume * percent of passenger vehicles and buses in vehicle flow * persons per vehicle * share of hours during which roadway operates at or above V/C ratios of 0.75 (for moderate congestion) and 1.0 (for severe congestion).
- **Percent of ton-hours-traveled under congested conditions** = Hourly traffic volume * percent of trucks in vehicle flow * tons per truck * share of hours during which roadway operates at or above V/C ratios of 0.75 (for moderate congestion) and 1.0 (for severe congestion).

Network Connectivity and Continuity

An analysis of Network Connectivity and Continuity is independently processed and should be conducted for each mode using the roadway network, including automobiles and light trucks; heavy trucks, buses and commercial vehicles; bicycles; and pedestrians. The analysis procedures for bicycle and pedestrian facilities can be found in the Implementation Recommendations for the Bicycle and Pedestrian project category (Section 3.10).

<u>Inputs (for automobiles and light trucks; heavy trucks, buses, and commercial vehicles):</u>

- Road network information:
  - Block length or segment length, in feet. *For example, 6,000 feet between interchanges or 300 –foot block length in an urban area.*
  - Density of nodes (intersections) and segments, per mile. *For example, on a major suburban arterial or collector roadway, intersections may be spaced at half-mile intervals. On local streets, there may be 15 or more intersections per mile.*
  - Functional classification. *Use NJDOT functional classifications.*
  - Locations of restrictions on heavy trucks and commercial vehicles (height, width, and/or weight).

<u>Evaluation (automobiles and light trucks; heavy trucks, buses and commercial vehicles):</u> Use GIS to evaluate connectivity of roadway network before and after improvement. Evaluate connectivity on both a local scale and a regional scale. The *Smart Transportation Guidebook*, published in March 2008 through a partnership between Pennsylvania Department of Transportation and the New Jersey Department of Transportation, suggests the following connectivity measures:

- **Internal Connectivity.** Use either of the following two measures:
  - Beta Index — Expressed as a ratio, a beta index is the number of street links in the study area divided by the number of nodes or link ends. *A higher ratio indicates higher street connectivity. Traditional urban grid networks generally yield values above 1.4, while suburban cul-de-sac subdivisions may have beta index values closer to 1.0. A beta index can be calculated for the entire network (all functional classifications), for specific functional classifications (e.g., Interstate Highways, Expressways, and major arterials) or for one functional classification. For heavy trucks, buses, and commercial vehicles the index should take into account any restrictions on vehicle size and weight and restrictions on commercial vehicles.*
  - Intersections per square mile. *Strict grid systems have about 25 intersections per square mile, while conventional branching systems have about one-third to one-half that many.*
- **External Connectivity**
  - The *Smart Transportation Guidebook*recommends that all neighborhoods in the community should be connected to the larger street system at least every ¼ mile.*This measure can be evaluated qualitatively as a "yes/no" indicator.*

- **Route Directness**
  - Route directness measures the distance a vehicle would drive between two points over the roadway network compared to the straight line (or radial) distance between the same two points. *The closer the ratio is to 1.0, the more direct the route; route directness values of 1.2-1.5 describe reasonably connected networks. Route directness may vary depending on the vehicle type being analyzed, due to restrictions on vehicle size and weight and restrictions on commercial vehicles.*
- Connectivity and continuity in the "no-build" condition are simply the conditions that existed before construction.
- Compare route directness analysis for "no-build' and after conditions.

Additional resources on network connectivity include the following:

- Carlos A. Alba and Edward Beimborn (2005), *Analysis Of The Effects Of Local Street Connectivity On Arterial Traffic*, Transportation Research Board Annual Meeting (www.trb.org); at www.uwm.edu/Dept/CUTS//lu/conn.pdf.
- Dill, Jennifer (2004). "Measuring Network Connectivity for Bicycling and Walking." Presented at the 83rd Annual Meeting of the Transportation Research Board, Washington, DC
- Portland Metro (2001), "Street Connectivity Standards," *Planning for Future Streets: Implementing the Regional Transportation Plan*, Portland Metro Regional Services (www.metro-region.org/library_docs/trans/streetconnect.pdf).
- Portland Metro (2004), Street Connectivity: An Evaluation of Case Studies in the Portland Region, Portland Metro (http://library.oregonmetro.gov/files/connectivityreport.pdf).

Recommendations for Future Performance Evaluation: System Coordination Measures

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, 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, NJTPA could improve estimates of link-level travel times, and in turn measurement of Travel Time Reliability, Delay, and the 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, microsimulation 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).

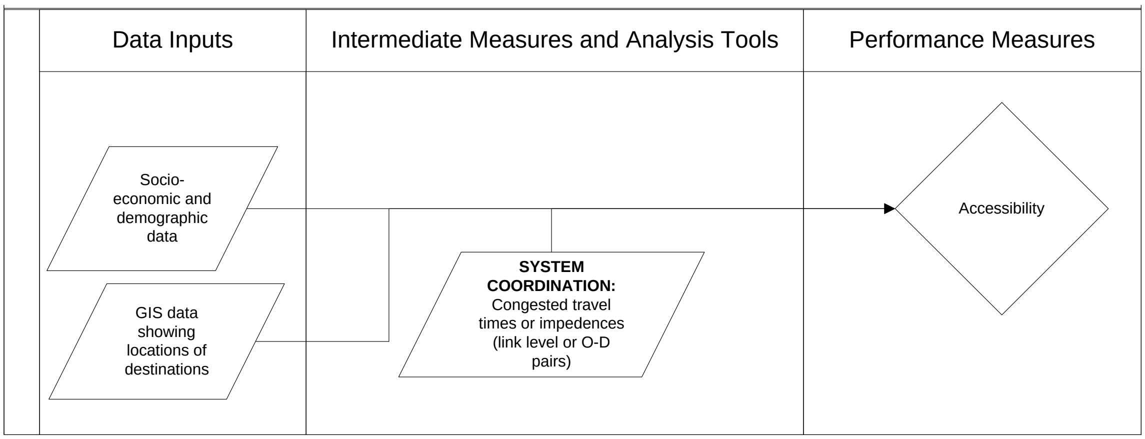
Improve network GIS data, particularly restrictions on oversize/overweight and commercial vehicles. Network connectivity and continuity data could be enhanced with additional information on system condition, facility attributes, and restrictions on use by certain vehicle types.

3.2.2 Evaluating User Responsiveness Measures

NJTPA User Responsiveness Goal - Provide affordable, accessible and dynamic transportation systems responsive to current and future customers.

Interdependencies between Data, Analysis Tools, and Performance Measures

The following diagram is a simplification of the interdependencies between User Responsiveness and System Coordination measures. *Note: Customer Satisfaction is independently evaluated and not included in this diagram. For further information, see page 3.2-27.*



Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Socio-economic, demographic, and employment data (Census Block Group, Traffic Analysis Zone (TAZ), or Place level)	U.S. Census Bureau's American Fact Finder; U.S. Census Bureau's American Community Survey 5-year estimates; U.S. Census Bureau's Local Employment-Household Dynamics data, NJTPA. *Note that ACS 5-year estimates should not be compared for overlapping time periods and are mainly intended to be used for population characteristics, not population totals, particularly at smaller geographies (e.g., Census tracts)*
GIS data showing location of local destinations and opportunities (health clinics, grocery stores and sources of fresh food, local parks and playgrounds, elementary and secondary schools, and neighborhood-oriented retail and service establishments like restaurants, bars, dry cleaners, banks, and hardware stores)	Counties and local municipalities, NJDOT, NJDEP, Google Maps, WalkScore.com
GIS data showing locations of regional destinations and opportunities (major hospitals, four-year colleges and universities, major concentrations of retail activity, and	Counties and local municipalities, NJDOT, NJDEP, Google Maps, WalkScore.com

recreational and tourist destinations with more than 100 employees, like amusement parks, sports arenas, performing arts venues, museums, and historic sites)	
Observed congested travel times OR Estimated congested travel times	INRIX or other vehicle probe data Intermediate measure calculated in **System Coordination**; see methodology above

Geographic Scale of Analysis

Access is best measured at a regional level or at a corridor level, grouping multiple facilities and modes together to determine the corridor-level or systemwide impacts of any given roadway enhancement project.

Time Frame of Analysis

The impacts of roadway enhancement projects as measured in terms of User Responsiveness measures may be small or may not be measurable at all shortly after completion of the improvement. However, as years pass many changes as measured by User Responsiveness measures may become more pronounced over time. Therefore, it is important to evaluate User Responsiveness measures on a continuous basis, using multiple data points from several years before the project and for as many years after the project as data are available.

Customer Satisfaction measures are an exception. The reaction to a Roadway Enhancement project may peak shortly after project completion, but as time goes on, people may not be able to distinguish the project's impacts from other changes that have happened in the mean time (for example, other transportation improvements or economic shifts).

Analysis Steps

Accessibility

Accessibility is a measure of the ability of people to reach opportunities and activities that they undertake in their daily lives such as work, school, shopping, medical service, etc., or the ability of businesses to reach their labor force, sources of raw materials and inputs to their production facilities, and the consumer markets for their finished products. Roadway enhancement projects are likely to impact the following measures of access:

Access to regional amenities can include the ability to reach major hospitals, universities, major concentrations of retail activity, and recreational and tourist destinations like amusement parks, beaches, sports arenas, performing arts venues, museums, and historic sites. Regional amenities can be screened using employment (only destinations with more than 100 employees, or retail employment density greater than 100 per acre, for example).

Access to community amenities can be defined as the ability to reach destinations that are sources of basic services and daily needs, and may include health clinics, grocery stores and sources of fresh food, local parks and playgrounds, elementary and secondary schools, and neighborhood-oriented retail and service establishments like restaurants, bars, dry cleaners, banks, and hardware stores.

Inputs:

- Locations of working-age population (U.S. Census Bureau) aggregated to traffic analysis zones (TAZs).
- Locations of jobs (from U.S. Census Bureau, U.S. Bureau of Labor Statistics, NJ Department of Labor and Workforce Development, Center for Economic Studies, Longitudinal Employer-Household Dynamics Program) aggregated to NJTPA's TAZs.
- Locations of regional amenities (from GIS database of regional amenities).
- Locations of local amenities (from GIS database of local amenities).
- Peak hour travel speed data for links in the NJRTM-E model network (from INRX or other vehicle probe data).
- NJRTM-E model network link attributes (link length, toll information).

Calculations:

a. Access to Community Amenities: Distance-Based Cumulative Opportunity accessibility measure

- For local amenities, a distance-based threshold may be the only option. *If travel times by walking, biking, and competing modes are known, one of the other accessibility measures mentioned in this section can be used instead of the following procedure.*
- Using a GIS tool, in an area within a ½-mile radius or less depending on the determined geographic scale of the project limits, calculate the number of local amenities in this ½-mile radius that can be reached within a ½-mile walk before and after implementation of the roadway enhancement project. The change in access to local amenities is the difference in cumulative opportunities that can be reached before and after implementation. *For example, before implementation there may be five grocery stores within a ½-mile radius, and due to access restrictions imposed as a result of the project's construction, there may be only two grocery stores accessible after implementation.*
- *Access to community amenities should be evaluated at as fine-grained a geographic scale as possible (e.g., Census blocks or block groups), because many TAZs may be more than ½-mile across.*
- *If no sub-TAZ data are available, access to community amenities can be evaluated qualitatively using maps showing before-and-after local street network, sidewalk network, and bike network connectivity.*

b. Access to regional amenities: Travel-time-based Cumulative Opportunity accessibility measure

- For period before construction (average of three years) and period after construction (three-year moving average for all available years), use GIS to calculate the shortest travel time between all O-D pairs in the regional network. If possible, calculate travel time on a multimodal basis, since at peak times some trips may be faster by transit.
- Aggregate the number of "opportunities" that lie in the TAZs that can be reached within the following time thresholds:

- Regional amenities: 90 minutes (using average weekend day travel time)

- The relevant equation is:

$$A_i = \sum_{j=1}^{J} B_j O_j$$

where A_i is accessibility measured at point *i* to potential activities in zone *j*,

O_j is the opportunities in zone *j*, and

B_j is a binary value equal to 1 if zone *j* is within the predetermined threshold and 0 otherwise.

- The change in access is the difference in cumulative opportunities across all TAZ pairs that can be reached in the specified travel time. Cumulative opportunity estimates for each TAZ in a given area can be aggregated using the following equation:

$$A_{Area} = (\Sigma A_i * P_i) / P_{Area}$$

where:

A_i = Accessibility of zone *i*

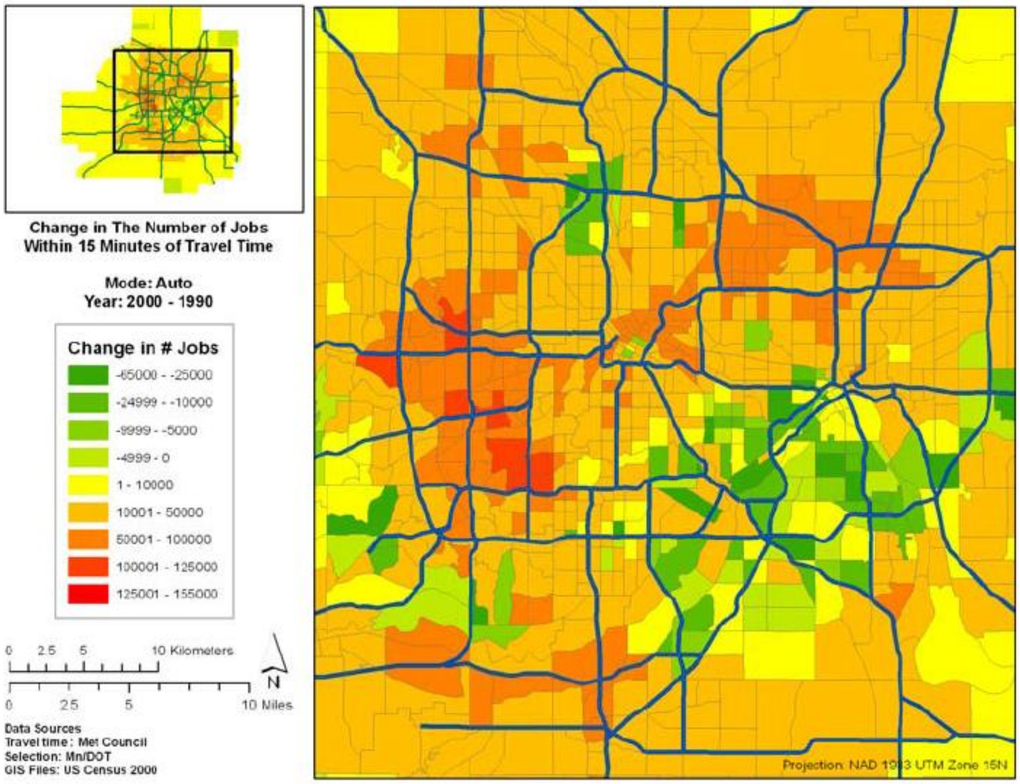
P_i= Population of zone *i*

P_{Area}= Population of the study area (could be a county or the NJTPA region)

A_{Area}= Accessibility of the region (could be a county or the NJTPA region)

- *For example, before construction, five hospitals might be accessible within a 60-minute drive or transit trip of a given location. After construction of a roadway enhancement project, seven shopping centers might be accessible within 60 minutes. The net impact of the project is access to an additional two shopping centers at that location. The net impacts for each TAZ or analysis area can be plotted on a map to determine where the biggest net accessibility benefits accrue, as in the example below from the Minneapolis-St. Paul metro area (using jobs as the measure of accessibility).*

Figure 3.2-A: Example of a Map of Regional Accessibility Change



Source: El-Geneidy, A and D. Levinson, 2005. "Place Rank: A New Accessibility Measure," Nexus (Networks, Economics, and Urban Systems) Research Group, Department of Civil Engineering, University of Minnesota.

- *A cumulative opportunity measure of accessibility is perhaps the simplest way to measure accessibility, but this measure requires the use of an arbitrary radius that, for example, attributes no value to hospitals 91 minutes from an origin. Because the measure is being used to compare before and after conditions, rather than rank the accessibility of individual zones, choosing an arbitrary threshold is not as problematic. A sensitivity analysis could be employed by varying the time threshold by +/- 10 minutes to see if the results change significantly.*

<u>Additional resources on accessibility measures include the following:</u>

- El-Geneidy, A and D. Levinson, 2005. "Place Rank: A New Accessibility Measure," Nexus (Networks, Economics, and Urban Systems) Research Group, Department of Civil Engineering, University of Minnesota. El-Geneidy and Levinson propose the use of a so-called "Place Rank" accessibility measure that uses actual information about origins and destinations by trip purpose and takes into account the relative attractiveness of each zone in calculating accessibility. The Place Rank accessibility calculation is an iterative process that uses the following equations:

$$R_{j,t} = \sum_{i=1}^{I} E_{ij} * P_{it-1}$$

$$P_{it-1} = [E_j * [R_{j,t-1} / E_i]]$$

Where:

- $R_{j,t}$ The *place rank* of *j* in iteration *t*
- *I* The total number of *i* zones that are linked to zone *j*
- E_{ij} The number of people leaving *i* to reach an activity in *j*
- P_{it-1} The power of each person leaving *i* in the previous iteration
- E_j The original number of people destined for *j* $Ej = \sum_i$
- $R_{j,t-1}$ The *place rank*ing of *j* from the previous iteration
- E_i The original number of people residing in zone *i*: $Ei = \sum_j j$

Customer Satisfaction

Customer Satisfaction is a measure that does not depend on inputs from any other performance measure. Customer Satisfaction measures can be obtained from the results of surveys performed by NJDOT or other agencies after completion of a project.

Inputs:

- Surveys of transportation system users, ideally including information about the relative importance of each system attribute being queried
- Typical questions on roadway-related customer satisfaction surveys include:
  - Customer perception of improvement's impacts across NJTPA goal areas: Built and natural environment, congestion, travel speed, access to destinations, safety, economic impacts.
  - Project's impact on travel behavior: Whether the improvement caused mode shifts ("What was the previous mode used to make the trip?") and destination choice decisions (e.g., enabled a longer trip to a destination not previously accessible).
  - Impacts of roadway construction: Safety, congestion and delays, access to businesses, environmental impacts during construction.

Recommendations for Future Performance Evaluation: User Responsiveness Measures

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, such as the map shown above in Figure 3.2-A, 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.

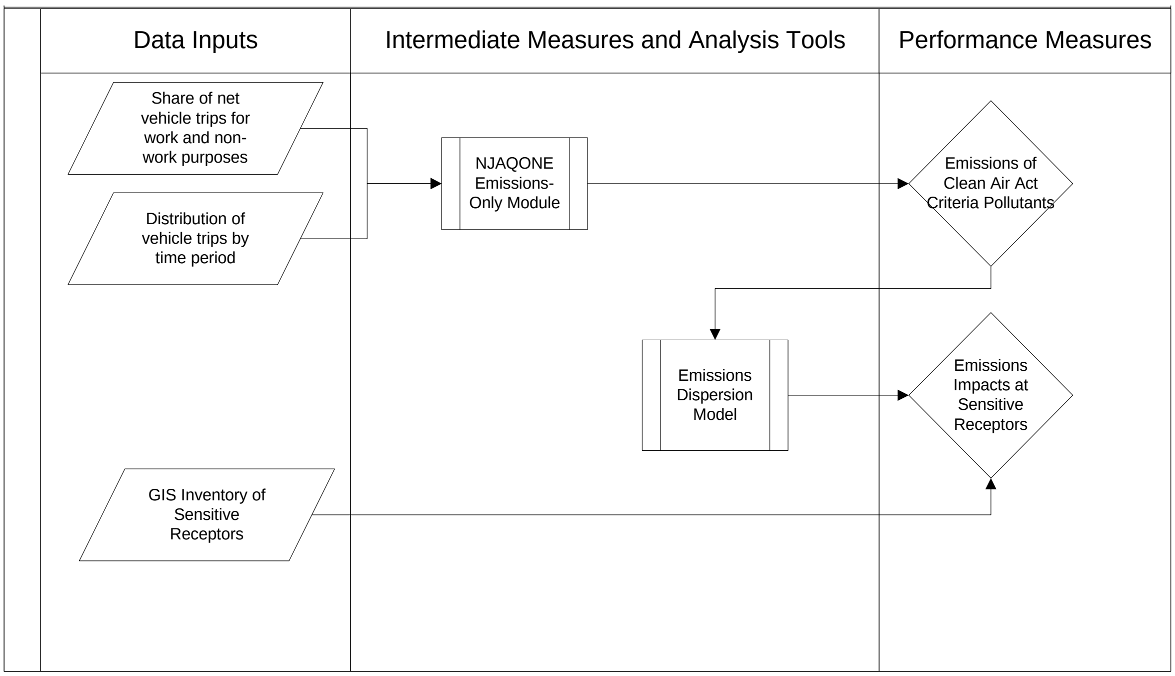
Undertake more customer satisfaction surveys for all modes on a regular basis. Agencies responsible for building, maintaining, and operating the transportation system in the region should undertake regular customer satisfaction surveys to collect a range of qualitative and quantitative data about customer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

3.2.3 Evaluating Environment Measures

NJTPA Environment Goal - Protect and improve the quality of natural ecosystems and human environment.

Interdependencies between Data, Analysis Tools, and Performance Measures

The following diagram is a simplification of the interdependencies between Environmental measures and the intermediate and ultimate measures discussed in the System Coordination and User Responsiveness sections:



Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Project planning documents	Implementing agency
Photos and project descriptions after project completion	Implementing agency; county or local municipality in which project is located
Local comprehensive plans and other relevant planning documents for the area in which the project was constructed	County or local municipality in which project is located
List of commitments to stakeholders that was developed and maintained during planning and design and/or was incorporated into construction documents prior to beginning construction	Implementing agency; county or local municipality in which project is located
Results of post-construction surveys of project team members from the implementing agency and consultants	Post-construction surveys
Results of post-construction surveys of community stakeholders (residents and businesses) and regulatory agency staff	Post-construction surveys

Geographic Scale of Analysis

The geographic scale of analysis depends on the measure being assessed. The following table shows the recommended geographic scale of each measure.

Measure	Geographic Scale(s) of Analysis
Emissions of Clean Air Act criteria air pollutants and greenhouse gases	Air quality (AQ) data are collected at the facility level as well as at the regional scale. The regional and statewide travel demand models that are necessary to quantify emissions are based on this state and regional data collection. Transportation-related emissions, for example greenhouse gases, do not respect state and regional boundaries; therefore regional and statewide data are necessary The Clean Air Act requires regional and project level hotspot analysis. Most non-attainment areas have on the ground monitoring units in set locations. These units are not typically moved to measure emissions for specific projects Transportation emissions that lead to respiratory conditions and other health impacts should be estimated at sensitive receptors within ¼ mile of project limits
Visual aesthetics and context sensitivity	Project limits (project-specific design features); adjacent properties; neighborhoods and municipalities in which project is located; architectural and environmental features in view shed

Time Frame of Analysis

Impacts on visual aesthetics of the built environment and the degree to which a project was implemented in a context sensitive manner are best measured immediately after completion of a project, unless features like landscaping or development are expected to mature over time.

Analysis Steps

Emissions of Clean Air Act Criteria Pollutants

OPTION A: NJAQONE

Inputs:

- Total change in work and non-work related vehicle trips attributable to project, in trips per year (from regional household travel surveys)
- Distribution of travel by time period (based on available NJDOT traffic volume data, either hourly, 15-minute, or continuous counts)

Calculations:

- Use NJAQONE Emissions-Only module to estimate emissions in forecast year. (Please refer to Figure 3.2-B)
- Conduct one run for "no-build" condition and a second run for the "build" condition

Output measures:

- Estimated **net change in emissions by criteria pollutant**, in tons per year

OPTION B: MOVES

Primary Inputs:

- Link traffic volume, vehicles per hour, for each hour in the analysis period
- Roadway link length, miles
- Link average speed, MPH, for each hour in the analysis period
- Fraction of light duty, heavy duty, and other types of vehicles, percent, for each hour in the analysis period
- Fraction of vehicles utilizing gasoline, ethanol, diesel, or alternative fuels, percent by type, for each hour in the analysis period
- Fraction of vehicles in network by model year, percent by type, for each hour in the analysis period
- Link functional classification
- Road grade, in percent

Secondary/optional inputs:

- *In place of link average speed, can input a link "drive schedule" or "operating mode distribution"; see EPA's MOVES technical documentation for details on the data requirements and formats for these inputs*

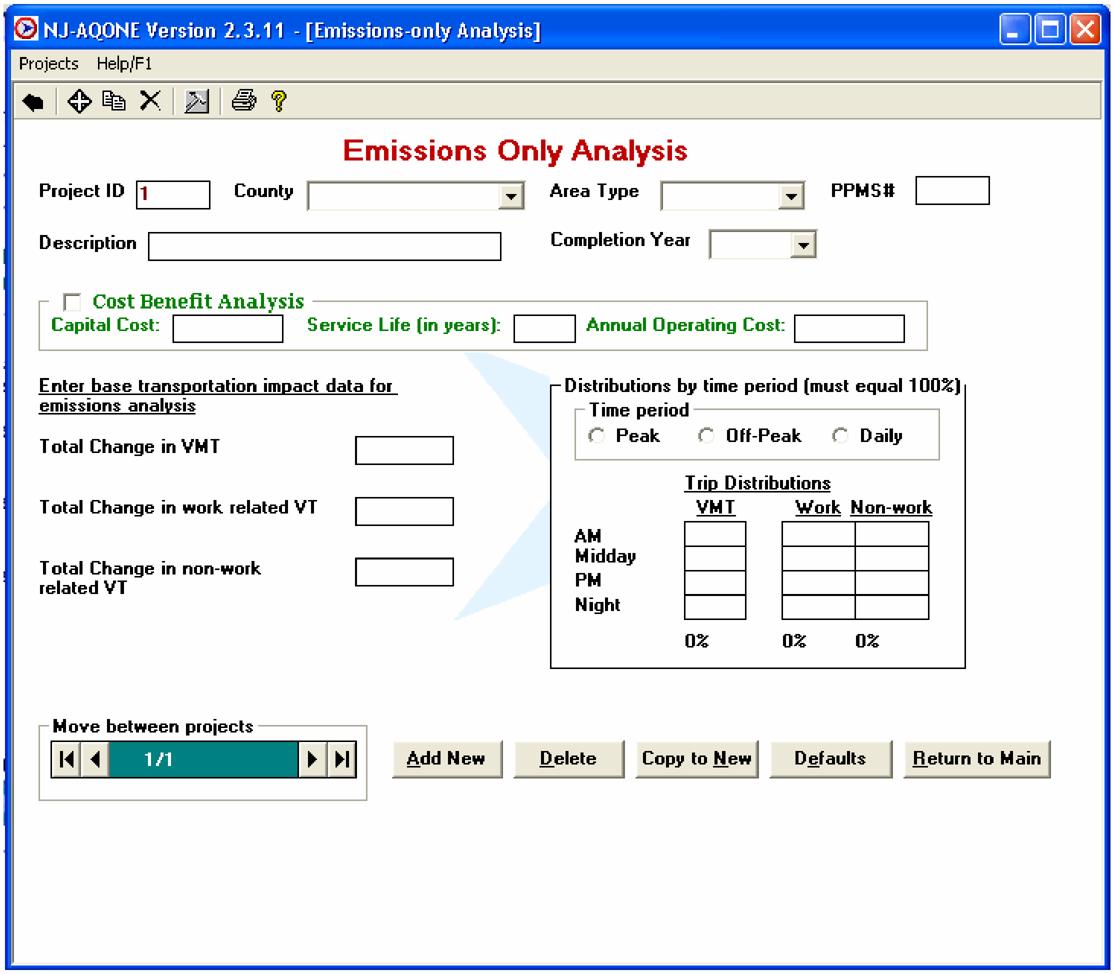
Calculations:

- Use EPA's MOVES Project-level model to estimate emissions in analysis period after construction
- Each hour of the day requires a separate MOVES model run
- Conduct one set of model runs for the "no-build" and a second set of model runs for "build" conditions

Output measures:

- Estimated net change in **criteria pollutant emissions**, **greenhouse gas emissions**, **mobile source air toxics**, and **energy consumption** (total, petroleum-based, and fossil-based)

Figure 3.2-B: Example Emissions Only Analysis Input Screen from NJAQONE



Emissions Impacts at Sensitive Receptors

1. Generate emissions contour maps.

   <u>Inputs:</u>

   - Estimated change in emissions by criteria pollutant, from NJAQONE or MOVES.
   - Baseline emissions estimates, from NJAQONE or MOVES baseline data.
   - Geography-specific climate data. Can use defaults built into models.

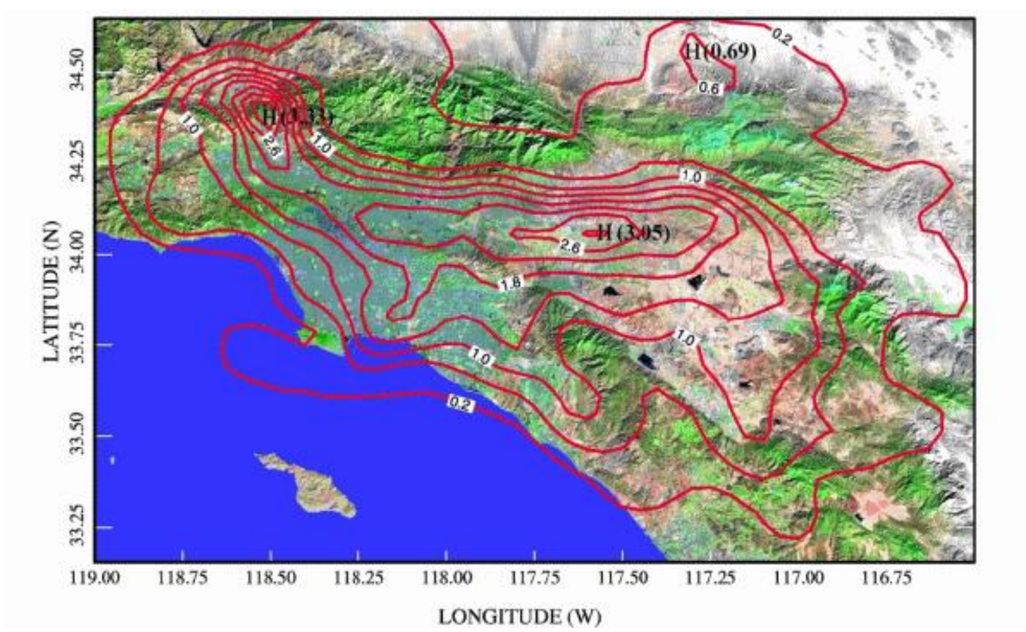
   <u>Analysis Tools:</u>

   - Use Emissions Dispersion model to allocate emissions to points or subregions in the analysis area. Conduct one run for baseline conditions and a second run for "build" condition.

   <u>Outputs:</u>

   - Emissions contour maps showing concentrations by criteria pollutant for baseline condition and for "build" condition.

Figure 3.2-C: Example map of daily emissions of soot in micrograms per cubic meter for Los Angeles Metropolitan Area



2. Overlay sensitive receptor points on emissions contour maps.

Inputs:

- Emissions contour maps for baseline condition and "build" condition from dispersion model.
- GIS layer of sensitive receptors in NJTPA region.

Calculations:

Net emissions impact at any given sensitive receptor is the difference between the build condition and the baseline condition. Repeat calculation for each sensitive receptor.

Outputs:

- **Estimated emissions impacts by sensitive receptor.** *For example, "Emissions of particulate matter (PM 2.5) increased from 1.2 micrograms per cubic meter to 1.8 micrograms per cubic meter as a result of the project."*

Visual Aesthetics and Context Sensitivity

Inputs:

- Project purpose and need statement or project description from planning documents, funding applications, etc.
- Photos and project descriptions after project completion.
- Local comprehensive plans and other relevant planning documents for the area in which the project was constructed.
- List of commitments to stakeholders that was developed and maintained during planning and design and/or was incorporated into construction documents prior to beginning construction.
- Results of post-construction surveys of project team members from the implementing agency and consultants.
- Results of post-construction surveys of community stakeholders (residents and businesses) and regulatory agency staff.

Calculations:

Conduct surveys using the following criteria[1]. Score one point for each criterion if 67% or more of implementing agency staff (and/or the agency's project consultants) surveyed respond "yes"; score one additional point for each criterion if 67% or more of community stakeholders and regulatory agency staff surveys respond "yes". Maximum 12 points.

1. The executed project meets the goals and objectives identified in the original purpose and need statement.

---

[1] Adapted from project-level evaluation criteria listed in NCHRP Web-Only Document 69: *Performance Measures for Context Sensitive Solutions- A Guidebook for State DOTs*

2. The project was designed and implemented in a manner that is consistent with local comprehensive plans, the Americans with Disabilities Act, and other relevant planning documents.

3. The implemented project meets or exceeds a list of commitments to stakeholders that was developed and maintained during planning and design, was incorporated into construction documents prior to beginning construction, and is monitored during construction and operation of the completed project.

4. *(If the project is located in a developed area)* Architectural elements were incorporated into the design of the project to make users of all modes feel comfortable and welcome. These elements include, but are not limited to:wayfinding signage for users of all modes for which the facility is designed (including freight and non-motorized users); signage clearly indicating access points totransit services (including park-and-ride lots, bus stops, and fixed guideway transit stations); signage clearly indicating access points and amenities for bicyclists and pedestrians (including signage indicating nearby alternate routes if non-motorized users are prohibited from using the facility); a physical barrier between non-motorized traffic (bicyclists and pedestrians) and vehicles or, if a physical barrier was not possible, a defined pavement marking separation; adequate lighting for evening and nighttime use by motorized and non-motorized users; an open view shed into public spaces for people passing by and security officers; and amenities such as artwork and landscaping to enhance the surrounding built and natural environment.

   *(If the project is located in an undeveloped area)*Environmental resources, scenic and historic resources, and aesthetic values, such as architectural styles and landscaping that complement the surrounding environmental, have been maintained or enhanced by the project as completed.

5. Nearby residents and representatives of nearby institutions, schools, and business associations are directly or indirectly (e.g., via an advisory council) involved in the ongoing maintenance and operations of the facility or service.

6. Based on surveys of area residents and businesses, the project appears to have been implemented in a manner that will result in increased economic activity, such as new commercial or residential activity, and it appears to have the potential to create a positive neighborhood impact.

Outputs:

- Qualitative assessment of the degree to which a project improved or detracted from the **visual aesthetics of the built environment**.

Recommendations for Future Performance Evaluation: Environment Measures

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 opportunities that improve 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.

3.2.4 Evaluating Land Use/Transportation Coordination Measures

NJTPA Land Use/Transportation Coordination Goal - Select transportation investments that support the coordination of land use with transportation system.

Interdependencies between Data, Analysis Tools, and Performance Measures

There are no interdependencies in the data evaluated in the Land Use/Transportation Coordination goal area.

Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Population	U.S. Census Bureau's American Community Survey 5-year estimates
Employment	U.S. Census Bureau's Local Employment-Household Dynamics data; NJ Labor and Workforce Development, and/or U.S. Bureau of Labor Statistics
Census tract area	U.S. Census Bureau TIGER Line Shape Files

Geographic Scale of Analysis

An analysis of population and employment changes for roadway enhancement projects should be performed for areas within 5 miles of the project limits.

Time Frame of Analysis

The impacts of roadway enhancement projects as measured in terms of Land Use/Transportation Coordination measures may be small or may not be measurable at all shortly after completion of the improvement, because development induced by a roadway enhancement project will happen gradually over time. However, as years pass many changes as measured by Land Use/Transportation Coordination measures may become less pronounced over time. Therefore, it is important to evaluate Land Use/Transportation Coordination measures on a continuous basis, using multiple data points from several years before the project and for as many years after the project as data are available.

Analysis Steps

Population and Employment Density

<u>Inputs:</u>

- Population in census tracts or census blocks, if available, within 5 miles of project limits, from periods before and after implementation of the roadway enhancement project. *Use U.S. Census Bureau's American Community Survey (ACS) 5-year Estimates for a rolling annual estimate of census-tract-level population data. Note that the Census Bureau cautions against comparing ACS data from overlapping time periods. ACS is mainly intended to be used for population characteristics, not population totals, especially at smaller geographies (e.g., Census tracts).*

- Employment in census tracts within 5 miles of project limits, from periods before and after implementation. *Use U.S. Census Bureau's Longitudinal Employer-Household Dynamics (LEHD) data.*
- Area of census tracts within 5 miles of project limits, in miles, from U.S. Census Bureau's Topologically Integrated Geographic Encoding and Referencing (TIGER) system. *Note that census tract boundaries may change over time, particularly when a new decennial Census is undertaken. It is important to use areas that are as identical as possible for the before and after comparison.*

<u>Calculation:</u>

- Use GIS to aggregate population in census tracts within 5 miles of project limits and divide by aggregate area of those tracts. Calculate population density for periods before implementation and period after implementation.
- Use U.S. Census Bureau's Longitudinal Employer-Household Dynamics online mapping tool, called "OntheMap", to aggregate employment in census tracts within 5 miles of project limits and divide by aggregate area of those tracts. Calculate employment density for periods before implementation and after implementation.
- *The net change in population and employment density cannot be calculated, but a qualitative analysis of the circumstances before and after implementation of the project may provide clues to whether any changes in population and employment density can be attributable to the project. For example, similar to the net new ridership calculation as shown in Transit Expansion section 3.6-14, population and employment density in the study area can be compared to a "control" area that had conditions similar to the study area before implementation.*

<u>Output:</u>

- **Population density**, in persons per square mile.
- **Employment density**, in jobs per square mile.

<u>Additional resources on population and employment density include the following:</u>

- U.S. Census Bureau Longitudinal Employer-Household Dynamics website, http://lehd.did.census.gov/led/.
- U.S. Census Bureau's Topologically Integrated Geographic Encoding and Referencing (TIGER) system website, http://www.census.gov/geo/www/tiger/index.html.

Recommendations for Future Performance Evaluation: Land Use/Transportation Coordination Measures

- **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).

3.2.5 Evaluating Repair, Maintenance, Safety, and Security Measures

NJTPA Repair/Maintain/Safety/Security Goal - Maintain a safe and reliable transportation system in a state of good repair.

Only safety and security measures are discussed in this section. See Roadway and Bridge Preservation project type for evaluation of Repair and Maintenance-related measures.

Interdependencies between Data, Analysis Tools, and Performance Measures

All data used in the analysis of safety performance measures are drawn from crash databases (e.g., NJDOT Crash Records Database, NJTPA Safety Management System, Plan4Safety), and NJDOT asset management systems. Therefore, for safety measures, there are no interdependencies with previous analyses.

Evaluation of security measures related to resiliency and redundancy use the results of network connectivity and continuity calculations performed under the System Coordination goal area.

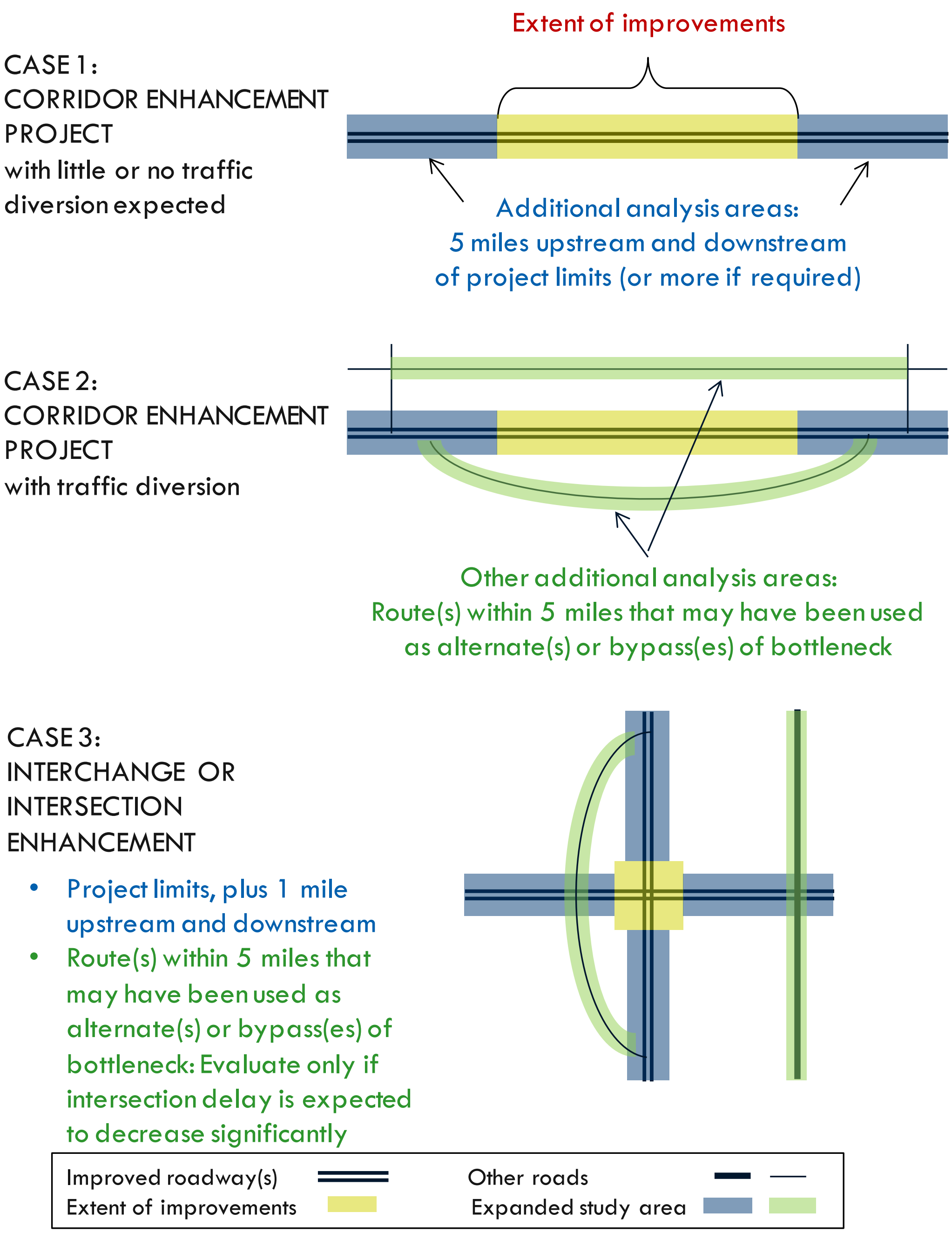
Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Crash records	NJDOT Crash Records Database; Plan4Safety; NJTPA Safety Management System data
VMT data at regional, county, and local level	NJDOT Public Roadway Mileage and Vehicle Miles Traveled, from Highway Performance Monitoring System (HMPS) data
Information on measures taken to prevent or protect against incidents, incursions, attacks, and illicit activity	Facility owner or operator: construction documents and as-built drawings
Facility functional class (Interstate, freeway or expressway, major arterial, or other)	NJDOT Roadway Network File, NJDOT Straight-Line Diagrams
Availability of t alternate routes (same or higher functional class/lower functional class/no alternate route)	NJDOT Roadway Network File, NJDOT Straight-Line Diagrams
Traffic volume data (vehicles per day), Link capacity (vehicles per day), and Volume-to-capacity ratio	NJDOT Roadway Network File, NJDOT Straight-Line Diagrams, NJDOT Traffic Monitoring System
Tonnage of freight moved on each link from commodity flow data	IHS Global Insight's TRANSEARCH database or FHWA Freight Analysis Framework 3 (FAF3) data
Facilities that are designated evacuation routes	NJDOT Roadway Network File
Planning studies to identify critical assets and future needs for project development in the study area	State and local governments; NJTPA needs assessments
Network Connectivity and Continuity results	Calculated using methodologies specified in System Coordination goal area
Extent and redundancy of technology and systems available to provide information to system operators and users	Facility owner or operator: construction documents and as-built drawings

Geographic Scale of Analysis

Both safety and security measures should be evaluated within the project limits. In the case of a project that is expected to generate significant diversions of auto and truck traffic (in the case of safety improvements) or accommodate significant diversions of auto and truck traffic (in the case of system redundancy projects undertaken for security reasons), the analysis area for safety and security measures may be expanded to a corridor encompassing multiple facilities, to a county, or to the entire NJTPA region.



Time Frame of Analysis

The project-specific impacts of Roadway Enhancement, ITS and Safety projects as measured in terms of safety measures are likely to be most pronounced shortly after completion of the improvement. Therefore, it is important to evaluate these measures using multiple data points from several years before the project, during the construction phase, and for as many years after the project as data are available. Security measures, which tend to be discrete improvements whose benefits do not accumulate or diminish over time, should be analyzed for one year before and after implementation of the project. For example, construction of a security fence along a new highway right of way to prevent unauthorized access would have a one-time benefit to security along that highway segment; therefore, conditions for the year before construction can simply be compared to conditions in the year following completion of the project.

Analysis Steps

Intermediate Measures and Analysis Tools

1. Assign a "criticality" index to infrastructure and services in the study area.

   Inputs: (required for each link in the highway network)

   - Facility functional class (Interstate, freeway or expressway, major arterial, or other facility type);
   - Whether or not alternate routes are available (same or higher functional class/lower functional class/no alternate route);
   - Traffic volume data (vehicles per day), link capacity (vehicles per day), and volume-to-capacity ratio, to help establish which facilities carry the greatest absolute volumes and which facilities have the ability to absorb excess volumes;
   - Tonnage of freight moved on each link from commodity flow data (TRANSEARCH, FAF), as a proxy of the facility's economic value;
   - Whether or not the facility is a designated evacuation route (yes/no); and
   - Planning and traffic studies done in the study area to identify critical assets and future needs for project development.

   Calculations

   Calculate a composite criticality score or index for each facility. Several analysis tools are available to perform the calculation. For example, the New Jersey Department of Transportation as a license to the Disruption Impact Estimating Tool—Transportation (DIETT), which is a database and spreadsheet-based tool for prioritizing the criticality of transportation choke points.

   Intermediate output measures:

   - Criticality index or score for each facility in the network. Facilities should be grouped into broad categories like "most critical", "critical" and "not critical". *Note that this index must be guarded from the public due to the sensitive nature of the information.*

Crashes

Inputs:

- Facility-specific crash data(minimum 3 years before and after project).
- Regional, county-level, and corridor-level aggregate safety statistics.

Calculations:

- Compare project-level changes in absolute number of crashes to estimates of crashes at the regional and county-level, for corridors of the same functional class, and potentially for specific comparison corridors as an estimate of what may have happened in the absence of the project. *If the project was anticipated to result in significant diversions of traffic to or from other roadways, compile data on absolute numbers of crashes on alternate within 5 miles of the improved roadway that could reasonably be expected to accommodate bypass traffic.*

For safety or ITS improvements, compare the before and after changes in the number of crashes for the targeted vehicle movements. Outputs:

- Absolute number of **crashes** that occurred before and after construction**.** *For example, a project may result in a net reduction of 20 property-damage-only crashes, 5 injury crashes, and 1 fatality per year.*

Crash Rate

Inputs:

- Absolute number of crashes occurred before and after construction.
- VMT data at regional, county, and local level.
- Regional, county-level, and corridor-level aggregate crash rates.

Calculations:

- Divide crashes by VMT in the study area to calculate crash rate per million VMT.
- Compare project-level changes in crash rates to estimates of changes in crash rates at a regional or county-level, for corridors of the same functions class, or in specific comparison corridors as an estimate of what may have happened in the absence of the project.
- The net increase or decrease in crash rate attributable to the project can be estimated by subtracting the regional, county-level, or corridor-level crash rate from the observed crash rate after project completion.

Outputs:

- **Crash rate**, in terms of crashes per million VMT. *In the NJTPA region, crash rates typically range from 0-10 crashes per million VMT, but some roads have higher crash rates.*

Transportation Resiliency

Transportation resiliency is a term that describes the ability of the transportation system to adapt and respond to incidents and disruptions. Transportation resiliency applies to natural threats, such as hurricane storm surges and floods, as well as man-made threats such as terrorist attacks. According to NCHRP Report 525, "Incorporating Security into the Transportation Planning Process", four major categories of security incident countermeasures exist to address threats and vulnerabilities to the nation's transportation infrastructure. These four categories include prevention, protection, redundancy, and recovery. These four measures apply more broadly than security. For example, climate change adaptation strategies often are grouped into similar categories.

The categories "prevention" and "protection" are discussed together below because they both refer to proactive, preventative measures taken in advance of an attack or unauthorized access. Their results are measured in terms of the extent of the system's critical services or pieces of infrastructure from being damaged, destroyed, or used for illicit purposes. Projects addressing "redundancy" and "recovery" address the operations of the system after a major disruption occurs. Their results are measured in terms of how well the system operates (or would operate) after a major disruption.

<u>Inputs: Prevention and Protection</u>

- Measures taken to *prevent or discourage* unauthorized access to a transportation facility or a specific sensitive feature of a transportation facility like a bridge or equipment room, before and after construction; measures taken to prevent or discourage illicit activity in or near a transportation facility; measures taken to prevent or discourage direct and indirect attacks on a facility; and measures taken to protect against the impacts of natural events like extreme weather events. *Examples cited in NCHRP Report 525 include access control systems like fences and locked doors, highly visible closed circuit television (CCTV) systems, and intrusion detection systems such as alarmed entrances and fence-line detection systems. The design of the facility is also important, for example, allowing for open sight lines into a park-and-ride lot from nearby roadways and development, adding lighting to a pedestrian pathway, hardening a facility to prevent physical incursions and/or increase blast resilience, or building a levee and pumping system to protect a roadway from flooding.*
- Criticality index of the facility or service. *Calculated above in intermediate measures and analysis.*

<u>Evaluation: Prevention and Protection</u>

- Measure the mileage of roadways with prevention and protection measures in place (per Federal, state, and local design guidelines) before and after the project is completed.

<u>Outputs: Prevention and Protection</u>

- Share of most critical assets hardened against unauthorized access, illicit activity, attacks, and/or natural events. The definition of "most critical assets" must be defined in the process for assigning a criticality score above.

Inputs: Redundancy and Recovery

- Results of **Network Connectivity and Continuity** calculations, using the process defined in the System Coordination goal area. *For purposes of this analysis, connectivity calculations should be performed for the subset of the system consisting of critical and/or most critical assets, as defined in the intermediate measure above.*
- Extent and redundancy of technology and systems available to provide information to system operators and users.

Evaluation: Redundancy and Recovery

- Using results of before-and-after network connectivity analysis, determine extent to which the project improves connectivity in the designated evacuation route system or in the subset of the system consisting of arterials, expressways, and Interstate Highways. *As described in the System Coordination goal area, system connectivity can be defined in terms of several indices and measures. The evaluation here should assess the change that the Roadway Enhancement project would cause in these indices or measures.*
- Qualitatively compare the extent of information technology available to provide information to system operators and to users during an emergency, system failure, or system disruption, before and after project implementation.

Outputs: Redundancy and Recovery

- Change in System Connectivity for the region's critical and/or most critical transportation assets. *For example, the beta index could change from 1.1 to 1.2 as a result of the project, indicating greater network connectivity and availability of alternative routes in case of a disruption or blockage.*
- Extent to which communication systems are deployed in a redundant fashion to ensure information is available to system operators and users in an emergency, system failure, or system disruption. *For example, "The project provided a diesel generator to power a backup communication system in case of a power failure concurrent with the event or disruption."*

Recommendations for Future Performance Evaluation: Repair/Maintenance/Safety/Security Measures

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 for purposes of transportation security, climate change

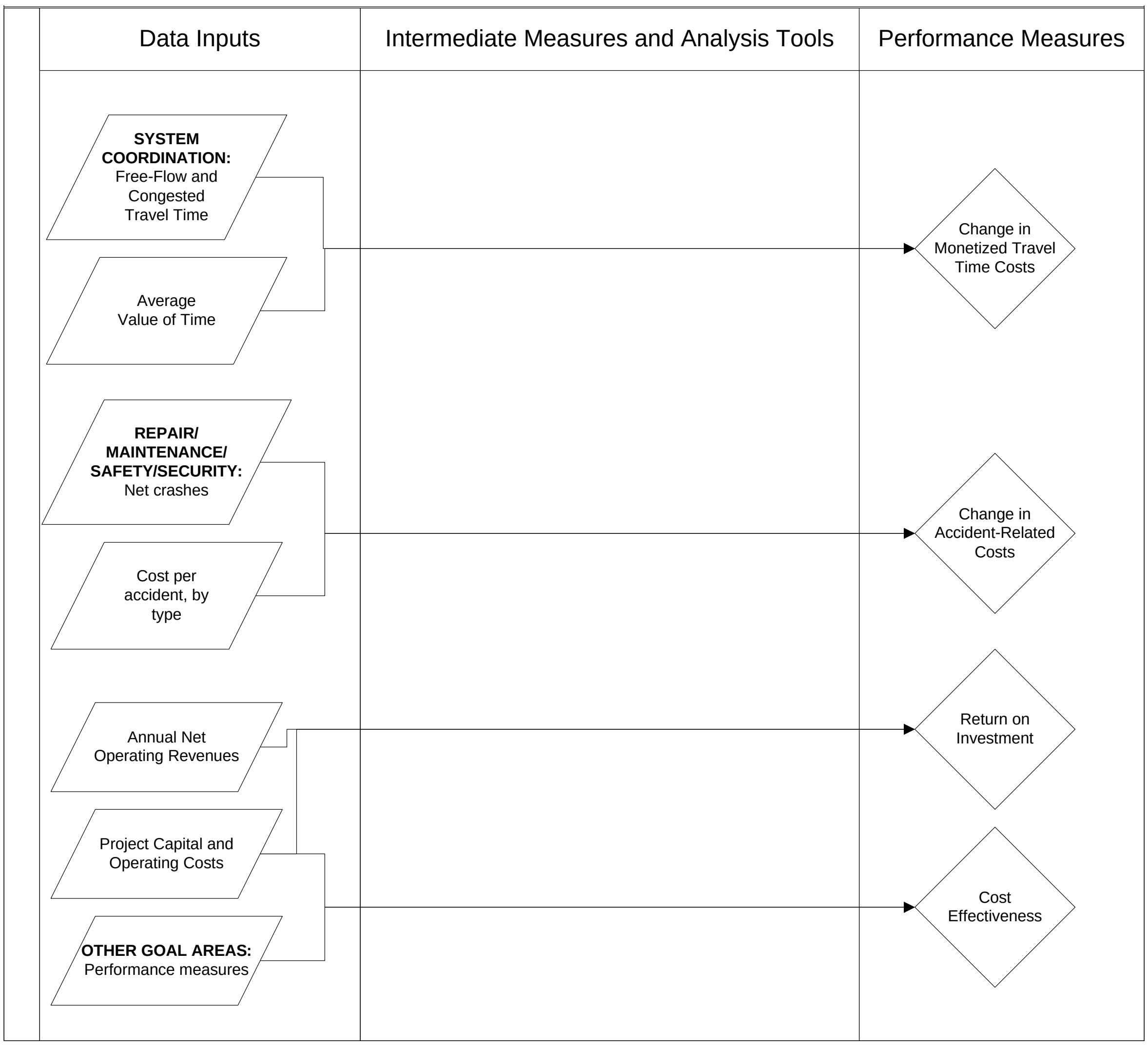
adaptation, and related uses. NJDOT, in cooperation with Federal and local governments and other state agencies, has performed an assessment of critical transportation infrastructure. NJDOT should continue to work with the Departments of Transportation, Defense and Homeland Security, other relevant Federal 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).

3.2.6 Evaluating Economy Measures

NJTPA Economy Goal - Retain and increase economic activity and competitiveness.

Interdependencies between Data, Analysis Tools, and Performance Measures

The following diagram is a simplification of the interdependencies between Economy measures and the intermediate and ultimate measures discussed in the System Coordination and User Responsiveness sections. No intermediate measures or analysis tools were used in the analysis.



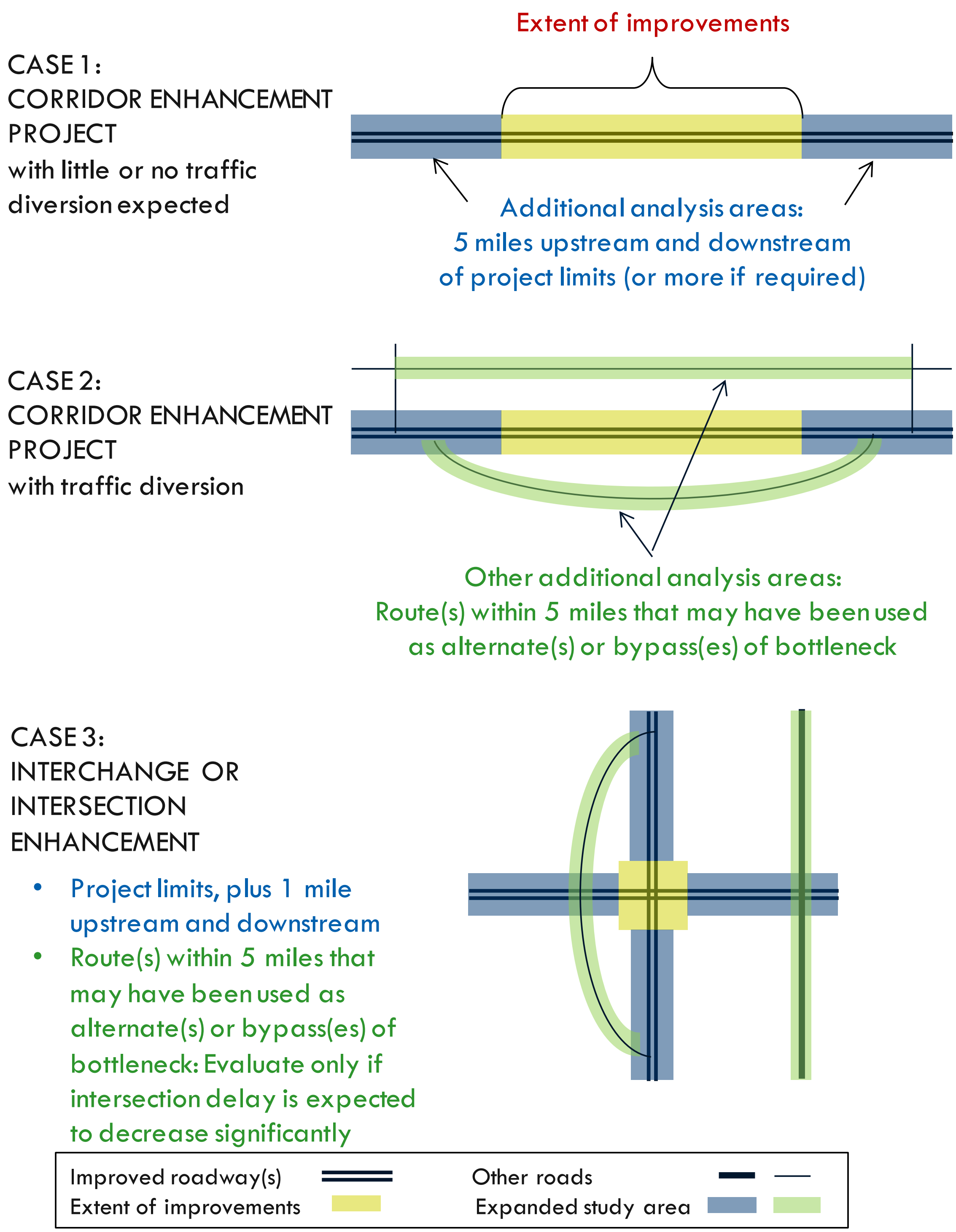
Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Estimated "build" and "no-build" congested travel times by link	Intermediate measure calculated in **System Coordination**; see methodology above
Average value of time	NJTPA Regional Household Travel Survey
Net crashes by severity	Output measure of **Repair/Maintenance/Safety/ Security** goal area; see above
Cost per crash, by severity	NJDOT and National Highway Traffic Safety Administration (NHTSA)

Geographic Scale of Analysis

All measures in the Economy goal area should be evaluated within the project limits. In the case of a project that is expected to generate significant diversions of auto and truck traffic, the analysis area may be expanded to a corridor encompassing multiple facilities, to a county, or to the entire NJTPA region.



Time Frame of Analysis

The impacts of Roadway Enhancement, ITS and Safety projects as measured in terms of Economy measures may be small or may not be measurable at all shortly after completion of the improvement, because travel time benefits, operating cost savings, and accident cost reductions generated by a roadway enhancement project will accrue gradually over time. However, as years pass many changes as measured by Economy measures may become less pronounced over time. Therefore, it is important to evaluate Economy measures on a continuous basis, using multiple data points from several years before the project and for as many years after the project as data are available.

Analysis Steps

Transportation Costs

Transportation costs can be quantified in terms of change in monetized travel time costs, change in vehicle operating costs, and change in accident-related costs.

Inputs:

- Estimated "build" and "no-build" congested travel times by link (see diagram above for study area).
- Average value of time, in dollars.

Calculation:

- Multiply change in travel time by average value of time for users of the facility.

Outputs:

- **Net change in travel time costs** associated with the project. *An example is shown in the following table:*

Table 3.2-B: Sample of Estimated Daily Travel Time Savings
(NOTE: Contains fictional data for illustration purposes only)

	Net Change
Daily Person Hours of Travel	-2,200
Value of Time (in 2009 dollars)	$21.00
Estimated Travel Time Savings (Daily)	-$42,000

Inputs:

- Net change in crashes associated with the project, by severity.
- Average cost of crash, by severity.

Calculation:

- Multiply change in crashes by the average cost of crash for each severity level.

<u>Outputs:</u>

- **Net change in accident-related costs** associated with the project. According to NJDOT in 2009, the *average costs for accidents range from nearly $9,000 for a property-damage-only crash, to around $50,000 for an injury crash, to more than $2 million for a fatal crash. Accident cost savings due to roadway enhancement projects may be modest depending on the extent to which crashes are reduced.*

Return on Investment

<u>Inputs:</u>

- Project capital cost and annual operating costs.
- Annual net operating revenue.

<u>Calculations:</u>

- Calculate the net present value of net operating revenue. The net operating revenue is simply revenues from all sources minus operating costs.
- Return on investment is the (Capital Cost minus the Net Present Value of Operating Costs) divided by the Capital Cost. *For example, a transportation project could have a return on investment of 10 percent, meaning the project's annual income exceeds the net present value of its operating costs plus the capital cost.*

<u>Outputs:</u>

- **Return on investment***, expressed as a percentage.*

Cost Effectiveness

<u>Inputs:</u>

- Project capital cost, in dollars.
- Performance measures from previous calculations (e.g., crashes, travel time savings, and emissions reduction).

<u>Calculations:</u>

- Divide the capital cost by any performance measure to calculate the dollar-weighted impacts of the project. *For example, a million-dollar project that reduces carbon emissions by 1,000 tons has a cost-effectiveness index of $1,000/ton.*

<u>Outputs:</u>

- **Cost Effectiveness***, expressed in dollars per unit of benefit per dollar (e.g., dollars per accident reduced; dollar per minute of travel time savings; dollars per ton of reduced carbon emissions).*

NOTE: While cost-effectiveness measures are constituents of a broader benefit-cost analysis approach, many cost-effectiveness measures are not additive. Therefore, extreme caution should be exercised in presenting and explaining results of a project-level cost-effectiveness analysis.

Recommendations for Future Performance Evaluation: Economy Measures

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.

3.3 Roadway Expansion Projects

Roadway Expansion: Projects that seek to improve the connectivity and accessibility of the existing transportation network by adding capacity to existing roadways and/or by building new roadways. These include new grade separations, new travel lanes, new roadways, and other similar improvements.

Contents of This Section

Suggested Work Flow for Roadway Expansion Projects

The following sequence of goal areas for this project category was developed specifically to enable an ordered evaluation of performance measures. This allows the results of calculations from one goal area to serve as inputs for measures in subsequent goal areas:

1. System Coordination Measures
2. User Responsiveness Measures
3. Environment Measures
4. Land Use/Transportation Coordination Measures
5. Repair/Maintenance/Safety/Security Measures
6. Economy Measures

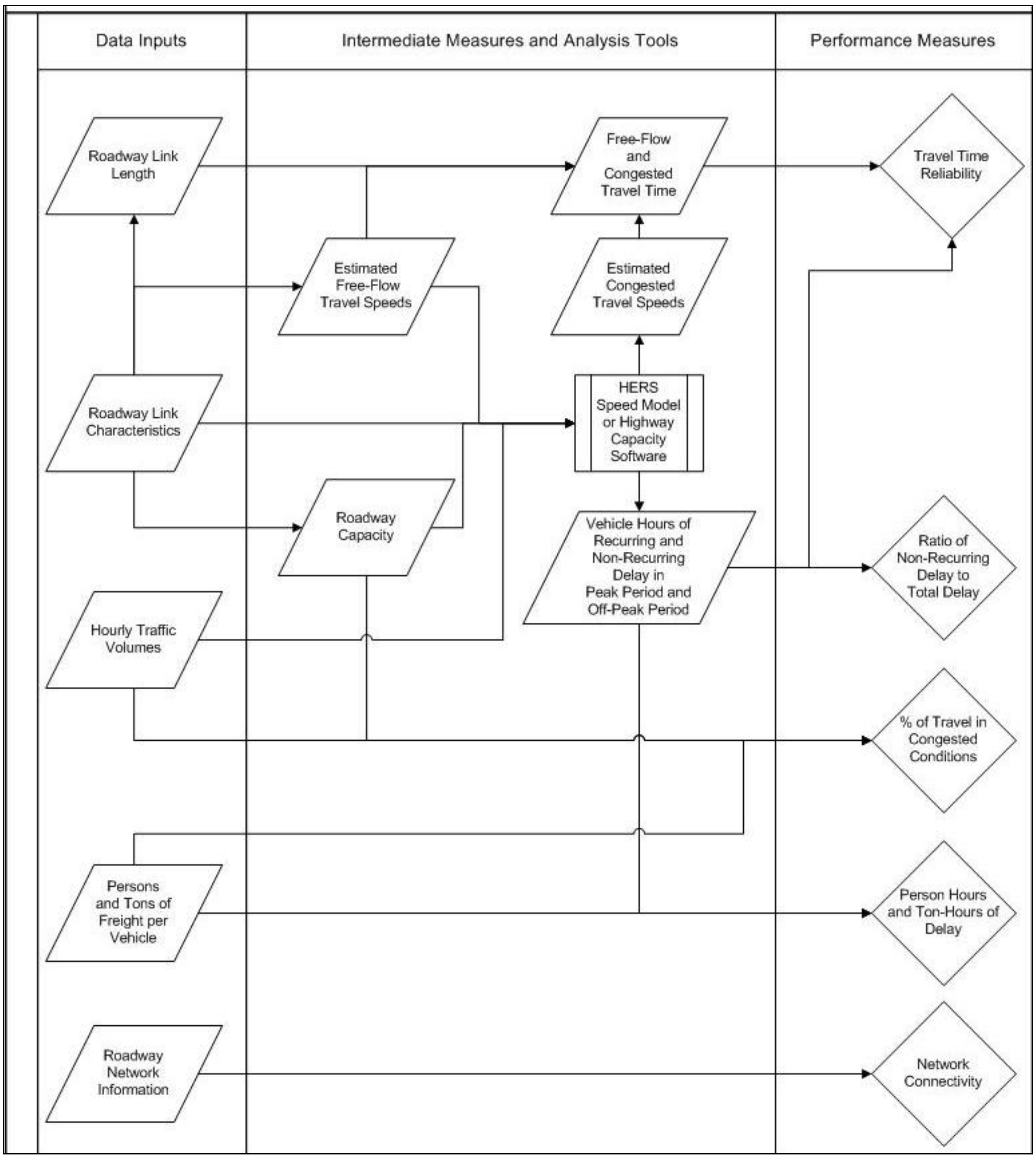
The methodology for calculating each measure is presented in the following sections. Measures in **BOLD** in the table above can be calculated independently. The remaining measures rely on interdependent data, or, in some cases, depend on each other.

3.3.1 Evaluating System Coordination Measures

NJTPA System Coordination Goal - Enhance system coordination, efficiency and intermodal connectivity.

Interdependencies between Data, Analysis Tools, and Performance Measures

The following diagram is a simplification of the interdependencies between System Coordination measures:



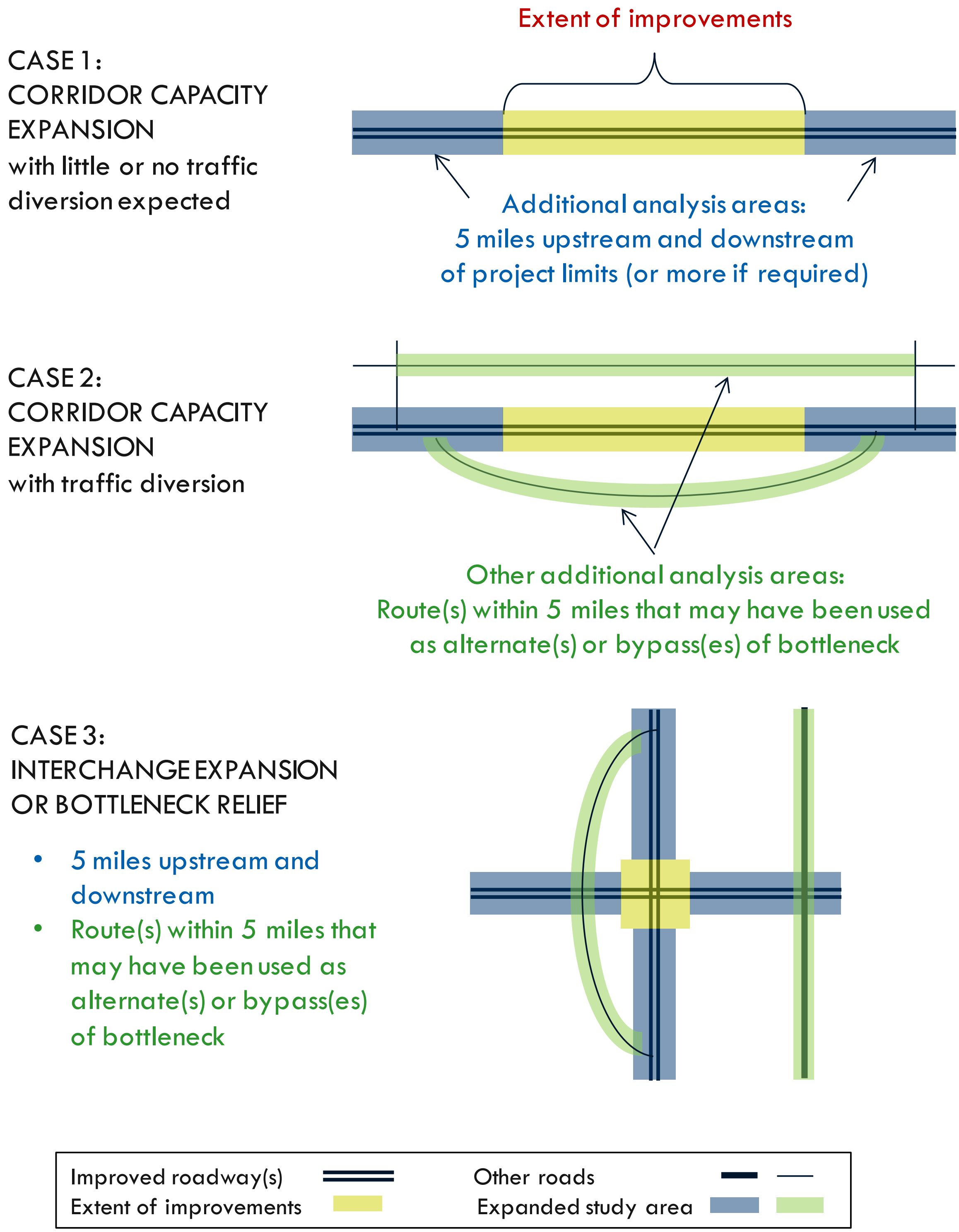
Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Roadway link length	NJDOT Roadway Network File, NJDOT Straight-Line Diagrams, Aerial Photos
Roadway link characteristics: • Roadway functional classification • Number of lanes and lane widths in each travel direction • Number of shoulders and shoulder widths in each travel direction • Terrain type, horizontal and vertical curvature[1] • Vehicle classification and composition (percent trucks and heavy vehicles in traffic flow)[2] • Median type and lateral clearance[2] • Number of access points and bottlenecks per mile[2] • Number of signals and estimated green time for primary flow as a proportion of total cycle length[2]	NJDOT Roadway Network File, NJDOT Straight-Line Diagrams, Aerial Photos [1]Can assume zero grade if terrain information is not available [2]Default value may be available in software. Also can use average values for roadways of similar functional class in same county or in NJTPA region if link-specific data are not available
Hourly traffic volumes in each direction and directional distribution of peak hour traffic	NJDOT Traffic Monitoring System
Persons per vehicle	Household travel survey data collected by NJTPA or American Community Survey 5-year average data for work/commute trips in place/county in which link is located
Tons of freight and TEUs per vehicle	Commodity flow survey data and related databases (e.g., IHS/Global Insight's Transearch database) *Note: The commodity flow data is estimated at regional system level which may not be suitable for use at local level. The use of number of trucks may be more appropriate based on data suitability*
VMT on roadways of similar functional classification as improved roadway, in the county in which the project is located	NJDOT Public Roadway Mileage and Vehicle Miles Traveled, from Highway Performance Monitoring System (HMPS) data
Block lengths and density of nodes	NJTPA GIS
Truck restrictions	NJDOT Truck Map and GIS data

Geographic Scale of Analysis

An analysis of System Coordination measures for roadway projects requires that all affected roadways be evaluated. The figure below shows the geographic extent for which data should be analyzed:



Time Frame of Analysis

The impacts of roadway expansion projects as measured in terms of System Coordination measures are likely to be most pronounced shortly after completion of the improvement. However, as years pass and induced demand and general economic growth lead to traffic growth, many changes as measured by System Coordination measures may diminish over time. Therefore, it is important to evaluate System Coordination measures using multiple data points from several years before the project, during the construction phase, and for as many years after the project as data are available. Using delay as an example, compared to pre-construction conditions, delay may increase slightly during construction as lanes are narrowed or closed temporarily, and then decrease as phases of construction are completed. Impacts can be estimated as follows:

- The overall impact of the project can be estimated by comparing delay after the project to delay before the project.
- The net impact can be estimated by comparing delay after the project to delay in a hypothetical "no-build" scenario.
- Finally, delay due to construction can be estimated by comparing delay during construction to delay before and after construction. Or, if enough data are available, delay during construction can be aggregated for the entire construction period and compared to the net impact on delay.

Analysis Steps

Intermediate Measures and Analysis Tools

*NOTE: The following steps should be used to estimate free-flow and congested travel times on each roadway link under analysis, where travel time data do not exist. If travel time data are available for the roadway links under analysis, skip these intermediate calculations and begin with estimation of **Travel Time Reliability** below.*

1. Estimate free-flow travel speeds

Inputs: (required for each link in each direction before, during, and after construction)

- Observed average overnight travel speeds or 85th percentile overnight travel speeds in miles per hour. *Use actual observed travel speed data if possible. Where data are not available, use posted speed limit as a proxy for free flow travel speed.*

Intermediate output measures:

- Actual or estimated **free-flow travel speed** in miles per hour (MPH) by link and by direction before, during, and after construction. *Typical range: 25-65 MPH. Typically free-flow travel speed will not vary in the before-construction and after-construction periods, but free-flow speed may vary during construction depending on construction conditions.*
- **No-build free-flow travel speed** in miles per hour (MPH). *Typical range: 25-65 MPH. Required by link; before, during, and after construction. Use pre-construction free-flow travel speed as proxy for no-build free-flow travel speed.*

2. Estimate link capacity

Inputs: (required for each link in each direction before, during, and after construction)

- Number of lanes in each direction of flow f_L.
- Lane widths, *w*, in feet. *Use to calculate adjustment factor f_W. Typical range: 10-12 feet.*
- Percent heavy vehicles in traffic flow, HV. *Use to calculate adjustment factor f_{HV}. Typically 0-25 percent, but may be higher in areas with heavy freight traffic.*
- Peak hour factor, or hourly volume during the maximum-volume hour of the day divided by the peak 15-minute flow rate within the peak hour expressed as an equivalent hourly volume; a measure of traffic demand fluctuations within the peak hour. *In the absence of 15-minute traffic volume data, can assume 0.88 for rural conditions, 0.92 for urban conditions.*
- Effective ratio of green time to cycle length, or g/C ratio. *Range of 0.0-1.0; typically falls between 0.40-0.60. Can use observed values, or assume 0.55 for principal arterials, 0.45 for minor arterials, or 0.40 for collectors.*

Calculation:

- Link Capacity = 1900 *Number of lanes * f_L * f_{HV}* Peak hour factor * g/C ratio
- Lane adjustment factor $f_L = 1 + \frac{w-12}{30}$

- Heavy vehicle factor $f_{HV} = \frac{100}{[100+HV(E_T-1)]}$

Passenger Car Equivalents for Trucks (E_T)

Two-Way Flow Rates	Type of Terrain		
(passenger cars per hour)	**Level**	**Rolling**	**Mountainous**
0-600	1.7	2.5	7.2
>600-1,200	1.2	1.9	7.2
>1,200	1.1	1.5	7.2

- Peak hour factor = hourly volume during the maximum-volume hour of the day divided by the peak 15-minute flow rate within the peak hour. *Default values are 0.92 for urban links and 0.88 for rural links.*
- Ratio of green time to total cycle length = g/C. *Use the minimum g/C ratio if there are multiple signalized intersections in the study area.*

<u>Intermediate output measures:</u>

- **Link capacity** in vehicles per hour by link before, during, and after construction. *The maximum capacity for a single lane on a straight, level freeway is around 2,200 vehicles per hour. Calculate link capacity for each link on the study facility (or facilities) for periods before, during, and after construction.*
- **No-build link capacity** in vehicles per hour. *No-build link capacity should reflect conditions that existed before construction.*

3. Estimate congested travel speed and delay for each link in each direction before, during, and after construction.

<u>Inputs:</u> (required for each link before, during, and after construction)

- Roadway functional classification. *Use standard NJDOT definitions, for example, "urban principal arterial" or "rural collector".*
- Number of lanes in each travel direction.
- Lane widths in each travel direction. *Typical range: 10-12 feet.*
- Number of shoulders and shoulder widths in each travel direction. *Typical range: 0-12 feet.*
- Terrain type, horizontal and vertical curvature. *Can assume zero grade if terrain information is not available.*
- Vehicle classification and composition (percent trucks and heavy vehicles in traffic flow). *Default values may be available in software. Also can use average values for roadways of similar functional class in same county or in NJTPA region if link-specific data are not available. As an example, percent trucks may range from 0 to 5 percent on suburban arterials to upwards of 20 percent on major interregional corridors and roads serving ports, rail terminals, and industrial areas.*
- Median type and lateral clearance. *Default values may be available in software. Also can use average values for roadways of similar functional class in same county or in*

NJTPA region if link-specific data are not available. For example, many design standards for freeways and expressways call for at least 6-foot left shoulders and 10-foot right shoulders, with center medians and/or median barriers. Local roads and arterials often have painted center medians or no medians or shoulders at all. HERS, HCS, and other software packages assume shoulders at least 6-feet wide provide the maximum benefit to a roadway's capacity, while shoulders less than 6 feet begin to decrease roadway capacity.

- Number of access points and bottlenecks per mile. *Default values may be available in software. Also can use average values for roadways of similar functional class in same county or in NJTPA region if link-specific data are not available. For example, in HERS and HCS, the default value for bottlenecks per mile is 0.083.*
- Number of signals and estimated green time for primary flow as a proportion of total cycle length. *Default values may be available in software. Also can use average values for roadways of similar functional class in same county or in NJTPA region if link-specific data are not available. For example, green time for the primary flow on a major arterial may be 50-60 percent of total cycle length, while the green time for the primary flow at a major intersection of two arterials may be less than 25 percent of the total cycle length, when time devoted to left turn signals, pedestrian walk cycles, and yellow and all-red phases are considered.*
- Traffic volumes in each direction, in terms of Annual Average Daily Traffic (AADT).
- Estimated free-flow travel speed, in miles per hour. *Use value from Step 1.*
- Link capacity, in vehicles per hour. *Use value from Step 2. Can use peak hour link capacity or use link capacity for various times of day (AM peak, mid-day, PM peak, and overnight).*

Analysis tools: The main analysis tool required for this analysis is a set of delay equations. These equations are automated into software such as the Speed Model of the Highway Economic Requirements System (HERS) or Highway Capacity Software (HCS). HERS is capable of modeling a single link or an entire network and is applicable for a roadway that is classified as minor arterial and above, while HCS can be used to analyze a multi-link corridor such as an arterial or freeway.

Intermediate output measures: The outputs of HERS, HCS, or a network simulation model should include the following (for before, during, and after construction):

- **Estimated congested travel speed** for determined hour of the day (or for the entire day if resources permit), by link and by direction of travel, in miles per hour. *Typical range: 0-55 MPH. Note that estimated congested travel speeds can be generated for the before, during, and after-construction time periods using data from each respective period. Congested travel speeds may be as low as 20 MPH or lower on extremely congested roadways, and it is possible that a roadway expansion project would increase travel speeds to something approaching free flow speed (55 MPH or higher) in the best case, in the years immediately following completion of an expansion project. Over time, congested travel speeds may begin to decrease as traffic volumes increase, so it is important to monitor speeds for many years following a project's completion.*
- **Vehicle hours of recurring and non-recurring delay** the peak and off-peak periods, in hours per year. *Vehicle hours of delay on a congested roadway can exceed 1 million*

hours per year and can drop as low as 10,000 hours per year immediately after construction of a major capacity expansion. Over time, the vehicle hours of both recurring and non-recurring delay will gradually increase if traffic volumes increase, so it is important to monitor travel delay for many years following a project's completion.

4. Estimate no-build congested travel speed and delay for each link.

   Inputs:

   - Roadway functional classification. *Use standard NJDOT definitions, for example, "urban principal arterial" or "rural collector".*
   - Number of lanes in each travel direction.
   - Lane widths in each travel direction. *Typical range: 10-12 feet.*
   - Number of shoulders and shoulder widths in each travel direction. *Typical range: 0-12 feet.*
   - Terrain type, horizontal and vertical curvature. *Can assume zero grade if terrain information is not available.*
   - Vehicle classification and composition (percent trucks and heavy vehicles in traffic flow). *Default values may be available in software. Also can use average values for roadways of similar functional class in same county or in NJTPA region if link-specific data are not available. As an example, percent trucks may range from 0 to 5 percent on suburban arterials to upwards of 20 percent on major interregional corridors and roads serving ports, rail terminals, and industrial areas.*
   - Median type and lateral clearance. *Default values may be available in software. Also can use average values for roadways of similar functional class in same county or in NJTPA region if link-specific data are not available. For example, many design standards for freeways and expressways call for at least 6-foot left shoulders and 10-foot right shoulders, with center medians and/or median barriers. Local roads and arterials often have painted center medians or no medians or shoulders at all. HERS, HCS, and other software packages assume shoulders at least 6-feet wide provide the maximum benefit to a roadway's capacity, while shoulders less than 6 feet begin to decrease roadway capacity.*
   - Number of access points and bottlenecks per mile. *Default values may be available in software. Also can use average values for roadways of similar functional class in same county or in NJTPA region if link-specific data are not available. For example, in HERS and HCS, the default value for bottlenecks per mile is 0.083.*
   - Number of signals and estimated green time for primary flow as a proportion of total cycle length. *Default values may be available in software. Also can use average values for roadways of similar functional class in same county or in NJTPA region if link-specific data are not available. For example, green time for the primary flow on a major arterial may be 50-60 percent of total cycle length, while the green time for the primary flow at a major intersection of two arterials may be less than 25 percent of the total cycle length, when time devoted to left turn signals, pedestrian walk cycles, and yellow and all-red phases are considered.*

- Traffic volumes in each direction before construction, in terms of Average Annual Daily Traffic (AADT).
- No-build free-flow travel speed, in miles per hour. *Use value from Step 1.*
- No-build link capacity, in vehicles per hour. *Use value from Step 2.*
- Vehicle miles traveled (VMT) on roadways of similar functional classification as the improved roadway, in the county in which the improvement is located, before and after construction. For example, if the roadway is a Principal Arterial, use county-wide VMT for Principal Arterials.

Calculation:

- In order to estimate what travel speeds may have been had the improvement not been made (a **"no-build" congested travel speed**), multiply the pre-construction traffic volumes on each link by the growth rate in VMT for all roadways of a similar functional classification in the county in which the project is located, as follows:

$$Volume_{Post-constr.,\text{"No-Build"}} = Volume_{Pre-constr.} * \frac{VMT_{Countywide, same\ func.class., Post-Constr.}}{VMT_{Countywide, same\ func.class., Pre-Constr.}}$$

Analysis tools: The main analysis tool required for this analysis is a set of delay equations. These equations are automated into software such as the Speed Model of the Highway Economic Requirements System (HERS) or Highway Capacity Software (HCS). HERS is capable of modeling a single link or an entire network and is applicable for roadway that is classified as rural collector and above, while HCS can be used to analyze a multi-link corridor such as an arterial or freeway.

Intermediate output measures: The outputs of HERS, HCS, or a network simulation model should include the following:

- **Estimated no-build congested travel speeds** for each hour of the day, by link and by direction of travel, in miles per hour; and
- **No-build vehicle hours of recurring and non-recurring delay** in the peak and off-peak periods, in hours.

5. Calculate congested and free flow travel times for each link, for build and no-build conditions.

Inputs: (required for each link before, during, and after construction)

- Estimated free-flow travel speed, in miles per hour. From Step 1.
- No-build free-flow travel speed, in miles per hour. *From Step 1.*
- Estimated congested travel speed, in miles per hour. *From Step 3.*
- No-build congested travel speed, in miles per hour. From Step 4.
- Length of link to which travel speed estimate applies, in miles.

Calculations: Travel time = Link length / travel speed

Intermediate output measures: (for each link, before, during, and after construction)

- **Free-flow travel time**, in minutes.
- **No-build free-flow travel time**, in minutes.
- **Congested travel time**, in minutes.
- **No-build congested travel time**, in minutes.
- *Travel time values will vary depending on the link length. For shorter links, travel times may be measured in fractions of a minute; for longer links, travel times may be several minutes. As an example, before construction, a 1-mile segment with free-flow travel speed of 60 MPH and a congested travel speed of 30 MPH will have a free-flow travel time of 1 minute and a congested travel time of 2 minutes.*
- *After construction, the free-flow travel speed may increase slightly or stay the same at 60 MPH, but the congested travel speed should increase to something above 30 MPH. Therefore, the after-construction free-flow travel time should be 1 minute or less, and the after-construction congested travel time should ideally reflect some improvement, falling between 2 minutes and 1 minute.*
- *The no-build free-flow travel time can be assumed to be 1 minute (the same as pre-construction conditions), and the no-build congested travel time would likely be greater than 2 minutes, assuming traffic volumes increased between the pre-construction and post-construction periods.*

6. Repeat steps 1-5 for each link, and then aggregate travel times across all links on the roadways being analyzed. The net impact of the project is the difference between actual conditions and "no-build" conditions.

Travel Time Reliability

Inputs:

- Congested travel times, in minutes. *Ideally, use continuous travel time monitoring data or data aggregated to 15-minute increments, or use estimated congested travel time from calculations above. Required for each roadway before, during, and after construction, ideally for 15-minute increments throughout the day. If estimated congested travel time is used, can use peak-period congested travel time.*
- Free-flow travel times, in minutes. *Ideally, use observed average overnight travel times or 85th percentile overnight travel times, based on continuous travel time monitoring data or data aggregated to 15-minute increments. The 85th percentile speed in free-flow conditions is often used as the basis for setting speed limits in engineering analyses, so the 85th percentile overnight travel time is a suitable proxy for free-flow travel time. Or use estimated free-flow travel time from calculations above. Free-flow travel times may vary throughout the day in cases when signal timing changes by time of day.*

Calculations:

- Using congested travel time data, determine the **95th percentile travel times**. *The 95th percentile travel time represents the peak hour travel time on the two worst traffic days of the month. Note that 95th percentile travel time is a guideline. For trips where reliability is not as important, for example recreational trips, a lower threshold may be used.*
- **Buffer time** = 95th percentile travel time – average travel time. *Buffer time, expressed in minutes, represents the extra time (or time cushion) that travelers must add to their average travel time when planning trips to ensure on-time arrival 95 percent of the time. Typical values for a complete trip range from as low as 5 minutes or less in light congestion to a maximum of 30 minutes or more in heavy congestion. On a shorter roadway segment in a particular study area, buffer time could be measured in seconds.*
- **Buffer index** = (95th percentile travel time – average travel time) / average travel time, expressed as a percentage. *Buffer index values closer to 0% indicate that 95th percentile travel time is close to average travel time, i.e. there is little or no variability in congestion. Buffer index values above 100% indicate severe congestion, i.e. travel time is more than twice as long on the worst traffic days than in average conditions.*
- **Planning time index** = 95th percentile travel time / free-flow travel time. *The planning time index reflects how much total time a traveler should allow to ensure on-time arrival 95 percent of the time (in contrast to buffer index, which represents extra time). For example, a planning time index of 1.60 means that for a trip that takes 15 minutes in light traffic a traveler should budget a total of 24 minutes to ensure on-time arrival 90 percent of the time.*
- For an estimate of **"no-build" reliability indices**, use estimated "no-build" congested travel times. *Continuous or 15-minute congested travel times may not be available for the no-build condition because no-build conditions must necessarily be simulated or calculated. Therefore, use peak hour travel times to estimate the improvement in travel time reliability that is attributable to the project.*

Additional resources on travel time reliability include the following:

- Federal Highway Administration Office of Operations Web site, www.ops.fhwa.dot.gov
- Margiotta, Richard, Taylor, Rich, 2006. "Traffic Congestion and Reliability: Making the Connection with Operations: Part 1: Measuring and Tracking Reliability." Institute of Transportation Engineers. ITE Journal, Feb 2006.
- Federal Highway Administration, 2005. "Traffic Congestion and Reliability: Trends and Advanced Strategies for Congestion Mitigation," prepared by Cambridge Systematics and Texas Transportation Institute.
- SHRP 2 Project L03, 2010. "Analytical Procedures for Determining the Impacts of Reliability Mitigation Strategies," prepared by Cambridge Systematics et al.

Ratio of Non-Recurring Delay to Total Delay

Inputs: (required for each link before, during, and after construction)

- Vehicle hours of recurring and non-recurring delay in the peak and off-peak periods. *See Step 3 in calculations of Intermediate Measures.*
- No-build vehicle hours of recurring and non-recurring delay in the peak and off-peak periods. *See Step 3 in calculations of Intermediate Measures.*

Calculations:

1) Divide non-recurring delay by total delay to determine **ratio of non-recurring delay to total delay** for each link. *The ratio should be between 0.0 and 1.0, where values closer to 0.0 indicate roads with little non-recurring delay (e.g., due to incidents) or roads with large amounts of recurring delay (e.g., congestion due to physical roadway characteristics like bottlenecks). Values closer to 1.0 indicate large amounts of non-recurring delay, and may indicate the need for safety or operational improvements to reduce incidents.*
2) Repeat for all links and calculate **average ratio of non-recurring delay to total delay**, weighted by link length or link traffic volume or both.
3) The net impact attributable to the project is the difference between after construction and no-build conditions.

Person-Hours and Ton-Hours of Delay

Inputs: (required for each link before, during, and after construction and "no build" estimates)

- Vehicle hours of recurring and non-recurring delay in the peak and off-peak periods. *See Step 3 in calculations of Intermediate Measures.*
- Vehicle classification and composition (percent trucks in traffic flow). *Can range from less than 1 percent for local roads to over 20 percent for the busiest highways.*
- Persons per vehicle. *Use 1 for single-occupant vehicles, or up to 50 or more for buses.*
- Tons per truck. *Typical values range from 1 ton for local deliveries up to 25 tons for long-distance trucks transporting ore or building materials. Note: Commodity flow data are estimated at a regional or system level, and may not be suitable for use at local level. The use of observed truck counts may be more appropriate based on data suitability and availability.*

Calculations:

1) Multiply vehicle hours of delay by percent passenger vehicles and percent heavy vehicles to determine passenger vehicle hours of delay and truck hours of delay. Then add passenger and truck hours of delay together to determine total vehicle hours of delay.
2) Multiply personal-vehicle-hours of delay by persons per vehicle to determine **total person-hours of delay.**
3) Multiply no-build personal-vehicle-hours of delay by persons per vehicle to determine **total no-build person hours of delay**.

4) Multiply truck hours of delay by tons per truck to determine **ton-hours of delay**. If value per ton can be assumed, multiply value per ton by ton-hours of delay to estimate impact of delay in dollars per hour of freight. *Note: Commodity flow data are estimated at a regional or system level, and may not be suitable for use at local level. The use of observed truck counts may be more appropriate based on data suitability and availability.*

5) Multiply no-build truck hours of delay by tons per truck to determine **no-build ton-hours of delay**. If value per ton can be assumed, multiply value per ton by ton-hours of delay to estimate impact of delay in dollars per hour of freight.

6) The net impact attributable to the project is the difference between actual delay for after construction and no-build estimates of delay.

Table 3.3-A. Sample of Outputs of Person-hours and Ton-hours of Delay Calculations for One Direction of Flow
(NOTE: Contains fictional data for illustration purposes only)

	Before Construction	During Construction	After Construction	No-Build
Link delay (hours per year)	**390,000**	**420,000**	**150,000**	**500,000**
Percent passenger vehicles	92%	92%	92%	92%
Persons per vehicle	2.1	2.1	2.1	2.1
Annual person-hours of delay	**753,480**	**811,440**	**289,800**	**966,000**
Estimated net project impact ("After Construction"- "No Build") Annual person-hours of delay				**-676,200**
Percent heavy vehicles	8%	8%	8%	8%
Tons per truck	16	16	16	16
Annual ton-hours of delay	**499,200**	**537,600**	**192,000**	**640,000**
Estimated net project impact ("After Construction"-"No Build") Annual ton-hours of delay				**-448,000**

Percent of Travel under Congested Conditions

Inputs: (required for each link before, during, and after construction)

- Hourly traffic volumes, vehicles per hour.
- Roadway capacity, vehicles per hour.
- Persons per vehicle. *Use 1 for single-occupant vehicles, or up to 50 or more for buses.*
- Tons per truck. *Typical values range from 1 ton for local deliveries up to 25 tons for long-distance trucks transporting ore or building materials.*

Calculations:

- Volume/capacity ratio per hour = Hourly traffic volumes / capacity. *If 15-minute traffic counts or continuous traffic counts are available, calculate V/C ratio at finer level of detail. V/C ratio for the "no-build" condition can be estimated using pre-construction capacity and post-construction traffic volume data.*
- The definition of "congested conditions" must be determined by policy. *A V/C ratio between 0.75 and 1.0 typically indicates a roadway is becoming congested, and a V/C ratio above 1.0 indicates severe congestion.*
- **Percent of person-hours-traveled under congested conditions** = Hourly traffic volume * percent of passenger vehicles and buses in vehicle flow * persons per vehicle * share of hours during which roadway operates at or above V/C ratios of 0.75 (for moderate congestion) and 1.0 (for severe congestion).
- **Percent of ton-hours-traveled under congested conditions** = Hourly traffic volume * percent of trucks in vehicle flow * tons per truck * share of hours during which roadway operates at or above V/C ratios of 0.75 (for moderate congestion) and 1.0 (for severe congestion).

Network Connectivity and Continuity

An analysis of Network Connectivity and Continuity is independently processed and should be conducted for each mode using the roadway network, including automobiles and light trucks; heavy trucks, buses and commercial vehicles; bicycles; and pedestrians. The analysis procedures for bicycle and pedestrian facilities can be found in the Implementation Recommendations for the Bicycle and Pedestrian project category (Section 3.10).

<u>Inputs (for automobiles and light trucks; heavy trucks, buses, and commercial vehicles):</u>

- Road network information:
  - Block length or segment length (distance between interchanges), in feet. *For example, 6,000 feet between interchanges or 300 –foot block length in an urban area.*
  - Density of nodes (intersections) and segments, per mile. *For example, on a major suburban arterial or collector roadway, intersections may be spaced at half-mile intervals. On local streets, there may be 15 or more intersections per mile.*
  - Functional classification. *Use NJDOT functional classifications.*
  - Locations of restrictions on heavy trucks and commercial vehicles (height, width, and/or weight).

<u>Evaluation (automobiles and light trucks; heavy trucks, buses and commercial vehicles):</u> Use GIS to evaluate connectivity of roadway network before and after improvement. Evaluate connectivity on both a local scale and a regional scale. The *Smart Transportation Guidebook*, published in March 2008 through a partnership between Pennsylvania Department of Transportation and the New Jersey Department of Transportation, suggests the following connectivity measures:

- **Internal Connectivity.** Use either of the following two measures:
  - Beta Index —Express as a ratio, a beta index is the number of street links in the study area divided by the number of nodes or link ends. *A higher ratio indicates higher street connectivity. Traditional urban grid networks generally yield values above 1.4, while suburban cul-de-sac subdivisions may have beta index values closer to 1.0.A beta index can be calculated for the entire network (all functional classifications), for specific functional classifications (e.g., Interstate Highways, Expressways, and major arterials) or for one functional classification. For heavy trucks, buses, and commercial vehicles the index should take into account any restrictions on vehicle size and weight and restrictions on commercial vehicles.*
  - Intersections per square mile. *Strict grid systems have about 25 intersections per square mile, while conventional branching systems have about one-third to one-half that many.*

- **External Connectivity**
  - The *Smart Transportation Guidebook* recommends that all neighborhoods in the community should be connected to the larger street system at least every ¼ mile. *This measure can be evaluated qualitatively as a "yes/no" indicator.*
- **Route Directness**
  - Route directness measures the distance a vehicle would drive between two points over the roadway network compared to the straight line (or radial) distance between the same two points. *The closer the ratio is to 1.0, the more direct the route; route directness values of 1.2-1.5 describe reasonably connected networks. Route directness may vary depending on the vehicle type being analyzed, due to restrictions on vehicle size and weight and restrictions on commercial vehicles.*
- Connectivity and continuity in the "no-build" condition are simply the conditions that existed before construction.
- Compare route directness analysis for "no-build' and after conditions.

<u>Additional resources on network connectivity include the following:</u>

- Carlos A. Alba and Edward Beimborn (2005), *Analysis Of The Effects Of Local Street Connectivity On Arterial Traffic*, Transportation Research Board Annual Meeting (www.trb.org); at www.uwm.edu/Dept/CUTS//lu/conn.pdf.
- Dill, Jennifer (2004). "Measuring Network Connectivity for Bicycling and Walking." Presented at the 83rd Annual Meeting of the Transportation Research Board, Washington, DC.
- Portland Metro (2001), "Street Connectivity Standards," *Planning for Future Streets: Implementing the Regional Transportation Plan*, Portland Metro Regional Services (www.metro-region.org/library_docs/trans/streetconnect.pdf).
- Portland Metro (2004), Street Connectivity: An Evaluation of Case Studies in the Portland Region, Portland Metro (www.metro-region.org/library_docs/trans/connectivityreport.pdf).

Recommendations for Future Performance Evaluation: System Coordination Measures

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, 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, 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, microsimulation 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).

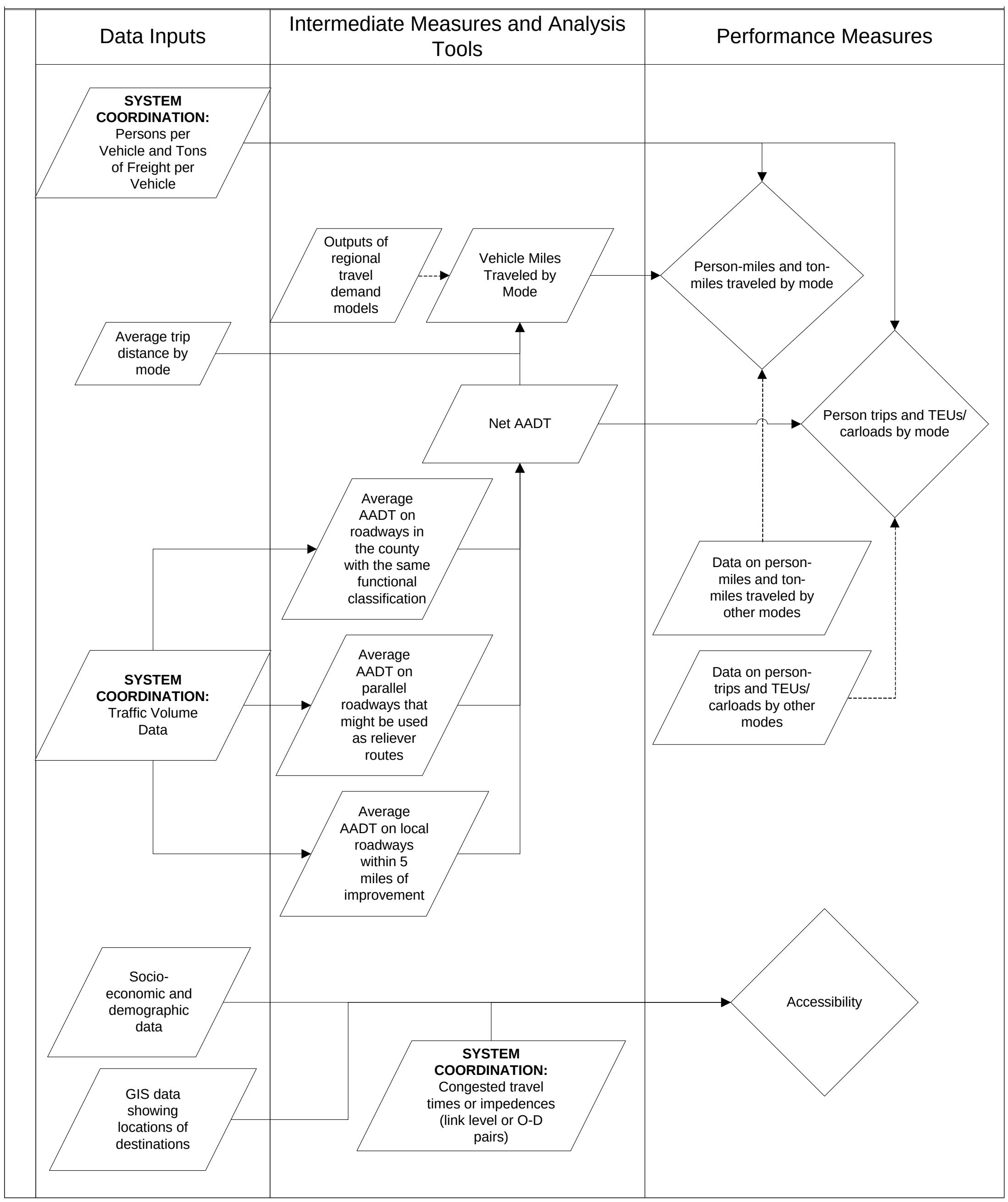
Improve network GIS data, particularly restrictions on oversize/overweight and commercial vehicles. Network connectivity and continuity data could be enhanced with additional information on system condition, facility attributes, and restrictions on use by certain vehicle types.

3.3.2 Evaluating User Responsiveness Measures

NJTPA User Responsiveness Goal - Provide affordable, accessible and dynamic transportation systems responsive to current and future customers.

Interdependencies between Data, Analysis Tools, and Performance Measures

The following diagram is a simplification of the interdependencies between User Responsiveness and System Coordination measures. *Note: Customer Satisfaction is independently evaluated and not included in this diagram. For further information, see page 3.3-38.*



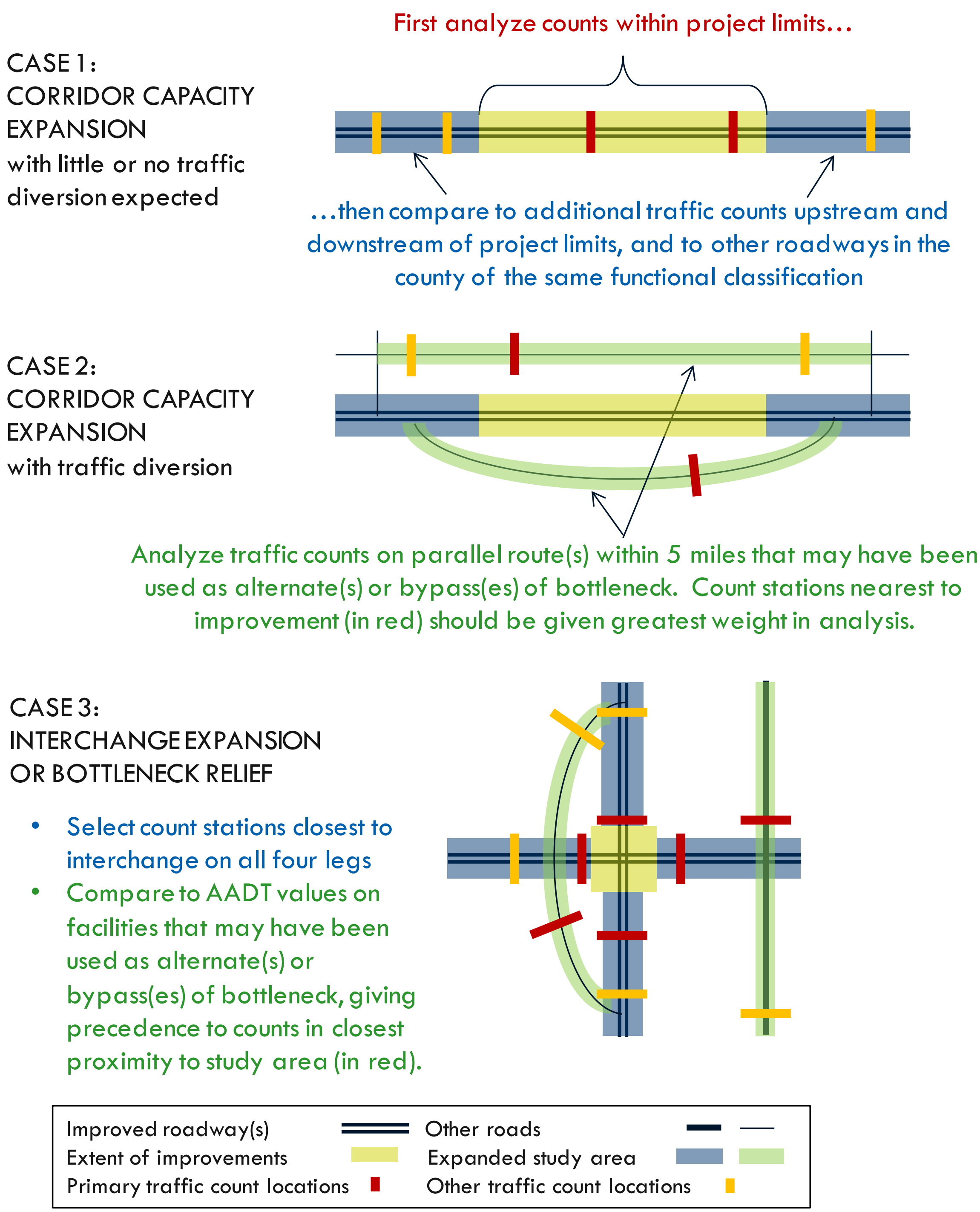
Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Persons per vehicle	Household travel survey data collected by NJTPA or American Community Survey 5-year average data for place/county in which link is located (from American Fact Finder). *Note that ACS data focus on work/commute trips, and therefore the data may need to be adjusted to account for all trip types using the facility*
Tons of freight and TEUs per vehicle	Commodity flow survey data and related databases (e.g., Transearch) *Note: The commodity flow data is estimated at regional system level which may not be suitable for use at local level. The use of number of trucks may be more appropriate based on data suitability*
Average trip distance	National Household Travel Survey (NHTS); Household travel survey data collected by NJTPA or American Community Survey 5-year average data for place/county in which link is located *Note that ACS data focus on work/commute trips, and therefore the data may need to be adjusted to account for all trip types using the facility*
Hourly traffic volumes in each direction and directional distribution of peak hour traffic	NJDOT Traffic Monitoring System
Socio-economic, demographic, and employment data (Census Block Group, Traffic Analysis Zone (TAZ), or Place level)	U.S. Census Bureau's American Fact Finder; U.S. Census Bureau's American Community Survey 5-year estimates; U.S. Census Bureau's Local Employment-Household Dynamics data, NJTPA. *Note that ACS 5-year estimates should not be compared for overlapping time periods and are mainly intended to be used for population characteristics, not population totals, particularly at smaller geographies (e.g., Census tracts)*
GIS data showing location of local destinations and opportunities (health clinics, grocery stores and sources of fresh food, local parks and playgrounds, elementary and secondary schools, and neighborhood-oriented retail and service establishments like restaurants, bars, dry cleaners, banks, and hardware stores)	Counties and local municipalities, NJDOT, NJDEP, Google Maps, WalkScore.com
GIS data showing locations of regional destinations and opportunities (major hospitals, four-year colleges and universities, major concentrations of retail activity, and recreational and tourist destinations with more than 100 employees, like amusement parks, sports arenas, performing arts venues, museums, and historic sites)	Counties and local municipalities, NJDOT, NJDEP, Google Maps, WalkScore.com

Geographic Scale of Analysis

The three User Responsiveness measures are best measured at a regional level or at a corridor level, grouping multiple facilities and modes together to determine the corridor-level or systemwide impacts of any given roadway expansion project. The figure below shows the geographic extent for which data should be analyzed:



Time Frame of Analysis

The impacts of roadway expansion projects as measured in terms of User Responsiveness measures may be small or may not be measurable at all shortly after completion of the improvement. However, as years pass many changes as measured by User Responsiveness measures may become more pronounced over time. Therefore, it is important to evaluate User Responsiveness measures on a continuous basis, using multiple data points from several years before the project and for as many years after the project as data are available.

Customer Satisfaction measures are an exception. The reaction to a Roadway Expansion project may peak shortly after project completion, but as time goes on, people may not be able to distinguish the project's impacts from other changes that have happened in the mean time (for example, other transportation improvements or economic shifts).

Using person-miles traveled by mode as an example, compared to pre-construction conditions, transit usage may increase slightly during construction as capacity decreases on the roadway and delay increases. Transit ridership may then decrease after completion of the project as the roadway has less congestion and delay. Impacts can be estimated as follows:

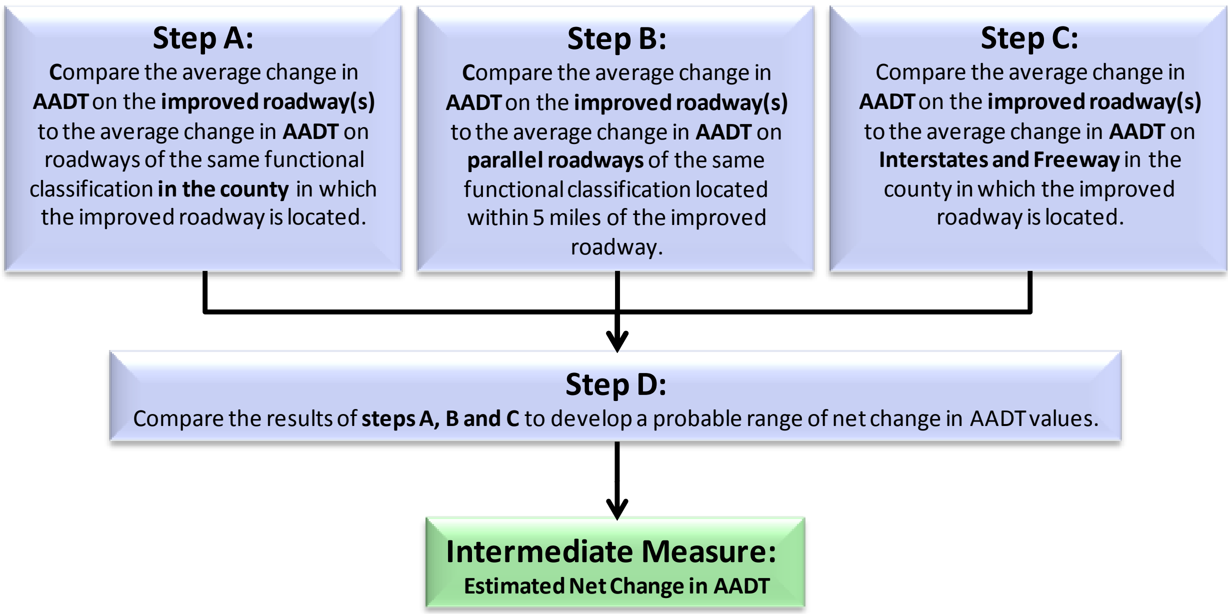
- The overall impact of the project can be estimated by comparing person-miles traveled by mode after the project to mode share before the project.
- The net impact can be estimated by comparing person-miles traveled by mode after the project to person-miles traveled by mode in a hypothetical "no-build" scenario.
- Finally, the impacts associated with construction can be estimated by comparing person-miles traveled by mode during construction to mode shares before and after construction.

Analysis Steps

Intermediate Measures and Analysis Tools

1. Calculate Net Change in Average Annual Daily Traffic (AADT)

Figure 3.3-A: Steps to estimate the value of "Net Change in Average Annual Daily Traffic (AADT) "[1]



Inputs: (Required for each link for the periods before construction and after construction)

- Traffic volumes (expressed in AADT) on roadway(s) within project limits, plus at least five miles upstream and downstream. *On a case-by-case basis, select the extent of roadway for which traffic volumes may have been affected by the project. For major regional bottlenecks, look at a longer segment. For smaller expansion projects with more localized impacts, choose a smaller segment. For example, AADT might range from less than 100 on community streets to over 200,000 on the busiest Interstate Highways in the NJTPA region.*
- Average AADT levels on roadways in the county in which the project is located that are of the same functional class as the improved roadway. *Calculated as total VMT on all roads or a given functional class of roads divided by total miles of road (or of a given functional class). For example: in Passaic County, the average AADT on Principal Arterials is around 25,000 AADT.*

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[1] If the facility is new, the net change in AADT may be 100 percent of the traffic observed on the new facility, or some adjustments may be made to account for traffic shifts from parallel roadways.

- Traffic volumes (expressed in AADT) on parallel roads and relievers that could reasonably be expected to carry traffic flows that may have shifted to or from the study area roadway before, during, or after construction.
- Average AADT levels on Interstates and freeways in the county in which the project is located. *As above, calculate by dividing total VMT on these facilities by total miles of road. For example, the average Freeway in Passaic County carries around 90,000 AADT.*
- *Note that continuous traffic counts are preferred because they allow consistent comparison of traffic data in the before- and after-construction periods. In cases in which continuous counts are not available, and only occasional data are collected at the count location, some interpolation or extrapolation of data may be necessary using annual county VMT data as a proxy for general economic conditions that may have affected traffic levels on the link.*

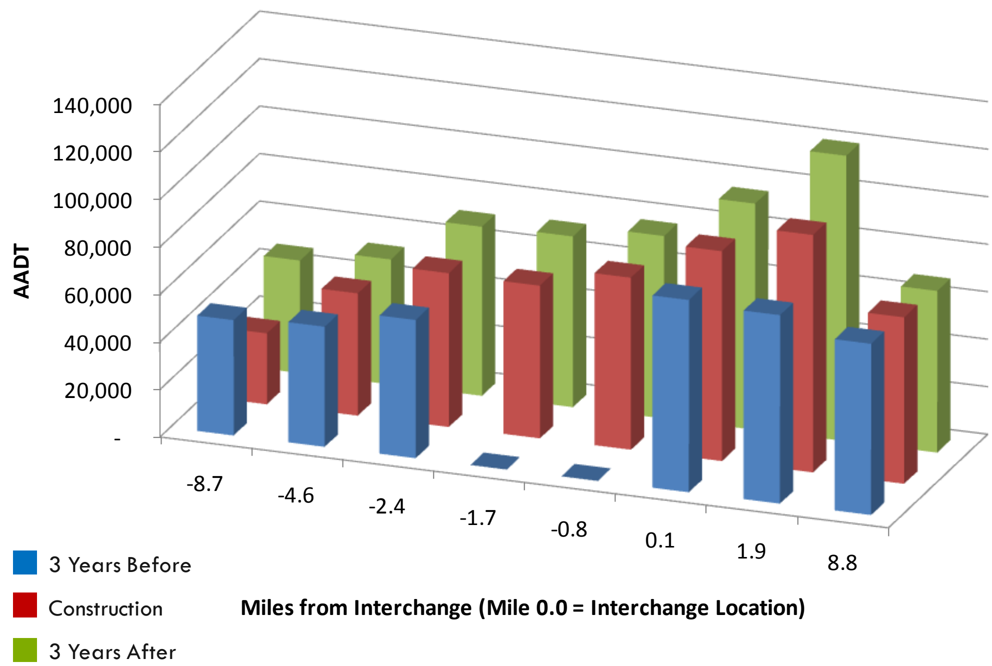
Calculations:

The recommended approach to calculating Net Change in AADT is to use a variety of methods to "triangulate" the estimated value. The calculation steps are as follows:

a. **STEP A:** Compare change in AADT (or change in average AADT) on the improved roadway(s) to the average AADT on roadways of the same functional class in the county in which the project is located.

   - Analyze the AADT levels observed at count stations on the improved roadway expansion section for at least three years before the project, during project construction, and at least three years after. Gather AADT data at least five miles upstream and downstream of the project limits. The change in AADT on the improved facility is the starting point in the analysis. The change in AADT may be averaged across several count locations if, for example, there are AADT data for four legs of an intersection/interchange or there are data just upstream and downstream of the project limits.

Figure 3.3-B: Sample of Upstream and Downstream AADT Values for a Roadway Expansion Project
(NOTE: Contains fictional data for illustration purposes only)



- The change in AADT at the count stations within (or closest to) the project limits should be given the greatest weight in the analysis. AADT values from further upstream and downstream of the project limits should be used as a comparison. *For example, inside the project limits, AADT values might range from 60,000 to 80,000, but upstream and downstream the AADT values might be much lower. If the AADT growth rates are wildly different from one count station to the next along the roadway, it may be difficult to draw any conclusions about the net AADT impact of the project. If there were other improvements in the study area during the analysis period, the impacts of construction on travelers' route choices, the reduction in roadway capacity in a construction zone, and the subsequent capacity or operational improvement after project opening may also impact the observed AADT levels. If, however, the AADT growth rates at various count stations along the facility are within a reasonable range of each other, continue with the next step.*
- Compare change in AADT (or change in average AADT) on the improved roadway(s) to the average change in AADT on roadways of the same functional classification in the county in which the project is located. To calculate average AADT for a functional classification, simply divide VMT by miles of roadway in that functional classification in the county. The growth rate in average AADT on roadways of the same functional classification, if applied to pre-construction traffic levels on the study facility, could lead to one estimate of what the change in AADT on the study facility may have been in the absence of the project. Note that this calculation could be biased if the AADT of the roadway project dominates the county wide average AADT for that functional classification. The difference between the actual absolute change in AADT on the

improved roadway and the adjusted change in AADT on the improved roadway is one way to estimate the net AADT impact of the project. Calculations are as follows:

$$\text{Adjusted AADT}_{\text{Post-constr.,Improved Road}} = \text{AADT}_{\text{Pre-constr.,Improved Road}} * \frac{\text{Average AADT}_{\text{Countywide,same func.class.,Post-Constr.}}}{\text{Average AADT}_{\text{Countywide,same func.class.,Pre-Constr.}}}$$

$$\text{Net AADT Change} = \text{Actual AADT}_{\text{Post-constr.,Improved Road}} - \text{Adjusted AADT}_{\text{Post-constr.,Improved Road}}$$

- *Note that, when comparing pre and post data, caution should be used as roads are regularly reclassified as a result of changing development and roadway investments. If roads appear to have been reclassified during the study time frame, the comparison analysis should include all functional classes necessary to have an 'apples to apples' comparison. That is, if the road being analyzed is a major arterial and a significant amount of minor arterials were reclassified to major arterials, then all arterials should be the basis of comparison, not major arterials.*

b. **STEP B:** Compare change in AADT (or change in average AADT) on the improved roadway(s) to the change in AADT on parallel roads of similar functional classification that may be used as reliever routes or bypasses of a bottleneck.

- Analyze AADT levels at count stations on parallel roadways within 5 miles of the improved roadway. Ideally, use parallel roadways of the same functional classification as the improved roadway and that face the same degree of capacity constraint (i.e., similar volume/capacity ratio). Using a combination of technical and professional judgment, select roads that were likely to have been used as bypasses of the bottleneck that was relieved by the capacity expansion. Count stations that are closest to improved section of the study roadway should be given the greatest weight in the analysis.

Table 3.3-B: Sample Analysis of Average AADT in Study Area and on Comparison Routes
(NOTE: Contains fictional data for illustration purposes only)

	Study Area		Comparison Routes	
	Primary Route	**Cross Route**	**Parallel Arterial**	**Connecting Road**
Before Construction	70,000	35,000	20,000	15,000
During Construction	80,000	n/a	25,000	n/a
After Construction	90,000	40,000	24,000	17,000
Percent change (Before to After)	**29%**	**14%**	**20%**	**13%**

- Analyze the available AADT data on each road to determine the range of variations in traffic levels from before construction to after project implementation. Calculate an average change in AADT on parallel roadways.
- The growth rate in AADT on these comparison roadways, if applied to pre-construction traffic levels on the study facility, could be a second estimate of what the change in AADT may have been on the study facility in the absence of the improvement. The difference between the actual absolute change in AADT on the improved roadway and the adjusted change in AADT on the improved roadway is in turn, a second basis for estimating the net AADT impact of the project. Calculations are as follows:

$$\text{Adjusted AADT}_{\text{Post-constr.,Improved Road}} = \text{AADT}_{\text{Pre-constr.,Improved Road}} * \frac{\text{AADT}_{\text{Comparison facilities,Post-Constr.}}}{\text{AADT}_{\text{Comarison facilities,Pre-Constr.}}}$$

$$\text{Net AADT Change} = \text{Actual AADT}_{\text{Post-constr.,Improved Road}} - \text{Adjusted AADT}_{\text{Post-constr.,Improved Road}}$$

- *Selecting the comparison count stations is critical to this step. If appropriate comparison count stations are not available, it may still be possible to make inferences about whether net AADT changed in a positive or negative direction due to the project, and perhaps even the magnitude of this change (small or large), even if a net AADT estimate cannot be calculated.*
- *Caution must be exercised in the case when improvements were made on the parallel roads or elsewhere in the network that may have affected traffic levels on the parallel roads. In some cases, data for parallel roads may not be useable because the data may not tell a consistent story about before and after conditions.*

c. **STEP C:** Compare change in AADT (or change in average AADT) on the improved roadway(s) to the change in average AADT on Interstates and freeways in the county in which the project is located.

- Compare change in AADT (or change in average AADT) on the improved roadway(s) to the average AADT on roadways of the functional classifications “Interstate” and “Freeway” in the county in which the project is located. To calculate average AADT for a functional class, simply divide VMT by miles of roadway in that functional class in the county.
- The growth in average AADT on Interstates and Freeways, if applied to pre-construction traffic levels on the study facility, is a third way to triangulate what the change in AADT

may have been in the absence of the project. The difference between the actual absolute change in AADT on Interstates and Freeways and the actual absolute change in AADT on the study area roadway is a third way to estimate the net AADT impact of the project, assuming that average AADTs on Interstates and Freeways reflect background growth (or decline) due to changing economic conditions. Calculations are as follows:

$$\text{Adjusted AADT}_{\text{Post-constr.,Improved Facility}} = \text{AADT}_{\text{Pre-constr.,Improved Facility}} * \frac{\text{Average AADT}_{\text{Interstates and Freeways,Post-Constr.}}}{\text{Average AADT}_{\text{Interstates and Freeways,Pre-Constr.}}}$$

$$\text{Net AADT Change} = \text{Actual AADT}_{\text{Post-constr.,Improved Road}} - \text{Adjusted AADT}_{\text{Post-constr.,Improved Road}}$$

- *It is important to note if any significant changes occurred on Interstates and Freeways in the county during the analysis period. For example, if a large project was completed or if the study project itself occurred on an Interstate or Freeway, the average AADT estimates for those functional classifications is not a good proxy for regional traffic. In this case, one could substitute the average AADT on all Interstates and Freeways in the NJTPA region as a comparison metric.*

d. Compare the results of steps "a", "b", and "c" to develop a probable range of net AADT values. If the net change in AADT is within the same order of magnitude, proceed to the next step in the calculation. If the net change varies wildly, or if the net change is positive in one calculation and negative in another calculation, re-examine the results in light of the caveats discussed after each calculation above. If necessary, use professional judgment to eliminate any net AADT estimates that appear unreasonable. Then use either the average, median, high, or low value depending on the purpose of the analysis.

e. If all three estimates are wildly different, it may not be possible to proceed with the next step.

Intermediate output measures:

- Range in values of **net change in AADT** attributable to construction of the project, in vehicles per day. For example, net change in AADT might be in the range of 1,000 to 5,000 vehicles per day, or even higher for a large capacity expansion analyzed over a relatively long period of time.
- If the facility is new, the net AADT may be 100 percent of the traffic observed on the new facility, or some adjustments may be made to account for traffic shifts from parallel roadways.

2. Calculate Net Change in VMT

Inputs:

- Range in values of estimated net change in AADT from previous step (for before and after construction).
- Average trip distance for vehicles using the roadways in the analysis (use a single year, perhaps the midpoint of the analysis, so as not to introduce additional uncertainties

into the calculation). *Average trip distance for work trips in the NJTPA region is about 10 miles.*

- VMT data and aggregate lengths by roadway functional classification in the county in which the project is located (from HPMS or other source); in the NJTPA region; and in the state (for pre-construction and post-construction years).

<u>Calculations:</u>

a. Convert net AADT estimates to net VMT estimates.

- If traveler survey data are available, gather information on average trip distance for the vehicles using the study area roadways or from the county where the project is located. If survey data are not available, use county-level or regional average trip lengths from NHTS, Journey to Work data developed by the U.S. Census from both decennial censuses and the American Community Survey.
- Multiply range of net AADT estimates by average trip length to calculate a range of estimated net change in VMT attributable to the project. *For example, a major roadway expansion project may result in a net VMT impact of 50-100 million VMT per year.*

b. Compare the VMT change in the county in which the project is located to the NJTPA region and the State of New Jersey.

- For large projects in particular, VMT impacts may be perceived at a county level. As another point in the "triangulation" process, at this point the range of net VMT estimates produced in the previous step can be compared to the rates of change in VMT at the county, region, and state level. Compare the rate of change in county-level VMT to the rate of change of facility-level AADTs, and also compare the county-level VMT to the rate of change in VMT at the regional and state level. The differences between these respective VMT changes can be used to estimate a range of probable net VMT impacts of the project. *VMT changes could be positive or negative depending on the type of improvement and economic conditions in the study period. Typical VMT impacts range from -30% to +30%.*

c. The result of this approach will be a range of estimates of net change in VMT, comparable to the range of estimates of net change in AADT produced above. Divide the mean value by the difference between the largest and smallest VMT change estimates. If this value is greater than 1, then the estimates are within a reasonable range of each other. If this value is less than 1, then there is great variability in the estimates and they should be reported with caution. In any case, the full range of potential sources of uncertainty should be clearly documented in the report of net change in VMT.

<u>Intermediate output measures:</u>

- **Net change in vehicle miles traveled.**

Person-Miles and Ton-Miles of Travel by Mode (Mode Choice)

Inputs:

- Net vehicle miles traveled, *from Intermediate Calculations above.*
- Persons per vehicle. *Use 1 for single-occupant vehicles, or up to 50 or more for buses.*
- Tons per truck. *Typical values range from 1 ton for local deliveries up to 25 tons for long-distance trucks transporting ore or building materials. Note: The commodity flow data is estimated at regional system level which may not be suitable for use at local level. The use of number of trucks may be more appropriate based on data suitability.*
- *Use estimates of persons per vehicle and tons per vehicle from a single year, perhaps the midpoint of the analysis, so as not to introduce additional error into the calculation.*

Calculations:

- Multiply estimates of net vehicle miles traveled by persons per vehicle and tons of freight per vehicle to determine the net change in person-miles traveled by vehicle and ton-miles traveled by truck. *The calculation can be enhanced if vehicle classification data are available along with the traffic counts used to generate AADT values. In this case, vehicle-specific net VMT estimates can be produced, which then will help generate estimates of net person-miles traveled and net ton-miles traveled.*
- *Combined with estimates of person-miles traveled by other modes (e.g., transit and non-motorized modes) and estimates of ton-miles traveled by other modes (e.g., freight rail or marine highway), this measure can help estimate the impact of the project on mode choice. See the Non-Motorized, Transit Expansion and Freight sections, respectively, for guidance on how to calculate person-miles traveled by bicycling and walking, person-miles traveled by transit, and ton-miles traveled by other freight modes.*

Outputs:

- **Net person-miles of travel by mode.** *For example, a roadway expansion project may increase person-miles of travel by roadway by 1.2 million miles per year and reduce person-miles of travel by transit by 0.5 million miles per year. The discrepancy is explained by the number of new trips that are induced by the roadway expansion in addition to the existing trips that shift from transit to roadway.*
- **Net ton-miles of travel by mode.** *For example, a roadway expansion project may increase ton-miles of travel by truck by 17 million miles per year and reduce ton-miles of travel by freight rail by 18.5 million miles per year. The discrepancy is explained by the longer distance required by rail trips over a less connected network.*

Person-Trips and Tons/TEUs by Mode (Mode Choice)

Inputs:

- Net AADT, *from Intermediate Calculations above.*
- Persons per vehicle. *Use 1 for single-occupant vehicles, or up to 50 or more for buses.*
- Tons per truck. *Typical values range from 1 ton for local deliveries up to 25 tons for long-distance trucks transporting ore or building materials. Note: Commodity flow data are estimated at a regional or system level, and may not be suitable for use at local level. The use of observed truck counts may be more appropriate based on data suitability and availability.*
- *Use estimates of persons per vehicle and tons per vehicle from a single year, perhaps the midpoint of the analysis, so as not to introduce additional error into the calculation.*

Calculations:

- Multiply estimates of net AADT by persons per vehicle and tons of freight per vehicle to determine the net change in person-trips by motor vehicles and tons or TEUs by truck. The calculation can be enhanced if vehicle classification data are available along with the traffic counts used to generate AADT values. In this case, vehicle-specific net AADT estimates can be produced, which then will help generate estimates of net person-trips moved by motor vehicles and net tons moved by truck.
- Combined with estimates of person-trips by other modes (e.g., transit and non-motorized modes) and estimates of tons and TUEs moved by other modes (e.g., freight rail or marine highway), this measure can help estimate the impact of the project on mode choice. See the Non-Motorized, Transit Expansion and Freight sections, respectively, for guidance on how to calculate person-trips by bicycling and walking, person trips by transit and tons and TEUs moved by other freight modes.

Outputs:

- **Net person-trips by mode.** *For example, a roadway expansion project may increase person-trips by auto by 50,000 per year and reduce person-trips by transit by 30,000 miles per year. The discrepancy is explained by the number of new trips that are induced by the roadway expansion in addition to the existing trips that shift from transit to roadway.*
- **Net tons and TEUs by mode.** *For example, a roadway expansion project may increase mode share by truck and reduce mode share by freight rail by a similar share.*

Accessibility

Accessibility is a measure of the ability of people to reach opportunities and activities that they undertake in their daily lives such as work, school, shopping, medical service, etc., or the ability of businesses to reach their labor force, sources of raw materials and inputs to their production facilities, and the consumer markets for their finished products.

Access to jobs refers to the ability of the residents of a given area to access employment opportunities via any mode of transportation. Increased access to jobs is correlated with reduced unemployment rates and improved per capita income.

Access to labor force refers to the ability of businesses to access a pool of labor in a given market area. Increased access to labor force makes a business more competitive as more people with the skills necessary to do a job can compete for the same job opening.

Access to regional amenities can include the ability to reach major hospitals, universities, major concentrations of retail activity, and recreational and tourist destinations like amusement parks, beaches, sports arenas, performing arts venues, museums, and historic sites. Regional amenities can be screened using employment (only destinations with more than 100 employees, or retail employment density greater than 100 per acre, for example).

Access to trading partners refers to the ability of a business to reach destinations where their products are sold and origins of inputs and raw materials to their production facilities. Because the region's trading partners may be outside the NJTPA region, a proxy for locations of trading partners can be county centroids across the U.S.

Access to community amenities can be defined as the ability to reach destinations that are sources of basic services and daily needs, and may include health clinics, grocery stores and sources of fresh food, local parks and playgrounds, elementary and secondary schools, and neighborhood-oriented retail and service establishments like restaurants, bars, dry cleaners, banks, and hardware stores.

Inputs:

- Locations of working-age population (U.S. Census Bureau) aggregated to traffic analysis zones (TAZs).
- Locations of jobs (from U.S. Census Bureau, U.S. Bureau of Labor Statistics, NJ Department of Labor and Workforce Development, Center for Economic Studies, Longitudinal Employer-Household Dynamics Program) aggregated to NJTPA's TAZs.
- Locations of regional amenities (from GIS database of regional amenities).
- Locations of local amenities (from GIS database of local amenities).
- Peak hour travel speed data for links in the NJRTM-E model network (from INRX or other vehicle probe data).
- NJRTM-E model network link attributes (link length, toll information).

Calculations:

a. Access to Community Amenities: Distance-Based Cumulative Opportunity accessibility measure

- For local amenities, a distance-based threshold may be the only option. *If travel times by walking, biking, and competing modes are known, one of the other accessibility measures mentioned in this section can be used instead of the following procedure.*
- Using a GIS tool, in an area within a ½-mile radius or less depending on the determined geographic scale of the project limits, calculate the number of local amenities in this ½-mile radius that can be reached within a ½-mile walk before and after construction of the roadway expansion project. The change in access to local amenities is the difference in cumulative opportunities that can be reached before and after construction. *For example, before construction there may be five grocery stores within a* ½-mile *radius, and due to access restrictions imposed as a result of the project's construction, there may be only two grocery stores accessible after construction.*
- *Access to community amenities should be evaluated at as fine-grained a geographic scale as possible (e.g., Census blocks or block groups), because many TAZs may be more than ½-mile across.*
- *If no sub-TAZ data are available, access to community amenities can be evaluated qualitatively using maps showing before-and-after local street network, sidewalk network, and bike network connectivity.*

b. For all destinations other than community amenities: Travel-time-based Cumulative Opportunity accessibility measure

- For period before construction (average of three years) and period after construction (three-year moving average for all available years), use GIS to calculate the shortest travel time between all O-D pairs in the regional network. If possible, calculate travel time on a multimodal basis, since at peak times some trips may be faster by transit.
- Aggregate the number of "opportunities" that lie in the TAZs that can be reached within the following time thresholds:
  - Jobs: 60 minutes (using peak hour travel times).
  - Labor force: 60 minutes (using peak hour travel times).
  - Regional amenities: 90 minutes (using average weekend day travel time).
  - Buyer and supplier markets: 5 hours (using average weekday travel time).
- The relevant equation is:

$$A_i = \sum_{j=1}^{J} B_j O_j$$

where A_i is accessibility measured at point i to potential activities in zone j,

O_j is the opportunities in zone j, and

B_j is a binary value equal to 1 if zone j is within the predetermined threshold and 0 otherwise.

- The change in access is the difference in cumulative opportunities across all TAZ pairs that can be reached in the specified travel time. Cumulative opportunity estimates for each TAZ in a given area can be aggregated using the following equation:

  $A_{Area} = (\Sigma A_i * P_i) / P_{Area}$

  where:

  A_i = Accessibility of zone *i*

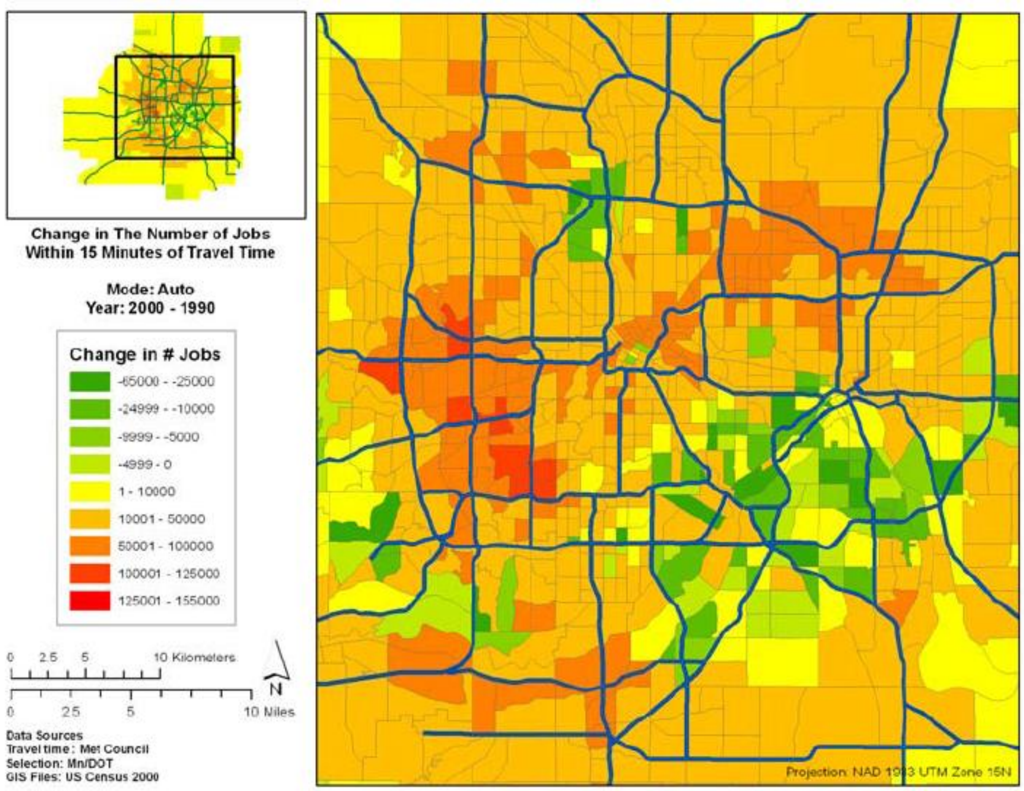
  P_i= Population of zone *i*

  P_{Area}= Population of the study area (could be a county or the NJTPA region)

  A_{Area}= Accessibility of the region (could be a county or the NJTPA region)

- *For example, before construction, 200,000 jobs might be accessible within a 60-minute commute of a given location. After construction of a roadway expansion project, 250,000 jobs might be accessible within 60 minutes. The net impact of the project is access to an additional 50,000 jobs at that location. The net impacts for each TAZ or analysis area can be plotted on a map to determine where the biggest net accessibility benefits accrue, as in the example below from the Minneapolis-St. Paul metro area.*

Figure 3.3-C: Example of a Map of Regional Accessibility Change



Source: El-Geneidy, A and D. Levinson, 2005. "Place Rank: A New Accessibility Measure," Nexus (Networks, Economics, and Urban Systems) Research Group, Department of Civil Engineering, University of Minnesota.

- *Note that population is not necessarily the most appropriate weighting factor. Employment could be used in place of population for access to employment and access to labor force, for example.*

- *A cumulative opportunity measure of accessibility is perhaps the simplest way to measure accessibility, but this measure requires the use of an arbitrary radius that, for example, attributes no value to jobs 61 minutes from an origin or regional amenities 91 minutes away. Because the measure is being used to compare before and after conditions, rather than rank the accessibility of individual zones, choosing an arbitrary threshold is not as problematic. A sensitivity analysis could be employed by varying the time threshold by +/- 10 minutes to see if the results change significantly.*

Additional resources on accessibility measures include the following:

- El-Geneidy, A and D. Levinson, 2005. "Place Rank: A New Accessibility Measure," Nexus (Networks, Economics, and Urban Systems) Research Group, Department of Civil Engineering, University of Minnesota. El-Geneidy and Levinson propose the use of a so-called "Place Rank" accessibility measure that uses actual information about origins and destinations by trip purpose and takes into account the relative attractiveness of each zone in calculating accessibility. The Place Rank accessibility calculation is an iterative process that uses the following equations:

$$R_{j,t} = \sum_{i=1}^{I} E_{ij} * P_{it-1}$$
$$P_{it-1} = [E_j * [R_{j,t-1} / E_i]]$$

Where:

- $R_{j,t}$ The *place rank* of *j* in iteration *t*
- *I* The total number of *i* zones that are linked to zone *j*
- E_{ij} The number of people leaving *i* to reach an activity in *j*
- P_{it-1} The power of each person leaving *i* in the previous iteration
- E_j The original number of people destined for *j* $Ej= \sum_{i}$
- $R_{j,t-1}$ The *place rank*ing of *j* from the previous iteration
- E_i The original number of people residing in zone *i*: $Ei= \sum_{j} j$

Customer Satisfaction

Customer Satisfaction is a measure that does not depend on inputs from any other performance measure. Customer Satisfaction measures can be obtained from the results of surveys performed by NJDOT or other agencies after completion of a project.

<u>Inputs:</u>

- Surveys of transportation system users, ideally including information about the relative importance of each system attribute being queried.
- Typical questions on roadway-related customer satisfaction surveys include:
    - Customer perception of improvement's impacts across NJTPA goal areas: Built and natural environment, congestion, travel speed, access to destinations, safety, economic impacts.
    - Project's impact on travel behavior: Whether the improvement caused mode shifts ("What was the previous mode used to make the trip?") and destination choice decisions (e.g., enabled a longer trip to a destination not previously accessible).
    - Impacts of roadway construction: Safety, congestion and delays, access to businesses, environmental impacts during construction.

Recommendations for Future Performance Evaluation: User Responsiveness Measures

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, such as the map shown above in Figure 3.3-C, 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.

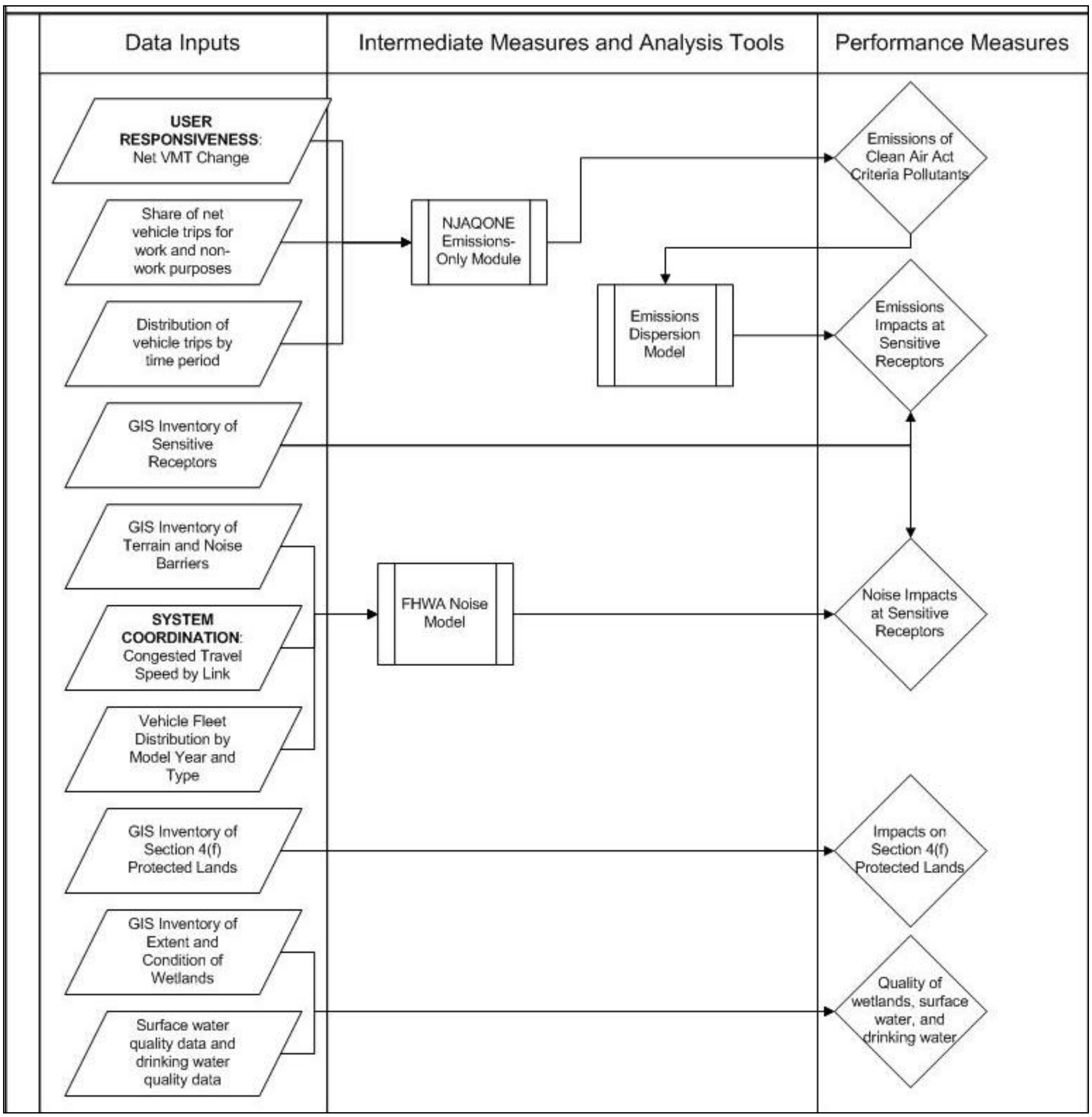
Undertake more customer satisfaction surveys for all modes on a regular basis. Agencies responsible for building, maintaining, and operating the transportation system in the region should undertake regular customer satisfaction surveys to collect a range of qualitative and quantitative data about customer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

3.3.3 Evaluating Environment Measures

NJTPA Environment Goal - Protect and improve the quality of natural ecosystems and human environment.

Interdependencies between Data, Analysis Tools, and Performance Measures

The following diagram is a simplification of the interdependencies between Environmental measures and the intermediate and ultimate measures discussed in the System Coordination and User Responsiveness sections. Note: Visual aesthetics and context is independently evaluated and not included in this diagram. For further information, see page 3.3-52.



Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Change in VMT	Intermediate measure calculated in **User Responsiveness**; see methodology above
Traffic volumes (hourly, 15-minute, or continuous)	NJDOT Traffic Monitoring System, county- and/or project-specific traffic counts
Roadway link characteristics[2]: • Roadway link length • Roadway functional classification • Terrain type/road grade* Vehicle classification and composition	NJDOT Roadway Network File, NJDOT Straight-Line Diagrams, Aerial Photos, Project plans/as-built diagrams *Can assume zero grade if terrain information is not available.
Share of net vehicle trips for work and non-work purposes	NJTPA Regional household travel surveys
Distribution of vehicle trips by time of day	Hourly/15-minute/continuous traffic volume data
GIS Inventory of Sensitive Receptors	NJDOT and NJDEP GIS; Google Maps and other commercial sources
Archived data on noise levels at sensitive receptors	NJDOT and local municipalities
Fraction of vehicles utilizing gasoline, ethanol, diesel, or alternative fuels, percent by type, for each hour in the analysis period[2]	U.S. Department of Energy Alternative Fuels and Advanced Vehicles Data Center
Fraction of vehicles in network by model year, percent by type, for each hour in the analysis period[2]	U.S. Department of Energy Alternative Fuels and Advanced Vehicles Data Center
GIS inventory of terrain and noise barriers	NJDOT and NJDEP GIS; NJDOT Straight Line Diagrams
Congested travel speeds by link	Intermediate measure calculated in **System Coordination**; see methodology above
Vehicle trip distribution by model year and type	NJMVC Registration data; NJDOT vehicle classification count data
GIS inventory of Section 4(f) protected lands	NJDEP GIS Wildlife and waterfowl refuges: US Fish and Wildlife Service Historic properties: National Historic Geographic Information System (NHGIS), state historic preservation office (SHPO) and

[2] Optional (required only if using MOVES for emissions modeling)

	local historical commissions/societies
GIS Inventory of extent and condition of wetlands	NJDEP GIS; US Army Corp of Engineers
Surface and drinking water quality	NJDEP Division of Water Quality; NJDEP Bureau of Safe Drinking Water
Net person-miles of travel by biking and walking	Performance measure calculated in **User Responsiveness**; see methodology above
Project purpose and need statement or project description from planning documents, funding applications, etc.	Implementing agency; county or local municipality in which project is located
Photos and project descriptions after project completion	Implementing agency; county or local municipality in which project is located
Local comprehensive plans and other relevant planning documents for the area in which the project was constructed	County or local municipality in which project is located
List of commitments to stakeholders that was developed and maintained during planning and design and/or was incorporated into construction documents prior to beginning construction	Implementing agency; county or local municipality in which project is located
Results of post-construction surveys of project team members from the implementing agency and consultants	Post-construction surveys
Results of post-construction surveys of community stakeholders (residents and businesses) and regulatory agency staff	Post-construction surveys

Geographic Scale of Analysis

The geographic scale of analysis depends on the measure being assessed. The following table shows the recommended geographic scale of each measure.

Measure	Geographic Scale(s) of Analysis
Emissions of Clean Air Act criteria air pollutants and greenhouse gases	Air quality (AQ) data are collected at the facility level as well as at the regional scale. The regional and statewide travel demand models that are necessary to quantify emissions are based on this state and regional data collection. Transportation-related emissions, for example greenhouse gases, do not respect state and regional boundaries; therefore regional and statewide data are necessary. The Clean Air Act requires regional and project level hotspot analysis. Most non-attainment areas have on the ground monitoring units in set locations. These units are not typically moved to measure emissions for specific projects. Transportation emissions that lead to respiratory conditions and other health impacts should be estimated at sensitive receptors within ¼ mile of project limits.
Transportation-related noise and vibrations at sensitive receptors	Sensitive receptors within ¼ mile of project limits
Quality of wetlands, surface water, and drinking water	Primary/direct impacts (wetlands): Project limits Secondary/cumulative impacts: Project-specific as defined in NEPA Scoping document; could be several miles from project limits; use natural boundaries such as water sheds as study area boundaries
Impacts on Section 4(f) protected lands	Primary/direct impacts: Project limits Secondary/cumulative impacts: Project-specific as defined in NEPA Scoping document; could be several miles from project limits; use natural boundaries such as water sheds as study area boundaries
Visual aesthetics and context sensitivity	Project limits (project-specific design features); adjacent properties; neighborhoods and municipalities in which project is located; architectural and environmental features in view shed

Time Frame of Analysis

The ability to measure the net Environmental impacts of a project over time is directly dependent on the ability to measure net VMT impacts, net changes in AADT, net impacts on congested travel speeds, and net impacts on mode choice decisions. As the quality or credibility of these estimates deteriorate over time, so does the credibility of the results of an environmental impact assessment. Therefore, the time frame of analysis for Environmental performance measures should mirror the time frames for System Coordination and User Responsiveness measures: measures should be on a continuous basis if possible, using multiple data points from several years before the project and for as many years after the project as data are available to draw valid conclusions about the net impacts of a project.

As indicated in the above table, the environmental impacts of roadway expansion projects are often measured at a regional scale. Therefore, the net impacts of any one project may be clouded over time by economic growth that generates additional travel demand (in turn affecting emissions and noise), by other development that increases impervious cover and impacts wetlands and water quality, or by changes in the region's socioeconomic and demographic profile that affect public health outcomes. On a project-by-project basis, professional judgment will be necessary to determine the limits of credibility of the following analysis.

Analysis Steps

Emissions of Clean Air Act Criteria Pollutants

<u>OPTION A: NJAQONE</u>

<u>Inputs:</u>

- Total change in VMT attributable to project, in miles per year (intermediate output measure of **User Responsiveness** analysis)
- Total change in work and non-work related vehicle trips attributable to project, in trips per year (from regional household travel surveys)
- Distribution of travel by time period (based on available NJDOT traffic volume data, either hourly, 15-minute, or continuous counts)

<u>Calculations:</u>

- Use NJAQONE Emissions-Only module to estimate emissions in forecast year. (Please refer to Figure 3.3-D)
- Conduct one run for "no-build" condition and a second run for the "build" condition

<u>Output measures:</u>

- Estimated **net change in emissions by criteria pollutant**, in tons per year

<u>OPTION B: MOVES</u>

Primary Inputs:

- Link traffic volume, vehicles per hour, for each hour in the analysis period
- Roadway link length, miles
- Link average speed, MPH, for each hour in the analysis period
- Fraction of light duty, heavy duty, and other types of vehicles, percent, for each hour in the analysis period
- Fraction of vehicles utilizing gasoline, ethanol, diesel, or alternative fuels, percent by type, for each hour in the analysis period
- Fraction of vehicles in network by model year, percent by type, for each hour in the analysis period
- Link functional classification
- Road grade, in percent

Secondary/optional inputs:

- *In place of link average speed, can input a link "drive schedule" or "operating mode distribution"; see EPA's MOVES technical documentation for details on the data requirements and formats for these inputs*

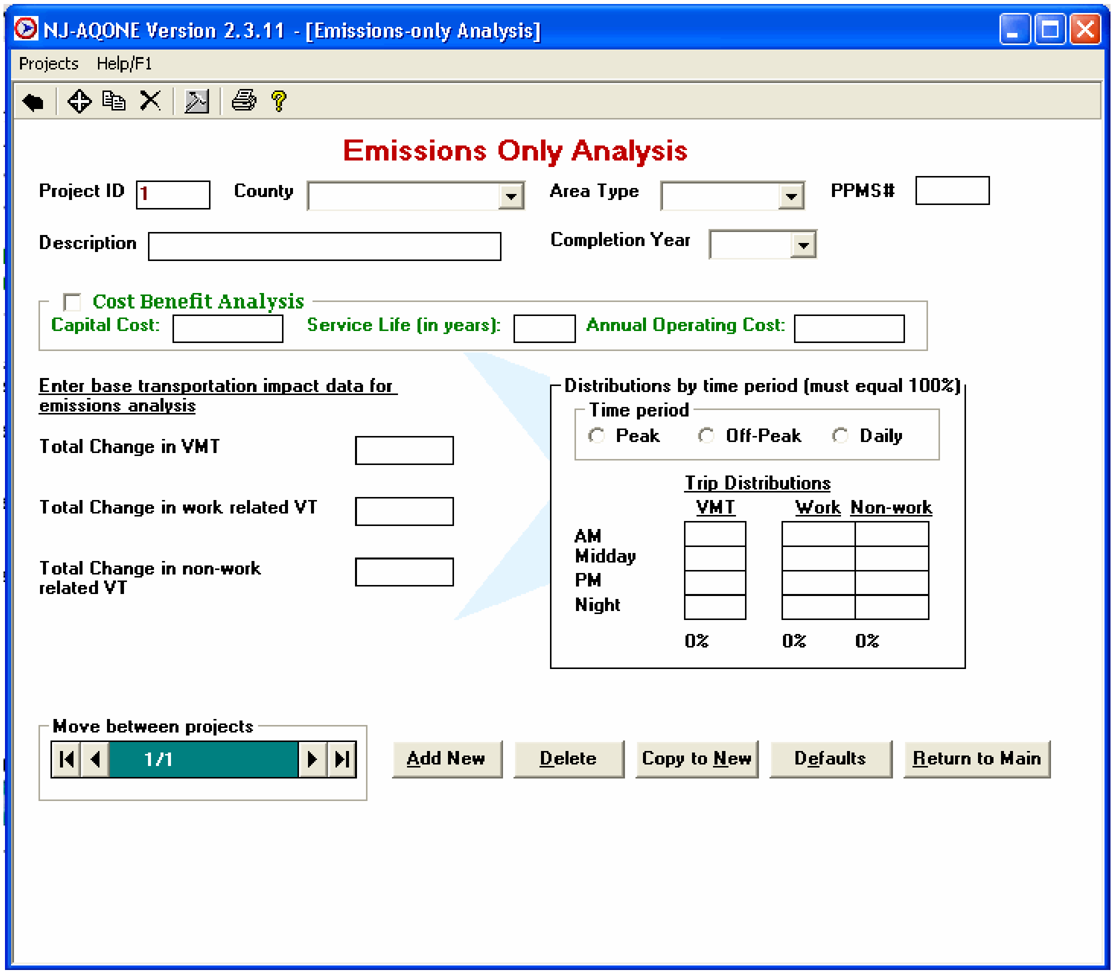
Calculations:

- Use EPA's MOVES Project-level model to estimate emissions in analysis period after construction
- Each hour of the day requires a separate MOVES model run
- Conduct one set of model runs for the "no-build" and a second set of model runs for "build" conditions

Output measures:

- Estimated net change in **criteria pollutant emissions**, **greenhouse gas emissions**, **mobile source air toxics**, and **energy consumption** (total, petroleum-based, and fossil-based)

Figure 3.3-D: Example Emissions Only Analysis Input Screen from NJAQONE



Emissions Impacts at Sensitive Receptors

1. Generate emissions contour maps.

   Inputs:

   - Estimated change in emissions by criteria pollutant, from NJAQONE or MOVES.
   - Baseline emissions estimates, from NJAQONE or MOVES baseline data.
   - Geography-specific climate data. Can use defaults built into models.

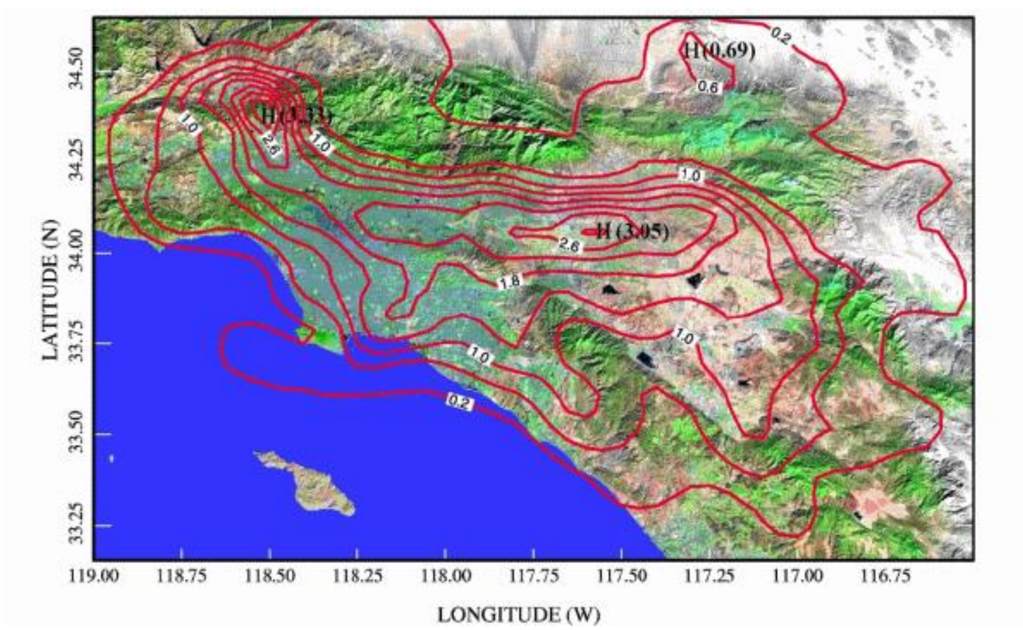
   Analysis Tools:

   - Use Emissions Dispersion model to allocate emissions to points or subregions in the analysis area. Conduct one run for baseline conditions and a second run for "build" condition.

   Outputs:

   - Emissions contour maps showing concentrations by criteria pollutant for baseline condition and for "build" condition.

Figure 3.3-E: Example map of daily emissions of soot in micrograms per cubic meter for Los Angeles Metropolitan Area



2. Overlay sensitive receptor points on emissions contour maps.

   Inputs:

   - Emissions contour maps for baseline condition and "build" condition from dispersion model.
   - GIS layer of sensitive receptors in NJTPA region.

   Calculations:

   Net emissions impact at any given sensitive receptor is the difference between the build condition and the baseline condition. Repeat calculation for each sensitive receptor.

   Outputs:

   - **Estimated emissions impacts by sensitive receptor.** *For example, "Emissions of particulate matter (PM 2.5) increased from 1.2 micrograms per cubic meter to 1.8 micrograms per cubic meter as a result of the project."*

Noise and Vibration Impacts at Sensitive Receptors

Inputs:

- Peak hour volume and average speed by vehicle type, by link (intermediate output measures of **System Coordination** analysis).
- GIS inventory of terrain type.
- Location and extent of noise barriers (NJDOT GIS and Straight Line Diagrams).
- GIS inventory of sensitive receptors.
- Archived data on noise levels at sensitive receptors at regional, county level, and/or corridor level.

Calculations:

- Use FHWA Noise Model to generate noise contours and estimated impacts at sensitive receptors. To estimate net impacts, run one scenario with "build" conditions using most recent available data and a second "no-build" scenario with estimated "no-build" inputs. Repeat for each sensitive receptor.
- If enough data are available about changes in decibel levels at sensitive receptors over time, the project-specific impacts also can be compared to regional, county-level, or corridor-level average impacts over the same analysis period as another estimate of what may have happened in the absence of the project.

Outputs:

- **Net noise and vibration impacts at sensitive receptors, in decibels.** *For example, "The hourly equivalent sound level $L_{EQ}(h)$ increased from 60 dB to 75 dB as a result of the project."*

Impacts on Section 4(f) Protected Lands

Inputs:

- GIS inventory of Section 4(f) Protected Lands.

Calculations:

- Compare before and after conditions to determine direct impacts on Section 4(f) Protected Lands. Depending on NEPA scoping effort, may need to expand analysis area to take into account cumulative impacts of the project on Section 4(f) Protected Lands.
- Also compare "after" conditions in project analysis area to regional, county-level, or corridor-level estimates of change in extent of Section 4(f) protected lands over the same analysis period. The percent change in regional extent can be compared to the project-specific impact as one estimate of the net project-specific impact, compared to what would have happened in the project area due to non-transportation-related land consumption.

Outputs:

- Change in **extent and condition of Section 4(f) Protected Lands**. *For example, "5 acres of parks were directly taken for construction of the project and replaced in a 2-for-1 ratio in a new 10-acre park created adjacent to a nearby school."*

Impacts on Wetlands, Surface Water Quality, and Drinking Water Quality

Inputs:

- GIS inventory of wetland extent and condition.
- Surface water quality data within project limits and downstream of project.
- Drinking water quality data within project limits and downstream of project.

Calculations:

- Compare before and after conditions to determine direct impacts on wetlands, surface water quality, and drinking water quality.
- Depending on contents of NEPA scoping effort (if available), may need to expand analysis area to take into account cumulative impacts of the project on wetlands, surface water quality, and drinking water quality. Study area should be consistent with what was used in the original environmental assessment.
- Also compare "after" conditions in project analysis area to regional, county-level, or corridor-level estimates of change in extent of wetlands, and change in condition of wetlands and water quality over the same analysis period. The percent change in regional extent can be compared to the project-specific impact as one estimate of the net project-specific impact, compared to what would have happened in the project area due to non-transportation-related land consumption and runoff.

Outputs:

- Change in **extent and condition of wetlands.** *For example, "20 acres of wetlands were directly taken for construction of the project and replaced in a 2-for-1 ratio in a wetlands mitigation bank maintained by NJDOT in the watershed."*
- Change in **condition of surface water quality and drinking water quality**. *[To be defined in discussions with NJDEP.]*

Visual Aesthetics and Context Sensitivity

Inputs:

- Project purpose and need statement or project description from planning documents, funding applications, etc.
- Photos and project descriptions after project completion.
- Local comprehensive plans and other relevant planning documents for the area in which the project was constructed.
- List of commitments to stakeholders that was developed and maintained during planning and design and/or was incorporated into construction documents prior to beginning construction.
- Results of post-construction surveys of project team members from the implementing agency and consultants.
- Results of post-construction surveys of community stakeholders (residents and businesses) and regulatory agency staff.

Calculations:

Conduct surveys using the following criteria[3]. Score one point for each criterion if 67% or more of implementing agency staff (and/or the agency's project consultants) surveyed respond "yes"; score one additional point for each criterion if 67% or more of community stakeholders and regulatory agency staff surveys respond "yes". Maximum 12 points.

1. The executed project meets the goals and objectives identified in the original purpose and need statement.
2. The project was designed and implemented in a manner that is consistent with local comprehensive plans, the Americans with Disabilities Act, and other relevant planning documents.
3. The implemented project meets or exceeds a list of commitments to stakeholders that was developed and maintained during planning and design, was incorporated into construction documents prior to beginning construction, and is monitored during construction and operation of the completed project.

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[3] Adapted from project-level evaluation criteria listed in NCHRP Web-Only Document 69: *Performance Measures for Context Sensitive Solutions- A Guidebook for State DOTs*

4. *(If the project is located in a developed area)* Architectural elements were incorporated into the design of the project to make users of all modes feel comfortable and welcome. These elements include, but are not limited to wayfinding signage for users of all modes for which the facility is designed (including freight and non-motorized users); signage clearly indicating access points to transit services (including park-and-ride lots, bus stops, and fixed guideway transit stations); signage clearly indicating access points and amenities for bicyclists and pedestrians (including signage indicating nearby alternate routes if non-motorized users are prohibited from using the facility); a physical barrier between non-motorized traffic (bicyclists and pedestrians) and vehicles or, if a physical barrier was not possible, a defined pavement marking separation; adequate lighting for evening and nighttime use by motorized and non-motorized users; an open view shed into public spaces for people passing by and security officers; and amenities such as artwork and landscaping to enhance the surrounding built and natural environment.

   *(If the project is located in an undeveloped area)*Environmental resources, scenic and historic resources, and aesthetic values, such as architectural styles and landscaping that complement the surrounding environment, have been maintained or enhanced by the project as completed.

5. Nearby residents and representatives of nearby institutions, schools, and business associations are directly or indirectly (e.g., via an advisory council) involved in the ongoing maintenance and operations of the facility or service.
6. Based on surveys of area residents and businesses, the project appears to have been implemented in a manner that will result in increased economic activity, such as new commercial or residential activity, and it appears to have the potential to create a positive neighborhood impact.

Outputs:

- Qualitative assessment of the degree to which a project improved or detracted from the **visual aesthetics of the built environment**.

Recommendations for Future Performance Evaluation: Environment Measures

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 emissions, 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 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. 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 do 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. Agencies are hesitant to encourage monitoring and reporting for political reasons as well. 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 (CEs) 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 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 data sharing and could help to streamline the NEPA planning process.

Improve monitoring of impacts on Section 4(f) properties. 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 opportunities that improve 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.

3.3.4 Evaluating Land Use/Transportation Coordination Measures

NJTPA Land Use/Transportation Coordination Goal - Select transportation investments that support the coordination of land use with transportation system.

Interdependencies between Data, Analysis Tools, and Performance Measures

The evaluation of the Land Use/Transportation Coordination measure per capita vehicle miles traveled depends on a calculation of the intermediate measure vehicle miles traveled in the **User Responsiveness** goal area.

Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Net VMT Change	Intermediate measure calculated in **User Responsiveness**; see methodology above
Population	U.S. Census Bureau's American Community Survey 5-year estimates
Employment	U.S. Census Bureau's Local Employment-Household Dynamics data; NJ Labor and Workforce Development, and/or U.S. Bureau of Labor Statistics
Census tract area	U.S. Census Bureau TIGER Line Shape Files

Geographic Scale of Analysis

An analysis of net per capita VMT for roadway projects should be performed on the same scale as the net VMT calculation. Often, this calculation will be performed at a regional scale.

Time Frame of Analysis

The impacts of roadway expansion projects as measured in terms of Land Use/Transportation Coordination measures may be small or may not be measurable at all shortly after completion of the improvement, because development induced by a roadway expansion project will happen gradually over time. However, as years pass many changes as measured by Land Use/Transportation Coordination measures may become less pronounced over time. Therefore, it is important to evaluate Land Use/Transportation measures on a continuous basis, using multiple data points from several years before the project and for as many years after the project as data are available.

Analysis Steps

Population and Employment Density

<u>Inputs:</u>

- Population in census tracts or census blocks, if available, within 5 miles of project limits, from periods before and after implementation of the roadway expansion project. *Use U.S. Census Bureau's American Community Survey (ACS) 5-year Estimates for a rolling annual estimate of census-tract-level population data. Note: The Census Bureau cautions against comparing ACS data from overlapping periods and ACS is intended to* *be used for population characteristics, not population totals, especially at smaller geographies (e.g., Census tracts).*

- Employment in census tracts within 5 miles of project limits, from periods before and after implementation. *Use U.S. Census Bureau's Longitudinal Employer-Household Dynamics (LEHD) data.*
- Area of census tracts within 5 miles of project limits, in miles, from U.S. Census Bureau's Topologically Integrated Geographic Encoding and Referencing (TIGER) system. *Note that census tract boundaries may change over time, particularly when a new decennial Census is undertaken. It is important to use areas that are as identical as possible for the before and after comparison.*

Calculation:

- Use GIS to aggregate population in census tracts within 5 miles of project limits and divide by aggregate area of those tracts. Calculate population density for periods before implementation and period after implementation.
- Use U.S. Census Bureau's Longitudinal Employer-Household Dynamics online mapping tool, called "OntheMap", to aggregate employment in census tracts within 5 miles of project limits and divide by aggregate area of those tracts. Calculate employment density for periods before implementation and after implementation.
- *The net change in population and employment density cannot be calculated, but a qualitative analysis of the circumstances before and after implementation of the project may provide clues to whether any changes in population and employment density can be attributable to the project. For example, similar to the net new ridership calculation as shown in Transit Expansion section 3.6-14, population and employment density in the study area can be compared to a "control" area that had conditions similar to the study area before implementation.*

Output:

- **Population density**, in persons per square mile.
- **Employment density**, in jobs per square mile.

Additional resources on population and employment density include the following:

- U.S. Census Bureau Longitudinal Employer-Household Dynamics website, http://lehd.did.census.gov/led/
- U.S. Census Bureau's Topologically Integrated Geographic Encoding and Referencing (TIGER) system website, http://www.census.gov/geo/www/tiger/index.html

Per Capita Vehicle Miles Traveled

Inputs:

- Net regionwide vehicle miles of travel attributable to the project.
- Regional population data from before and after construction.

Calculation:

- Divide regionwide vehicle miles of travel before construction by population before construction, perform the same calculation for the period after construction, and subtract the two values to calculate an estimate of net change in per capita vehicle miles traveled.

Output:

- **Daily per capita vehicle miles traveled**. *The daily VMT per capita in the NJTPA region is around 13.8 miles per capita according to recent survey results.*

Recommendations for Future Performance Evaluation: Land Use/Transportation Coordination Measures

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 databases 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).

3.3.5 Evaluating Repair, Maintenance, Safety, and Security Measures

NJTPA Repair/Maintain/Safety/Security Goal - Maintain a safe and reliable transportation system in a state of good repair.

Only safety and security measures are discussed in this section. See Roadway and Bridge Preservation project type for evaluation of Repair and Maintenance-related measures.

Interdependencies between Data, Analysis Tools, and Performance Measures

All data used in the analysis of safety performance measures are drawn from crash databases (e.g., NJDOT Crash Records Database, NJTPA Safety Management System, NJDOT Plan4Safety), and NJDOT asset management systems. Therefore, for safety measures, there are no interdependencies with previous analyses.

Evaluation of security measures related to resiliency and redundancy use the results of network connectivity and continuity calculations performed under the System Coordination goal area.

Data Inputs and Sources

Primary data inputs to the analysis include the following:

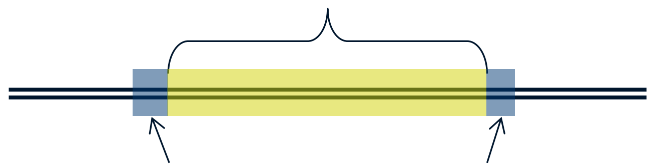
Data Inputs	Sources
Crash records	NJDOT Crash Records Database; Plan4Safety; NJTPA Safety Management System data
VMT data at regional, county, and local level	NJDOT Public Roadway Mileage and Vehicle Miles Traveled, from Highway Performance Monitoring System (HMPS) data
Information on measures taken to prevent or protect against incidents, incursions, attacks, and illicit activity	Facility owner or operator: construction documents and as-built drawings
Facility functional class (Interstate, freeway or expressway, major arterial, or other)	NJDOT Roadway Network File, NJDOT Straight-Line Diagrams
Availability of alternate routes (same or higher functional class/lower functional class/no alternate route)	NJDOT Roadway Network File, NJDOT Straight-Line Diagrams
Traffic volume data (vehicles per day), Link capacity (vehicles per day), and Volume-to-capacity ratio	NJDOT Roadway Network File, NJDOT Straight-Line Diagrams, NJDOT Traffic Monitoring System
Tonnage of freight moved on each link from commodity flow data	IHS Global Insight's TRANSEARCH database or FHWA Freight Analysis Framework 3 (FAF3) data, assigned to the NJTPA network
Facilities that are designated evacuation routes	NJDOT Roadway Network File
Planning studies to identify critical assets and future needs for project development in the study area	State and local governments; NJTPA needs assessments
Network Connectivity and Continuity results	Calculated using methodologies specified in System Coordination goal area
Extent and redundancy of technology and systems available to provide information to system operators and users	Facility owner or operator: construction documents and as-built drawings

Geographic Scale of Analysis

Both safety and security measures should be evaluated within the project limits. In the case of a project that is expected to generate significant diversions of auto and truck traffic (in the case of safety improvements) or accommodate significant diversions of auto and truck traffic (in the case of system redundancy projects undertaken for security reasons), the analysis area for safety and security measures may be expanded to a corridor encompassing multiple facilities, to a county, or to the entire NJTPA region.

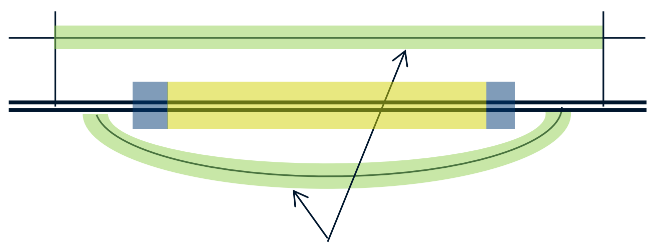
First analyze data within project limits…

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



…then compare to available data immediately upstream and downstream of project limits

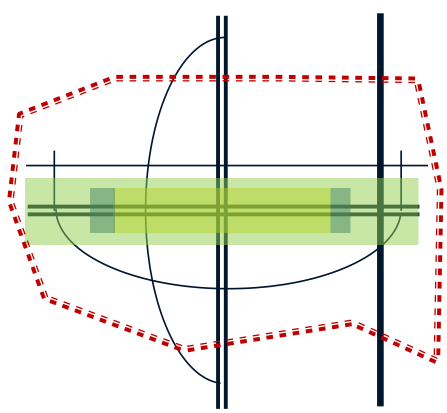
CASE 2:
CORRIDOR CAPACITY EXPANSION
with traffic diversion

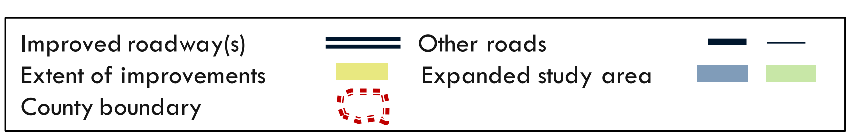


Analyze data on parallel route(s) within 5 miles that may have been used as alternate(s) or bypass(es) of bottleneck. Some impacts of the project may accrue to parallel facilities that saw increases or reductions in traffic.

ALL CASES:
Corridor and Regional Comparison

- Compare to data for the entire corridor in which the project is located (green).
- Compare to data in the county in which the project is located (red).





Time Frame of Analysis

The project-specific impacts of roadway expansion projects as measured in terms of safety measures are likely to be most pronounced shortly after completion of the improvement. Therefore, it is important to evaluate these measures using multiple data points from several years before the project, during the construction phase, and for as many years after the project as data are available. Security measures, which tend to be discrete improvements whose benefits do not accumulate or diminish over time, should be analyzed for one year before and after implementation of the project. For example, construction of a security fence along a new highway right of way to prevent unauthorized access would have a one-time benefit to security along that highway segment; therefore, conditions for the year before construction can simply be compared to conditions in the year following completion of the project.

Analysis Steps

Intermediate Measures and Analysis Tools

1. Assign a "criticality" index to infrastructure and services in the study area.

   Inputs: (required for each link in the highway network)

   - Facility functional class (Interstate, freeway or expressway, major arterial, or other facility type);
   - Whether or not alternate routes are available (same or higher functional class/lower functional class/no alternate route);
   - Traffic volume data (vehicles per day), link capacity (vehicles per day), and volume-to-capacity ratio, to help establish which facilities carry the greatest absolute volumes and which facilities have the ability to absorb excess volumes;
   - Tonnage of freight moved on each link, based on an assignment of commodity flow data (TRANSEARCH, FAF) to the NJTPA regional network, as a proxy of the facility's economic value;
   - Whether or not the facility is a designated evacuation route (yes/no); and
   - Planning and traffic studies done in the study area to identify critical assets and future needs for project development.

   Calculations

   Calculate a composite criticality score or index for each facility. Several analysis tools are available to perform the calculation. For example, the New Jersey Department of Transportation as a license to the Disruption Impact Estimating Tool—Transportation (DIETT), which is a database and spreadsheet-based tool for prioritizing the criticality of transportation choke points.

   Intermediate output measures:

   - Criticality index or score for each facility in the network. Facilities should be grouped into broad categories like "most critical", "critical" and "not critical". *Note that this index must be guarded from the public due to the sensitive nature of the information.*

Crashes

Inputs:

- Facility-specific crash data (minimum 3 years before and after project).
- Regional, county-level, and corridor-level aggregate safety statistics.

Calculations:

- Compare project-level changes in absolute number of crashes to estimates of crashes at the regional and county-level, for corridors of the same functional class, and potentially for specific comparison corridors as an estimate of what may have happened in the absence of the project. *If the project was anticipated to result in significant diversions of traffic to or from other roadways, compile data on absolute numbers of crashes on alternate within 5 miles of the improved roadway that could reasonably be expected to accommodate bypass traffic.*

Outputs:

- Absolute number of **crashes** that occurred before and after construction. *For example, a project may result in a net reduction of 20 property-damage-only crashes, 5 injury crashes, and 1 fatality per year.*

Crash Rate

Inputs:

- Absolute number of crashes that occurred before and after construction.
- VMT data at regional, county, and local level.
- Regional, county-level, and corridor-level aggregate crash rates.

Calculations:

- Divide crashes by VMT in the study area to calculate crash rate per million VMT.
- Compare project-level changes in crash rates to estimates of changes in crash rates at a regional or county-level, for corridors of the same functions class, or in specific comparison corridors as an estimate of what may have happened in the absence of the project.
- The net increase or decrease in crash rate attributable to the project can be estimated by subtracting the regional, county-level, or corridor-level crash rate from the observed crash rate after project completion.

Outputs:

- **Crash rate**, in terms of crashes per million VMT. *In the NJTPA region, crash rates typically range from 0-10 crashes per million VMT, but some roads have higher crash rates.*

Transportation Resiliency

Transportation resiliency is a term that describes the ability of the transportation system to adapt and respond to incidents and disruptions. Transportation resiliency applies to natural threats, such as hurricane storm surges and floods, as well as man-made threats such as terrorist attacks. According to NCHRP Report 525, "Incorporating Security into the Transportation Planning Process", four major categories of security incident countermeasures exist to address threats and vulnerabilities to the nation's transportation infrastructure. These four categories include prevention, protection, redundancy, and recovery. These four measures apply more broadly than security. For example, climate change adaptation strategies often are grouped into similar categories.

Below, the categories "prevention" and "protection" are discussed together below because they both refer to proactive, preventative measures taken in advance of an attack or unauthorized access. Their results are measured in terms of the extent to which they prevent the system's critical services or pieces of infrastructure from being damaged, destroyed, or used for illicit purposes. Projects addressing "redundancy" and "recovery" address the operations of the system after a major disruption occurs. Their results are measured in terms of how well the system operates (or would operate) after a major disruption.

<u>Inputs: Prevention and Protection</u>

- Measures taken to *prevent or discourage* unauthorized access to a transportation facility or a specific sensitive feature of a transportation facility like a bridge or equipment room, before and after construction; measures taken to prevent or discourage illicit activity in or near a transportation facility; measures taken to prevent or discourage direct and indirect attacks on a facility; and measures taken to protect against the impacts of natural events like extreme weather events. *Examples cited in NCHRP Report 525 include access control systems like fences and locked doors, highly visible closed circuit television (CCTV) systems, and intrusion detection systems such as alarmed entrances and fence-line detection systems. The design of the facility is also important, for example, allowing for open sight lines into a park-and-ride lot from nearby roadways and development, adding lighting to a pedestrian pathway, hardening a facility to prevent physical incursions and/or increase blast resilience, or building a levee and pumping system to protect a roadway from flooding.*
- Criticality index of the facility or service. *Calculated above in intermediate measures and analysis.*

<u>Evaluation: Prevention and Protection</u>

- Measure the mileage of roadways with prevention and protection measures in place (per Federal, state, and local design guidelines) before and after the project is completed.

<u>Outputs: Prevention and Protection</u>

- Share of most critical assets hardened against unauthorized access, illicit activity, attacks, and/or natural events. The definition of "most critical assets" must be defined in the process for assigning a criticality score above.

Inputs: Redundancy and Recovery

- Results of **Network Connectivity and Continuity** calculations, using the process defined in the System Coordination goal area. *For purposes of this analysis, connectivity calculations should be performed for the subset of the system consisting of critical and/or most critical assets, as defined in the intermediate measure above.*
- Extent and redundancy of technology and systems available to provide information to system operators and users.

Evaluation: Redundancy and Recovery

- Using results of before-and-after network connectivity analysis, determine extent to which the project improves connectivity in the designated evacuation route system or in the subset of the system consisting of arterials, expressways, and Interstate Highways. *As described in the System Coordination goal area, system connectivity can be defined in terms of several indices and measures. The evaluation here should assess the change that the project would cause in these indices or measures.*
- Qualitatively compare the extent of information technology available to provide information to system operators and to users during an emergency, system failure, or system disruption, before and after project implementation.

Outputs: Redundancy and Recovery

- Change in System Connectivity for the region's critical and/or most critical transportation assets. *For example, the beta index could change from 1.1 to 1.2 as a result of the project, indicating greater network connectivity and availability of alternative routes in case of a disruption or blockage.*
- Extent to which communication systems are deployed in a redundant fashion to ensure information is available to system operators and users in an emergency, system failure, or system disruption. *For example, "The project provided a diesel generator to power a backup communication system in case of a power failure concurrent with the event or disruption."*

Recommendations for Future Performance Evaluation: Repair/Maintenance/Safety/Security Measures

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.

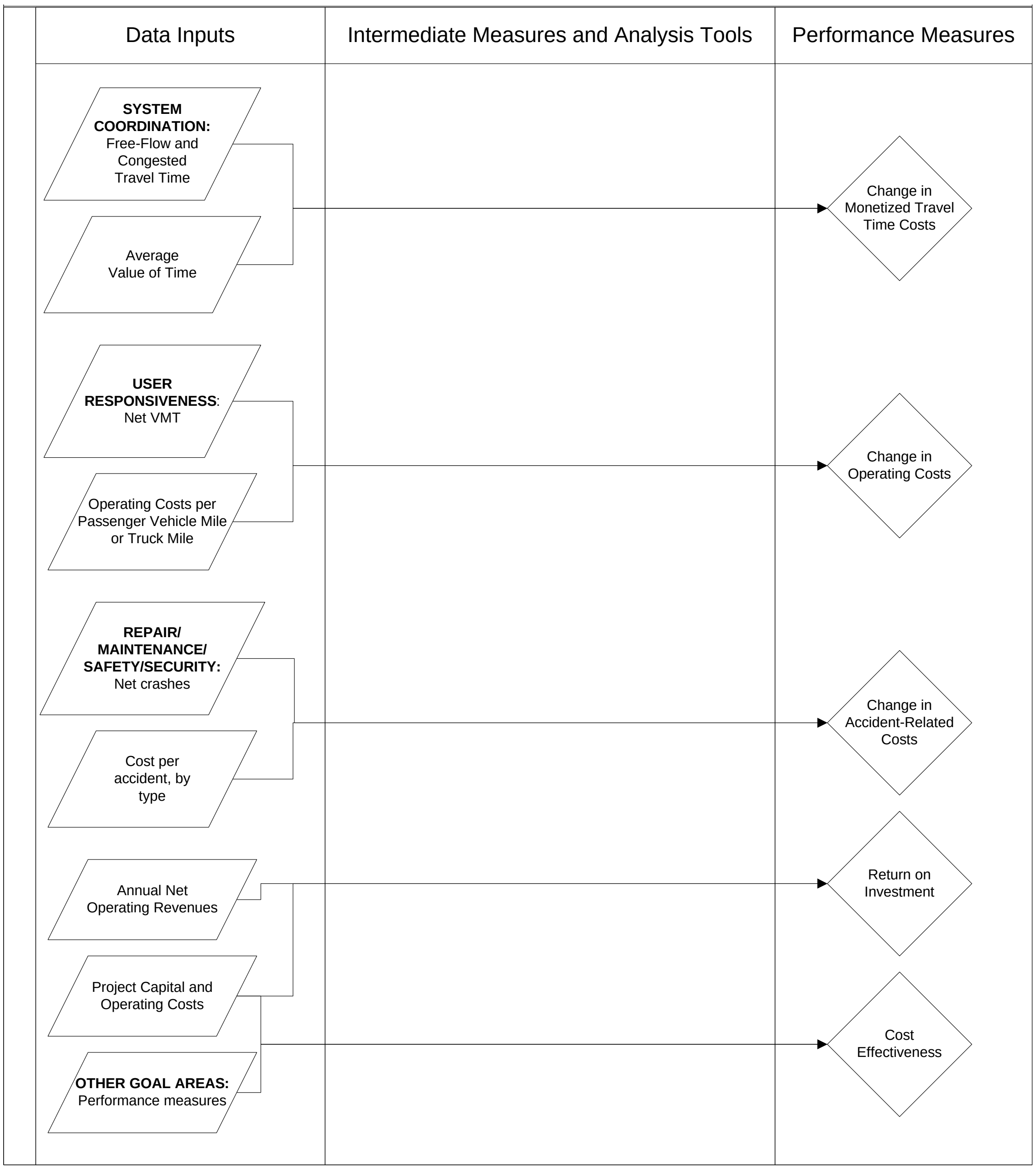
Reassess and periodically update definitions of critical transportation infrastructure and services to support analysis of system resiliency for purposes of transportation security, climate change adaptation, and related uses. NJDOT, in cooperation with Federal and local governments and other state agencies, has performed an assessment of critical transportation infrastructure. NJDOT 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).

3.3.6 Evaluating Economy Measures

NJTPA Economy Goal - Retain and increase economic activity and competitiveness.

Interdependencies between Data, Analysis Tools, and Performance Measures

The following diagram is a simplification of the interdependencies between Economy measures and the intermediate and ultimate measures discussed in the System Coordination and User Responsiveness sections. No intermediate measures or analysis tools were used in the analysis.



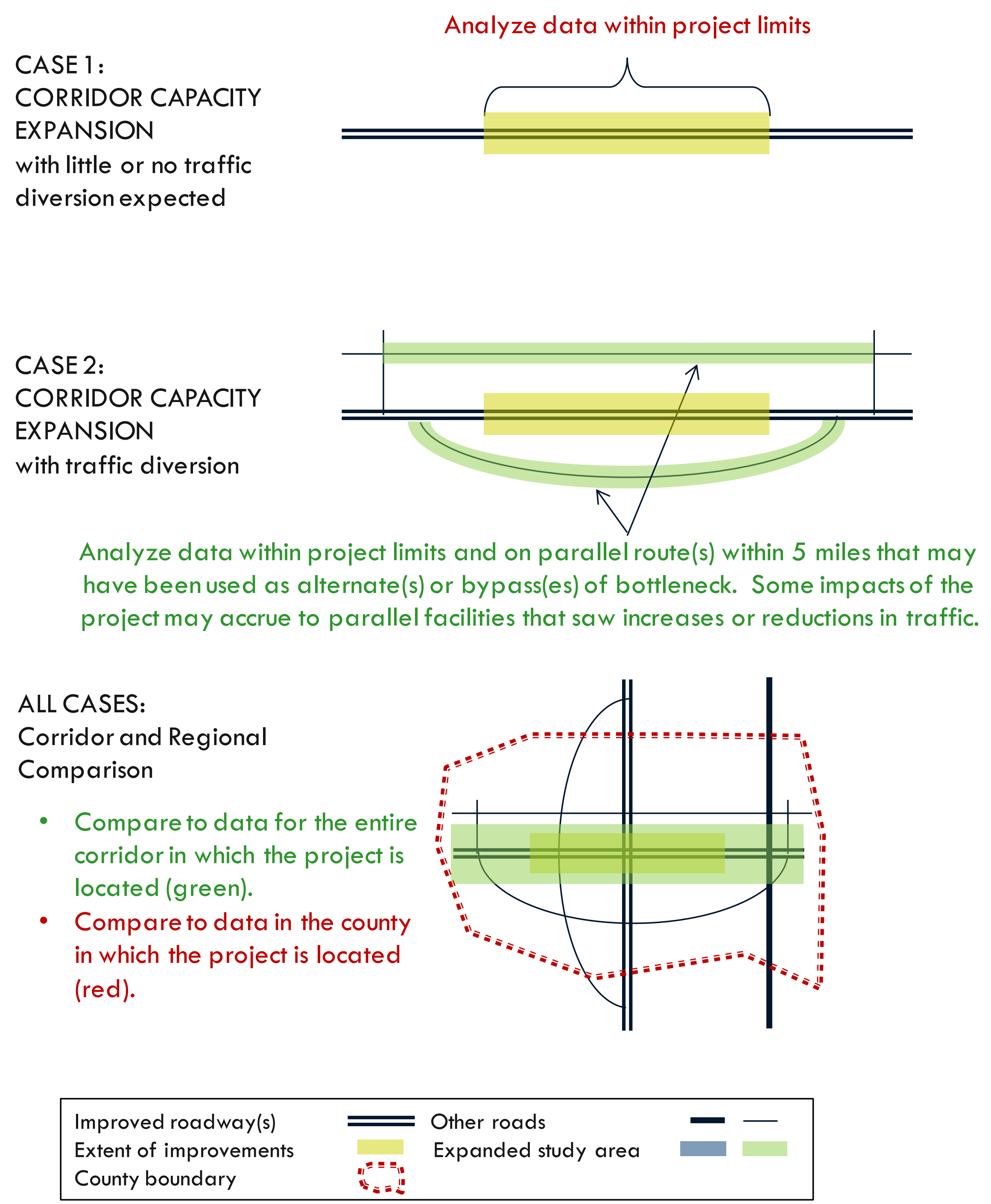
Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Estimated "build" and "no-build" congested travel times by link	Intermediate measure calculated in **System Coordination**; see methodology above
Average value of time	NJTPA Regional Household Travel Survey
Net VMT change	Intermediate measure calculated in **User Responsiveness**; see methodology above
Operating costs per passenger vehicle mile or truck mile	FHWA and NJTPA survey data
Net crashes by severity	Output measure of **Repair/Maintenance/Safety/ Security** goal area; see above
Cost per crash, by severity	NJDOT and National Highway Traffic Safety Administration (NHTSA)

Geographic Scale of Analysis

All measures in the Economy goal area should be evaluated within the project limits. In the case of a project that is expected to generate significant diversions of auto and truck traffic, the analysis area may be expanded to a corridor encompassing multiple facilities, to a county, or to the entire NJTPA region.



Time Frame of Analysis

The impacts of roadway expansion projects as measured in terms of Economy measures may be small or may not be measurable at all shortly after completion of the improvement, because travel time benefits, operating cost savings, and accident cost reductions generated by a roadway expansion project will accrue gradually over time. However, as years pass many changes as measured by Economy measures may become less pronounced over time. Therefore, it is important to evaluate Economy measures on a continuous basis, using multiple data points from several years before the project and for as many years after the project as data are available.

Analysis Steps

Transportation Costs

Transportation costs can be quantified in terms of change in monetized travel time costs, change in vehicle operating costs, and change in accident-related costs.

Inputs:

- Estimated "build" and "no-build" congested travel times by link (see diagram above for study area).
- Average value of time, in dollars.

Calculation:

- Multiply change in travel time by average value of time for users of the facility.

Outputs:

- **Net change in travel time costs** associated with the project. *An example is shown in the following table:*

Table 3.3-C: Sample of Estimated Daily Travel Time Savings
(NOTE: Contains fictional data for illustration purposes only)

	Net Change
Daily Person Hours of Travel	-2,000
Value of Time (in 2009 dollars)	$21.00
Estimated Travel Time Savings (Daily)	-$42,000

Inputs:

- Net change in VMT associated with the project, by vehicle type.
- Average vehicle operating costs for passenger vehicles and trucks, in dollars.

Calculation:

- Multiply change in VMT by vehicle type by average vehicle operating costs by vehicle type.

Outputs:

- **Net change in vehicle operating costs** associated with the project. *An example is shown in the following table:*

Table 3.3-D: Sample of Estimated Auto Operating Cost Savings
(NOTE: Contains fictional data for illustration purposes only)

Estimated Auto Operating Costs (2009 dollars per mile)	$0.20
Estimated Net Daily VMT savings (miles)	200,000
Estimated Net Daily Auto Operating Cost Savings (2009 dollars)	$40,000

Inputs:

- Net change in crashes associated with the project, by severity.
- Average cost of crash, by severity.

Calculation:

- Multiply change in crashes by the average cost of a crash for each severity level.

Outputs:

- **Net change in accident-related costs** associated with the project. *According to NJDOT, in 2009, average costs for accidents ranged from nearly $9,000 for a property-damage-only crash, to around $50,000 for an injury crash, to more than $2 million for a fatal crash. Accident cost savings due to major roadway expansion projects often range in the millions of dollars per year.*

Return on Investment

Inputs:

- Project capital cost and annual operating costs.
- Annual net operating revenue.

Calculations:

- Calculate the net present value of net operating revenue. The net operating revenue is simply revenues from all sources minus operating costs.
- Return on investment is the (Capital Cost minus the Net Present Value of Operating Costs) divided by the Capital Cost. *For example, a transportation project could have a return on investment of 10 percent, meaning the project's annual income exceeds the net present value of its operating costs plus the capital cost.*

Outputs:

- **Return on investment***, expressed as a percentage.*

Cost Effectiveness

Inputs:

- Project capital cost, in dollars.
- Performance measures from previous calculations (e.g., crashes, travel time savings, and emissions reduction).

Calculations:

- Divide the capital cost by any performance measure to calculate the dollar-weighted impacts of the project. *For example, a million-dollar project that reduces carbon emissions by 1,000 tons has a cost-effectiveness index of $1,000/ton.*

Outputs:

- **Cost Effectiveness***, expressed in dollars per unit of benefit per dollar (e.g., dollars per accident reduced; dollar per minute of travel time savings; dollars per ton of reduced carbon emissions).*

  NOTE: While cost-effectiveness measures are constituents of a broader benefit-cost analysis approach, many cost-effectiveness measures are not additive. Therefore, extreme caution should be exercised in presenting and explaining results of a project-level cost-effectiveness analysis.

Recommendations for Future Performance Evaluation: Economy Measures

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.

3.4 Transit Preservation Projects

Transit Preservation: Includes programs and projects that seek to ensure long-term continuation and availability of viable 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 projects.

Contents of This Section

Suggested Work Flow for Transit Preservation Projects

The following sequence of goal areas for this project category was developed specifically to enable an ordered evaluation of performance measures. This allowed calculations from earlier intermediate (and final) measures in one goal area to serve as inputs for measures in other goal areas:

1. System Coordination Measures
2. User Responsiveness Measures
3. Environment Measures
4. Repair/Maintenance/Safety/Security Measures
5. Economy Measures

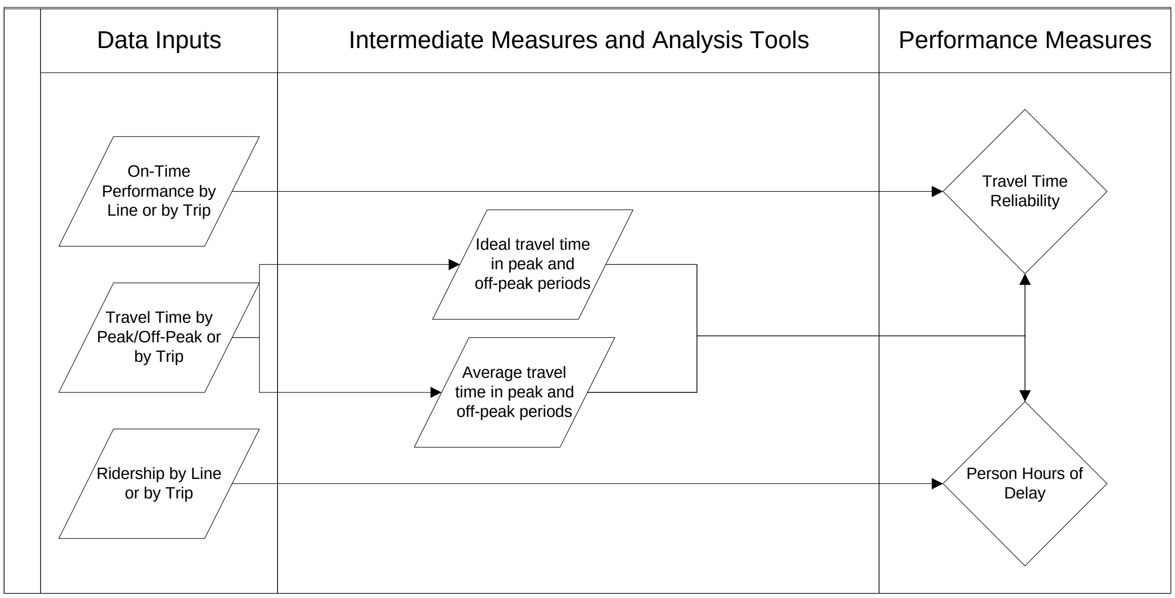
The methodology for calculating each measure is presented in the following sections. Measures in **BOLD** in the table above can be calculated independently. The remaining measures rely on interdependent data, or, in some cases, depend on each other.

3.4.1 Evaluating System Coordination Measures

NJTPA System Coordination Goal - Enhance system coordination, efficiency, and intermodal connectivity.

Interdependencies between Data, Analysis Tools, and Performance Measures

The following diagram is a simplification of the interdependencies between System Coordination measures:



Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
On-time performance by line or by trip	Transit operators
Travel time by trip	Transit operators
Ridership by line or by trip	Transit operators
Transit line or vehicle capacity	Transit operators, vehicle manufacturer specifications

Geographic Scale of Analysis

An analysis of System Coordination measures for transit projects requires that all affected transit services be evaluated. The geographic scale of the analysis will most likely be determined by the extent of the project's impacts and data limitations.

Time Frame of Analysis

System Coordination measures for transit should be evaluated using multiple data points from several years before the project, during the construction phase, and for as many years after the project as data are available.

Analysis Steps

Intermediate Measures and Analysis Tools

1. Estimate average travel time in peak and off-peak periods

Inputs: (required for each route or trip to be evaluated, before and after implementation of enhancement project)

- Travel time by trip, in minutes.

Intermediate output measures:

- Estimated **average travel time** in peak and off-peak periods, in minutes. *Collect data by route or by trip for time periods before and after implementation.*
- **Free flow travel time** in peak and off-peak periods. *Collect data by route or trip for time periods before and after implementation of the transit enhancement. Free flow travel time is defined as the shortest transit travel time that can be expected under uncongested conditions on the roadway system or the shortest rail travel time that can be achieved under transit operating policies for the infrastructure that is in place at the time (e.g., considering track speed restrictions, signal systems, standard station dwell times, and other dispatching policies). As a proxy, can use average run time for early morning (before morning peak period) and/or late evening (after evening peak period) trips.*

Travel Time Reliability

Note that travel time reliability for transit can be measured in two ways: either compare actual travel times to scheduled travel times (on-time performance), or compare actual travel times to free-flow travel times (which takes into account differences between transit performance in congested periods and off-peak periods). On-time performance is the reliability metric that matters more to transit passengers, and therefore should be reported publicly, while comparisons of actual travel times to free-flow travel times is a management-oriented measure of how well the system is operating with respect to operating and dispatching policies.

<u>Inputs:</u> (required for each route or trip before and after implementation)

- On-time performance by route or trip. *Use as detailed information as possible. On-time performance may only be available for the departure time from the first stop and the arrival time at destination, or it may be available for intermediate time points.*
- Actual travel times and free-flow travel times by route and by trip, in minutes, as available.

<u>Calculations: Transit On-Time Performance</u>

- **On-time performance** is the percentage of transit trips that arrive at a destination within five minutes and 59 seconds of their scheduled time. *For example, if nine out of ten buses on a particular route arrive within five minutes 59 seconds of their scheduled times, that route has a 90% on-time performance rating.*

<u>Calculations: Transit Travel Time Reliability</u>

- Using actual travel time data, determine the **95th percentile travel times**. *To calculate the 95th percentile travel time, rank order the actual travel times for all trips in the analysis period (usually one week or month worth of weekday trips). The travel time that is longer than 95 percent of trips (or longer than all but 5 percent of trips) represents 95th percentile travel time. Note that 95th percentile travel time is a guideline. For trips where reliability is not as important, for example recreational trips, a lower threshold may be used.*
- **Buffer time** = 95th percentile travel time – average travel time. *Buffer time, expressed in minutes, represents the extra time (or time cushion) that travelers must add to their average travel time when planning trips to ensure on-time arrival 95 percent of the time. Typical values for a complete trip range from as low as 5 minutes or less for off-peak trips to a maximum of 30 minutes or more in the peak.*
- **Buffer index** = (95th percentile travel time – average travel time) / average travel time, expressed as a percentage. *Buffer index values closer to 0% indicate that 95th percentile travel time is close to average travel time, i.e. there is little or no variability in congestion. Buffer index values above 100% indicate severe congestion, i.e. travel time is more than twice as long on the worst travel days than in average conditions.*
- **Planning time index** = 95th percentile travel time / free-flow travel time. *The planning time index reflects how much <u>total</u> time a traveler should allow to ensure on-time arrival 95 percent of the time (in contrast to buffer index, which represents <u>extra</u> time). For example, a planning time index of 1.60 means that for a trip that takes 15 minutes*

off-peak, a traveler should budget a total of 24 minutes to ensure on-time arrival 95 percent of the time.

- For an estimate of **"no-build" reliability indices**, use estimated "no-build" congested travel times. *Continuous or 15-minute congested travel times may not be available for the no-build condition because no-build conditions must necessarily be simulated or calculated. Therefore, use peak travel times to estimate the improvement in travel time reliability that is attributable to the project.*

Person-Hours of Delay

Inputs: (required for each route or service before and after implementation)

- Free-flow and average actual travel times by route or trip, in minutes
- Ridership by route or trip, in passengers

Calculations:

- Average delay = average travel time – free-flow travel time, in minutes. *If sufficient data are available, delay can be calculated on a per-trip basis.*
- **Person-hours of delay** = average delay x ridership. *Person hours of delay can also be calculated by multiplying actual delay per trip by ridership per trip, and then summing the results over all trips. For example, if the 7:30 train carries 800 passengers and takes an average of 3 minutes longer than free-flow conditions, and the 7:45 train carries 1000 passengers and arrives an average of 5 minutes late, the total person-hours of delay for these two trains is (800 x 3) + (1000 x 5) = 7,400 minutes per day. Repeat for all other trains on the schedule.*
- Multiply no-build vehicle-hours of delay by persons per vehicle to determine total **no-build person hours of delay**.
- The net impact attributable to the project is the difference between actual delay and no-build estimates of delay.

Recommendations for Future Performance Evaluation: System Coordination Measures

Collect and use transit travel time data for direct observations of congested and free-flow travel speeds. With better travel time data for buses as well as trains, transit operators could improve estimates of "free-flow" and "congested" stop-to-stop travel times, and in turn measurement of Travel Time Reliability, Delay, and Percent of Travel Under Congested Conditions. The use of archived TRANSCOM, INRIX, and transit operators' GPS data should help to better measure congested and free-flow speeds.

Use simulation models to improve estimates of network-level congestion and delay measures. The methodology presented above assumes transit impacts are expected to be limited to the immediate vicinity of the project. When the analysis involves many links in a network of roadways or a system or rail lines, simulation models can be used to calculate all of the System Coordination performance measures on a network scale. Network simulation models have extensive data requirements (for example, they require field observations of free-flow and congested travel speeds and very detailed roadway and rail geometry data and operational 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, for example from one roadway or track 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).

3.4.2 Evaluating User Responsiveness Measures

NJTPA User Responsiveness Goal - Provide affordable, accessible and dynamic transportation systems responsive to current and future customers.

Interdependencies between Data, Analysis Tools, and Performance Measures

Customer satisfaction is a free-standing measure that is not dependent on inputs from other measures.

Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Customer satisfaction survey results	Surveys of transit riders

Geographic Scale of Analysis

Customer satisfaction should be measured for all users of an affected facility or service.

Time Frame of Analysis

The reaction to a Transit preservation project may peak shortly after project completion, but as time goes on, people may not be able to distinguish the project's impacts from other changes that have happened in the mean time (for example, other transportation improvements or economic shifts). Therefore, customer satisfaction surveys should be performed shortly after a project's completion.

Analysis Steps

Customer Satisfaction

Customer Satisfaction is a measure that does not depend on inputs from any other performance measure. Customer Satisfaction measures can be obtained from the results of surveys performed by NJ Transit, other transit operators, or other agencies after completion of a project.

Inputs:

- Surveys of transportation system users, ideally including information about the relative importance of each system attribute being queried
- Typical questions on transit-related customer satisfaction surveys include:
    - Customer perception of improvement's impacts across NJTPA goal areas: Built and natural environment, travel speed, travel time reliability/on-time performance, access to destinations, safety, economic impacts
    - Project's impact on travel behavior: Whether the improvement caused mode shifts ("What was the previous mode used to make the trip?") and destination choice decisions (e.g., enabled a longer trip to a destination not previously accessible)
    - Impacts of transit preservation program (if any): Safety, congestion and delays, access to businesses, environmental impacts during construction, net change in transit ridership
- For projects that are likely to result in a change in transit ridership levels, it is suggested that surveys be conducted both before and after project implementation. Please refer to the Transit Enhancement & Transit-oriented Development chapter for measurement methods to address net change in transit ridership, if applicable.

Recommendations for Future Performance Evaluation: User Responsiveness Measures

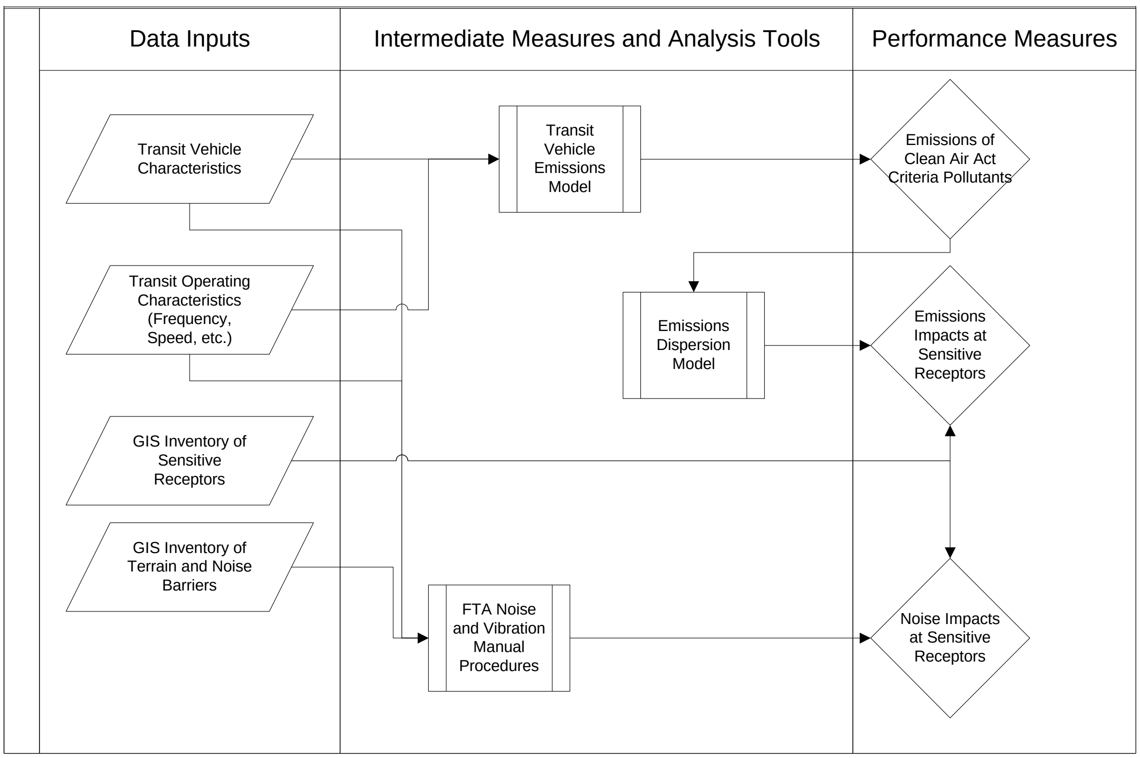
System-wide customer satisfaction surveys should be performed regularly.

3.4.3 Evaluating Environment Measures

NJTPA Environment Goal - Protect and improve the quality of natural ecosystems and human environment.

Interdependencies between Data, Analysis Tools, and Performance Measures

The following diagram is a simplification of the interdependencies between Environmental measures and the intermediate and ultimate measures discussed in the System Coordination and User Responsiveness sections:



Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Distribution of vehicle trips by time of day and vehicle/locomotive type	Transit bus and train schedules Transit equipment manifest lists
Annual vehicle miles of service or vehicle revenue miles	Transit operations/ revenue reports
GIS Inventory of Sensitive Receptors	NJDOT and NJDEP GIS; Google Maps and other commercial sources
GIS inventory of terrain and noise barriers	NJDOT and NJDEP GIS; NJDOT Straight Line Diagrams

Geographic Scale of Analysis

The geographic scale of analysis depends on the measure being assessed. The following table shows the recommended geographic scale of each measure.

Measure	Geographic Scale(s) of Analysis
Emissions of Clean Air Act criteria air pollutants and greenhouse gases	Air quality (AQ) data are collected at the facility level as well as at the regional scale. The regional and statewide travel demand models that are necessary to quantify emissions are based on this state and regional data collection. Transportation-related emissions, for example greenhouse gases, do not respect state and regional boundaries; therefore regional and statewide data are necessary. The Clean Air Act requires regional and project level hotspot analysis. Most non-attainment areas have on the ground monitoring units in set locations. These units are not typically moved to measure emissions for specific projects. Transportation emissions that lead to respiratory conditions and other health impacts should be estimated at sensitive receptors within ¼ mile of project limits.
Transportation-related noise and vibrations at sensitive receptors	Sensitive receptors within ¼ mile of project limits

Time Frame of Analysis

Measures should be evaluated on a continuous basis if possible, using multiple data points from several years before the project and for as many years after the project as data are available in order to draw valid conclusions about the net impacts of a project.

As indicated in the above graphic, the environmental impacts of transit projects are often measured at a regional scale. Therefore, the net impacts of any one project may be obscured over time by economic growth that generates additional travel demand (in turn affecting emissions and noise). On a project-by-project basis, professional judgment will be necessary to determine the limits of applying the following analysis.

Analysis Steps

Emissions of Clean Air Act Criteria Pollutants (Vehicles and Locomotives only)

Inputs:

- Number of buses or locomotives replaced/retrofitted by model and fuel type
- Annual miles of service per vehicle/locomotive
- Average speed of service

Analysis Tools:

- Use NJAQONE Bus Replacement model or US EPA's MOVES model to estimate net emissions in forecast year. .

Output measures:

- Estimated **change in emissions by criteria pollutant.**

1. Generate emissions contour maps.

Inputs:

- Estimated change in emissions by criteria pollutant, from NJAQONE or MOVES.
- Baseline emissions estimates, from NJAQONE or MOVES baseline data.
- Geography-specific climate data. Can use defaults built into models.

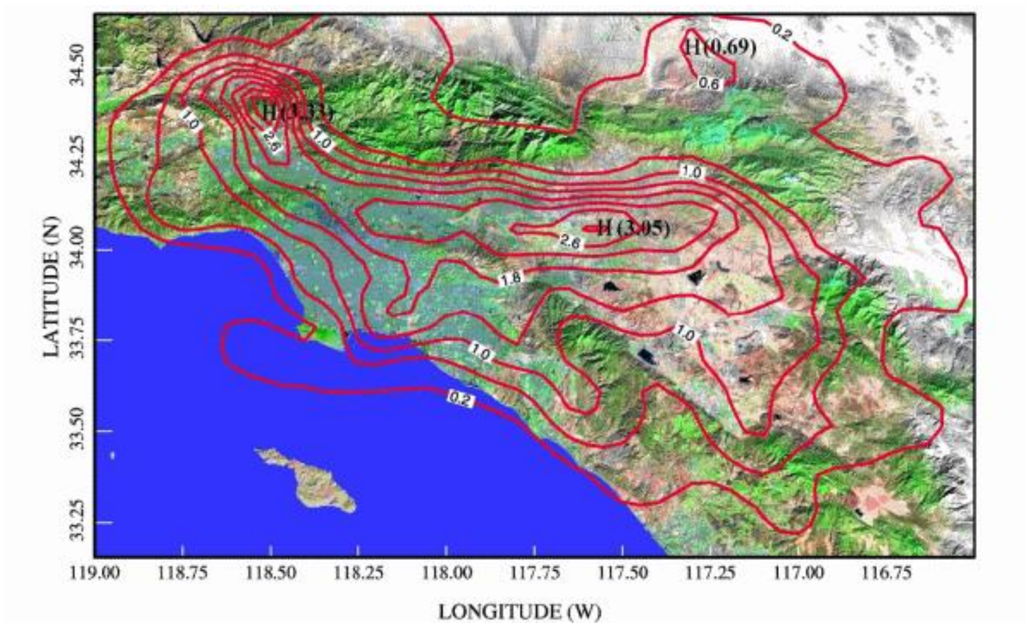
Analysis Tools:

- Use Emissions Dispersion model to allocate emissions to points or subregions in the analysis area. Conduct one run for baseline conditions and a second run for "build" condition.

Outputs:

- Emissions contour maps showing concentrations by criteria pollutant for baseline condition and for "build" condition.

Figure 3.4-A: Map of daily emissions of soot in micrograms per cubic meter for Los Angeles Metropolitan Area:



2. Overlay sensitive receptor points on emissions contour maps.

   Inputs:

   - Emissions contour maps for baseline condition and "build" condition from dispersion model
   - GIS layer of sensitive receptors in NJTPA region

   Calculations:

   Net emissions impact at any given sensitive receptor is the difference between the build condition and the baseline condition. Repeat calculation for each sensitive receptor.

   Outputs:

   - **Estimated emissions impacts by sensitive receptor.** *For example, "Emissions of particulate matter (PM 2.5) increased from 1.2 micrograms per cubic meter to 1.8 micrograms per cubic meter as a result of the project."*

Noise and Vibration Impacts at Sensitive Receptors

Inputs:

- Peak hour volume and average speed by vehicle type, by link (intermediate output measures of **System Coordination** analysis)
- GIS inventory of terrain type
- Location and extent of noise barriers (NJDOT GIS and Straight Line Diagrams)
- GIS inventory of sensitive receptors
- Archived data on background noise levels at sensitive receptors at regional, county level, and/or corridor level

Calculations:

- See FTA Noise and Vibration Manual for procedures and calculations used to generate noise contours and estimated impacts at sensitive receptors. *To estimate net impacts, run one scenario with "build" conditions using most recent available data and a second "no-build" scenario with estimated "no-build" inputs. Repeat for each sensitive receptor.*
- *If enough data are available about changes in decibel levels at sensitive receptors over time, the project-specific impacts also can be compared to regional, county-level, or corridor-level average impacts over the same analysis period as another estimate of what may have happened in the absence of the project.*

Outputs:

- **Net noise and vibration impacts at sensitive receptors**, in decibels. *For example, "The hourly equivalent sound level LEQ(h) increased from 60 dB to 75 dB as a result of the project."*

Recommendations for Future Performance Evaluation: Environment Measures

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 emissions, 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
- 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 in Roadway section)
- 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. While it may not always 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 only require implementation monitoring on an "as appropriate" basis. . 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 costs could 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. Agencies are hesitant to encourage monitoring and reporting for political reasons as well. 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 (CEs) 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 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 the 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. 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 opportunity 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.

3.4.4 Evaluating Repair/Maintenance/Safety/Security Measures

NJTPA Repair/Maintain/Safety/Security Goal *- Maintain a safe and reliable transportation system in a state of good repair.*

See Transit Expansion and Transit Enhancement and Transit-Oriented Development chapters for evaluation of safety and security measures.

Interdependencies between Data, Analysis Tools, and Performance Measures

All data used in the analysis of repair/maintain/safety/security performance measures are drawn from transit operators' operational and maintenance data, crash databases (e.g., NJDOT Crash Records Database, NJTPA Safety Management System, Plan4Safety), and NJDOT asset management systems. Therefore, for safety measures, there are no interdependencies with previous analyses.

Evaluation of security measures related to resiliency and redundancy use the results of network connectivity and continuity calculations performed under the System Coordination goal area.

Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Number of riders impacted by service disruptions per year	NJ Transit, PATH, and other transit operators
Hours of service disruptions per year	NJ Transit, PATH, and other transit operators
Mean time between failure	NJ Transit, PATH, and other transit operators
Bridge and viaduct conditions	NJ Transit and PATH
Pavement conditions on NJ-Transit-maintained facilities	NJ Transit
Track conditions (including rail ties, tracks, rail bed, switches, overhead catenary, third rail, signal systems, etc.)	NJ Transit and PATH
Crash and passenger accident records	Exclusive guideway transit facilities: NJ Transit safety records Transit services operated on roadways: NJDOT Crash Records Database; Plan4Safety; NJTPA Safety Management System data
Information on measures taken to prevent or protect against incidents, incursions, attacks, and illicit activity	Facility owner or operator: construction documents and as-built drawings.
Availability of alternate routes	NJ Transit
Bus Revenue Miles or annual mile of service, Daily ridership, Link capacity (passengers per day), and Volume-to-capacity ratio	Transit service operator
Facilities designated as component of an emergency evacuation plan	Transit service operator
Planning studies identifying critical assets and future needs for project development in study area	State and local governments; NJTPA needs assessments
Network Connectivity and Continuity results	Calculated using methodologies specified in System Coordination goal area.
Extent and redundancy of technology and systems available to provide information to system operators and users.	Facility owner or operator: construction documents and as-built drawings.

Geographic Scale of Analysis

All measures in the Repair/Maintenance/Safety/Security goal area should be evaluated within the project limits.

Time Frame of Analysis

The project-specific impacts of transit projects as measured in terms of safety measures are likely to be most pronounced shortly after completion of the improvement. Therefore, it is important to evaluate these measures using multiple data points from several years before the project, during the construction phase, and for as many years after the project as data are available. Security measures, which tend to be discrete improvements whose benefits do not accumulate or diminish over time, should be analyzed for one year before and after implementation of the project. For example, construction of a security fence along a rail line to prevent unauthorized access would have a one-time benefit to security along that rail segment; therefore, conditions for the year before construction can simply be compared to conditions in the year following completion of the project.

Analysis Steps

Intermediate Measures and Analysis Tools

1. Assign a “criticality” index to infrastructure and services in the study area.

   Inputs: (required for each link in the transit network)

   - Facility/service type (exclusive guideway, shared lanes, shared tracks);
   - Whether or not alternate routes are available (same or higher functional class/lower functional class/no alternate route);
   - Ridership data (passengers per day), link capacity (passengers per day), and volume-to-capacity ratio, to help establish which facilities and services carry the greatest absolute volumes and which facilities and services have the ability to absorb excess volumes;
   - Whether or not the facility is a designated component of an emergency evacuation plan (yes/no); and
   - Plans and studies done in the study area to identify critical assets and future needs for project development.

   Calculations

   Calculate a composite criticality score or index for each facility or service. Several analysis tools are available to perform the calculation. For example, the New Jersey Department of Transportation has a license to the Disruption Impact Estimating Tool—Transportation (DIETT), which is a database and spreadsheet-based tool for prioritizing the criticality of transportation choke points.

   Intermediate output measures:

   - Criticality index or score for each facility and service in the network. Facilities should be grouped into broad categories like “most critical”, “critical” and “not critical”. *Note* *that this index must be guarded from the public due to the sensitive nature of the information.*

Number of riders impacted by service disruptions per year; Hours of service disruptions per year; Mean time between failure

Inputs:

- NJ Transit operational data
- Ridership by line or service

Outputs:

- **Number of riders impacted by service disruptions per year,**
- **Hours of service disruptions per year,**
- **Mean time between failure**

Percent of bridges in good/fair condition (NJ Transit-maintained bus and rail infrastructure only);
Percent of pavement in good/fair condition (NJ Transit-maintained bus lanes only);
Percent of track in good/fair condition (Rail infrastructure only)

Inputs: (Required for each link systemwide for the periods before construction and after construction)

- Link-level pavement and track characteristics for entire transit system in NJTPA region (from NJ Transit and PATH Management Systems)
- Bridge inventory and condition data (from NJ Transit Bridge Management System)

Analysis:

- Perform a systemwide analysis of pavement conditions and bridge conditions, calculating the percentage of all facilities in good, fair, and poor condition before construction and after construction of the project.

Outputs:

- **Percent of bridges in good/fair condition**
- **Percent of pavement in good/fair condition**
- **Percent of track in good/fair condition**

Crashes and Passenger Accidents

For transit services operated on exclusive guideways: Compare before-and-after NJ Transit and PATH safety data to determine safety impact of the project. Compare project-specific data to systemwide statistics for an indication of how much of the change in crashes was attributable to the project.

For transit services operated on roadways: Inputs:

- Facility-specific crash and passenger incident data, preferably with indication about whether a transit vehicle or transit passenger was involved
- Regional, county-level, and corridor-level aggregate safety statistics

Calculations:

- Compare project-level changes in absolute number of crashes and passenger incidents to estimates of regional, county-level, and/or corridor level changes in absolute number of crashes as an estimate of what may have happened in the absence of the project.

Caution is warranted when using and applying crash data for safety analyses. See Recommendations section below for further details. Outputs:

- Absolute number of **crashes and passenger incidents** occurred before and after construction

Crash and Incident Rate

For transit services operated on exclusive guideways: Divide number of incidents or crashes by passenger miles or transit revenue vehicle miles to determine crash rate. Also, compare the crash rate to the system-wide average crash rate.

For transit services operated on roadways: Inputs:

- Absolute number of crashes occurred before and after construction
- Bus Revenue Miles or Annual miles of service
- VMT data at regional, county, and local level
- Regional, county-level, and corridor-level aggregate crash rates

Calculations:

- Divide crashes by VMT in the study area to calculate crash rate in terms of VMT.
- Compare system-level changes in absolute number of crashes to estimates of regional, county-level, and/or corridor level changes in absolute number of crashes over a period of time.
- The net increase or decrease in crash rate attributable to the project can be estimated by subtracting the regional, county-level, or corridor-level crash rate from the observed crash rate after project completion.

Outputs:

- **Crash and incident rate**, in crashes per million vehicle miles traveled or incidents per million trips

Transportation Resiliency

Transportation resiliency is a term that describes the ability of the transportation system to adapt and respond to incidents and disruptions. Transportation resiliency applies to natural threats, such as hurricane storm surges and floods, as well as man-made threats such as terrorist attacks. According to NCHRP Report 525, "Incorporating Security into the Transportation Planning Process", four major categories of security incident countermeasures exist to address threats and vulnerabilities to the nation's transportation infrastructure. These four categories include prevention, protection, redundancy, and recovery. These four measures apply more broadly than security. For example, climate change adaptation strategies often are grouped into similar categories.

Below, the categories "prevention" and "protection" are discussed together below because they both refer to proactive, preventative measures taken in advance of an attack or unauthorized access. Their results are measured in terms of the extent to which they prevent the system's critical services or pieces of infrastructure from being damaged, destroyed, or used for illicit purposes. Projects addressing "redundancy" and "recovery" address the operations of the system after a major disruption occurs. Their results are measured in terms of how well the system operates (or would operate) after a major disruption.

<u>Inputs: Prevention and Protection</u>

- Measures taken to *prevent or discourage* unauthorized access to a transportation facility or a specific sensitive feature of a transportation facility like a bridge or equipment room, before and after construction; measures taken to prevent or discourage illicit activity in or near a transportation facility; measures taken to prevent or discourage direct and indirect attacks on a facility; and measures taken to protect against the impacts of natural events like extreme weather events. *Examples cited in NCHRP Report 525 include access control systems like fences and locked doors, highly visible closed circuit television (CCTV) systems, and intrusion detection systems such as alarmed entrances and fence-line detection systems. The design of the facility is also important, for example, allowing for open sight lines into a park-and-ride lot from nearby roadways and development, adding lighting to a pedestrian pathway, hardening a facility to prevent physical incursions and/or increase blast resilience, or building a levee and pumping system to protect a railbed from flooding.*
- Criticality index of the facility or service. *Calculated above in intermediate measures and analysis.*

<u>Evaluation: Prevention and Protection</u>

- Measure the mileage of transit facilities with prevention and protection measures in place (per Federal, state, and local design guidelines) before and after the project is completed.

<u>Outputs: Prevention and Protection</u>

- Share of most critical assets hardened against unauthorized access, illicit activity, attacks, and/or natural events. The definition of "most critical assets" must be defined in the process for assigning a criticality score above.

Inputs: Redundancy and Recovery

- Results of **Network Connectivity and Continuity** calculations, using the process defined in the System Coordination goal area. *For purposes of this analysis, connectivity calculations should be performed for the subset of the system consisting of critical and/or most critical assets, as defined in the intermediate measure above.*
- Extent and redundancy of technology and systems available to provide information to system operators and users.

Evaluation: Redundancy and Recovery

- Using results of before-and-after network connectivity analysis, determine extent to which the project improves connectivity in the designated evacuation route system. *As described in the System Coordination goal area, system connectivity can be defined in terms of several indices and measures. The evaluation here should assess the change that the Transit Preservation project would cause in these indices or measures.*
- Qualitatively compare the extent of information technology available to provide information to system operators and to users during an emergency, system failure, or system disruption, before and after project implementation.

Outputs: Redundancy and Recovery

- Change in System Connectivity for the region's critical and/or most critical transportation assets. *For example, the beta index could change from 1.1 to 1.2 as a result of the project, indicating greater network connectivity and availability of alternative routes in case of a disruption or blockage.*
- Extent to which communication systems are deployed in a redundant fashion to ensure information is available to system operators and users in an emergency, system failure, or system disruption. *For example, "The project provided a diesel generator to power a backup communication system in case of a power failure concurrent with the event or disruption."*

Recommendations for Future Performance Evaluation: Repair/Maintenance/Safety/Security Measures

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 for purposes of transportation security, climate change adaptation, and related uses. NJ Transit, PATH, and other transit operators, in cooperation with Federal and local governments and other state agencies, have performed an assessment of critical transportation infrastructure. NJ Transit, PATH, and other transit operators should continue to work with the 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).

Improve data collection and reporting for other repair/maintenance programs that are driven by life-cycle replacement cost. NJTPA should continue to work with NJ TRANSIT and other transit operators in collecting and reporting system-wide preservation data to support performance measures for station platforms, age of the bus fleet, bus garages, station buildings, ADA accessibility, turnouts, ties, Transit ITS (message boards, etc.) and other.

3.4.5 Evaluating Economy Measures

NJTPA Economy Goal - Retain and increase economic activity and competitiveness.

Interdependencies between Data, Analysis Tools, and Performance Measures

Calculations of transportation costs rely on estimates of net crashes by severity in the Repair/Maintenance/Safety/Security area. There are no interdependencies between return on investment and other previous measures. No intermediate measures or analysis tools are required for the analysis.

Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Change in vehicle operating conditions (vehicle miles, speeds, stops/starts)	Transit operator
Operating costs per revenue vehicle mile	Transit operator
Net crashes by severity	Output measure of **Repair/Maintenance/Safety/ Security** goal area; see above
Cost per crash, by severity	NJDOT and National Highway Traffic Safety Administration (NHTSA)

Geographic Scale of Analysis

All measures in the Economy goal area should be evaluated within the project limits. In the case of a project that is expected to generate significant diversions of passenger traffic, the analysis area may be expanded to a corridor encompassing multiple facilities, to a county, or to the entire NJTPA region.

Time Frame of Analysis

The impacts of transit preservation projects as measured in terms of Economic measures may be small or may not be measurable at all shortly after completion of the improvement, because travel time benefits, operating cost savings, and accident cost reductions generated by a transit preservation project will accrue gradually over time. However, as years pass many changes as measured by Economic measures may become less pronounced over time. Therefore, it is important to evaluate Economic measures on a continuous basis, using multiple data points from several years before the project and for as many years after the project as data are available.

Analysis Steps

Transportation Costs

Transportation costs can be quantified in terms of change in vehicle operating costs and change in accident-related costs.

<u>Inputs:</u>

- Average transit service operating costs, in dollars, before and after project implementation. *For example, a track improvement project that increases train speeds may reduce operating costs on a line by reducing the need for slowing and acceleration through a slow zone. The savings may be difficult to measure on a per-train basis, but over the course of a year the reduced maintenance costs may be evident.*
- Revenue service hours for affected services, before and after project implementation.

<u>Calculation:</u>

- Divide net change in transit operating costs by revenue service hours before and after project implementation.

<u>Outputs:</u>

- **Net change in transit operating costs per revenue service hour** associated with the project. *An example is shown in the following table:*

Table 3.4-B: Sample of Estimated Net Transit Operating Cost Savings
(NOTE: Contains fictional data for illustration purposes only)

	Before	After	Net Change
Estimated Annual Transit Operating Costs (2009 dollars per year)	$600,000	$550,000	$50,000
Revenue service hours	6,000	5,900	100
Estimated Transit Operating Costs per Revenue Service Hour (2009 dollars)	$100.00	$93.22	-$6.78

Inputs:

- Net change in crashes associated with the project, by severity
- Average cost of crash, by severity

Calculation:

- Multiply change in crashes by the average cost of crash for each severity level.

Outputs:

- **Net change in accident-related costs** associated with the project. Based on NJDOT data for 2009, the *average costs for accidents range from nearly $9,000 for a property-damage-only crash, to around $50,000 for an injury crash, to more than $2 million for a fatal crash.*

Cost Effectiveness

Inputs:

- Project capital cost, in dollars.
- Net reduction in transit operating costs, in dollars per year.
- Performance measures from previous calculations (e.g., crashes, travel time savings, and emissions reduction)

Calculations:

- Divide the capital cost by any performance measure to calculate the dollar-weighted impacts of the project. *For example, a million-dollar project that reduces carbon emissions by 1,000 tons has a cost-effectiveness index of $1,000/ton. A project that reduces operating costs by $50,000 per year and reduces carbon emissions by 25 tons has a cost-effectiveness index of $2,000/ton/year.*

Outputs:

- **Cost Effectiveness***, expressed in dollars per unit of benefit per dollar (e.g., dollars per accident reduced; dollar per minute of travel time savings; dollars per ton of reduced carbon emissions).*

  NOTE: While cost-effectiveness measures are constituents of a broader benefit-cost analysis approach, many cost-effectiveness measures are not additive. Therefore, extreme caution should be exercised in presenting and explaining results of a project-level cost-effectiveness analysis.

Recommendations for Future Performance Evaluation: Economy Measures

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.

3.5 Transit Enhancement and Transit-Oriented Development Projects

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 projects.

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 projects.

Contents of This Section

Suggested Work Flow for Transit Enhancement and Transit-Oriented Development Projects

The following sequence of goal areas for this project category was developed specifically to enable an ordered evaluation of performance measures. This allowed calculations from earlier intermediate (and final) measures in one goal area to serve as inputs for measures in other goal areas:

1. System Coordination Measures

2. User Responsiveness Measures

3. Environment Measures

4. Land Use/Transportation Coordination Measures

5. Repair/Maintenance/Safety/Security Measures

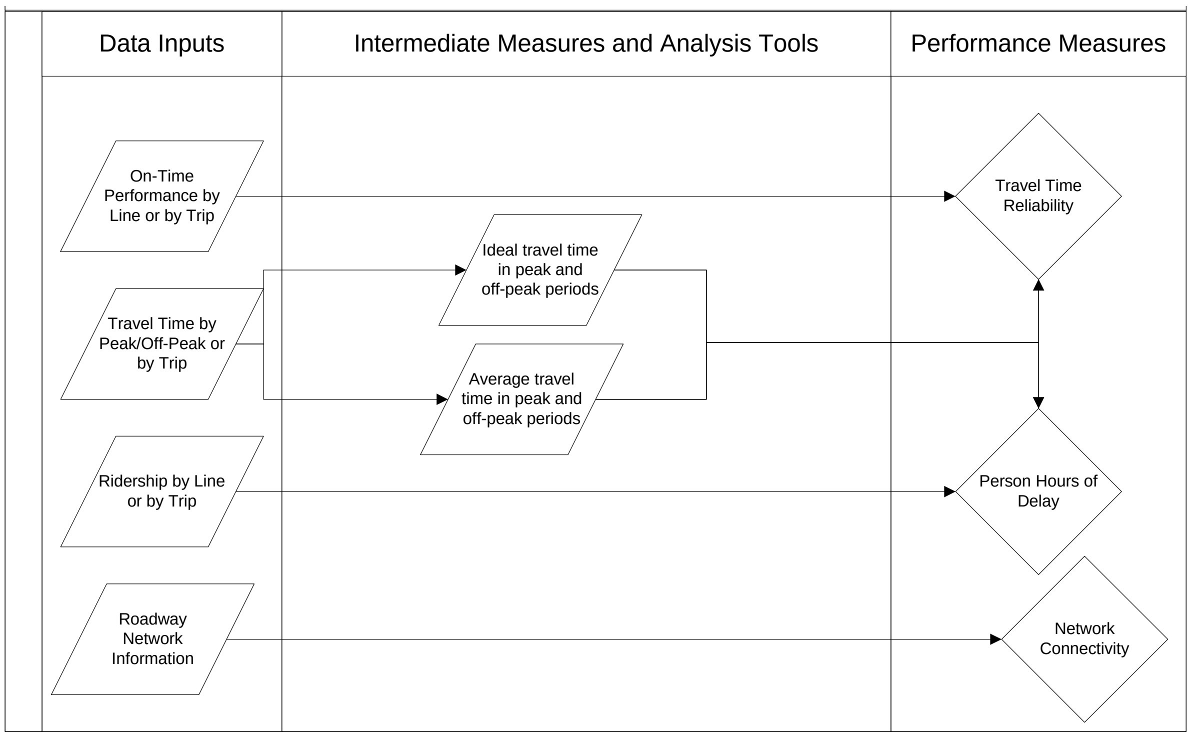
6. Economy Measures

3.5.1 Evaluating System Coordination Measures

NJTPA System Coordination Goal - Enhance system coordination, efficiency and intermodal connectivity.

Interdependencies between Data, Analysis Tools, and Performance Measures

The following diagram is a simplification of the interdependencies between System Coordination measures:



Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
On-time performance by line or by trip	Transit operators
Transit routes and Stations	Transit operators, NJTPA GIS
Travel time by trip	Transit operators
Availability of pedestrian and bicycle facilities and the conditions near stations	Transit operators, NJTPA GIS, local municipalities
Ridership by line or by trip	Transit operators
Transit line or vehicle capacity	Transit operators, vehicle manufacturer specifications

Geographic Scale of Analysis

An analysis of System Coordination measures for Transit Enhancement and TOD projects requires that all affected transit services be evaluated. The geographic scale of the analysis will most likely be determined by data limitations.

Time Frame of Analysis

System Coordination measures for Transit Enhancement and TOD projects should be evaluated using multiple data points from several years before the project, during the construction phase (if any), and for as many years after the project as data are available. For TOD projects, it is recommended to have at least 3 years of before and after year data. TOD projects require long-term data monitoring.

Analysis Steps

Intermediate Measures and Analysis Tools

1. Estimate average travel time in peak and off-peak periods.

   Inputs: (required for each route or trip to be evaluated, before and after implementation of enhancement project).

   - Travel time by trip, in minutes.

   Intermediate output measures:

   - Estimated **average travel time** in peak and off-peak periods, in minutes. *Collect data by route or by trip for time periods before and after implementation.*
   - **Free flow travel time** in peak and off-peak periods. *Collect data by route or trip for time periods before and after implementation of the transit enhancement. Free flow travel time is defined as the shortest bus travel time that can be expected under uncongested conditions on the roadway system (for buses) or the shortest rail travel time that can be achieved under transit operating policies for the infrastructure that is in place at the time (e.g., considering track speed restrictions, standard station dwell times, and other dispatching policies). As a proxy, can use average run time for early morning (before morning peak period) and/or late evening (after evening peak period) trips.*

Travel Time Reliability

Note that travel time reliability for transit can be measured in two ways: either compare actual travel times to scheduled travel times (on-time performance), or compare actual travel times to free-flow travel times (which takes into account differences between transit performance in congested periods and off-peak periods). On-time performance is the reliability metric that matters more to transit passengers, and therefore should be reported publicly, while comparisons of actual travel times to free-flow travel times is a management-oriented measure of how well the system is operating with respect to operating and dispatching policies.

Inputs: (required for each route or trip before and after implementation).

- On-time performance by route or trip. *Use as detailed information as possible. On-time performance may only be available for the departure time from the first stop and the arrival time at destination, or it may be available for intermediate time points.*
- Actual travel times and free-flow travel times by route and by trip, in minutes, as available.

Calculations: Transit On-Time Performance

- **On-time performance** is the percentage of transit trips that arrive at a destination within five minutes and 59 seconds of their scheduled time. *For example, if nine out of ten buses on a particular route arrive within five minutes 59 seconds of their scheduled times, that route has a 95% on-time performance rating.*

Calculations: Transit Travel Time Reliability

- Using actual travel time data, determine the **95th percentile travel times**. *To calculate the 95th percentile travel time, rank order the actual travel times for all trips in the analysis period (usually one week or month worth of weekday trips). The travel time that is longer than 95 percent of trips (or longer than all but 5 percent of trips) represents 95th percentile travel time. Note that 95th percentile travel time is a guideline. For trips where reliability is not as important, for example recreational trips, a lower threshold may be used.*
- **Buffer time** = 95th percentile travel time – average travel time. *Buffer time, expressed in minutes, represents the extra time (or time cushion) that travelers must add to their average travel time when planning trips to ensure on-time arrival 95 percent of the time. Typical values for a complete trip range from as low as 5 minutes or less for off-peak trips to a maximum of 30 minutes or more in the peak.*
- **Buffer index** = (95th percentile travel time – average travel time) / average travel time, expressed as a percentage. *Buffer index values closer to 0% indicate that 95th percentile travel time is close to average travel time, i.e. there is little or no variability in congestion. Buffer index values above 100% indicate severe congestion, i.e. travel time is more than twice as long on the worst travel days than in average conditions.*
- **Planning time index** = 95th percentile travel time / free-flow travel time. *The planning time index reflects how much total time a traveler should allow to ensure on-time arrival 95 percent of the time (in contrast to buffer index, which represents extra time). For example, a planning time index of 1.60 means that for a trip that takes 15 minutes off-peak, a traveler should budget a total of 24 minutes to ensure on-time arrival 95 percent of the time.*
- For an estimate of **"no-build" reliability indices**, use estimated "no-build" congested travel times. *Continuous or 15-minute congested travel times may not be available for the no-build condition because no-build conditions must necessarily be simulated or calculated. Therefore, use peak travel times to estimate the improvement in travel time reliability that is attributable to the project.*

Person-Hours of Delay

Inputs: (required for each route or service before and after implementation).

- Free-flow and average actual travel times by route or trip, in minutes.
- Ridership by route or trip, in passengers.

Calculations:

- Average delay = average travel time – free-flow travel time, in minutes. *If sufficient data are available, delay can be calculated on a per-trip basis.*
- **Person-hours of delay** = average delay x ridership. *Person hours of delay can also be calculated by multiplying actual delay per trip by ridership per trip, and then summing the results over all trips. For example, if the 7:30 train carries 800 passengers and takes an average of 3 minutes longer than free-flow conditions, and the 7:45 train carries 1000 passengers and arrives an average of 5 minutes late, the total person-hours of delay for these two trains is (800 x 3) + (1000 x 5) = 7,400 minutes per day. Repeat for all other trains on the schedule.*
- Multiply no-build person-hours of delay by persons per vehicle to determine total **no-build person hours of delay**.
- The net impact attributable to the project is the difference between actual delay and no-build estimates of delay.

Network Connectivity and Continuity

Network connectivity and continuity by mode is independently processed.

Inputs:

- Transit network information:
  - Density of transit nodes (intersections) and segments, in intersections per square mile and segments per square mile;
  - Presence or absence of sidewalks, bike lanes, and multi-use trails near stations; and
  - Condition of sidewalks and bike lanes (e.g., ADA compliance) within 2 miles of the station.

Evaluation: Use GIS to evaluate connectivity of the transit network before and after improvement. Evaluate connectivity on both a local scale and a regional scale. The *Smart Transportation Guidebook*, published in March 2008 through a partnership between Pennsylvania Department of Transportation and the New Jersey Department of Transportation, suggests the following connectivity measures:

- **Internal Connectivity.** Use either of the following two measures:
  - Beta Index, the number of links divided by the number of nodes or link ends. *A higher ratio indicates higher street connectivity.*
  - Intersections per square mile. *Strict grid systems have about 25 intersections per square mile, while conventional branching systems have about one-third to one-half that many.*

- **External Connectivity**
  - All neighborhoods in the community should be connected to the larger street system at least every ¼ mile.
- **Route Directness**
  - This measures the distance a traveler would rider transit between two points compared to the straight line (or radial) distance between the same two points. *The closer the ratio is to 1.0, the more direct the route; route directness values of 1.2-1.5 describe reasonably connected transit networks.*
- Connectivity and continuity in the "no-build" condition are simply the conditions that existed before implementation of the transit enhancement.
- Compare route directness analysis for "no-build' and after conditions.

Additional resources on network connectivity include the following:

- Carlos A. Alba and Edward Beimborn (2005), *Analysis Of The Effects Of Local Street Connectivity On Arterial Traffic*, Transportation Research Board Annual Meeting (www.trb.org); at www.uwm.edu/Dept/CUTS//lu/conn.pdf.
- Dill, Jennifer (2004). "Measuring Network Connectivity for Bicycling and Walking." Presented at the 83rd Annual Meeting of the Transportation Research Board, Washington, DC.
- Portland Metro (2001), "Street Connectivity Standards," *Planning for Future Streets: Implementing the Regional Transportation Plan*, Portland Metro Regional Services (www.metro-region.org/library_docs/trans/streetconnect.pdf).
- Portland Metro (2004), Street Connectivity: An Evaluation of Case Studies in the Portland Region, Portland Metro (www.metro-region.org/library_docs/trans/connectivityreport.pdf).

Recommendations for Future Performance Evaluation: System Coordination Measures

Collect and use transit travel time data for direct observations of congested and free-flow travel speeds. With better travel time data for buses as well as trains, transit operators could improve estimates of “free-flow” and “congested” stop-to-stop travel times, and in turn measurement of Travel Time Reliability, Delay, and Percent of Travel Under Congested Conditions. The use of archived TRANSCOM, INRIX, and transit operators’ GPS data should provide better measure of congested and free-flow speeds.

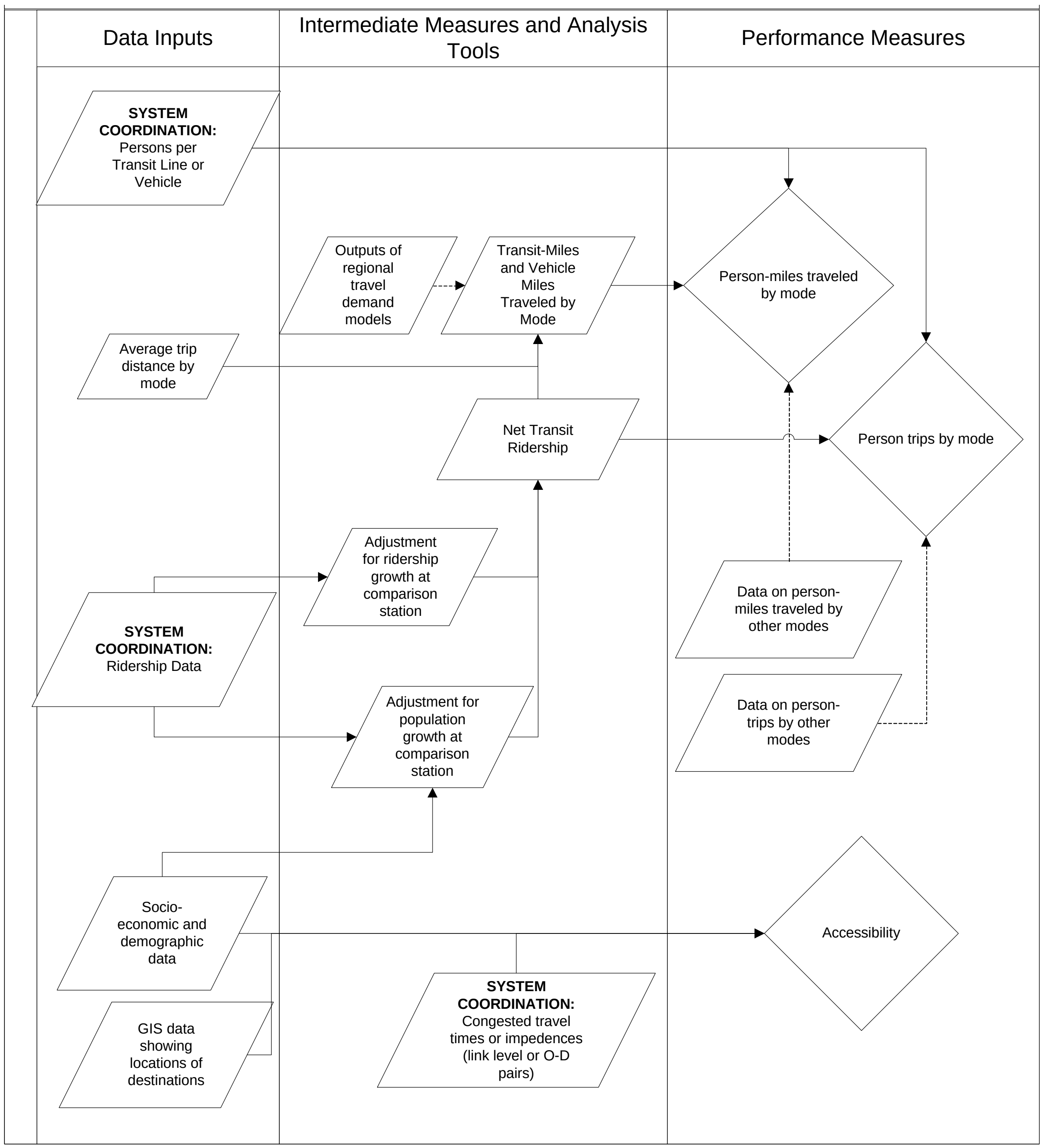
Use simulation models to improve estimates of network-level congestion and delay measures. The methodology presented above assumes transit impacts are expected to be limited to the immediate vicinity of the project. When the analysis involves many links in a network of roadways or a system or rail lines, simulation models can be used to calculate all of the System Coordination performance measures on a network scale. Network simulation models have extensive data requirements (for example, they require field observations of free-flow and congested travel speeds and very detailed roadway and rail geometry data and operational 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, for example from one roadway or track 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).

3.5.2 Evaluating User Responsiveness Measures

NJTPA User Responsiveness Goal - Provide affordable, accessible, and dynamic transportation systems responsive to current and future customers.

Interdependencies between Data, Analysis Tools, and Performance Measures

The following diagram is a simplification of the interdependencies between User Responsiveness and System Coordination measures. *Note: Customer Satisfaction is independently evaluated and is not included in this diagram. For further information, see page 3.5-25.*



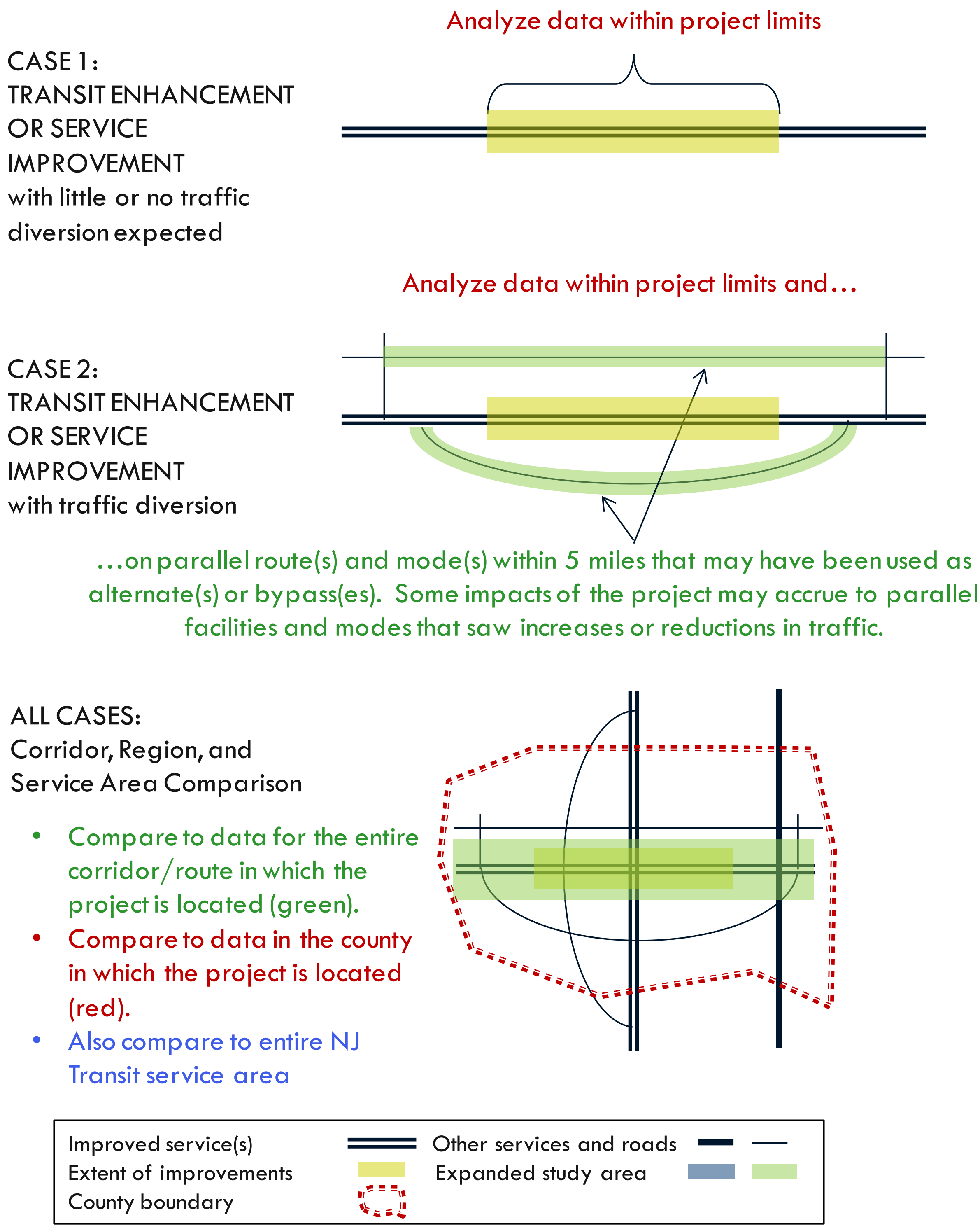
Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Persons per transit line or vehicle	NJ Transit run sheets and farebox data
Average trip distance	Household travel survey data collected by NJTPA or American Community Survey 5-year average data for place/county in which link is located. *Note that ACS data focus on work/commute trips, and therefore the data may need to be adjusted to account for all trip types using the facility.*
Ridership data	NJ Transit, Transit Operators
Socio-economic, demographic, and employment data (Census Block Group, Traffic Analysis Zone (TAZ), or Place level)	U.S. Census Bureau's American Community Survey 5-year estimates; U.S. Census Bureau's Local Employment-Household Dynamics data, NJTPA
GIS data showing location of local destinations and opportunities (health clinics, grocery stores and sources of fresh food, local parks and playgrounds, elementary and secondary schools, and neighborhood-oriented retail and service establishments like restaurants, bars, dry cleaners, banks, and hardware stores)	Counties and local municipalities, NJDOT, NJDEP, Google Maps, WalkScore.com
GIS data showing locations of regional destinations and opportunities (major hospitals, four-year colleges and universities, major concentrations of retail activity, and recreational and tourist destinations with more than 100 employees, like amusement parks, sports arenas, performing arts venues, museums, and historic sites)	Counties and local municipalities, NJDOT, NJDEP, Google Maps, WalkScore.com

Geographic Scale of Analysis

The three User Responsiveness measures are best measured at a regional level or at a corridor level, grouping multiple facilities and modes together to determine the corridor-level or systemwide impacts of any given transit project. The figure below shows the geographic extent for which data should be analyzed:



Time Frame of Analysis

The impacts of transit enhancement and TOD projects as measured in terms of User Responsiveness measures may be small or may not be measurable at all shortly after completion of the improvement. However, as years pass many changes as measured by User Responsiveness measures may become more pronounced over time. Therefore, it is important to evaluate User Responsiveness measures on a continuous basis, using multiple data points from several years before the project and for as many years after the project as data are available.

Customer Satisfaction measures are an exception. The reaction to a Transit enhancement project may peak shortly after project completion, but as time goes on, people may not be able to distinguish the project's impacts from other changes that have happened simultaneously (for example, other transportation improvements or economic shifts).

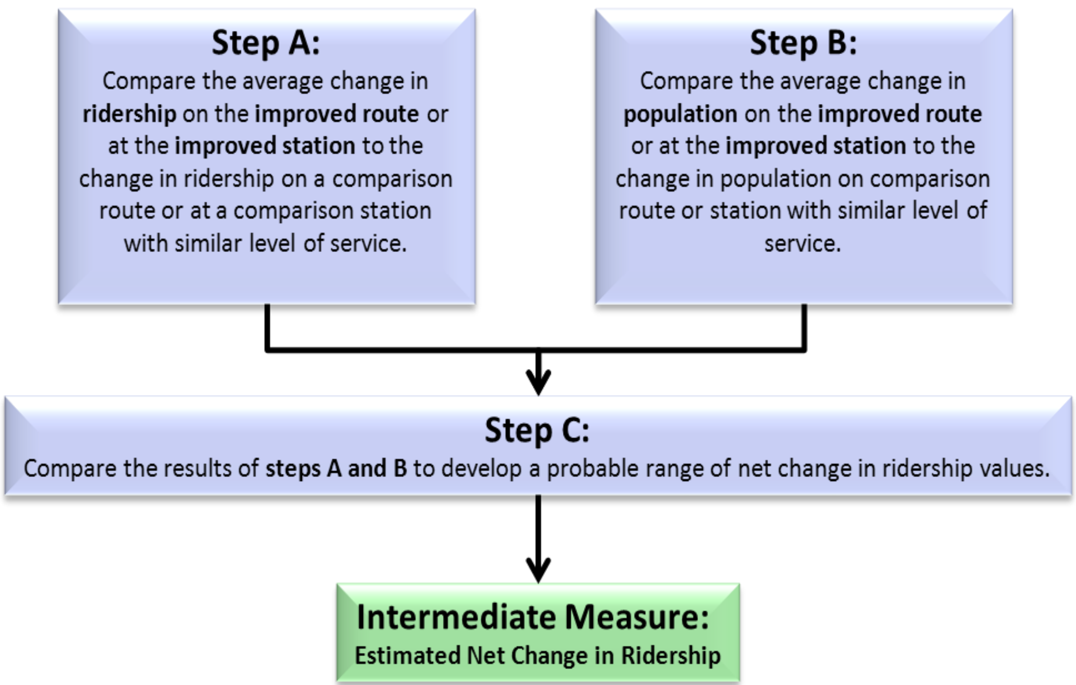
Using person-miles traveled by mode as an example, compared to pre-construction conditions, transit usage may increase after completion of the project, compared to "before" conditions. Impacts can be estimated as follows:

- The overall impact of the project can be estimated by comparing person-miles traveled by mode after the project to mode share before the project.
- The net impact can be estimated by comparing person-miles traveled by mode after the project to person-miles traveled by mode in a hypothetical "no-build" scenario.
- Finally, the impacts associated with construction can be estimated by comparing person-miles traveled by mode during construction to mode shares before and after construction.

Analysis Steps

Intermediate Measures and Analysis Tools

Figure 3.5-A: Steps to estimate the value of "Net Transit Ridership"[1]



1. Calculate Net Change in Transit Ridership

   Inputs: (Required for each link for the periods before implementation and after implementation).

   - Transit riders on the route that underwent an enhancement, or at a new or improved station. *For example, a local municipality, in cooperation with NJ Transit and NJDOT, initiated a series of policy changes, including zoning changes and tax incentives, to promote transit-oriented development in its downtown core. NJ Transit undertook a series of improvements to the transit station, and NJDOT or local municipalities coordinated improvements to sidewalks, crosswalks, and traffic calming measures along a state highway corridor adjacent to the station. As a result, the TOD station saw*

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[1] If the facility is new, the net ridership may be 100 percent of the riders observed on the new facility, or some adjustments may be made to account for rider shifts from parallel transit routes or nearby stations.

~~2~~ If the net change varies wildly, or if the net change is positive in one calculation and negative in the other calculation, re-examine the results in light of the caveats discussed after each calculation above. If necessary, use professional judgment to eliminate any net ridership estimates that appear unreasonable. Then use either the average, median, high, or low value depending on the purpose of the analysis.

an average of 200 weekday riders before implementation of the TOD initiative and an average of 250 riders after implementation.

- Transit riders on a comparison route or at a comparison station that remained static over the analysis period. *The comparison route or station should have similar levels of service and serve a similar demographic as the study area route. If a station is being analyzed, choose a station nearby on the same line, since a nearby station is most likely to have a similar level of service. For example, a station one station away on the same line downstream of the TOD station may have seen an average of 280 weekday riders before the TOD initiative was implemented and 290 riders after.*
- Population for the area within ½ mile of the route or station being analyzed, and within ½ mile of the comparison route or station. *If analyzing stations, population data should be gathered for an area within ½ mile of the study station(s) and the comparison station(s). For example, there may be 12,500 people living within ½ mile of the study-area stations upstream of the improvement project and 20,000 people within ½ mile of the comparison stations downstream of the project. After implementation of the project, there may be 12,700 people within ½ mile of the study-area station and 20,050 people within ½ mile of the comparison stations.*

<u>Calculations:</u>

The recommended approach to calculating Net Change in Transit Ridership is to use a variety of methods to "triangulate" the estimated value. The calculation steps are as follows:

a. Compare change in ridership (or average change in ridership) on the improved transit route(s) or station to the average change in ridership on a comparison route or at a comparison station. What if the ridership at the improved corridor or station(s) had grown at the same rate as the comparison corridor or station(s)? The net change in ridership would be the difference between the actual growth and the adjusted growth.

- Gather ridership data. The change in ridership may be averaged across several stations or boarding locations if a route is being analyzed. *See the example ridership data above for a study-area station and a comparison station.*
- Compare change in ridership (or average change in ridership) on the improved route(s) or at the improved station(s) to the change in ridership on comparison routes (and at comparison station(s)). *The growth rate in average ridership at the comparison stations, if applied to pre-implementation traffic levels on the study facility, could lead to one estimate of what the change in ridership at the TOD station may have been in the absence of the project.*
- The difference between the actual absolute change in ridership on the improved transit route (or at the improved station) and the adjusted change in ridership on the improved transit facility or service is one way to estimate the net ridership impact of the project. Calculations are as follows:

$$\text{Adjusted Ridership}_{\text{Improved corridor/station}} = \text{Ridership}_{\text{Pre-constr.,Improved corridor/station}} * \frac{\text{(Average) Ridership}_{\text{Comparison corridor/station,Post-Constr.}}}{\text{(Average)Ridership}_{\text{Comparison corridor/station,Pre-Constr.}}}$$

$$\text{Net Ridership Change} = \text{Actual Ridership}_{\text{Post-constr.,Improved corridor/station}} - \text{Adjusted Ridership}_{\text{Post-constr.,Improved corridor/station}}$$

- *Using the example ridership numbers from above:*

$$\text{Adjusted Ridership}_{\text{Improved corridor/station}} = 200 * \frac{290}{280} = 207 \text{ riders}$$

$$\text{Net Ridership Change} = 250 - 207 = 43 \text{ riders}$$

b. Compare change in population (or average change in population) on the improved routes(s) or at the improved station(s) to the change in population on comparison routes with similar levels of service. What if the population of the area around the improved corridor or station had grown at the same rate as the population of the comparison corridor or station? *This analysis assumes there is a direct correlation between ridership growth and population growth at the study area and comparison stations, meaning that population growth in a station area leads to corresponding ridership growth at that station, and population decline leads to reduction in ridership.*

- Collect population data for the areas within ½ mile of the study area and the comparison study area. *Use data from the examples from above.*
- The ridership at the study area station(s) can be adjusted to control for population growth at the comparison station(s). For any given year after the improvement is implemented, the adjusted population at the study area station can be calculated as follows:

$$\text{Adjusted Population}_{\text{After Improvement,Improved Corridor/Station}} = \text{Population}_{\text{Before Improvement,Improved Corridor/Station}} * \frac{\text{Population}_{\text{After Improvement,Comparison Corridor/Station}}}{\text{Population}_{\text{Before Improvement,Comparison Corridor/Station}}}$$

$$\text{Adjusted Population}_{\text{After Improvement,Improved Corridor/Station}} = 12{,}500 * \frac{20{,}050}{20{,}000}$$

$$\text{Adjusted Population}_{\text{After Improvement,Improved Corridor/Station}} = 12{,}531 \text{ people}$$

- The adjusted ridership can then be calculated using the following ratio:

$$\frac{\text{Adjusted Ridership}_{\text{After Improvement,Improved Corridor/Stations}}}{\text{Adjusted Population}_{\text{After Improvement,Improved Corridor/Station}}} = \frac{\text{Ridership}_{\text{Before Improvement,Improved Corridor/Stations}}}{\text{Population}_{\text{Before Improvement,Improved Corridor/Stations}}}$$

$$\text{Adjusted Ridership}_{\text{After Improvement,Improved Corridor/Stations}} = 200 \text{ passengers per day} * \frac{12{,}531 \text{ people}}{12{,}500 \text{ people}} = 201 \text{ passengers per day}$$

- The difference between the actual absolute change in ridership on the improved transit facility or service and the adjusted change in ridership on the improved facility or service is in turn, a second basis for estimating the net ridership impact of the project. Calculations are as follows:

$$\text{Net Ridership Change} = \text{Actual Ridership}_{\text{Improved Corridor/Stations}} - \text{Adjusted Ridership}_{\text{Improved Corridor/Stations}}$$

$$\text{Net Ridership Change} = 250 - 201 = 49 \text{ passengers per day}$$

c. Compare the results of steps “a” and “b” to develop a probable range of net ridership values. If the net change in ridership is within the same order of magnitude, proceed to the next step in the calculation. If the net change varies wildly, or if the net change is positive in one calculation and negative in the other calculation, re-examine the results in light of the caveats discussed after each calculation above. If necessary, use professional judgment to eliminate any net ridership estimates that appear unreasonable. Then use either the average, median, high, or low value depending on the purpose of the analysis. *In the above calculations, the net new ridership attributable to the TOD initiative is estimated to be between 43 and 49 passengers per day.*

d. If all three estimates are wildly different, it may not be possible to proceed with the next step.

Intermediate output measures:

- Range in values of **net change in transit ridership** attributable to implementation of the project.
- If the facility is new, the net ridership may be 100 percent of the riders observed on the new facility, or some adjustments may be made to account for rider shifts from parallel transit routes or nearby stations.

2. Calculate Net Change in VMT

Inputs:

- Range in values of estimated net change in ridership from previous step (for before and after implementation). *For example, 45 net new riders per day.*
- Share of riders who previously drove instead of using transit, from available survey data. *For example, 80 percent of new riders previously drove and the remaining 20 percent didn’t previously make the trip.*
- Average vehicle occupancy for the study area, county, or the NJTPA region, from the U.S. Census or recent household travel surveys. *Please note that ACS focuses only on the work/commuter trip. For example, 1.2 passengers per vehicle.*
- Average trip distance via driving for those people who switched from driving to transit, using estimates of average distance to out-of-county destinations and average distance to out-of-state destinations. *Can use average distance traveled to work, or the distance from the home zone to a point on the transit route that has high employment densities. For example, if the survey didn’t ask new transit riders what their previous*

driving distance was, one could use U.S. Census Bureau American Community Survey data to determine the average distance to work for people living in the study area. This distance might be 15 miles, for example. Or, if American Community Survey data are not available, one could use the average distance to downtown Newark or Midtown Manhattan from the TOD station.

<u>Calculations:</u>

a. Divide net new change in ridership numbers by average vehicle occupancy data for the county in which the transit enhancement project is, using most recent available data from the U.S. Census or NJTPA Household Travel Survey, to produce the net reduction in vehicle trips. *For example, 45 net new transit riders * 80 percent who previously drove / 1.2 riders per vehicle equals 30 net vehicles taken off the road due to the TOD initiative.*

b. Separate vehicle trips into destination groups, such as out-of-county and out-of-state trips, based on the proportion of transit trips traveling out-of-state and out-of-county from the U.S. Census Journey to Work data. *Suppose Journey to Work data or American Community Survey data indicate that 35 percent of trips originating in that county remain in the county, 45 percent go to out-of-county destinations within New Jersey, and the remaining 30 percent travel to out-of-state destinations. One can assume that none of the transit trips remain within the county, so that 60 percent of net new transit trips stay within New Jersey and 40 percent travel to New York City.*

c. Make an assumption about the average former driving trip distance for travelers in each destination group. *The average round-trip distance for trips that stay within New Jersey is assumed to be 30 miles in this example, and the average round-trip distance for trips to New York City is assumed to be 70 miles.*

d. For each destination group, multiply the number of trips by the average distance to the group destinations to produce the reduction in VMT for out-of-state trips. *For the in-state group, 30 miles * 60 percent * 30 net reduction in daily vehicle trips = a net reduction of 540 vehicle-miles traveled per day. The corresponding value for out-of-state trips is 70 miles * 40 percent * 30 net vehicle trips = 840 vehicle miles traveled per day. The annual reduction in VMT, assuming 200 working days per year, is (540 + 840) * 200 = a net annual reduction of 276,000 VMT.*

e. Adjust the net VMT reduction to account for modes used to access transit. *If 20 percent of the net new riders drive an average of 5 miles from home to access a transit station, the net VMT reduction needs to be decreased by 45 riders * 20 percent * 5 miles * 200 working days per year = 9,000 VMT. Therefore, the actual net VMT reduction is 276,000 - 9,000 = 267,000 VMT.*

f. Compare the VMT change in the county in which the project is located to the NJTPA region and the State of New Jersey. *For large projects in particular, VMT impacts may be perceived at a county level. As another point in the "triangulation" process, at this point the range of net VMT estimates produced in the previous step can be compared to the rates of change in VMT at the county, region, and state level. Compare the rate of change in county-level VMT to the rate of change of facility-level ridership values, and also compare the county-level VMT to the rate of change in VMT at the regional and state level. The* *differences between these respective VMT changes can be used to estimate a range of probable net VMT impacts of the project.*

g. Use professional judgment to specify a single value for estimated net change in VMT. As in the net ridership calculations, the estimated change in net VMT can be affected by many project-specific exogenous factors. The estimated net change in VMT could be the average of all estimated values, or the median value, or the high or low point, depending on the confidence level in the input assumptions and variables.

Intermediate output measures:

- **Net change in vehicle miles traveled.**

Person-Miles of Travel by Mode (Mode Choice)

Inputs:

- Net vehicle miles traveled*, from calculations above.*
- Persons per vehicle (use a single year, perhaps the midpoint of the analysis, so as not to introduce additional error into the calculation). *For example 1.2 persons per vehicle.*
- Modes used to access transit, and mode share for those access modes.

Calculations:

- Multiply estimates of net vehicle miles traveled by persons per vehicle to determine the net change in person-miles traveled by car. *Using values from the above examples, 267,000-mile reduction in net VMT * 1.2 persons per vehicle = net reduction of 320,400 person-miles traveled by car.*
- Multiply estimates of net new riders by average destination per rider to determine the net change in person-miles traveled by transit. *For example, 45 net new daily transit riders * 40 miles average round trip distance = 1,800 passenger-miles per day. Over 200 annual working days, this translates to 360,000 net new passenger-miles by transit per year.*
- Estimate the person-miles traveled by other modes. *For example, in the above example, if 20 percent of the net new transit passengers access the station by car, and the remaining 80 percent walk or bike, with an average trip distance of 1 mile, the average passenger miles traveled by nonmotorized modes is 45 net new daily transit riders * 80 percent * 1 mile = 36 miles per day or 7,200 miles per year.*

Person-Trips by Mode (Mode Choice)

Inputs:

- Net Change in Transit Ridership.
- Share of net new riders that previously traveled by car.
- Share of net new riders who access the expanded transit service by car, other transit modes, or nonmotorized modes.

Calculations:

- *From the above example, there are 45 new person-trips per day by transit.*
- Multiply estimates of net new transit ridership by the share who previously drove to determine the net change in person-trips by motor vehicles. *For example, 45 net new daily transit riders* 80 percent of whom previously commuted by car = a net reduction of 36 person-trips by car. However, if 20 percent of the net new riders drive to access the expanded transit service, the actual net reduction is only 45 * 80 percent = 36 person-trips by car.*
- Calculate the person-trips by other modes. *From the previous step, if 80 percent of net new riders use nonmotorized means to access transit, the net increase in nonmotorized trips is 45 * 80 percent = 36 person-trips.*

Accessibility

Accessibility is a measure of the ability of people to reach opportunities and activities that they undertake in their daily lives such as work, school, shopping, medical service, etc., or the ability of businesses to reach their labor force, sources of raw materials and inputs to their production facilities, and the consumer markets for their finished products. These measures below are also tied to the availability of transit service by days and hours.

Access to jobs refers to the ability of the residents of a given area to access employment opportunities via any mode of transportation. Increased access to jobs is correlated with reduced unemployment rates and improved per capita income.

Access to labor force refers to the ability of businesses to access a pool of labor in a given market area. Increased access to labor force makes a business more competitive as more people with the skills necessary to do a job can compete for the same job opening.

Access to regional amenities can include the ability to reach major hospitals, universities, major concentrations of retail activity, and recreational and tourist destinations like amusement parks, beaches, sports arenas, performing arts venues, museums, and historic sites. Regional amenities can be screened using employment (only destinations with more than 100 employees, or retail employment density greater than 100 per acre, for example).

Access to community amenities can be defined as the ability to reach destinations that are sources of basic services and daily needs, and may include health clinics, grocery stores and sources of fresh food, local parks and playgrounds, elementary and secondary schools, and neighborhood-oriented retail and service establishments like restaurants, bars, dry cleaners, banks, and hardware stores.

<u>Inputs:</u>

- Locations of working-age population (U.S. Census Bureau) aggregated to traffic analysis zones (TAZs).
- Locations of jobs (from U.S. Census Bureau, Center for Economic Studies, Longitudinal Employer-Household Dynamics Program) aggregated to TAZs.
- Locations of regional amenities (from GIS database of regional amenities).
- Locations of local amenities (from GIS database of local amenities).
- Peak hour travel speed data for links in the NJRTM-E model network (from INRX or other vehicle probe data).
- NJRTM-E model network link attributes (link length, toll information).

<u>Calculations:</u>

a. Access to Community Amenities: <u>Distance-Based</u> Cumulative Opportunity accessibility measure.

- For local amenities, a distance-based threshold may be the only option. *If travel times by walking, biking, and competing modes are known, one of the other accessibility measures mentioned in this section can be used instead of the following procedure.*

- Using GIS tool, in an area within a ½-mile radius of the project limits, or less depending on the determined geographic scale, calculate the number of local amenities that can be reached within a ½-mile walk before and after construction of the transit enhancement project. The change in access to local amenities is the difference in cumulative opportunities that can be reached before and after construction. *For example, before implementation there may be two grocery stores within a ½-mile walk of transit, and after construction there may be five.*
- *Access to community amenities should be evaluated at as fine-grained a geographic scale as possible (e.g., Census blocks or block groups), because many TAZs may be more than ½-mile across.*
- *If no sub-TAZ data are available, access to community amenities can be evaluated qualitatively using maps showing before-and-after local street network, sidewalk network, and bike network connectivity.*

b. For all destinations other than community amenities: Travel-time-based Cumulative Opportunity accessibility measure.

- For period before construction (average of three years) and period after construction (three-year moving average for all available years), use GIS to calculate the shortest travel time between all O-D pairs in the regional network. If possible, calculate travel time on a multimodal basis, since at peak times some trips may be faster by transit.
- Aggregate the number of "opportunities" that lie in the TAZs that can be reached within the following time thresholds:
  - Jobs: 60 minutes (using peak hour travel times).
  - Labor force: 60 minutes (using peak hour travel times).
  - Regional amenities: 90 minutes (using average weekend day travel time).
  - Buyer and supplier markets: 5 hours (using average weekday travel time).
- The relevant equation is:

$$A_i = \sum_{j=1}^{J} B_j O_j$$

where A_i is accessibility measured at point i to potential activities in zone j,

O_j is the opportunities in zone j, and

B_j is a binary value equal to 1 if zone j is within the predetermined threshold and 0 otherwise.

- The change in access is the difference in cumulative opportunities across all TAZ pairs that can be reached in the specified travel time. Cumulative opportunity estimates for each TAZ in a given area can be aggregated using the following equation:

$$A_{Area} = (\Sigma A_i * P_i) / P_{Area}$$

where:

A_i = Accessibility of zone i

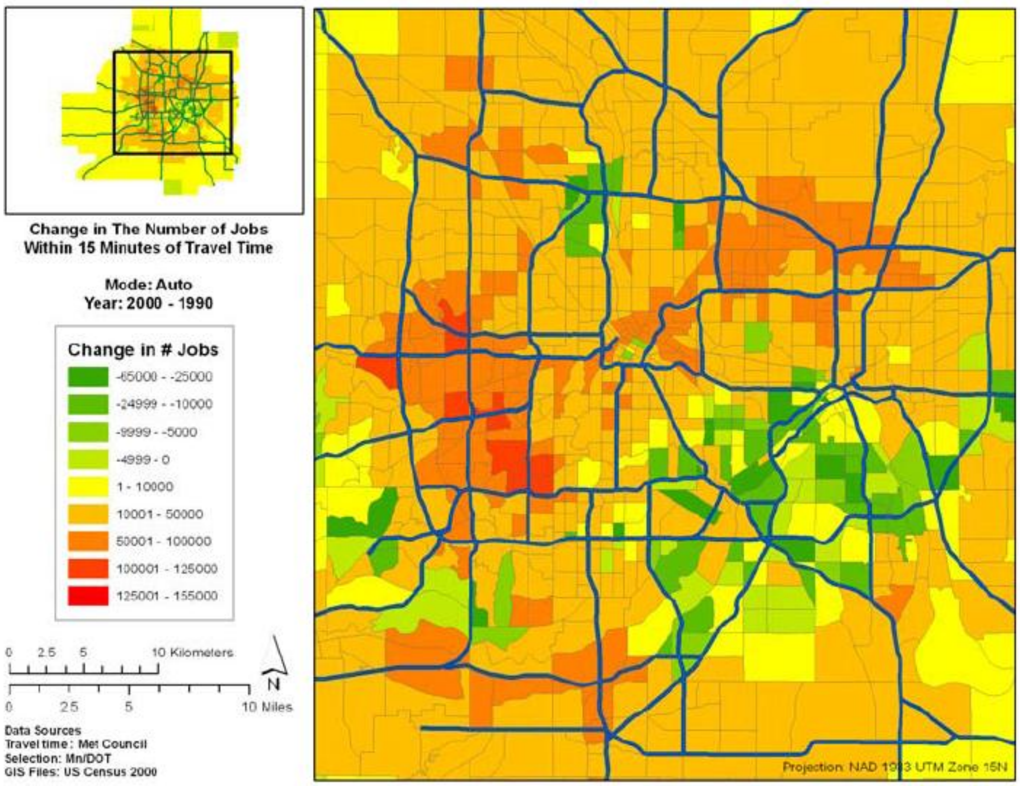
P_i = Population of zone i

P_{Area} = Population of the study area (could be a county or the NJTPA region)

A_{Area} = Accessibility of the region (could be a county or the NJTPA region)

- *For example, before construction, 200,000 jobs might be accessible within a 60-minute commute of a given location. After construction of a transit enhancement project, 250,000 jobs might be accessible within 60 minutes. The net impact of the project is access to an additional 50,000 jobs at that location. The net impacts for each TAZ or analysis area can be plotted on a map to determine where the biggest net accessibility benefits accrue, as in the example below from the Minneapolis-St. Paul metro area.*

Figure 3.5-B: Example of a Map of Regional Accessibility Change



Source: El-Geneidy, A and D. Levinson, 2005. "Place Rank: A New Accessibility Measure," Nexus (Networks, Economics, and Urban Systems) Research Group, Department of Civil Engineering, University of Minnesota.

- *Note that population is not necessarily the most appropriate weighting factor. Employment could be used in place of population for access to employment and access to labor force, for example.*

- *A cumulative opportunity measure of accessibility is perhaps the simplest way to measure accessibility, but this measure requires the use of an arbitrary radius that, for example, attributes no value to jobs 61 minutes from an origin or regional amenities 91 minutes away. Because the measure is being used to compare before and after conditions, rather than rank the accessibility of individual zones, choosing an arbitrary threshold is not as problematic. A sensitivity analysis could be employed by varying the time threshold by +/- 10 minutes to see if the results change significantly.*

<u>Additional resources on accessibility measures include the following:</u>

- El-Geneidy, A and D. Levinson, 2005. "Place Rank: A New Accessibility Measure," Nexus (Networks, Economics, and Urban Systems) Research Group, Department of Civil Engineering, University of Minnesota. El-Geneidy and Levinson propose the use of a so-called "Place Rank" accessibility measure that uses actual information about origins and destinations by trip purpose and takes into account the relative attractiveness of each zone in calculating accessibility. The Place Rank accessibility calculation is an iterative process that uses the following equations:

$$R_{j,t} = \sum_{i=1}^{I} E_{ij} * P_{it-1}$$
$$P_{it-1} = [E_j * [R_{j,t-1} / E_i]]$$

Where:

- $R_{j,t}$ The *place rank* of *j* in iteration *t*
- *I* The total number of *i* zones that are linked to zone *j*
- E_{ij} The number of people leaving *i* to reach an activity in *j*
- P_{it-1} The power of each person leaving *i* in the previous iteration
- E_j The original number of people destined for *j* $Ej = \sum_i ij$
- $R_{j,t-1}$ The *place rank*ing of *j* from the previous iteration
- E_i The original number of people residing in zone *i*: $Ei = \sum_j ij$

Customer Satisfaction

Customer Satisfaction is a measure that does not depend on inputs from any other performance measure. Customer Satisfaction measures can be obtained from the results of surveys performed by NJ TRANSIT, other transit operators, or other agencies after completion of a project.

Inputs:

- Surveys of transportation system users, ideally including information about the relative importance of each system attribute being queried.
- Typical questions on transit-related customer satisfaction surveys include:
  - Customer perception of improvement's impacts across NJTPA goal areas: Built and natural environment, travel speed, travel time reliability/on-time performance, access to destinations, safety, economic impacts.
  - Project's impact on travel behavior: Whether the improvement caused mode shifts ("What was the previous mode used to make the trip?") and destination choice decisions (e.g., enabled a longer trip to a destination not previously accessible).
  - Impacts of transit construction (if any): Safety, congestion and delays, access to businesses, environmental impacts during construction.

Recommendations for Future Performance Evaluation: User Responsiveness Measures

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 such GPS type of travel diaries and using TRANSCOM and INRIX data. Older methods such as household surveys, business surveys, and license plate surveys, are often extremely time-intensive in estimating origin-destination patterns on a regional scale.

Develop GIS tools to interface with travel demand model inputs and outputs to automate calculations of accessibility changes due to transportation investments. Accessibility maps, such as the map shown above in Figure 3.5-B, 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.

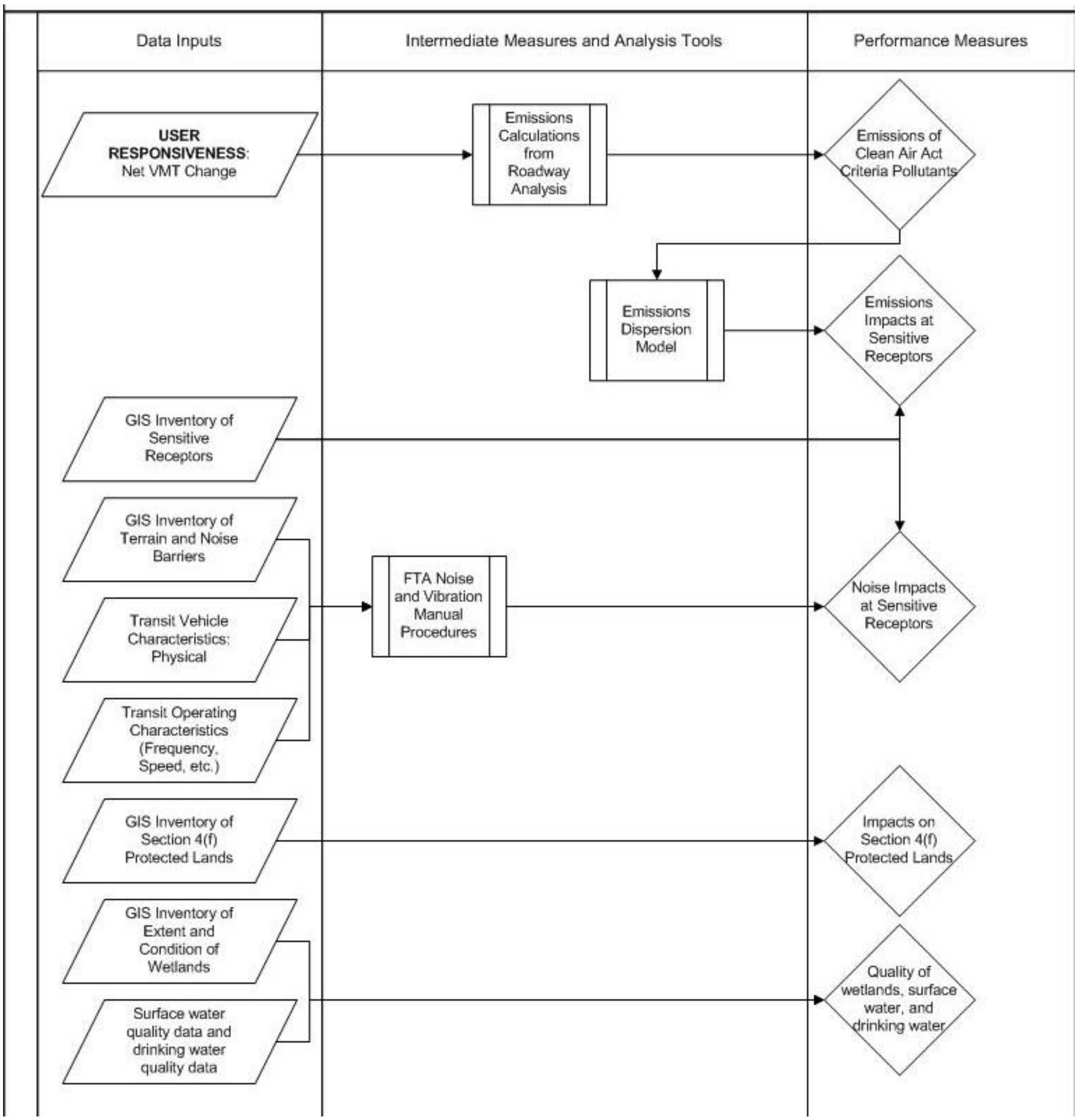
Undertake more customer satisfaction surveys for all modes on a more regular basis. Agencies responsible for building, maintaining, and operating the transportation system in the region should undertake regular customer satisfaction surveys to collect a range of qualitative and quantitative data about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

3.5.3 Evaluating Environment Measures

NJTPA Environment Goal - Protect and improve the quality of natural ecosystems and human environment.

Interdependencies between Data, Analysis Tools, and Performance Measures

The following diagram is a simplification of the interdependencies between Environmental measures and the intermediate and ultimate measures discussed in the System Coordination and User Responsiveness sections. *Note: The performance measure "Visual aesthetics and context sensitivity" is independently evaluated and not included in this diagram. For further information, see page 3.5-32.*



Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Distribution of vehicle trips by time of day	NJ Transit bus and train schedules
GIS Inventory of Sensitive Receptors	NJDOT and NJDEP GIS; Google Maps and other commercial sources
GIS inventory of terrain and noise barriers	NJDOT and NJDEP GIS; NJDOT Straight Line Diagrams
Vehicle trip distribution by model year and type	NJMVC Registration data; NJDOT vehicle classification count data
GIS inventory of Section 4(f) protected lands	NJDEP GIS Wildlife and waterfowl refuges: US Fish and Wildlife Service Historic properties: National Historic Geographic Information System (NHGIS), state historic preservation office (SHPO) and local historical commissions/societies
GIS Inventory of extent and condition of wetlands	NJDEP GIS; US Army Corp of Engineers
Surface and drinking water quality	NJDEP Division of Water Quality; NJDEP Bureau of Safe Drinking Water
Net person-miles of travel by biking and walking	Performance measure calculated in **User Responsiveness**; see methodology above
Project purpose and need statement or project description from planning documents, funding applications, etc.	Implementing agency; county or local municipality in which project is located
Photos and project descriptions after project completion	Implementing agency; county or local municipality in which project is located
Local comprehensive plans and other relevant planning documents for the area in which the project was constructed	County or local municipality in which project is located
List of commitments to stakeholders that was developed and maintained during planning and design and/or was incorporated into construction/service planning documents prior to beginning construction or implementing service changes	Implementing agency; county or local municipality in which project is located
Results of post-implementation surveys of project team members from the implementing agency and consultants	Post-implementation surveys
Results of post-implementation surveys of community stakeholders (residents and businesses) and regulatory agency staff	Post-implementation surveys

Geographic Scale of Analysis

The geographic scale of analysis depends on the measure being assessed. The following table shows the recommended geographic scale of each measure.

Measure	Geographic Scale(s) of Analysis
Emissions of Clean Air Act criteria air pollutants and greenhouse gases	Air quality (AQ) data are collected at the facility level as well as at the regional scale. The regional and statewide travel demand models that are necessary to quantify emissions are based on this state and regional data collection. Transportation-related emissions, for example greenhouse gases, do not respect state and regional boundaries; therefore regional and statewide data are necessary. The Clean Air Act requires regional and project level hotspot analysis. Most non-attainment areas have on the ground monitoring units in set locations. These units are not typically moved to measure emissions for specific projects. Transportation emissions that lead to respiratory conditions and other health impacts should be estimated at sensitive receptors within ¼ mile of project limits.
Transportation-related noise and vibrations at sensitive receptors	Sensitive receptors within ¼ mile of project limits
Impacts on Section 4(f) protected lands	Primary/direct impacts: Project limits Secondary/cumulative impacts: Project-specific as defined in NEPA Scoping document; could be several miles from project limits; use natural boundaries such as water sheds as study area boundaries
Visual aesthetics and context sensitivity	Project limits (project-specific design features); adjacent properties; neighborhoods and municipalities in which project is located; architectural and environmental features in view shed

Time Frame of Analysis

The ability to measure the net Environmental impacts of a project over time is directly dependent on the ability to measure net VMT impacts, net changes in transit ridership, net impacts on congested travel speeds, and net impacts on mode choice decisions. As the quality or reliability of these estimates deteriorate over time, so does the reliability of the results of an environmental impact assessment. Therefore, the time frame of analysis for Environment performance measures should mirror the time frames for System Coordination and User Responsiveness measures: measures should be on a continuous basis if possible, using multiple data points from several years before the project and for as many years after the project as data are available in order to draw valid conclusions about the net impacts of a project.

As indicated in the above graphic, the environmental impacts of transit projects are often measured at a regional scale. Therefore, the net impacts of any one project may be obscured over time by economic growth that generates additional travel demand (in turn affecting emissions and noise), by other development that increases impervious cover and impacts wetlands and water quality, or by changes in the region's socioeconomic and demographic profile that affect public health outcomes. On a project-by-project basis, professional judgment will be necessary to determine the limits of applying the following analysis.

Analysis Steps

Emissions of Clean Air Act Criteria Pollutants

Inputs:

- Total change in VMT attributable to project, in miles per year. *Intermediate output measure of **User Responsiveness** analysis. See above for example calculations.*
- Total change in work and non-work related vehicle trips attributable to project, in trips per year. *From regional household travel surveys. For example, 30,000 trips per year.*
- Distribution of travel by time period, based on available NJDOT traffic volume data for roadways affected by the project, either hourly, 15-minute, or continuous counts. *For example, 35 percent AM, 20 percent Midday, 35 percent PM, and 10 percent Night.*

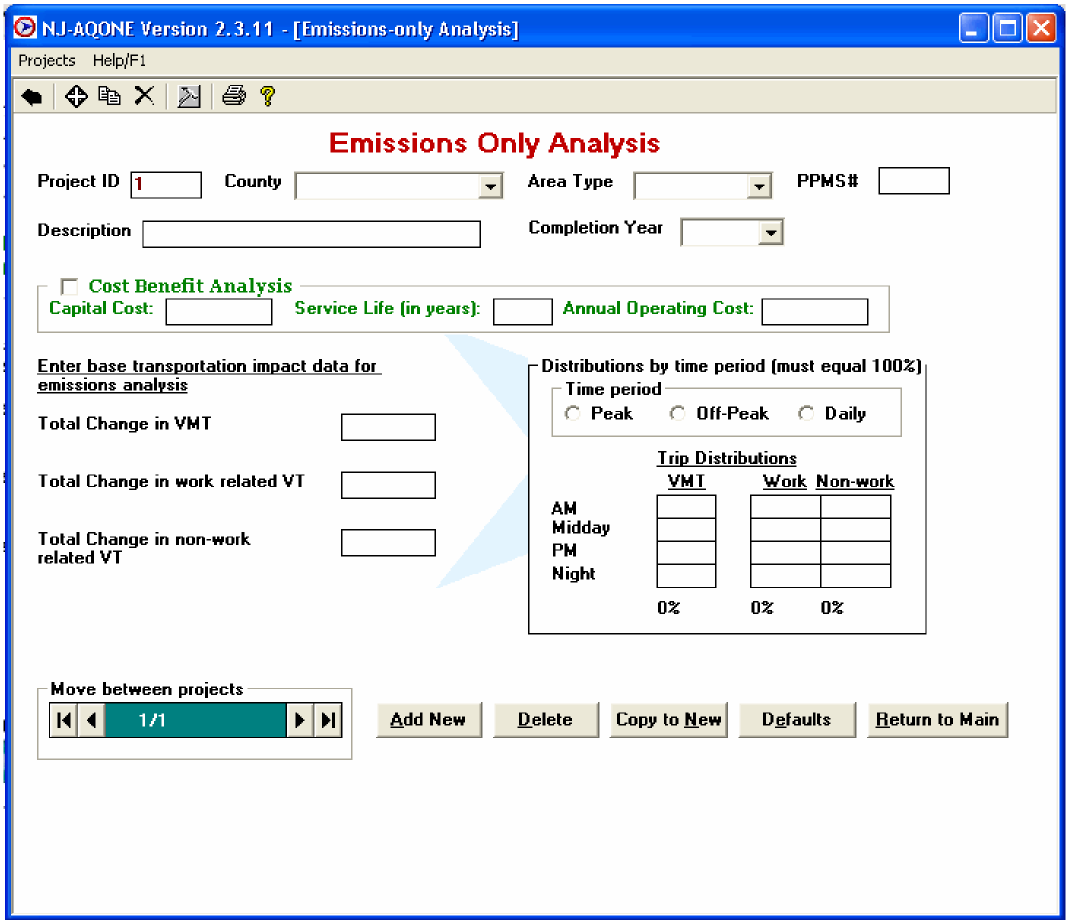
Analysis Tools:

- Use NJAQONE Emissions-Only module to estimate emissions in forecast year. Conduct one run for "no-build" condition and a second run for the "build" condition.

Output measures:

- Estimated **change in emissions by criteria pollutant.**

Figure 3.5-C: Example Emissions Only Analysis Input Screen from NJAQONE



Emissions Impacts at Sensitive Receptors

1. Generate emissions contour maps.

   Inputs:

   - Estimated change in emissions by criteria pollutant, from NJAQONE or MOVES.
   - Baseline emissions estimates, from NJAQONE or MOVES baseline data.
   - Geography-specific climate data. Can use defaults built into models.

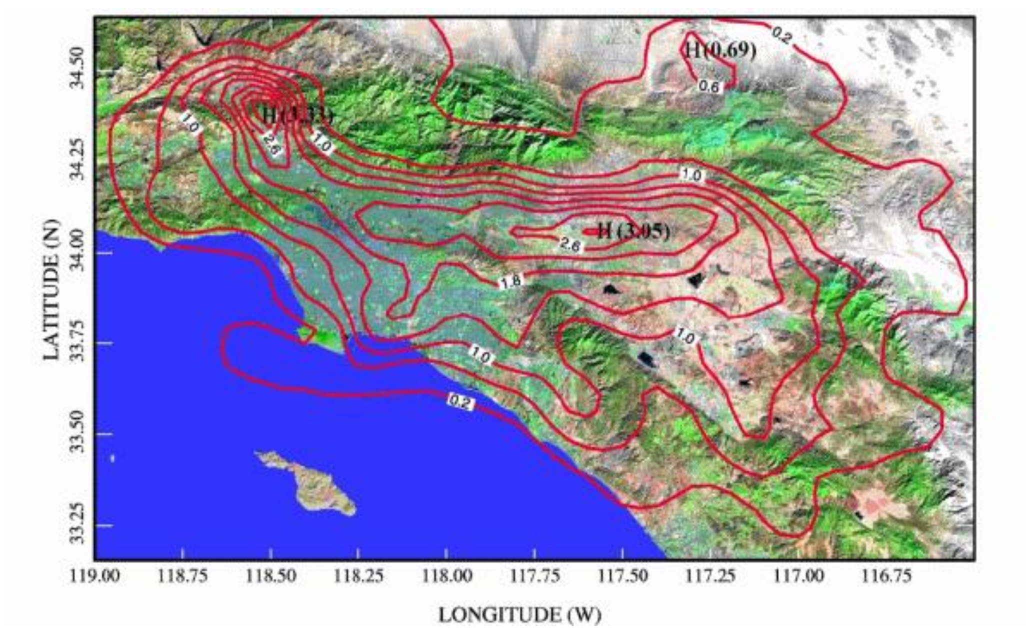
   Analysis Tools:

   - Use Emissions Dispersion model to allocate emissions to points or subregions in the analysis area. Conduct one run for baseline conditions and a second run for "build" condition.

   Outputs:

   - Emissions contour maps showing concentrations by criteria pollutant for baseline condition and for "build" condition.

Figure 3.5-D: Example map of daily emissions of soot in micrograms per cubic meter for Los Angeles Metropolitan Area:



2. Overlay sensitive receptor points on emissions contour maps.

   Inputs:

   - Emissions contour maps for baseline condition and "build" condition from dispersion model.
   - GIS layer of sensitive receptors in NJTPA region.

   Calculations:

   Net emissions impact at any given sensitive receptor is the difference between the build condition and the baseline condition. Repeat calculation for each sensitive receptor.

   Outputs:

   - **Estimated emissions impacts by sensitive receptor.** *For example, "Emissions of particulate matter (PM 2.5) increased from 1.2 micrograms per cubic meter to 1.8 micrograms per cubic meter as a result of the project."*

Noise and Vibration Impacts at Sensitive Receptors

Inputs:

- Peak hour volume and average speed by vehicle type, by link (intermediate output measures of **System Coordination** analysis).
- GIS inventory of terrain type.
- Location and extent of noise barriers (NJDOT GIS and Straight Line Diagrams).
- GIS inventory of sensitive receptors.
- Archived data on background noise levels at sensitive receptors at regional, county level, and/or corridor level.

Calculations:

- See FTA Noise and Vibration Manual for procedures and calculations used to generate noise contours and estimated impacts at sensitive receptors. *To estimate net impacts, run one scenario with "build" conditions using most recent available data and a second "no-build" scenario with estimated "no-build" inputs. Repeat for each sensitive receptor.*
- *If enough data are available about changes in decibel levels at sensitive receptors over time, the project-specific impacts also can be compared to regional, county-level, or corridor-level average impacts over the same analysis period as another estimate of what may have happened in the absence of the project.*

Outputs:

- **Net noise and vibration impacts at sensitive receptors**, in decibels. *For example, "The hourly equivalent sound level $L_{EQ}(h)$ increased from 60 dB to 75 dB as a result of the project."*

Visual Aesthetics and Context Sensitivity

Inputs:

- Project purpose and need statement or project description from planning documents, funding applications, etc.
- Photos and project descriptions after project completion.
- Local comprehensive plans and other relevant planning documents for the area in which the project was constructed.
- List of commitments to stakeholders that was developed and maintained during planning and design and/or was incorporated into construction documents prior to beginning construction.
- Results of post-construction surveys of project team members from the implementing agency and consultants.
- Results of post-construction surveys of community stakeholders (residents and businesses) and regulatory agency staff.

Calculations:

Conduct surveys using the following criteria[2]. Score one point for each criterion if 67% or more of implementing agency staff (and/or the agency's project consultants) surveyed respond "yes"; score one additional point for each criterion if 67% or more of community stakeholders and regulatory agency staff surveys respond "yes". Maximum 12 points.

1. The executed project meets the goals and objectives identified in the original purpose and need statement.
2. The project was designed and implemented in a manner that is consistent with local comprehensive plans, the Americans with Disabilities Act, and other relevant planning documents.
3. The implemented project meets or exceeds a list of commitments to stakeholders that was developed and maintained during planning and design, was incorporated into construction documents prior to beginning construction, and is monitored during construction and operation of the completed project.
4. *(If the project is located in a developed area)* Architectural elements were incorporated into the design of the project to make users of all modes feel comfortable and welcome. These elements include, but are not limited to: wayfinding signage for users of all modes for which the facility is designed; signage clearly indicating access points to transit services (including park-and-ride lots, bus stops, and fixed guideway transit stations); signage clearly indicating access points and amenities for bicyclists and pedestrians (including signage indicating nearby alternate routes if non-motorized users are prohibited from using the facility); a physical barrier between non-motorized traffic (bicyclists and pedestrians) and transit services or, if a physical barrier was not possible, a defined

[2] Adapted from project-level evaluation criteria listed in NCHRP Web-Only Document 69: *Performance Measures for Context Sensitive Solutions- A Guidebook for State DOTs*

pavement marking separation; adequate lighting for evening and nighttime use by motorized and non-motorized users; an open view shed into public spaces for people passing by and security officers; and amenities such as artwork and landscaping to enhance the surrounding built and natural environment.

(If the project is located in an undeveloped area) Environmental resources, scenic and historic resources, and aesthetic values, such as architectural styles and landscaping that complement the surrounding environmental, have been maintained or enhanced by the project as completed.

5. Nearby residents and representatives of nearby institutions, schools, and business associations are directly or indirectly (e.g., via an advisory council) involved in the ongoing maintenance and operations of the facility or service.
6. Based on surveys of area residents and businesses, the project appears to have been implemented in a manner that will result in increased economic activity, such as new commercial or residential activity, and it appears to have the potential to create a positive neighborhood impact.

<u>Outputs:</u>

- Qualitative assessment of the degree to which a project improved or detracted from the **visual aesthetics of the built environment**.

Recommendations for Future Performance Evaluation: Environment Measures

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 emissions, 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.
- 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 in Roadway section).
- 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. 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. 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 costs would be incurred if it is discovered that mitigation measures are not successful and additional actions must be undertaken. Monitoring activities, data collection, data clean up and database maintenance are also time consuming. Agencies are hesitant to encourage monitoring and reporting for political reasons as well. 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 (CEs) 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 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 the 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. 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 project 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 opportunities that improve 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.

3.5.4 Evaluating Land Use/Transportation Coordination Measures

NJTPA Land Use/Transportation Coordination Goal - Select transportation investments that support the coordination of land use with transportation system.

Interdependencies between Data, Analysis Tools, and Performance Measures

The evaluation of the Land Use/Transportation Coordination measure per capita vehicle miles traveled depends on a calculation of the intermediate measure vehicle miles traveled in the **User Responsiveness** goal area.

Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Net VMT Change	Intermediate measure calculated in **User Responsiveness**; see methodology above
Population	U.S. Census Bureau's American Community Survey 5-year estimates
Employment	U.S. Census Bureau's Local Employment-Household Dynamics data; NJ Labor and Workforce Development, and/or U.S. Bureau of Labor Statistics
Census tract area	U.S. Census Bureau TIGER Line Shape Files

Geographic Scale of Analysis

An analysis of net per capita VMT for transit enhancement projects should be performed on the same scale as the net VMT calculation. Often, this calculation will be performed at a regional scale.

Time Frame of Analysis

The impacts of transit enhancement projects as measured in terms of Land Use/Transportation Coordination measures may be small or may not be measurable at all shortly after completion of the improvement, because development induced by a transit project will happen gradually over time. However, as years pass many changes as measured by Land Use/Transportation Coordination measures may become less pronounced over time. Therefore, it is important to evaluate Land Use/Transportation Coordination measures on a continuous basis, using multiple data points from several years before the project and for as many years after the project as data are available.

Analysis Steps

Population and Employment Density

Inputs:

- Population in census tracts or block groups, if available within ¼ mile of project limits, from periods before and after implementation of the transit enhancement project. *Use U.S. Census Bureau's American Community Survey (ACS) 5-year Estimates for a rolling annual estimate of census-tract-level population data. Note that the Census Bureau cautions against comparing ACS data from overlapping time periods. , ACS is mainly intended to be used for population characteristics, not population totals, especially at smaller geographies (e.g., Census tracts).*
- Employment in census tracts within ¼ mile of project limits, from periods before and after implementation. *Use U.S. Census Bureau's Longitudinal Employer-Household Dynamics (LEHD) data.*
- Area of census tracts within ¼ mile of project limits, in miles, from U.S. Census Bureau's Topologically Integrated Geographic Encoding and Referencing (TIGER) system. *Note that census tract boundaries may change over time, particularly when a new decennial Census is undertaken. It is important to use areas that are as identical as possible for the before and after comparison.*

Calculation:

- Use GIS to aggregate population in census tracts within ¼ mile of project limits and divide by aggregate area of those tracts. Calculate population density for periods before implementation and period after implementation.
- Use U.S. Census Bureau's Longitudinal Employer-Household Dynamics online mapping tool, called "OntheMap", to aggregate employment in census tracts within ¼ mile of project limits and divide by aggregate area of those tracts. Calculate employment density for periods before implementation and after implementation.
- *The net change in population and employment density cannot be calculated, but a qualitative analysis of the circumstances before and after implementation of the project may provide clues to whether any changes in population and employment density can be attributable to the project. For example, similar to the net new ridership calculation above, population and employment density in the study area can be compared to a "control" area that had conditions similar to the study area before implementation.*

Output:

- **Population density**, in persons per square mile.
- **Employment density**, in jobs per square mile.

Additional resources on population and employment density include the following:

- U.S. Census Bureau Longitudinal Employer-Household Dynamics website, http://lehd.did.census.gov/led/.

- o U.S. Census Bureau's Topologically Integrated Geographic Encoding and Referencing (TIGER) system website, http://www.census.gov/geo/www/tiger/index.html.

Per Capita Vehicle Miles Traveled

Inputs:

- Net regionwide vehicle miles of travel attributable to the project.
- Regional population data from before and after implementation.

Calculation:

- Divide regionwide vehicle miles of travel before construction by population before construction, perform the same calculation for the period after construction, and subtract the two values to calculate an estimate of net change in per capita vehicle miles traveled.

Output:

- **Per capita vehicle miles traveled.** *VMT per capita in the NJTPA region is around 2.9 miles per capita according to recent survey results.*

Recommendations for Future Performance Evaluation: Land Use/Transportation Coordination Measures

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).

3.5.5 Evaluating Repair/Maintenance/Safety/Security Measures

NJTPA Repair/Maintain/Safety/Security Goal - Maintain a safe and reliable transportation system in a state of good repair.

Only safety and security measures are discussed in this section. See Roadway and Bridge Preservation project type sections of this guidebook for evaluation of using Repair and Maintenance-related measures.

Interdependencies between Data, Analysis Tools, and Performance Measures

All data used in the analysis of safety performance measures are drawn from crash databases (e.g., NJ Transit, PATH, and other transit operator safety records). Therefore, for safety measures, there are no interdependencies with previous analyses. Evaluation of security measures related to resiliency and redundancy use the results of network connectivity and continuity calculations performed under the System Coordination goal area.

Data Inputs and Sources

Primary data inputs to the analysis include the following:

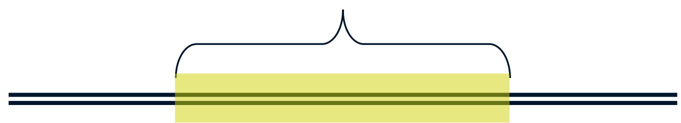
Data Inputs	Sources
Crash records	Exclusive guideway transit facilities: NJ Transit, PATH, or other operator safety records Transit services operated on roadways: NJDOT Crash Records Database; Plan4Safety; NJTPA Safety Management System data
Information on measures taken to prevent or protect against incidents, incursions, attacks, and illicit activity	Facility owner or operator: construction documents and as-built drawings
Available alternate routes	NJ Transit
Daily ridership, Link capacity (passengers per day), and Volume-to-capacity ratio	Transit service operator
Facility designate as component of an emergency evacuation plan	Transit service operator
Planning studies done in the study area to identify critical assets and future needs for project development in study area	State and local governments; NJTPA needs assessments
Network Connectivity and Continuity results	Calculated using methodologies specified in System Coordination goal area
Extent and redundancy of technology and systems available to provide information to system operators and users	Facility owner or operator: construction documents and as-built drawings

Geographic Scale of Analysis

Both safety and security measures should be evaluated within the project limits. In the case of a project that is expected to generate significant diversions of auto traffic (in the case of transit enhancement improvements) or accommodate significant diversions of auto traffic (in the case of system redundancy projects undertaken for security reasons), the analysis area for safety and security measures may be expanded to a corridor encompassing multiple facilities, to a county, or to the entire NJTPA region.

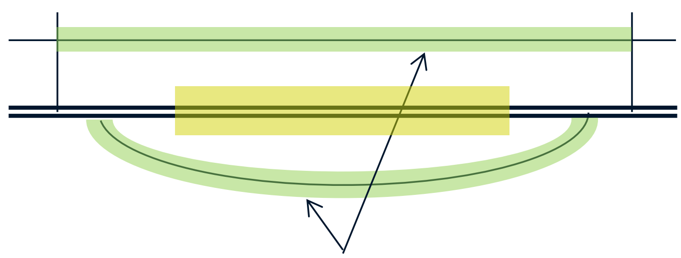
Analyze data within project limits

CASE 1:
TRANSIT ENHANCEMENT OR SERVICE IMPROVEMENT
with little or no traffic diversion expected



Analyze data within project limits and…

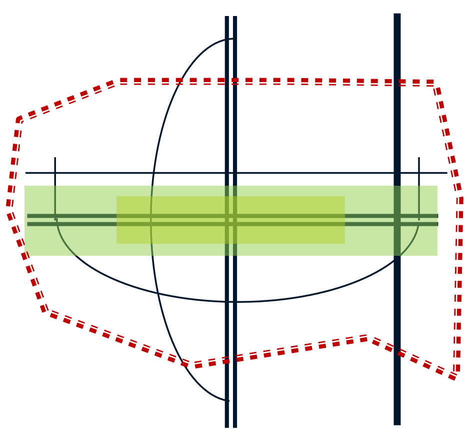
CASE 2:
TRANSIT ENHANCEMENT OR SERVICE IMPROVEMENT
with traffic diversion

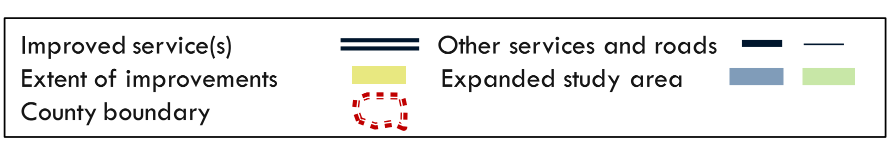


…on parallel route(s) and mode(s) within 5 miles that may have been used as alternate(s) or bypass(es). Some impacts of the project may accrue to parallel facilities and modes that saw increases or reductions in traffic.

ALL CASES:
Corridor, Region, and Service Area Comparison

- Compare to data for the entire corridor/route in which the project is located (green).
- Compare to data in the county in which the project is located (red).
- Also compare to entire NJ Transit service area





Time Frame of Analysis

The project-specific impacts of transit enhancement projects as measured in terms of safety measures are likely to be most pronounced shortly after completion of the improvement. Therefore, it is important to evaluate these measures using multiple data points from several years before the project, during the construction phase, and for as many years after the project as data are available. Security measures, which tend to be discrete improvements whose benefits do not accumulate or diminish over time, should be analyzed for one year before and after implementation of the project. For example, construction of a security fence along a new transit right of way to prevent unauthorized access would have a one-time benefit to security along that transit segment; therefore, conditions for the year before construction can simply be compared to conditions in the year following completion of the project.

Analysis Steps

Intermediate Measures and Analysis Tools

1. Assign a “criticality” index to infrastructure and services in the study area.

   Inputs: (required for each link in the transit network)

   - Facility/service type (exclusive guideway, shared lanes, shared tracks);
   - Whether or not alternate routes are available (same or higher functional class/lower functional class/no alternate route);
   - Ridership data (passengers per day), link capacity (passengers per day), and volume-to-capacity ratio, to help establish which facilities and services carry the greatest absolute volumes and which facilities and services have the ability to absorb excess volumes;
   - Whether or not the facility is a designated component of an emergency evacuation plan (yes/no); and
   - Plans and studies done in the study area to identify critical assets and future needs for project development.

   Calculations

   Calculate a composite criticality score or index for each facility or service. Several analysis tools are available to perform the calculation. For example, the New Jersey Department of Transportation as a license to the Disruption Impact Estimating Tool—Transportation (DIETT), which is a database and spreadsheet-based tool for prioritizing the criticality of transportation choke points.

   Intermediate output measures:

   - Criticality index or score for each facility and service in the network. Facilities should be grouped into broad categories like “most critical”, “critical” and “not critical”. *Note that this index must be guarded from the public due to the sensitive nature of the information.*

Crashes and Passenger Accidents

For transit services operated on exclusive guideways: Compare before-and-after NJ Transit, PATH, or other operator safety data to determine safety impact of the project. Compare project-specific data to systemwide statistics for an indication of how much of the change in crashes and passenger incidents was attributable to the project.

For transit services operated on roadways: Inputs:

- Facility-specific crash and passenger incident data, preferably with indication about whether a transit vehicle or transit passenger was involved.
- Regional, county-level, and corridor-level aggregate safety statistics.

Calculations:

- Compare project-level changes in absolute number of crashes and passenger incidents to estimates of regional, county-level, and/or corridor level changes in absolute number of crashes as an estimate of what may have happened in the absence of the project. If the project was anticipated to result in significant diversions of traffic to or from other roadways or transit routes, compile data on absolute numbers of crashes on alternate within 5 miles of the improved roadway that could reasonably be expected to accommodate bypass traffic.

Outputs:

- Absolute number of **crashes and passenger incidents** occurred before and after construction.

Crash and Incident Rate

For transit services operated on exclusive guideways: Divide number of incidents or crashes by passenger miles or transit revenue vehicle miles to determine crash rate.

For transit services operated on roadways: Inputs:

- Absolute number of crashes occurred before and after construction.
- VMT data at regional, county, and local level.
- Regional, county-level, and corridor-level aggregate crash rates.

Calculations:

- Divide crashes by VMT in the study area to calculate crash rate in terms of VMT.
- Compare project-level changes in absolute number of crashes to estimates of regional, county-level, and/or corridor level changes in absolute number of crashes as an estimate of what may have happened in the absence of the project.
- The net increase or decrease in crash rate attributable to the project can be estimated by subtracting the regional, county-level, or corridor-level crash rate from the observed crash rate after project completion.

Outputs:

- **Crash and incident rate**, in crashes per million vehicle miles traveled or incidents per million trips.

Transportation Resiliency

Transportation resiliency is a term that describes the ability of the transportation system to adapt and respond to incidents and disruptions. Transportation resiliency applies to natural threats, such as hurricane storm surges and floods, as well as man-made threats such as terrorist attacks. According to NCHRP Report 525, "Incorporating Security into the Transportation Planning Process", four major categories of security incident countermeasures exist to address threats and vulnerabilities to the nation's transportation infrastructure. These four categories include prevention, protection, redundancy, and recovery. These four measures apply more broadly than security. For example, climate change adaptation strategies often are grouped into similar categories.

Below, the categories "prevention" and "protection" are discussed together below because they both refer to proactive, preventative measures taken in advance of an attack or unauthorized access. Their results are measured in terms of the extent of the system's critical services or pieces of infrastructure from being damaged, destroyed, or used for illicit purposes. Projects addressing "redundancy" and "recovery" address the operations of the system after a major disruption occurs. Their results are measured in terms of how well the system operates (or would operate) after a major disruption.

<u>Inputs: Prevention and Protection</u>

- Measures taken to *prevent or discourage* unauthorized access to a transportation facility or a specific sensitive feature of a transportation facility like a bridge or equipment room, before and after construction; measures taken to prevent or discourage illicit activity in or near a transportation facility; measures taken to prevent or discourage direct and indirect attacks on a facility; and measures taken to protect against the impacts of natural events like extreme weather events. *Examples cited in NCHRP Report 525 include access control systems like fences and locked doors, highly visible closed circuit television (CCTV) systems, and intrusion detection systems such as alarmed entrances and fence-line detection systems. The design of the facility is also important, for example, allowing for open sight lines into a park-and-ride lot from nearby roadways and development, adding lighting to a pedestrian pathway, hardening a facility to prevent physical incursions and/or increase blast resilience, or building a levee and pumping system to protect a roadway from flooding.*
- Criticality index of the facility or service. *Calculated above in intermediate measures and analysis.*

<u>Evaluation: Prevention and Protection</u>

- Measure the mileage of transit facilities with prevention and protection measures in place (per Federal, state, and local design guidelines) before and after the project is completed.

<u>Outputs: Prevention and Protection</u>

- Share of most critical assets hardened against unauthorized access, illicit activity, attacks, and/or natural events. The definition of "most critical assets" must be defined in the process for assigning a criticality score above.

Inputs: Redundancy and Recovery

- Results of **Network Connectivity and Continuity** calculations, using the process defined in the System Coordination goal area. *For purposes of this analysis, connectivity calculations should be performed for the subset of the system consisting of critical and/or most critical assets, as defined in the intermediate measure above.*
- Extent and redundancy of technology and systems available to provide information to system operators and users.

Evaluation: Redundancy and Recovery

- Using results of before-and-after network connectivity analysis, determine extent to which the project improves connectivity in the designated evacuation route system. *As described in the System Coordination goal area, system connectivity can be defined in terms of several indices and measures. The evaluation here should assess the change that the Transit Enhancement project would cause in these indices or measures.*
- Qualitatively compare the extent of information technology available to provide information to system operators and to users during an emergency, system failure, or system disruption, before and after project implementation.

Outputs: Redundancy and Recovery

- Change in System Connectivity for the region's critical and/or most critical transportation assets. *For example, the beta index could change from 1.1 to 1.2 as a result of the project, indicating greater network connectivity and availability of alternative routes in case of a disruption or blockage.*
- Extent to which communication systems are deployed in a redundant fashion to ensure information is available to system operators and users in an emergency, system failure, or system disruption. *For example, "The project provided a diesel generator to power a backup communication system in case of a power failure concurrent with the event or disruption."*

Recommendations for Future Performance Evaluation: Repair/Maintenance/Safety/Security Measures

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. 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 for purposes of transportation security, climate change adaptation, and related uses. NJ TRANSIT, PATH and other transit operators, in cooperation with Federal and local governments and other state agencies, have performed an assessment of critical transportation infrastructure. NJTRANSIT, PATH and other transit operators should continue to work with the 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).

3.5.6 Evaluating Economy Measures

NJTPA Economy Goal - Retain and increase economic activity and competitiveness.

Interdependencies between Data, Analysis Tools, and Performance Measures

The following diagram is a simplification of the interdependencies between Economy measures and the intermediate and ultimate measures discussed in the System Coordination and User Responsiveness sections. No intermediate measures or analysis tools were used in the analysis. *Note: Cost Effectiveness is independently processed and is not included in this diagram. For further information, see page 3.5-49.*

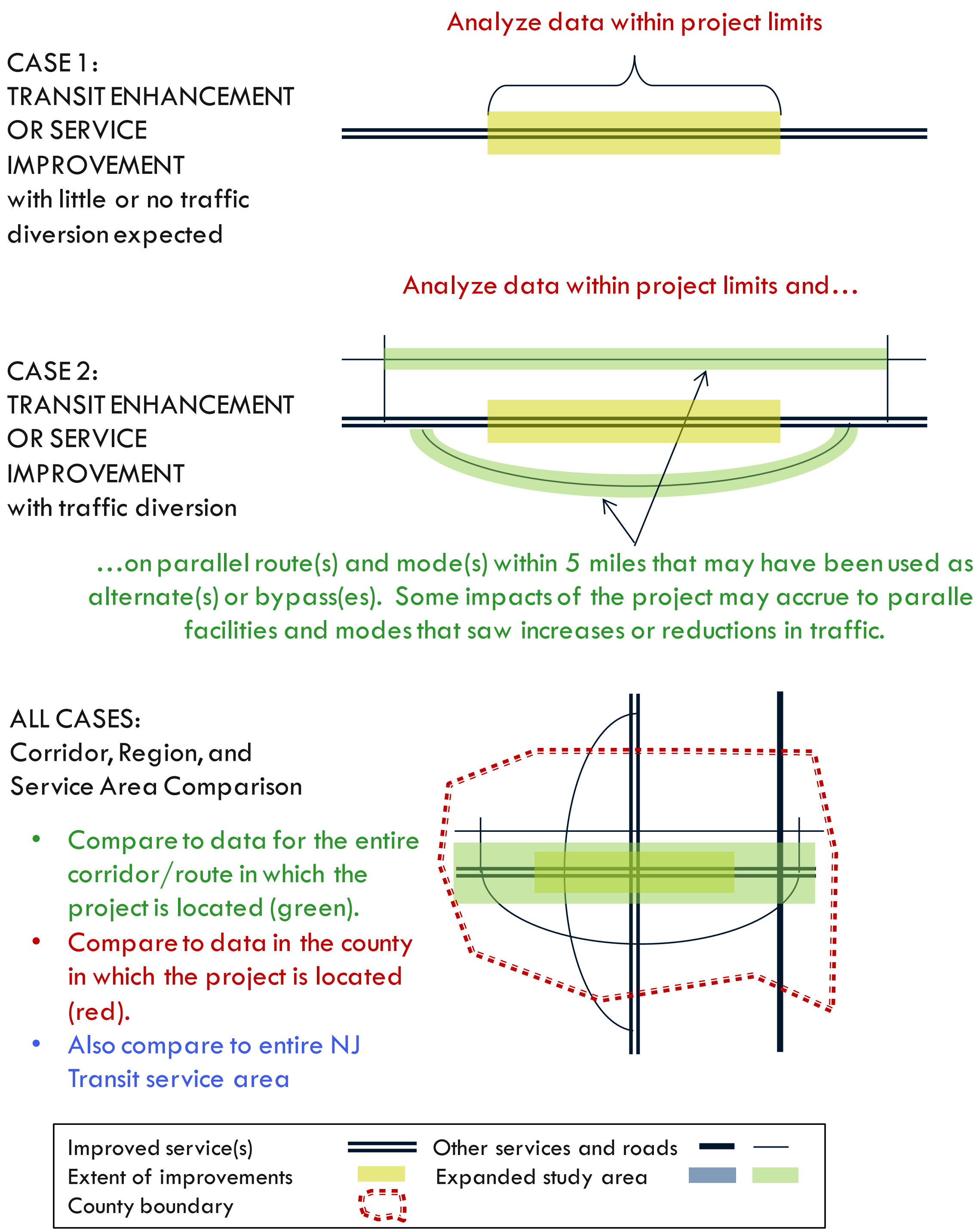
Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Estimated "build" and "no-build" travel times by link	Intermediate measure calculated in **System Coordination**; see methodology above
Average value of time	NJTPA 's NJTRM-E
Net change in revenue hours of service	NJ Transit; other transit operators
Transit vehicle operating cost data	NJ Transit; other transit operators
Net crashes by severity	Output measure of **Repair/Maintenance/Safety/ Security** goal area; see above
Cost per crash, by severity	Exclusive guideways: NJ Transit data Transit services operated on roadways: NJ Transit data, NJDOT and National Highway Traffic Safety Administration (NHTSA)

Geographic Scale of Analysis

All measures in the Economy goal area should be evaluated within the project limits. In the case of a project that is expected to generate significant diversions of auto traffic, the analysis area may be expanded to a corridor encompassing multiple facilities, to a county, or to the entire NJTPA region.



Time Frame of Analysis

The impacts of transit projects as measured in terms of Economy measures may be small or may not be measurable at all shortly after completion of the improvement, because development induced by a transit project will happen gradually over time. However, as years pass many changes as measured by Economy measures may become less pronounced over time. Therefore, it is important to evaluate Economy measures on a continuous basis, using multiple data points from several years before the project and for as many years after the project as data are available.

Analysis Steps

Transportation Costs

Transit-related costs can be quantified in terms of change in monetized travel time costs, change in vehicle operating costs, and change in accident-related costs.

Inputs:

- Estimated "build" and "no-build" travel times between key stations, in minutes. *Include wait time, transfer time, and in-vehicle time.*
- Average value of time for transit passengers, in dollars per minute. *Include wait time, transfer time, and in-vehicle time.*

Calculation:

- Multiply change in travel time by average value of time for users of the facility.

Outputs:

- **Change in travel time costs** associated with the project. *An example is shown in the following table:*

Table 3.5-A: Summary of Estimated Daily Travel Time Savings for illustration purpose only:

	Net Change
Daily Person Hours of Travel	-2,000
Value of Time (in 2009 dollars)	$21.00
Estimated Travel Time Savings (Daily)	-$42,000

Inputs:

- Average transit service operating costs, in dollars, before and after project implementation. *For example, a track improvement project that increases train speeds may reduce operating costs on a line by reducing the need for slowing and acceleration through a slow zone. The savings may be difficult to measure on a per-train basis, but over the course of a year the reduced maintenance costs may be evident.*
- Revenue service hours for affected services, before and after project implementation.

Calculation:

- Divide net change in bus or rail operating costs by revenue service hours before and after project implementation.

Outputs:

- **Net change in transit (bus or rail) operating costs per revenue service hour** associated with the project. *An example is shown in the following table:*

Table 3.5-B: Sample of Estimated Net Transit Operating Cost Savings
(NOTE: Contains fictional data for illustration purposes only)

	Before	After	Net Change
Estimated Annual Transit Operating Costs (2009 dollars per year)	$600,000	$550,000	$50,000
Revenue service hours	6,000	5,900	100
Estimated Transit Operating Costs per Revenue Service Hour (2009 dollars)	$100.00	$93.22	-$6.78

Inputs:

- Net change in crashes and accidents associated with the project, by severity.
- Average cost of crashes and accidents, by severity.

Calculation:

- Multiply change in crashes and accidents by the average cost of crash and accident for each severity level.

Outputs:

Change in accident-related costs associated with the project. According to NJDOT data from 2009, the *average costs for accidents range from nearly $9,000 for a property-damage-only crash, to around $50,000 for an injury crash, to more than $2 million for a fatal crash. Accident cost savings due to major roadway expansion projects often range in the millions of dollars per year.*

Cost Effectiveness

Inputs:

- Project capital cost, in dollars.
- Net reduction in transit (bus or rail) operating costs, in dollars per year.
- Performance measures from previous calculations (e.g., crashes, travel time savings, and emissions reduction).

Calculations:

- Divide the capital cost by any performance measure to calculate the dollar-weighted impacts of the project. *For example, a million-dollar project that reduces carbon emissions by 1,000 tons has a cost-effectiveness index of $1,000/ton. A project that* *reduces operating costs by $50,000 per year and reduces carbon emissions by 25 tons has a cost-effectiveness index of $2,000/ton/year.*

Outputs:

- **Cost Effectiveness***, expressed in dollars per unit of benefit per dollar (e.g., dollars per accident reduced; dollar per minute of travel time savings; dollars per ton of reduced carbon emissions).*

  NOTE: While cost-effectiveness measures are constituents of a broader benefit-cost analysis approach, many cost-effectiveness measures double-count the same things and therefore cannot be added together. Therefore, extreme caution should be exercised in presenting and explaining results of a project-level cost-effectiveness analysis.

Recommendations for Future Performance Evaluation: Economy Measures

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.

Develop analysis tools and methodologies to calculate property value impacts. Research on the economic impacts of transit investments suggests that new and expanded transit services can have strong positive impacts on property values within ¼-½ mile of transit access points. However, conducting a hedonic price analysis or comparable analysis can be time and labor intensive due to the state of property records (some records are available electronically, other are not), the difficulty in isolating the impacts of the transportation system change from other broader economic impacts (such as changes in interest rates or changes in demand for housing), and the difficulty in finding comparable properties to use as "control" properties. Improved tools for accessing and analyzing property-related data and tools to conduct analyses of property value changes are needed in order to capture an important element of the economic impacts of transit investments.

3.6 Transit Expansion Projects

Transit Expansion: 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 projects.

Contents of This Section

Suggested Work Flow for Transit Expansion Projects

The following sequence of goal areas for this project category was developed specifically to enable an ordered evaluation of performance measures. This allowed calculations from earlier intermediate (and final) measures in one goal area to serve as inputs for measures in other goal areas:

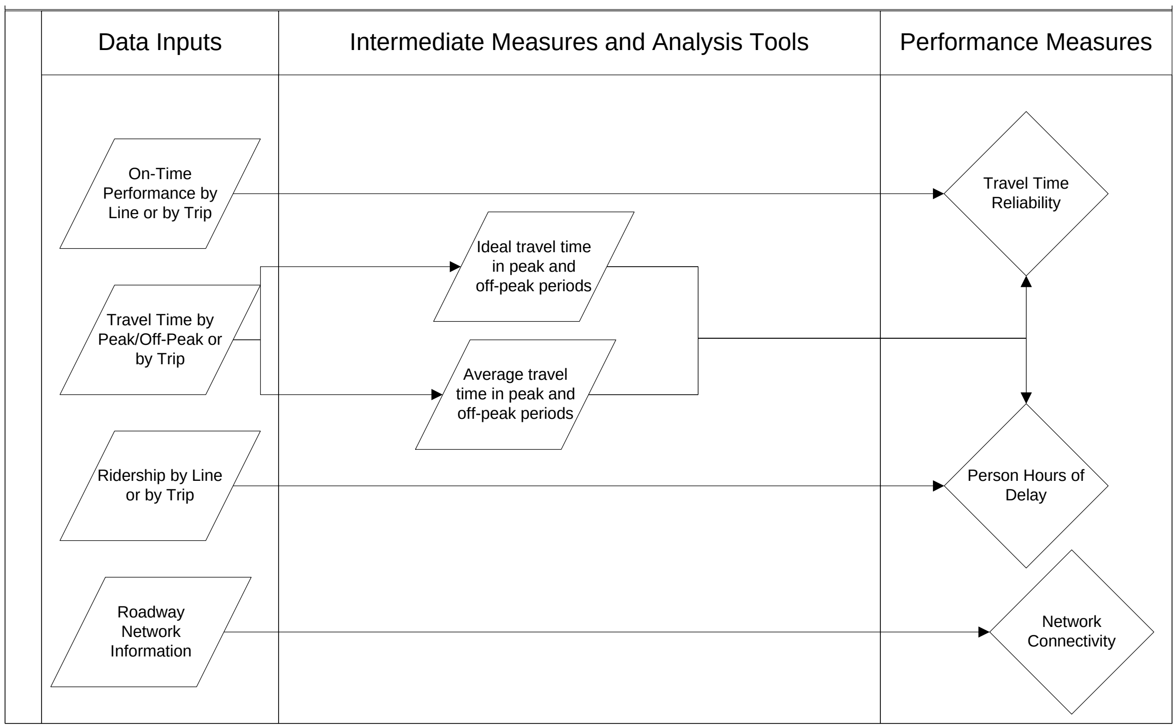
1. System Coordination Measures
2. User Responsiveness Measures
3. Environment Measures
4. Land Use/Transportation Coordination Measures
5. Repair/Maintenance/Safety/Security Measures
6. Economy Measures

3.6.1 Evaluating System Coordination Measures

NJTPA System Coordination Goal - Enhance system coordination, efficiency and intermodal connectivity.

Interdependencies between Data, Analysis Tools, and Performance Measures

The following diagram is a simplification of the interdependencies between System Coordination measures:



Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
On-time performance by line or by trip	Transit operators
Transit routes and Stations	Transit operators, NJTPA GIS
Travel time by trip	Transit operators
Availability of pedestrian and bicycle facilities and the conditions near stations	Transit operators, NJTPA GIS, local municipalities
Ridership by line or by trip	Transit operators
Transit line or vehicle capacity	Transit operators, vehicle manufacturer specifications

Geographic Scale of Analysis

An analysis of System Coordination measures for transit projects requires that all affected transit services be evaluated. The geographic scale of the analysis will most likely be determined by data limitations.

Time Frame of Analysis

System Coordination measures for transit should be evaluated using multiple data points from several years before the project (at least three years), during the construction phase (if any), and for as many years after the project (preferably at least three years) as data are available.

Analysis Steps

Intermediate Measures and Analysis Tools

1. Estimate average travel time in peak and off-peak periods

Inputs: (required for each route or trip to be evaluated, before and after implementation of enhancement project)

- Travel time by trip, in minutes.

Intermediate output measures:

- Estimated **average travel time** in peak and off-peak periods, in minutes. *Collect data by route or by trip for time periods before and after implementation.*
- **Free flow travel time** in peak and off-peak periods. *Collect data by route or trip for time periods before and after implementation of the capacity expansion. Free flow travel time is defined as the shortest bus travel time that can be expected under uncongested conditions on the roadway system (for buses) or the shortest rail travel time that can be achieved under transit operating policies for the infrastructure that is in place at the time (e.g., considering track speed restrictions, standard station dwell times, and other dispatching policies). As a proxy, can use average run time for early morning (before*

morning peak period) and/or late evening (after evening peak period) trips. One may use auto travel time if comparable transit service does not exist.

Travel Time Reliability

Note that travel time reliability for transit can be measured in two ways: either compare actual travel times to scheduled travel times (on-time performance), or compare actual travel times to free-flow travel times (which takes into account differences between transit performance in congested periods and off-peak periods). On-time performance is the reliability metric that matters more to transit passengers, and therefore should be reported publicly, while comparisons of actual travel times to free-flow travel times is a management-oriented measure of how well the system is operating with respect to operating and dispatching policies.

Inputs: (required for each route or trip before and after implementation)

- On-time performance by route or trip. *Use as detailed information as possible. On-time performance may only be available for the departure time from the first stop and the arrival time at destination, or it may be available for intermediate time points.*
- Actual travel times and free-flow travel times by route and by trip, in minutes, as available.

Calculations: Transit On-Time Performance

- **On-time performance** is the percentage of transit trips that arrive at a destination within five minutes and 59 seconds of their scheduled time. *For example, if nine out of ten buses on a particular route arrive within five minutes 59 seconds of their scheduled times, that route has a 90% on-time performance rating.*

Calculations: Transit Travel Time Reliability

- Using actual travel time data, determine the **95th percentile travel times**. *To calculate the 95^{h} percentile travel time, rank order the actual travel times for all trips in the analysis period (usually one week or month worth of weekday trips). The travel time that is longer than 95 percent of trips (or longer than all but 50 percent of trips) represents 5^{th} percentile travel time. Note that 95^{th} percentile travel time is a guideline. For trips where reliability is not as important, for example recreational trips, a lower threshold may be used.*
- **Buffer time** = 95^{th} percentile travel time – average travel time. *Buffer time, expressed in minutes, represents the extra time (or time cushion) that travelers must add to their average travel time when planning trips to ensure on-time arrival 95 percent of the time. Typical values for a complete trip range from as low as 5 minutes or less for off-peak trips to a maximum of 30 minutes or more in the peak.*
- **Buffer index** = (95^{th} percentile travel time – average travel time) / average travel time, expressed as a percentage. *Buffer index values closer to 0% indicate that 95^{th} percentile travel time is close to average travel time, i.e. there is little or no variability in congestion. Buffer index values above 100% indicate severe congestion, i.e. travel time is more than twice as long on the worst travel days than in average conditions.*
- **Planning time index** = 95^{th} percentile travel time / free-flow travel time. *The planning time index reflects how much total time a traveler should allow to ensure on-time*

arrival 95 percent of the time (in contrast to buffer index, which represents extra *time). For example, a planning time index of 1.60 means that for a trip that takes 15 minutes off-peak, a traveler should budget a total of 24 minutes to ensure on-time arrival 95 percent of the time.*

- For an estimate of **"no-build" reliability indices**, use estimated "no-build" congested travel times. *Continuous or 15-minute congested travel times may not be available for the no-build condition because no-build conditions must necessarily be simulated or calculated. Therefore, use peak travel times to estimate the improvement in travel time reliability that is attributable to the project.*

Person-Hours of Delay

Inputs: (required for each route or service before and after implementation)

- Free-flow and average actual travel times by route or trip, in minutes
- Ridership by route or trip, in passengers

Calculations:

- Average delay = average travel time – free-flow travel time, in minutes. *If sufficient data are available, delay can be calculated on a per-trip basis.*
- **Person-hours of delay** = average delay x ridership. *Person hours of delay can also be calculated by multiplying actual delay per trip by ridership per trip, and then summing the results over all trips. For example, if the 7:30 train carries 800 passengers and takes an average of 3 minutes longer than free-flow conditions, and the 7:45 train carries 1000 passengers and arrives an average of 5 minutes late, the total person-hours of delay for these two trains is (800 x 3) + (1000 x 5) = 7,400 minutes per day. Repeat for all other trains on the schedule.*
- Multiply no-build person-hours of delay by persons per vehicle to determine **total no-build person hours of delay**.
- The net impact attributable to the project is the difference between actual delay and no-build estimates of delay.

Network Connectivity and Continuity

Network connectivity and continuity by mode is independently processed.

Inputs:

- Transit network information:
  - Density of transit nodes (intersections) and segments, in intersections per square mile and segments per square mile;
  - Presence or absence of sidewalks, bike lanes, and multi-use trails near stations;
  - Condition of sidewalks and bike lanes (e.g., ADA compliance) within 2 miles of the station;

Evaluation: Use GIS to evaluate connectivity of the transit network before and after improvement. Evaluate connectivity on both a local scale and a regional scale. The *Smart Transportation Guidebook*, published in March 2008 through a partnership between

Pennsylvania Department of Transportation and the New Jersey Department of Transportation, suggests the following connectivity measures:

- **Internal Connectivity.** Use either of the following two measures:
  - Beta Index, the number of links divided by the number of nodes or link ends. *A higher ratio indicates higher street connectivity.*
  - Intersections per square mile. *Strict grid systems have about 25 intersections per square mile, while conventional branching systems have about one-third to one-half that many.*
- **External Connectivity**
  - All neighborhoods in the community should be connected to the larger street system at least every ¼ mile.
- **Route Directness**
  - This measures the distance a traveler would ride transit between two points compared to the straight line (or radial) distance between the same two points. *The closer the ratio is to 1.0, the more direct the route; route directness values of 1.2-1.5 describe reasonably connected transit networks.*
- Connectivity and continuity in the "no-build" condition are simply the conditions that existed before implementation of the capacity expansion.
- Compare route directness analysis for "no-build' and after conditions.

<u>Additional resources on network connectivity include the following:</u>

- Carlos A. Alba and Edward Beimborn (2005), *Analysis of The Effects of Local Street Connectivity On Arterial Traffic*, Transportation Research Board Annual Meeting (www.trb.org); at www.uwm.edu/Dept/CUTS//lu/conn.pdf.
- Dill, Jennifer (2004). "Measuring Network Connectivity for Bicycling and Walking." Presented at the 83rd Annual Meeting of the Transportation Research Board, Washington, DC
- Portland Metro (2001), "Street Connectivity Standards," *Planning for Future Streets: Implementing the Regional Transportation Plan*, Portland Metro Regional Services (www.metro-region.org/library_docs/trans/streetconnect.pdf).
- Portland Metro (2004), Street Connectivity: An Evaluation of Case Studies in the Portland Region, Portland Metro (www.metro-region.org/library_docs/trans/connectivityreport.pdf).

Recommendations for Future Performance Evaluation: System Coordination Measures

Collect and use transit travel time data for direct observations of congested and free-flow travel speeds. With better travel time data for buses as well as trains, transit operators could improve estimates of "free-flow" and "congested" stop-to-stop travel times, and in turn measurement of Travel Time Reliability, Delay, and Percent of Travel Under Congested Conditions. The use of archived TRANSCOM, INRIX, and transit operators' GPS data should provide better measure of congested and free-flow speeds.

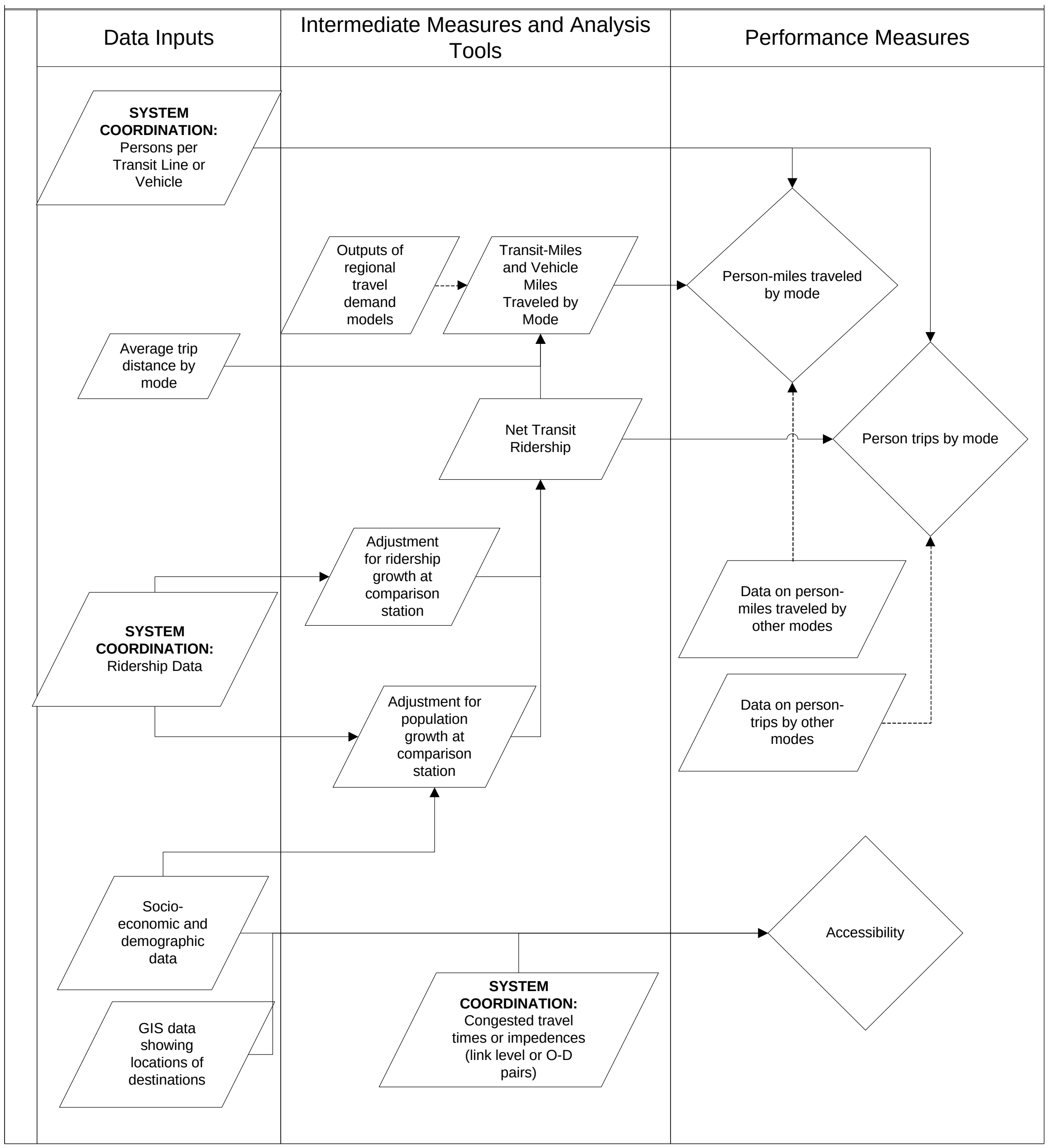
Use simulation models to improve estimates of network-level congestion and delay measures. The methodology presented above assumes transit impacts are expected to be limited to the immediate vicinity of the project. When the analysis involves many links in a network of roadways or a system or rail lines, simulation models can be used to calculate all of the System Coordination performance measures on a network scale. Network simulation models have extensive data requirements (for example, they require field observations of free-flow and congested travel speeds and very detailed roadway and rail geometry data and operational 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, for example from one roadway or track 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).

3.6.2 Evaluating User Responsiveness Measures

NJTPA User Responsiveness Goal - Provide affordable, accessible and dynamic transportation systems responsive to current and future customers.

Interdependencies between Data, Analysis Tools, and Performance Measures

The following diagram is a simplification of the interdependencies between User Responsiveness and System Coordination measures. *Note: Customer Satisfaction are independently evaluated and not included in this diagram. For further information, see page 3.6-24.*



Data Inputs and Sources

Primary data inputs to the analysis include the following:

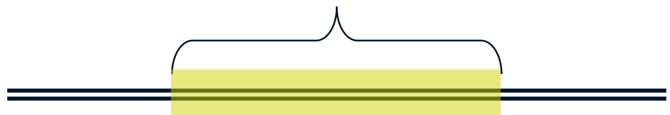
Data Inputs	Sources
Persons per transit line or vehicle	NJ Transit run sheets and farebox data
Average trip distance	Household travel survey data collected by NJTPA or American Community Survey 5-year average data for place/county in which link is located. *Note that ACS 5-year estimates should not be compared for overlapping time periods and are mainly intended to be used for population characteristics, not population totals, particularly at smaller geographies (e.g., Census tracts)*
Ridership data	NJ Transit; other transit operators
Socio-economic, demographic, and employment data (Census Block Group, Traffic Analysis Zone (TAZ), or Place level)	U.S. Census Bureau's American Community Survey 5-year estimates; U.S. Census Bureau's Local Employment-Household Dynamics data, NJTPA. *Note that ACS 5-year estimates should not be compared for overlapping time periods and are mainly intended to be used for population characteristics, not population totals, particularly at smaller geographies (e.g., Census tracts)*
GIS data showing location of local destinations and opportunities (health clinics, grocery stores and sources of fresh food, local parks and playgrounds, elementary and secondary schools, and neighborhood-oriented retail and service establishments like restaurants, bars, dry cleaners, banks, and hardware stores)	Counties and local municipalities, NJDOT, NJDEP, Google Maps, WalkScore.com
GIS data showing locations of regional destinations and opportunities (major hospitals, four-year colleges and universities, major concentrations of retail activity, and recreational and tourist destinations with more than 100 employees, like amusement parks, sports arenas, performing arts venues, museums, and historic sites)	Counties and local municipalities, NJDOT, NJDEP, Google Maps, WalkScore.com

Geographic Scale of Analysis

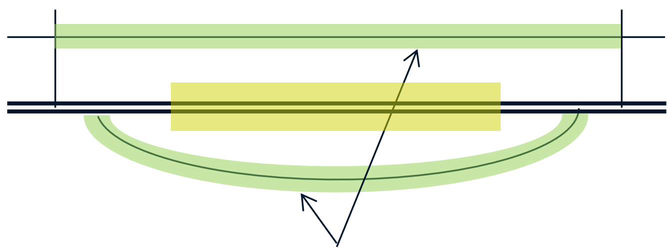
The three User Responsiveness measures are best measured at a regional level or at a corridor level, grouping multiple facilities and modes together to determine the corridor-level or systemwide impacts of any given transit project. The figure below shows the geographic extent for which data should be analyzed:

Analyze data within project limits

CASE 1:
TRANSIT CAPACITY EXPANSION OR SERVICE IMPROVEMENT
with little or no traffic diversion expected



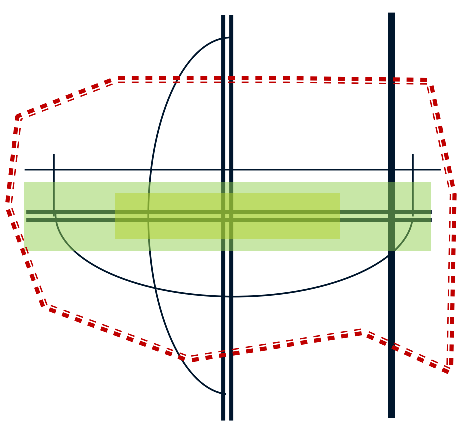
CASE 2:
TRANSIT CAPACITY EXPANSION OR SERVICE IMPROVEMENT
with traffic diversion

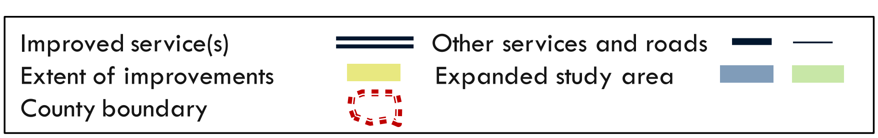


…on parallel route(s) and mode(s) within 5 miles that may have been used as alternate(s) or bypass(es). Some impacts of the project may accrue to parallel facilities and modes that saw increases or reductions in traffic.

ALL CASES:
Corridor, Region, and Service Area Comparison

- Compare to data for the entire corridor/route in which the project is located (green).
- Compare to data in the county in which the project is located (red).
- Also compare to entire NJ Transit service area





Time Frame of Analysis

The impacts of transit expansion projects as measured in terms of User Responsiveness measures may be small or may not be measurable at all shortly after completion of the improvement. However, as years pass many changes as measured by User Responsiveness measures may become more pronounced over time. Therefore, it is important to evaluate User Responsiveness measures on a continuous basis, using multiple data points from several years before the project and for as many years after the project as data are available.

Customer Satisfaction measures are an exception. The reaction to a Transit Expansion project may peak shortly after project completion, but as time goes on, people may not be able to distinguish the project's impacts from other changes that have happened in the meantime (for example, other transportation improvements or economic shifts).

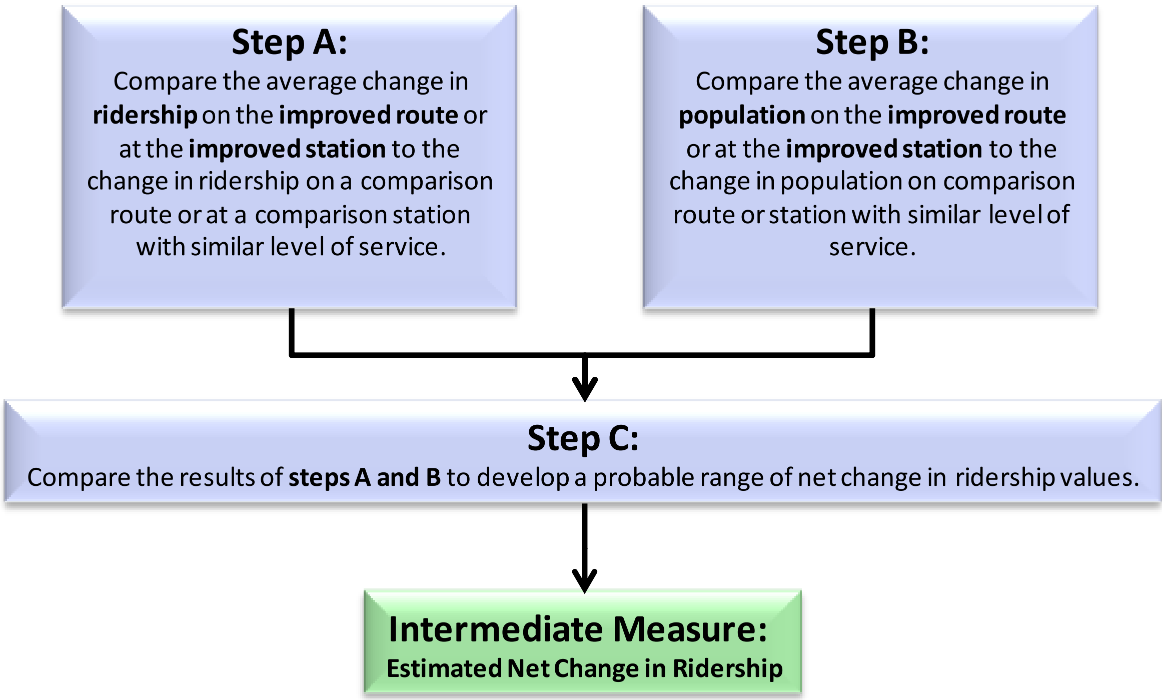
Using person-miles traveled by mode as an example, compared to pre-construction conditions, transit usage may increase slightly during construction as capacity decreases on the roadway and delay increases. Transit ridership may then decrease after completion of the project as the roadway has less congestion and delay. Impacts can be estimated as follows:

- The overall impact of the project can be estimated by comparing person-miles traveled by mode after the project to mode share before the project.
- The net impact can be estimated by comparing person-miles traveled by mode after the project to person-miles traveled by mode in a hypothetical "no-build" scenario.
- Finally, the impacts associated with construction can be estimated by comparing person-miles traveled by mode during construction to mode shares before and after construction.

Analysis Steps

Intermediate Measures and Analysis Tools

Figure3.6-A: Steps to estimate the value of "Net Transit Ridership"



1. Calculate Net Change in Transit Ridership

   Inputs: (Required for each link for the periods before implementation and after implementation)

   - Transit riders on the route that underwent a capacity expansion, or at a new or improved station. *For example, an additional track was added to a section of a NJ Transit rail line, allowing for additional peak-hour express service. Stations upstream of the project may have seen an average of 2,000 weekday riders before implementation of the double tracking project and service changes and an average of 2,500 riders after implementation.*

   - Transit riders on a comparison route that remained static over the analysis period. *The comparison route should have similar levels of service and serve a similar demographic as the study area route. If a station is being analyzed, choose a station nearby on the same line, since a nearby station is most likely to have a similar level of service. For example, a set of comparison stations on the same line downstream of the improvement may have experienced no change in frequency or reliability of service, and may have seen an average of 2,800 weekday riders before the improvement was made and 2,900 riders after.*

   - Population for the area within ½ mile of the route or station being analyzed, and within ½ mile of the comparison route or station. *If analyzing stations, population data* *should be gathered for an area within ½ mile of the study station(s) and the comparison station(s). For example, there may be 125,000 people living within ½ mile of the study-area stations upstream of the improvement project and 200,000 people within ½ mile of the comparison stations downstream of the project. After implementation of the project, there may be 127,000 people within ½ mile of the study-area station and 200,500 people within ½ mile of the comparison stations.*

<u>Calculations:</u>

The recommended approach to calculating Net Change in Transit Ridership is to use a variety of methods to “triangulate” the estimated value. The calculation steps are as follows:

a. Compare change in ridership (or average change in ridership) on the improved transit route(s) or station to the average change in ridership on a comparison route or at a comparison station. What if the ridership at the improved corridor or station(s) had grown at the same rate as the comparison corridor or station(s)? The net change in ridership would be the difference between the actual growth and the adjusted growth.

- Gather ridership data. The change in ridership may be averaged across several stations or boarding locations if a route is being analyzed. *See the example ridership data above for a series of study-area stations and a series of comparison stations.*
- Compare change in ridership (or average change in ridership) on the improved route(s) or at the improved station(s) to the change in ridership on comparison routes (and at comparison station(s)). *The growth rate in average ridership at similar stations, if applied to pre-implementation traffic levels on the study facility, could lead to one estimate of what the change in ridership on the study facility may have been in the absence of the project.*
- The difference between the actual absolute change in ridership on the improved transit route (or at the improved station) and the adjusted change in ridership on the improved transit facility or service is one way to estimate the net ridership impact of the project. Calculations are as follows:

$$\text{Adjusted Ridership}_{\text{Improved corridor/station}} = \text{Ridership}_{\text{Pre-constr.,Improved corridor/station}} * \frac{\text{(Average) Ridership}_{\text{Comparison corridor/station,Post-Constr.}}}{\text{(Average)Ridership}_{\text{Comparison corridor/station,Pre-Constr.}}}$$

$$\text{Net Ridership Change} = \text{Actual Ridership}_{\text{Post-constr.,Improved corridor/station}} - \text{Adjusted Ridership}_{\text{Post-constr.,Improved corridor/station}}$$

- *Using the example ridership numbers from above:*

$$\text{Adjusted Ridership}_{\text{Improved corridor/station}} = 2{,}000 * \frac{2{,}900}{2{,}800} = 2{,}071 \text{ riders}$$

$$\text{Net Ridership Change} = 2{,}500 - 2{,}071 = 429 \text{ riders}$$

b. Compare change in population (or average change in population) on the improved route(s) or at the improved station(s) to the change in population on comparison routes with similar levels of service. What if the population of the area around the improved corridor or station had grown at the same rate as the population of the comparison corridor or station? *This analysis assumes there is a direct correlation between ridership growth and population growth at the study area and comparison stations, meaning that population growth in a station area leads to corresponding ridership growth at that station, and population decline leads to reduction in ridership.*

- Collect population data for the areas within ½ mile of the study area and the comparison study area. *Use data from the examples from above.*
- The ridership at the study area station(s) can be adjusted to control for population growth at the comparison station(s). For any given year after the improvement is implemented, the adjusted population at the study area station can be calculated as follows:

$$\text{Adjusted Population}_{\text{After Improvement,Improved Corridor/Station}} = \text{Population}_{\text{Before Improvement,Improved Corridor/Station}} * \frac{\text{Population}_{\text{After Improvement,Comparison Corridor/Station}}}{\text{Population}_{\text{Before Improvement,Comparison Corridor/Station}}}$$

$$\text{Adjusted Population}_{\text{After Improvement,Improved Corridor/Station}} = 125{,}000 * \frac{200{,}500}{200{,}000}$$

$$\text{Adjusted Population}_{\text{After Improvement,Improved Corridor/Station}} = 125{,}312 \text{ people}$$

The adjusted ridership can then be calculated using the following ratio:

$$\frac{\text{Adjusted Ridership}_{\text{After Improvement,Improved Corridor/Stations}}}{\text{Adjusted Population}_{\text{After Improvement,Improved Corridor/Station}}} = \frac{\text{Ridership}_{\text{Before Improvement,Improved Corridor/Stations}}}{\text{Population}_{\text{Before Improvement,Improved Corridor/Stations}}}$$

$$\text{Adjusted Ridership}_{\text{After Improvement,Improved Corridor/Stations}} = 2{,}000 \text{ passengers per day} * \frac{125{,}312 \text{ people}}{125{,}000 \text{ people}} = 2{,}005 \text{ passengers per day}$$

The difference between the actual absolute change in ridership on the improved transit facility or service and the adjusted change in ridership on the improved facility or service is in turn, a second basis for estimating the net ridership impact of the project. Calculations are as follows:

$$\text{Net Ridership Change} = \text{Actual Ridership}_{\text{Improved Corridor/Stations}} - \text{Adjusted Ridership}_{\text{Improved Corridor/Stations}}$$

$$\text{Net Ridership Change} = 2{,}500 - 2{,}005 = 495 \text{ passengers per day}$$

c. Compare the results of steps “a” and “b” to develop a probable range of net transit ridership values. If the net change in transit ridership is within the same order of magnitude, proceed to the next step in the calculation. If the net change varies wildly, or if the net change is positive in one calculation and negative in the other calculation, re-examine the results in light of the caveats discussed after each calculation above. If necessary, use professional judgment to eliminate any net ridership estimates that appear unreasonable. Then use either the average, median, high, or low value depending on the purpose of the analysis. *In the above calculations, the net new transit ridership is estimated to be between 429 and 495 passengers per day.*

d. If all three estimates are wildly different, it may not be possible to proceed with the next step.

Intermediate output measures:

- Range in values of **net change in transit ridership** attributable to implementation of the project
- If the facility is new, the net change in transit ridership may be 100 percent of the riders observed on the new facility, or some adjustments may be made to account for rider shifts from parallel transit routes or nearby stations.

2. Calculate Net Change in VMT

Inputs:

- Range in values of estimated net change in ridership from previous step (for before and after implementation). *For example, 450 net new riders per day.*
- Share of riders who previously drove instead of using transit, from available survey data. *For example, 80 percent of new riders previously drove and the remaining 20 percent didn't previously make the trip.*
- Average vehicle occupancy for the study area, county, or the NJTPA region, from the U.S. Census or recent household travel surveys. *Please note that ACS focuses only on the work/commuter trips*. *For example, 1.2 passengers per vehicle.*
- Average trip distance via driving for those people who switched from driving to transit, using estimates of average distance to out-of-county destinations and average distance to out-of-state destinations. *Can use average distance traveled to work, or the distance from the home zone to a point on the transit route that has high employment densities. For example, if the survey didn't ask new transit riders what their previous driving distance was, one could use U.S. Census Bureau American Community Survey data to determine the average distance to work for people living in the study area. This distance might be 15 miles, for example. Or, if American Community Survey data are not available, one could use the average distance to downtown Newark or Midtown Manhattan from the stations that experienced the capacity expansion.*

Calculations:

a. Divide net change in transit ridership numbers by average vehicle occupancy data for the county in which the transit expansion project is, using most recent available data from the U.S. Census or NJTPA Household Travel Survey, to produce the net reduction in vehicle trips *For example, 450 net new transit riders * 80 percent who previously drove * 1.2 riders per vehicle equals 300 net vehicles taken off the road due to the transit capacity expansion project.*

b. Separate vehicle trips into destination groups, such as out-of-county and out-of-state trips, based on the proportion of transit trips traveling out-of-state and out-of-county from the U.S. Census Journey to Work data. *Suppose Journey to Work data or American Community Survey data indicate that 35 percent of trips originating in that county remain in the county, 45 percent go to out-of-county destinations within New Jersey, and the remaining 30 percent travel to out-of-state destinations. One can assume that none of the transit trips remain within the county, so that 60 percent of net new transit trips stay within New Jersey and 40 percent travel to New York City.*

c. Make an assumption about the average former driving trip distance for travelers in each destination group. *The average round-trip distance for trips that stay within New Jersey is assumed to be 30 miles in this example, and the average round-trip distance for trips to New York City is assumed to be 70 miles.*

d. For each destination group, multiply the number of trips by the average distance to the group destinations to produce the reduction in VMT for out-of-state trips. *For the in-state group, 30 miles * 60 percent * 300 net reduction in daily vehicle trips = a net reduction of 5,400 vehicle-miles traveled per day. The corresponding value for out-of-state trips is 70 miles * 40 percent * 300 net vehicle trips = 8,400 vehicle miles traveled per day. The annual reduction in VMT, assuming 200 working days per year, is (5,400 + 8,400) * 200 = a net annual reduction of 2.76 million VMT.*

e. Adjust the net VMT reduction to account for modes used to access transit. *If 80 percent of the net new riders drive an average of 5 miles from home to access a transit station, the net VMT reduction needs to be decreased by 450 riders * 80 percent * 5 miles * 200 working days per year = 360,000 VMT. Therefore, the actual net VMT reduction is 2.76 million - 360,000 = 2.4 million VMT.*

f. Compare the VMT change in the county in which the project is located to the NJTPA region and the State of New Jersey. *For large projects in particular, VMT impacts may be perceived at a county level. As another point in the "triangulation" process, at this point the range of net VMT estimates produced in the previous step can be compared to the rates of change in VMT at the county, region, and state level. Compare the rate of change in county-level VMT to the rate of change of facility-level ridership values, and also compare the county-level VMT to the rate of change in VMT at the regional and state level. The differences between these respective VMT changes can be used to estimate a range of probable net VMT impacts of the project.*

g. Use professional judgment to specify a single value for estimated net change in VMT. As in the net ridership calculations, the estimated change in net VMT can be affected by many project-specific exogenous factors. The estimated net change in VMT could be the average of all estimated values, or the median value, or the high or low point, depending on the confidence level in the input assumptions and variables.

Intermediate output measures:

- **Net change in vehicle miles traveled.**

Person-Miles of Travel by Mode (Mode Choice)

Inputs:

- Net vehicle miles traveled*, from calculations above.*
- Persons per vehicle (use a single year, perhaps the midpoint of the analysis, so as not to introduce additional error into the calculation). *For example 1.2 persons per vehicle.*
- Modes used to access transit, and mode share for those access modes.

Calculations:

- Multiply estimates of net vehicle miles traveled by persons per vehicle to determine the net change in person-miles traveled by car. *Using values from the above examples, 2.4 million reduction in net VMT * 1.2 persons per vehicle = net reduction of 2.88 million person-miles traveled by car.*
- Multiply estimates of net new riders by average destination per rider to determine the net change in person-miles traveled by transit. *For example, 450 net new daily transit riders * 40 miles average round trip distance = 18,000 passenger-miles per day. Over 200 annual working days, this translates to 3.6 million net new passenger-miles by transit per year.*
- Estimate the person-miles traveled by other modes. *For example, in the above example, if 80 percent of the net new transit passengers access the station by car, and the remaining 20 percent walk or bike, with an average trip distance of 1 mile, the average passenger miles traveled by non-motorized modes is 450 net new daily transit riders * 20 percent * 1 mile = 90 miles per day or 18,000 miles per year.*

Person-Trips by Mode (Mode Choice)

Inputs:

- Net Change in Transit Ridership.
- Share of net new riders that previously traveled by car.
- Share of net new riders who access the expanded transit service by car, other transit modes, or non-motorized modes.

Calculations:

- *From the above example, there are 450 new person-trips per day by transit.*
- Multiply estimates of net new transit ridership by the share who previously drove to determine the net change in person-trips by motor vehicles. *For example, 450 net new daily transit riders* 80 percent of whom previously commuted by car = a net reduction of 360 person-trips by car. However, if 80 percent of the net new riders drive to access the expanded transit service, the actual net reduction is only 450 * 20 percent = 90 person-trips by car.*
- Calculate the person-trips by other modes. *From the previous step, if 20 percent of net new riders use non-motorized means to access transit, the net increase in non-motorized trips is 450 * 20 percent = 90 person-trips.*

Accessibility

Accessibility a measure of the ability of people to reach opportunities and activities that they undertake in their daily lives, or the ability of businesses to reach their labor force, sources of raw materials and inputs to their production facilities, and the consumer markets for their finished products.

Access to jobs refers to the ability of the residents of a given area to access employment opportunities via any mode of transportation. Increased access to jobs is correlated with reduced unemployment rates and improved per capita income.

Access to labor force refers to the ability of businesses to access a pool of labor in a given market area. Increased access to labor force makes a business more competitive as more people with the skills necessary to do a job can compete for the same job opening.

Access to regional amenities can include the ability to reach major hospitals, universities, major concentrations of retail activity, and recreational and tourist destinations like amusement parks, beaches, sports arenas, performing arts venues, museums, and historic sites. Regional amenities can be screened using employment (only destinations with more than 100 employees, or retail employment density greater than 100 per acre, for example).

Access to community amenities can be defined as the ability to reach destinations that are sources of basic services and daily needs, and may include health clinics, grocery stores and sources of fresh food, local parks and playgrounds, elementary and secondary schools, and neighborhood-oriented retail and service establishments like restaurants, bars, dry cleaners, banks, and hardware stores.

Inputs:

- Locations of working-age population (U.S. Census Bureau) aggregated to traffic analysis zones (TAZs).
- Locations of jobs (from U.S. Census Bureau, Center for Economic Studies, Longitudinal Employer-Household Dynamics Program) aggregated to TAZs.
- Locations of regional amenities (from GIS database of regional amenities).
- Locations of local amenities (from GIS database of local amenities).
- Peak hour travel speed data for links in the NJRTM-E model network (from INRX or other vehicle probe data).
- NJRTM-E model network link attributes (link length, toll information).

Calculations:

a. Access to Community Amenities: Distance-Based Cumulative Opportunity accessibility measure

   - For local amenities, a distance-based threshold may be the only option. *If travel times by walking, biking, and competing modes are known, one of the other accessibility measures mentioned in this section can be used instead of the following procedure.*

- Using a GIS tool, in an area within a ½-mile radius of the project limits radius or less depending on the determined geographic scale, calculate the number of local amenities that can be reached within a ½-mile walk before and after construction of the transit expansion project. The change in access to local amenities is the difference in cumulative opportunities that can be reached before and after construction. *For example, before implementation there may be two grocery stores within a ½-mile walk of transit, and after construction there may be five.*
- *Access to community amenities should be evaluated at as fine-grained a geographic scale as possible (e.g., Census blocks or block groups), because many TAZs may be more than ½-mile across.*
- *If no sub-TAZ data are available, access to community amenities can be evaluated qualitatively using maps showing before-and-after local street network, sidewalk network, and bike network connectivity.*

b. For all destinations other than community amenities: Travel-time-based Cumulative Opportunity accessibility measure.

- For period before construction (average of three years) and period after construction (three-year moving average for all available years), use GIS to calculate the shortest travel time between all O-D pairs in the regional network. If possible, calculate travel time on a multimodal basis, since at peak times some trips may be faster by transit.
- Aggregate the number of "opportunities" that lie in the TAZs that can be reached within the following time thresholds:
  - Jobs: 60 minutes (using peak hour travel times).
  - Labor force: 60 minutes (using peak hour travel times).
  - Regional amenities: 90 minutes (using average weekend day travel time).
  - Buyer and supplier markets: 5 hours (using average weekday travel time).
- The relevant equation is:

$$A_i = \sum_{j=1}^{J} B_j O_j$$

where A_i is accessibility measured at point i to potential activities in zone j,

O_j is the opportunities in zone j, and

B_j is a binary value equal to 1 if zone j is within the predetermined threshold and 0 otherwise.

- The change in access is the difference in cumulative opportunities across all TAZ pairs that can be reached in the specified travel time. Cumulative opportunity estimates for each TAZ in a given area can be aggregated using the following equation:

$$A_{Area} = (\Sigma A_i * P_i) / P_{Area}$$

where:

A_i = Accessibility of zone i

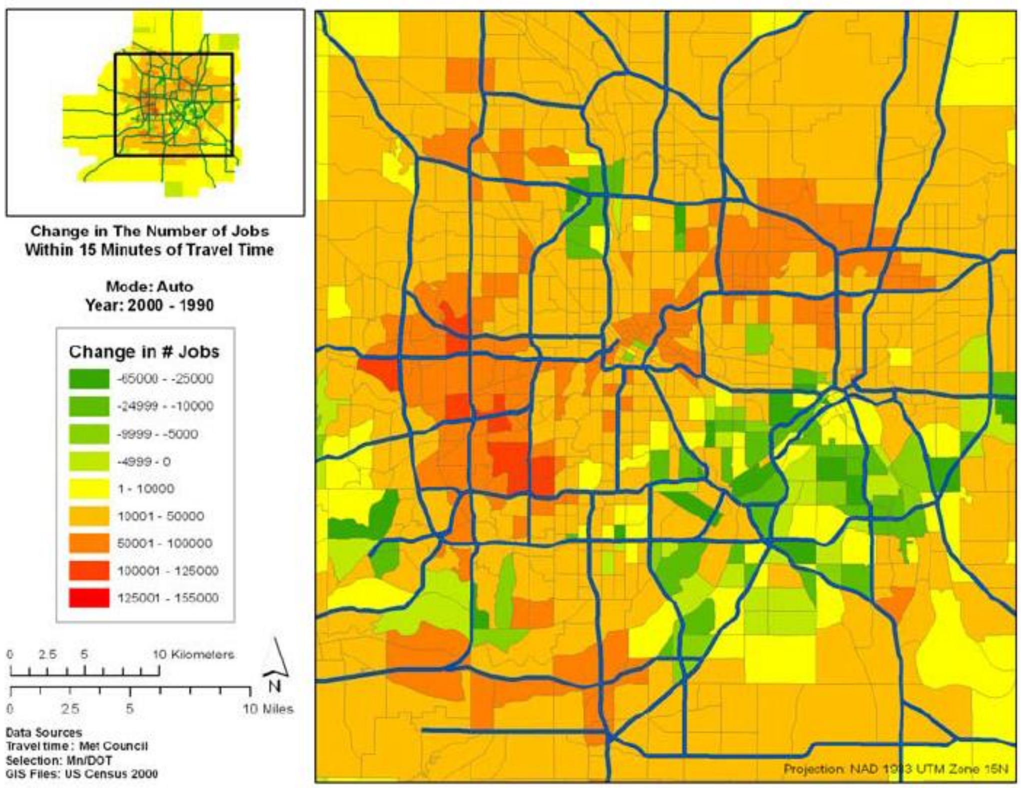
P_i = Population of zone *i*

P_{Area} = Population of the study area (could be a county or the NJTPA region)

A_{Area} = Accessibility of the region (could be a county or the NJTPA region)

- *For example, before construction, 200,000 jobs might be accessible within a 60-minute commute of a given location. After construction of a transit expansion project, 250,000 jobs might be accessible within 60 minutes. The net impact of the project is access to an additional 50,000 jobs at that location. The net impacts for each TAZ or analysis area can be plotted on a map to determine where the biggest net accessibility benefits accrue, as in the example below from the Minneapolis-St. Paul metro area.*

Figure 3.6-B: Example of a Map of Regional Accessibility Change



Source: El-Geneidy, A and D. Levinson, 2005. "Place Rank: A New Accessibility Measure," Nexus (Networks, Economics, and Urban Systems) Research Group, Department of Civil Engineering, University of Minnesota.

- *Note that population is not necessarily the most appropriate weighting factor. Employment could be used in place of population for access to employment and access to labor force, for example.*
- *A cumulative opportunity measure of accessibility is perhaps the simplest way to measure accessibility, but this measure requires the use of an arbitrary radius that, for example, attributes no value to jobs 61 minutes from an origin or regional amenities 91 minutes away. Because the measure is being used to compare before and after conditions, rather than rank the accessibility of individual zones, choosing an arbitrary threshold is not as problematic. A sensitivity analysis could be employed by varying the time threshold by +/- 10 minutes to see if the results change significantly.*

Additional resources on accessibility measures include the following:

- El-Geneidy, A and D. Levinson, 2005. "Place Rank: A New Accessibility Measure," Nexus (Networks, Economics, and Urban Systems) Research Group, Department of Civil Engineering, University of Minnesota. El-Geneidy and Levinson propose the use of a so-called "Place Rank" accessibility measure that uses actual information about origins and destinations by trip purpose and takes into account the relative attractiveness of each zone in calculating accessibility. The Place Rank accessibility calculation is an iterative process that uses the following equations:

$$R_{j,t} = \sum_{i=1}^{I} E_{ij} * P_{it-1}$$
$$P_{it-1} = [E_j * [R_{j,t-1} / E_i]]$$

Where:

- $R_{j,t}$ The *place rank* of *j* in iteration *t*
- *I* The total number of *i* zones that are linked to zone *j*
- E_{ij} The number of people leaving *i* to reach an activity in *j*
- P_{it-1} The power of each person leaving *i* in the previous iteration
- E_j The original number of people destined for *j* $Ej = \sum_i ij$
- $R_{j,t-1}$ The *place rank*ing of *j* from the previous iteration
- E_i The original number of people residing in zone *i*: $Ei = \sum_j ij$

Customer Satisfaction

Customer Satisfaction is a measure that does not depend on inputs from any other performance measure. Customer Satisfaction measures can be obtained from the results of surveys performed by NJ TRANSIT, other transit operators or other agencies after completion of a project.

Inputs:

- Surveys of transportation system users, ideally including information about the relative importance of each system attribute being queried.
- Typical questions on transit-related customer satisfaction surveys include:
  - Customer perception of improvement's impacts across NJTPA goal areas: Built and natural environment, travel speed, travel time reliability/on-time performance, access to destinations, safety, economic impacts.
  - Project's impact on travel behavior: Whether the improvement caused mode shifts ("What was the previous mode used to make the trip?") and destination choice decisions (e.g., enabled a longer trip to a destination not previously accessible).
  - Impacts of transit construction (if any): Safety, congestion and delays, access to businesses, environmental impacts during construction.

Recommendations for Future Performance Evaluation: User Responsiveness Measures

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 suggests that GPS-tracking 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. Older methods such as household surveys, business surveys, and license plate surveys are extremely time-intensive in estimating origin-destination patterns on a regional scale.

Develop GIS tools to interface with travel demand model inputs and outputs to automate calculations of accessibility changes due to transportation investments. Accessibility maps, such as the map shown above in Figure 3.6-B, 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.

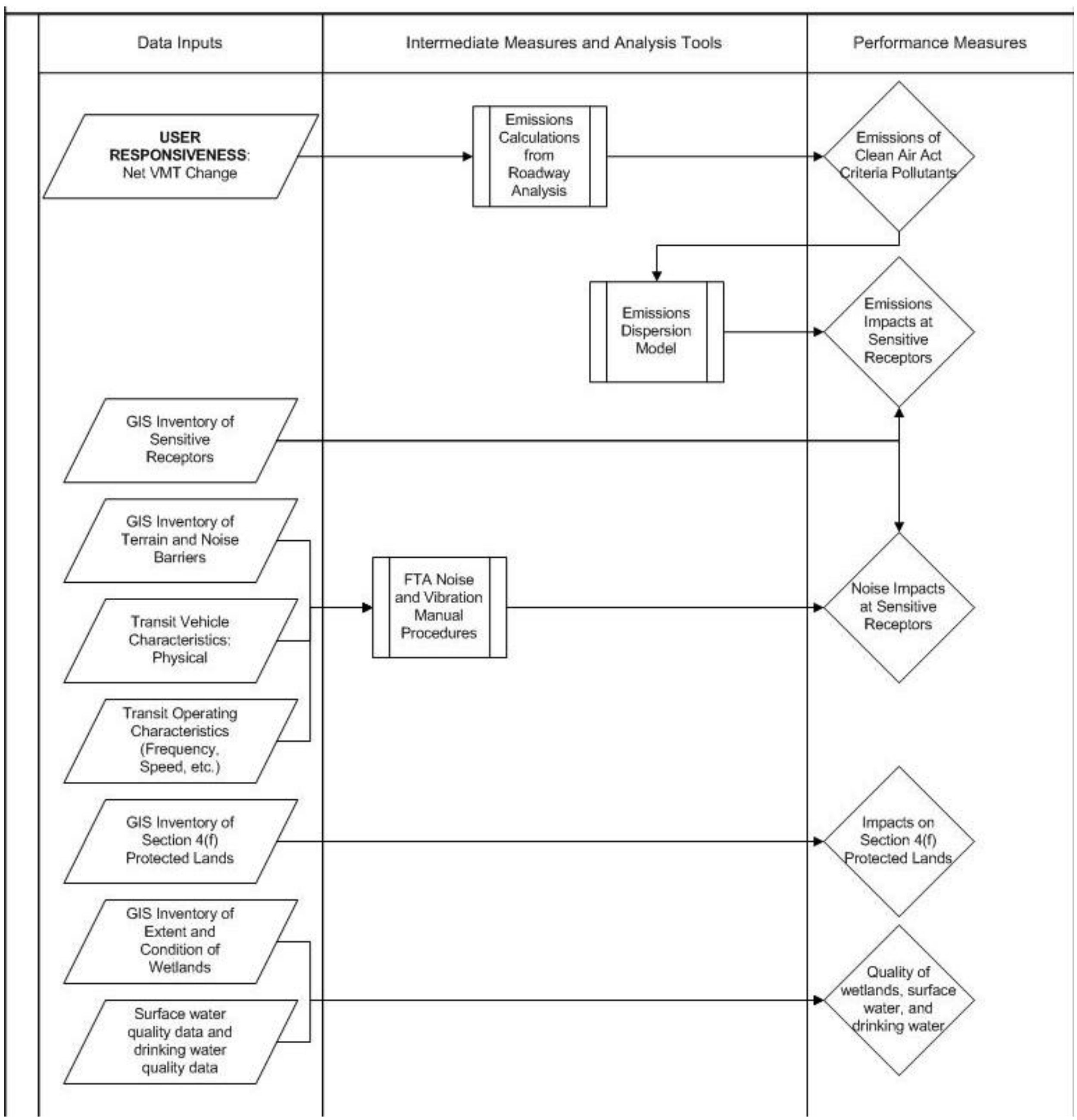
Undertake customer satisfaction surveys for all modes on a more regular basis. Agencies responsible for building, maintaining, and operating the transportation system in the region should undertake regular customer satisfaction surveys to collect a range of qualitative and quantitative data about customer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

3.6.3 Evaluating Environment Measures

NJTPA Environment Goal - Protect and improve the quality of natural ecosystems and human environment.

Interdependencies between Data, Analysis Tools, and Performance Measures

The following diagram is a simplification of the interdependencies between Environment measures and the intermediate and ultimate measures discussed in the System Coordination and User Responsiveness sections. *Note: Visual aesthetics and context is independently evaluated and not included in this diagram. For further information, see page 3.6-33.*



Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Distribution of vehicle trips by time of day	NJ Transit bus schedules, Other Transit Operators
GIS Inventory of Sensitive Receptors	NJDOT and NJDEP GIS; Google Maps and other commercial sources
GIS inventory of terrain and noise barriers	NJDOT and NJDEP GIS; NJDOT Straight Line Diagrams
Vehicle trip distribution by model year and type	NJMVC Registration data; NJDOT vehicle classification count data
GIS inventory of Section 4(f) protected lands	NJDEP GIS Wildlife and waterfowl refuges: US Fish and Wildlife Service Historic properties: National Historic Geographic Information System (NHGIS), state historic preservation office (SHPO) and local historical commissions/societies
GIS Inventory of extent and condition of wetlands	NJDEP GIS; US Army Corp of Engineers
Surface and drinking water quality	NJDEP Division of Water Quality; NJDEP Bureau of Safe Drinking Water.
Net person-miles of travel by biking and walking	Performance measure calculated in **User Responsiveness**; see methodology above
Project purpose and need statement or project description from planning documents, funding applications, etc.	Implementing agency; county or local municipality in which project is located
Photos and project descriptions after project completion	Implementing agency; county or local municipality in which project is located
Local comprehensive plans and other relevant planning documents for the area in which the project was constructed.	County or local municipality in which project is located
List of commitments to stakeholders that was developed and maintained during planning and design and/or was incorporated into construction/service planning documents prior to beginning construction or implementing service changes.	Implementing agency; county or local municipality in which project is located
Results of post-implementation surveys of project team members from the implementing agency and consultants	Post-implementation surveys
Results of post-implementation surveys of community stakeholders (residents and businesses) and regulatory agency staff	Post-implementation surveys

Geographic Scale of Analysis

The geographic scale of analysis depends on the measure being assessed. The following table shows the recommended geographic scale of each measure.

Measure	Geographic Scale(s) of Analysis
Emissions of Clean Air Act criteria air pollutants and greenhouse gases	Air quality (AQ) data are collected at the facility level as well as at the regional scale. The regional and statewide travel demand models that are necessary to quantify emissions are based on this state and regional data collection. Transportation-related emissions, for example greenhouse gases, do not respect state and regional boundaries; therefore regional and statewide data are necessary. The Clean Air Act requires regional and project level hotspot analysis. Most non-attainment areas have on the ground monitoring units in set locations. These units are not typically moved to measure emissions for specific projects. Transportation emissions that lead to respiratory conditions and other health impacts should be estimated at sensitive receptors within ¼ mile of project limits.
Transportation-related noise and vibrations at sensitive receptors	Sensitive receptors within ¼ mile of project limits
Quality of wetlands, surface water, and drinking water	Primary/direct impacts (wetlands): Project limits Secondary/cumulative impacts: Project-specific as defined in NEPA Scoping document; could be several miles from project limits; use natural boundaries such as water sheds as study area boundaries
Impacts on Section 4(f) protected lands	Primary/direct impacts: Project limits Secondary/cumulative impacts: Project-specific as defined in NEPA Scoping document; could be several miles from project limits; use natural boundaries such as water sheds as study area boundaries
Visual aesthetics and context sensitivity	Project limits (project-specific design features); adjacent properties; neighborhoods and municipalities in which project is located; architectural and environmental features in view shed

Time Frame of Analysis

The ability to measure the net Environmental impacts of a project over time is directly dependent on the ability to measure net VMT impacts, net changes in transit ridership, net impacts on congested travel speeds, and net impacts on mode choice decisions. As the quality or reliability of these estimates deteriorate over time, so does the reliability of the results of an environmental impact assessment. Therefore, the time frame of analysis for Environment performance measures should mirror the time frames for System Coordination and User Responsiveness measures: measures should be on a continuous basis if possible, using multiple data points from several years before the project and for as many years after the project as data are available in order to draw valid conclusions about the net impacts of a project.

As indicated in the above graphic, the environmental impacts of transit projects are often measured at a regional scale. Therefore, the net impacts of any one project may be obscured over time by economic growth that generates additional travel demand (in turn affecting emissions and noise), by other development that increases impervious cover and impacts wetlands and water quality, or by changes in the region's socioeconomic and demographic profile that affect public health outcomes. On a project-by-project basis, professional judgment will be necessary to determine the limits of applying the following analysis.

Analysis Steps

Emissions of Clean Air Act Criteria Pollutants

<u>Inputs:</u>

- Total change in VMT attributable to project, in miles per year. *Intermediate output measure of **User Responsiveness** analysis. See above for example calculations.*
- Total change in work and non-work related vehicle trips attributable to project, in trips per year. *From regional household travel surveys. For example, 30,000 trips per year.*
- Distribution of travel by time period, based on available NJDOT traffic volume data for roadways affected by the project, either hourly, 15-minute, or continuous counts. *For example, 35 percent AM, 20 percent Midday, 35 percent PM, and 10 percent Night.*

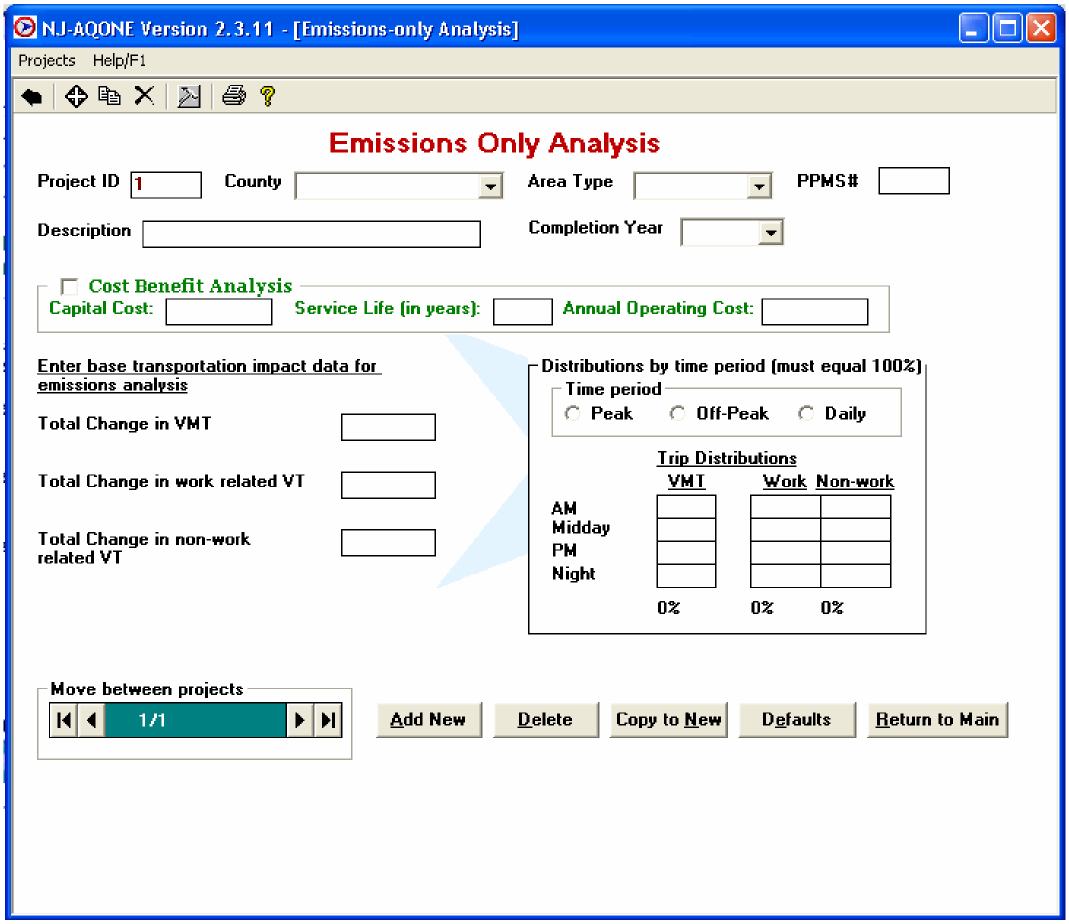
<u>Analysis Tools:</u>

- Use NJAQONE Emissions-Only module to estimate emissions in forecast year. Conduct one run for "no-build" condition and a second run for the "build" condition.

<u>Output measures:</u>

- Estimated **change in emissions by criteria pollutant.**

Figure 3.6-C: Example Emissions Only Analysis Input Screen from NJAQONE



Emissions Impacts at Sensitive Receptors

1. Generate emissions contour maps.

   Inputs:

   - Estimated change in emissions by criteria pollutant, from NJAQONE or MOVES.
   - Baseline emissions estimates, from NJAQONE or MOVES baseline data.
   - Geography-specific climate data. Can use defaults built into models.

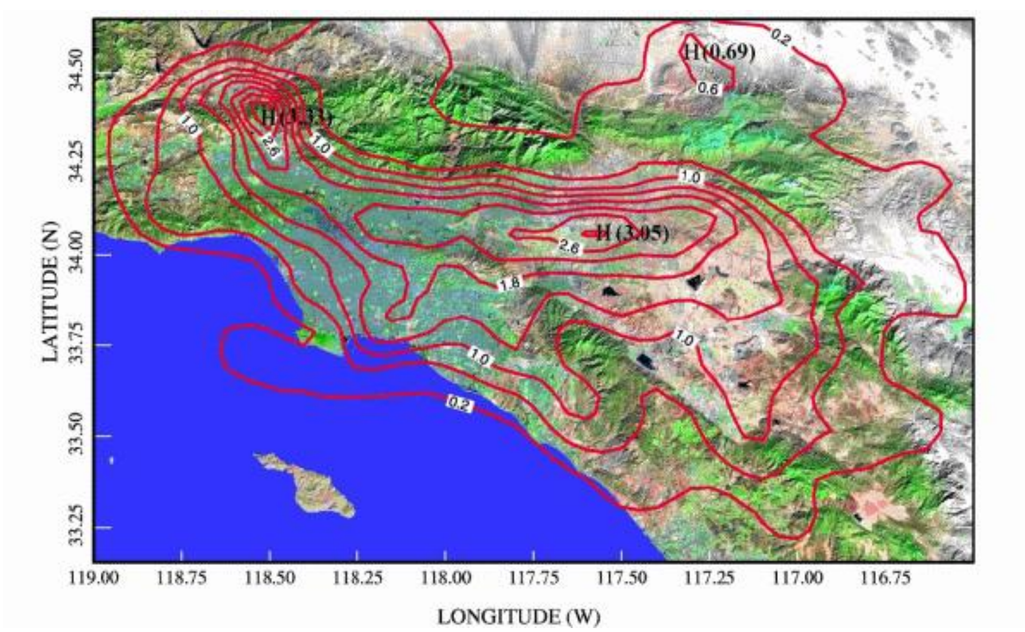
   Analysis Tools:

   - Use Emissions Dispersion model to allocate emissions to points or subregions in the analysis area. Conduct one run for baseline conditions and a second run for "build" condition.

   Outputs:

   - Emissions contour maps showing concentrations by criteria pollutant for baseline condition and for "build" condition.

Figure 3.6-D: Example map of daily emissions of soot in micrograms per cubic meter for Los Angeles Metropolitan Area:



2. Overlay sensitive receptor points on emissions contour maps.

Inputs:

- Emissions contour maps for baseline condition and "build" condition from dispersion model.
- GIS layer of sensitive receptors in NJTPA region.

Calculations:

Net emissions impact at any given sensitive receptor is the difference between the build condition and the baseline condition. Repeat calculation for each sensitive receptor.

Outputs:

- **Estimated emissions impacts by sensitive receptor.** *For example, "Emissions of particulate matter (PM 2.5) increased from 1.2 micrograms per cubic meter to 1.8 micrograms per cubic meter as a result of the project."*

Noise and Vibration Impacts at Sensitive Receptors

Inputs:

- Peak hour volume and average speed by vehicle type, by link (intermediate output measures of **System Coordination** analysis).
- GIS inventory of terrain type.
- Location and extent of noise barriers (NJDOT GIS and Straight Line Diagrams).
- GIS inventory of sensitive receptors.
- Archived data on background noise levels at sensitive receptors at regional, county level, and/or corridor level.

Calculations:

- See FTA Noise and Vibration Manual for procedures and calculations used to generate noise contours and estimated impacts at sensitive receptors. *To estimate net impacts, run one scenario with "build" conditions using most recent available data and a second "no-build" scenario with estimated "no-build" inputs. Repeat for each sensitive receptor.*
- *If enough data are available about changes in decibel levels at sensitive receptors over time, the project-specific impacts also can be compared to regional, county-level, or corridor-level average impacts over the same analysis period as another estimate of what may have happened in the absence of the project.*

Outputs:

- **Net noise and vibration impacts at sensitive receptors**, in decibels. *For example, "The hourly equivalent sound level $L_{EQ}(h)$ increased from 60 dB to 75 dB as a result of the project."*

Impacts on Section 4(f) Protected Lands

Inputs:

- GIS inventory of Section 4(f) Protected Lands.

Calculations:

- Compare before and after conditions to determine direct impacts on Section 4(f) Protected Lands. Depending on NEPA scoping effort, may need to expand analysis area to take into account cumulative impacts of the project on Section 4(f) Protected Lands.
- Also compare “after” conditions in project analysis area to regional, county-level, or corridor-level estimates of change in extent of Section 4(f) protected lands over the same analysis period. The percent change in regional extent can be compared to the project-specific impact as one estimate of the net project-specific impact, compared to what would have happened in the project area due to non-transportation-related land consumption.

Outputs:

- Change in **extent and condition of Section 4(f) Protected Lands**. *For example, “5 acres of parks were directly taken for construction of the project and replaced in a 2-for-1 ratio in a new 10-acre park created adjacent to a nearby school.”*

Impacts on Wetlands, Surface Water Quality, and Drinking Water Quality

Inputs:

- GIS inventory of wetland extent and condition.
- Surface water quality data within project limits and downstream of project.
- Drinking water quality data within project limits and downstream of project.

Calculations:

- Compare before and after conditions to determine direct impacts on wetlands, surface water quality, and drinking water quality.
- Depending on contents of NEPA scoping effort (if available), may need to expand analysis area to take into account cumulative impacts of the project on wetlands, surface water quality, and drinking water quality. Study area should be consistent with what was used in the original environmental assessment.
- Also compare “after” conditions in project analysis area to regional, county-level, or corridor-level estimates of change in extent of wetlands, and change in condition of wetlands and water quality over the same analysis period. The percent change in regional extent can be compared to the project-specific impact as one estimate of the net project-specific impact, compared to what would have happened in the project area due to non-transportation-related land consumption and runoff.

Outputs:

- Change in **extent and condition of wetlands.** *For example, "20 acres of wetlands were directly taken for construction of the project and replaced in a 2-for-1 ratio in a wetlands mitigation bank maintained by NJDOT in the watershed."*
- Change in **condition of surface water quality and drinking water quality**. *[To be defined in discussions with NJDEP.]*
- Use relationship between water quality and waterborne illness to calculate net impact of project on waterborne illness. If pathways and quantitative relationships are not available, perform a qualitative assessment of the project's impact.
- Compare the project-level estimates to estimates of regional, county-level, and/or corridor level changes in incidence of waterborne illness as an estimate of what would have happened in the absence of the project.

Visual Aesthetics and Context Sensitivity

Inputs:

- Project purpose and need statement or project description from planning documents, funding applications, etc.
- Photos and project descriptions after project completion.
- Local comprehensive plans and other relevant planning documents for the area in which the project was constructed.
- List of commitments to stakeholders that was developed and maintained during planning and design and/or was incorporated into construction documents prior to beginning construction.
- Results of post-construction surveys of project team members from the implementing agency and consultants.
- Results of post-construction surveys of community stakeholders (residents and businesses) and regulatory agency staff.

Calculations:

Conduct surveys using the following criteria[1]. Score one point for each criterion if 67% or more of implementing agency staff (and/or the agency's project consultants) surveyed respond "yes"; score one additional point for each criterion if 67% or more of community stakeholders and regulatory agency staff surveys respond "yes". Maximum 12 points.

1. The executed project meets the goals and objectives identified in the original purpose and need statement.

[1] Adapted from project-level evaluation criteria listed in NCHRP Web-Only Document 69: *Performance Measures for Context Sensitive Solutions- A Guidebook for State DOTs*

2. The project was designed and implemented in a manner that is consistent with local comprehensive plans, the Americans with Disabilities Act, and other relevant planning documents.
3. The implemented project meets or exceeds a list of commitments to stakeholders that was developed and maintained during planning and design, was incorporated into construction documents prior to beginning construction, and is monitored during construction and operation of the completed project.
4. *(If the project is located in a developed area)* Architectural elements were incorporated into the design of the project to make users of all modes feel comfortable and welcome. These elements include, but are not limited to: wayfinding signage for users of all modes for which the facility is designed; signage clearly indicating access points to transit services (including park-and-ride lots, bus stops, and fixed guideway transit stations); signage clearly indicating access points and amenities for bicyclists and pedestrians (including signage indicating nearby alternate routes if non-motorized users are prohibited from using the facility); a physical barrier between non-motorized traffic (bicyclists and pedestrians) and transit services or, if a physical barrier was not possible, a defined pavement marking separation; adequate lighting for evening and nighttime use by motorized and non-motorized users; an open view shed into public spaces for people passing by and security officers; and amenities such as artwork and landscaping to enhance the surrounding built and natural environment.

   (If the project is located in an undeveloped area) Environmental resources, scenic and historic resources, and aesthetic values, such as architectural styles and landscaping that complement the surrounding environmental, have been maintained or enhanced by the project as completed.
5. Nearby residents and representatives of nearby institutions, schools, and business associations are directly or indirectly (e.g., via an advisory council) involved in the ongoing maintenance and operations of the facility or service.
6. Based on surveys of area residents and businesses, the project appears to have been implemented in a manner that will result in increased economic activity, such as new commercial or residential activity, and it appears to have the potential to create a positive neighborhood impact.

Outputs:

- Qualitative assessment of the degree to which a project improved or detracted from the **visual aesthetics of the built environment**.

Recommendations for Future Performance Evaluation: Environment Measures

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 emissions, 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.
- 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 in Roadway section).
- 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. While it may not be always 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. 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 costs would be incurred if it is discovered that mitigation measures are not successful and additional actions must be undertaken. Monitoring activities, data collection, data clean up and database maintenance are also time consuming. Agencies are hesitant to encourage monitoring and reporting for political reasons as well. 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 (CEs) 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 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 the 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 data sharing and streamlining the NEPA planning process.

Improve monitoring of impacts on Section 4(f) properties. 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 project 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 opportunity 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.

3.6.4 Evaluating Land Use/Transportation Coordination Measures

NJTPA Land Use/Transportation Coordination Goal - Select transportation investments that support the coordination of land use with transportation system.

Interdependencies between Data, Analysis Tools, and Performance Measures

The evaluation of the Land Use/Transportation Coordination measure per capita vehicle miles traveled depends on a calculation of the intermediate measure vehicle miles traveled in the **User Responsiveness** goal area.

Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Net VMT Change	Intermediate measure calculated in **User Responsiveness**; see methodology above
Population	U.S. Census Bureau's American Community Survey 5-year estimates
Employment	U.S. Census Bureau's Local Employment-Household Dynamics data; NJ Labor and Workforce Development, and/or U.S. Bureau of Labor Statistics
Census tract area	U.S. Census Bureau TIGER Line Shape Files

Geographic Scale of Analysis

An analysis of net per capita VMT for transit expansion projects should be performed on the same scale as the net VMT calculation. Often, this calculation will be performed at a regional scale.

Time Frame of Analysis

The impacts of transit expansion projects as measured in terms of Land Use/Transportation Coordination measures may be small or may not be measurable at all shortly after completion of the improvement, because development induced by a transit project will happen gradually over time. However, as years pass many changes as measured by Land Use/Transportation Coordination measures may become less pronounced over time. Therefore, it is important to evaluate Land Use/Transportation Coordination measures on a continuous basis, using multiple data points from several years before the project and for as many years after the project as data are available.

Analysis Steps

Population and Employment Density

Inputs:

- Population in census tracts or block groups, if available within ¼ mile of project limits, from periods before and after implementation of the transit expansion project. *Use U.S. Census Bureau's American Community Survey (ACS) 5-year Estimates for a rolling* *annual estimate of census-tract-level population data. Note that the Census Bureau cautions against comparing ACS data from overlapping time periods. ACS is mainly intended to be used for population characteristics, not population totals, especially at smaller geographies (e.g., Census tracts).*

- Employment in census tracts within ¼ mile of project limits, from periods before and after implementation. *Use U.S. Census Bureau's Longitudinal Employer-Household Dynamics (LEHD) data.*
- Area of census tracts within ¼ mile of project limits, in miles, from U.S. Census Bureau's Topologically Integrated Geographic Encoding and Referencing (TIGER) system. *Note that census tract boundaries may change over time, particularly when a new decennial Census is undertaken. It is important to use areas that are as identical as possible for the before and after comparison.*

<u>Calculation:</u>

- Use GIS to aggregate population in census tracts within ¼ mile of project limits and divide by aggregate area of those tracts. Calculate population density for periods before implementation and period after implementation.
- Use U.S. Census Bureau's Longitudinal Employer-Household Dynamics online mapping tool, called "OntheMap", to aggregate employment in census tracts within ¼ mile of project limits and divide by aggregate area of those tracts. Calculate employment density for periods before implementation and after implementation.
- *The net change in population and employment density cannot be calculated, but a qualitative analysis of the circumstances before and after implementation of the project may provide clues to whether any changes in population and employment density can be attributable to the project. For example, similar to the net new ridership calculation above, population and employment density in the study area can be compared to a "control" area that had conditions similar to the study area before implementation.*

<u>Output:</u>

- **Population density**, in persons per square mile.
- **Employment density**, in jobs per square mile.

<u>Additional resources on population and employment density include the following:</u>

- U.S. Census Bureau Longitudinal Employer-Household Dynamics website, http://lehd.did.census.gov/led/.
- U.S. Census Bureau's Topologically Integrated Geographic Encoding and Referencing (TIGER) system website, http://www.census.gov/geo/www/tiger/index.html.

Per Capita Vehicle Miles Traveled

Inputs:

- Net regionwide vehicle miles of travel attributable to the project.
- Regional population data from before and after implementation.

Calculation:

- Divide regionwide vehicle miles of travel before construction by population before construction, perform the same calculation for the period after construction, and subtract the two values to calculate an estimate of net change in per capita vehicle miles traveled.

Output:

- **Per capita vehicle miles traveled.** *VMT per capita in the NJTPA region is around 2.9 miles per capita according to recent survey results.*

Recommendations for Future Performance Evaluation: Land Use/Transportation Coordination Measures

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).

3.6.5 Evaluating Repair/Maintenance/Safety/Security Measures

NJTPA Repair/Maintain/Safety/Security Goal - Maintain a safe and reliable transportation system in a state of good repair.

Only safety and security measures are discussed in this section. See Roadway and Bridge Preservation sections of this guidebook for evaluation using Repair and Maintenance-related measures.

Interdependencies between Data, Analysis Tools, and Performance Measures

All data used in the analysis of the safety performance measures are drawn from crash databases (e.g., NJ Transit, PATH, and other operator safety records). Therefore, for safety measures, there are no interdependencies with previous analyses.

Evaluation of security measures related to resiliency and redundancy use the results of network connectivity and continuity calculations performed under the System Coordination goal area.

Data Inputs and Sources

Primary data inputs to the analysis include the following:

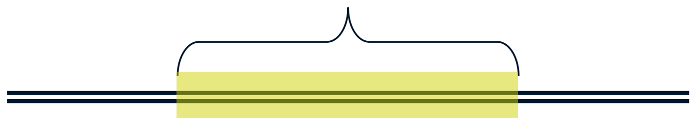
Data Inputs	**Sources**
Crash records	Exclusive guideway transit facilities: NJ Transit, PATH, or other operator safety records Transit services operated on roadways: NJDOT Crash Records Database; Plan4Safety; NJTPA Safety Management System data
Information on measures taken to prevent or protect against incidents, incursions, attacks, and illicit activity	Facility owner or operator: construction documents and as-built drawings.
Availability of alternate routes	NJ Transit
Daily ridership, Link capacity (passengers per day), and Volume-to-capacity ratio	Transit service operator
Facilities that are a designated component of an emergency evacuation plan	Transit service operator
Planning and traffic studies to identify critical assets and future needs for project development in the study area	State and local governments; NJTPA needs assessments
Network Connectivity and Continuity results	Calculated using methodologies specified in System Coordination goal area
Extent and redundancy of technology and systems available to provide information to system operators and users.	Facility owner or operator: construction documents and as-built drawings

Geographic Scale of Analysis

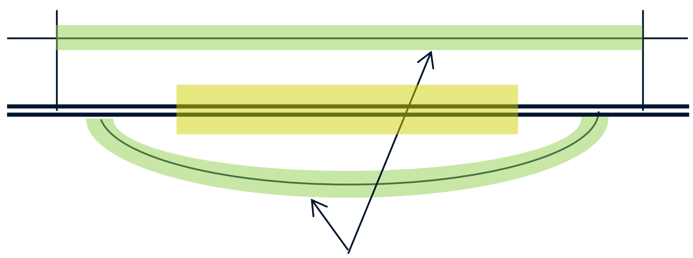
Both safety and security measures should be evaluated within the project limits. In the case of a project that is expected to generate significant diversions of auto traffic (in the case of safety improvements) or accommodate significant diversions of auto travel (in the case of system redundancy projects undertaken for security reasons), the analysis area for safety and security measures may be expanded to a corridor encompassing multiple facilities, to a county, or to the entire NJTPA region.

Analyze data within project limits

CASE 1:
TRANSIT CAPACITY EXPANSION OR SERVICE IMPROVEMENT
with little or no traffic diversion expected



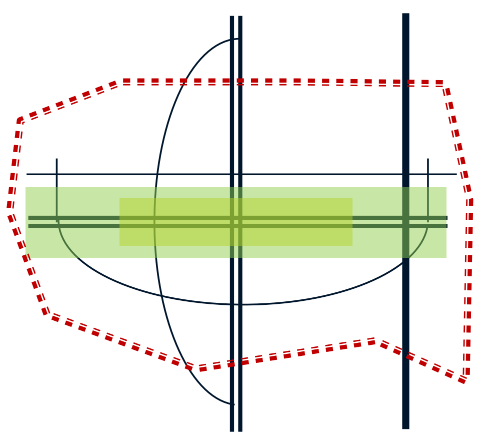
CASE 2:
TRANSIT CAPACITY EXPANSION OR SERVICE IMPROVEMENT
with traffic diversion

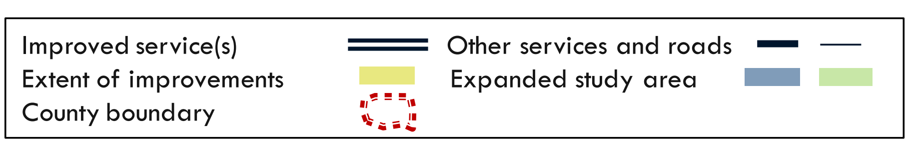


…on parallel route(s) and mode(s) within 5 miles that may have been used as alternate(s) or bypass(es). Some impacts of the project may accrue to parallel facilities and modes that saw increases or reductions in traffic.

ALL CASES:
Corridor, Region, and Service Area Comparison

- Compare to data for the entire corridor/route in which the project is located (green).
- Compare to data in the county in which the project is located (red).
- Also compare to entire NJ Transit service area





Time Frame of Analysis

The project-specific impacts of transit projects as measured in terms of safety measures are likely to be most pronounced shortly after completion of the improvement. Therefore, it is important to evaluate these measures using multiple data points from several years before the project, during the construction phase (if any), and for as many years after the project as data are available. Security measures, which tend to be discrete improvements whose benefits do not accumulate or diminish over time, should be analyzed for one year before and after implementation of the project. For example, construction of a security fence along a new transit right of way to prevent unauthorized access would have a one-time benefit to security along that transit segment; therefore, conditions for the year before construction can simply be compared to conditions in the year following completion of the project.

Analysis Steps

Intermediate Measures and Analysis Tools

1. Assign a "criticality" index to infrastructure and services in the study area.

   <u>Inputs:</u> (required for each link in the transit network).

   - Facility/service type (exclusive guideway, shared lanes, shared tracks);
   - Whether or not alternate routes are available (same or higher functional class/lower functional class/no alternate route);
   - Ridership data (passengers per day), link capacity (passengers per day), and volume-to-capacity ratio, to help establish which facilities and services carry the greatest absolute volumes and which facilities and services have the ability to absorb excess volumes;
   - Whether or not the facility is a designated component of an emergency evacuation plan (yes/no); and
   - Plans and studies done in the study area to identify critical assets and future needs for project development.

   <u>Calculations</u>

   Calculate a composite criticality score or index for each facility or service. Several analysis tools are available to perform the calculation. For example, the New Jersey Department of Transportation has a license to the Disruption Impact Estimating Tool—Transportation (DIETT), which is a database and spreadsheet-based tool for prioritizing the criticality of transportation choke points.

   <u>Intermediate output measures:</u>

   - Criticality index or score for each facility and service in the network. Facilities should be grouped into broad categories like "most critical", "critical" and "not critical". *Note that this index must be guarded from the public due to the sensitive nature of the information.*

Crashes and Passenger Accidents

For transit services operated on exclusive guideways: Compare before-and-after NJ Transit, PATH, or other operator safety data to determine safety impact of the project. Compare project-specific data to systemwide statistics for an indication of how much of the change in crashes and passenger incidents was attributable to the project.

For transit services operated on roadways: Inputs:

- Facility-specific crash and passenger incident data, preferably with indication about whether a transit vehicle or transit passenger was involved.
- Regional, county-level, and corridor-level aggregate safety statistics.

Calculations:

- Compare project-level changes in absolute number of crashes and passenger incidents to estimates of regional, county-level, and/or corridor level changes in absolute number of crashes as an estimate of what may have happened in the absence of the project. If the project was anticipated to result in significant diversions of traffic to or from other roadways, compile data on absolute numbers of crashes on alternate within 5 miles of the improved roadway that could reasonably be expected to accommodate bypass traffic.
- *There may be significant problems with crash data, including inaccurate reporting of crash locations and crash categorizations that would prevent any project-level analysis from being trustworthy. Quality of crash data is only as good as the people who input the data to the system. Extreme caution should be used in drawing any conclusions from before-and-after analyses of transit and highway safety data.*

Outputs:

- Absolute number of **crashes and passenger incidents** occurred before and after construction.

Crash and Incident Rate

For transit services operated on exclusive guideways: Divide number of incidents or crashes by passenger miles or transit revenue vehicle miles to determine crash rate.

For transit services operated on roadways: Inputs:

- Absolute number of crashes occurred before and after construction.
- VMT data at regional, county, and local level.
- Regional, county-level, and corridor-level aggregate crash rates.

Calculations:

- Divide crashes by VMT in the study area to calculate crash rate in terms of VMT.
- Compare project-level changes in absolute number of crashes to estimates of regional, county-level, and/or corridor level changes in absolute number of crashes as an estimate of what may have happened in the absence of the project.

- The net increase or decrease in crash rate attributable to the project can be estimated by subtracting the regional, county-level, or corridor-level crash rate from the observed crash rate after project completion.

Outputs:

- **Crash and incident rate**, in crashes per million vehicle miles traveled or incidents per million trips.

Transportation Resiliency

Transportation resiliency is a term that describes the ability of the transportation system to adapt and respond to incidents and disruptions. Transportation resiliency applies to natural threats, such as hurricane storm surges and floods, as well as man-made threats such as terrorist attacks. According to NCHRP Report 525, "Incorporating Security into the Transportation Planning Process", four major categories of security incident countermeasures exist to address threats and vulnerabilities to the nation's transportation infrastructure. These four categories include prevention, protection, redundancy, and recovery. These four measures apply more broadly than security. For example, climate change adaptation strategies often are grouped into similar categories.

Below, the categories "prevention" and "protection" are discussed together below because they both refer to proactive, preventative measures taken in advance of an attack or unauthorized access. Their results are measured in terms of the extent of the system's critical services or pieces of infrastructure from being damaged, destroyed, or used for illicit purposes. Projects addressing "redundancy" and "recovery" address the operations of the system after a major disruption occurs. Their results are measured in terms of how well the system operates (or would operate) after a major disruption.

Inputs: Prevention and Protection

- Measures taken to *prevent or discourage* unauthorized access to a transportation facility or a specific sensitive feature of a transportation facility like a bridge or equipment room, before and after construction; measures taken to prevent or discourage illicit activity in or near a transportation facility; measures taken to prevent or discourage direct and indirect attacks on a facility; and measures taken to protect against the impacts of natural events like extreme weather events. *Examples cited in NCHRP Report 525 include access control systems like fences and locked doors, highly visible closed circuit television (CCTV) systems, and intrusion detection systems such as alarmed entrances and fence-line detection systems. The design of the facility is also important, for example, allowing for open sight lines into a park-and-ride lot from nearby roadways and development, adding lighting to a pedestrian pathway, hardening a facility to prevent physical incursions and/or increase blast resilience, or building a levee and pumping system to protect a roadway from flooding.*
- Criticality index of the facility or service. *Calculated above in intermediate measures and analysis.*

Evaluation: Prevention and Protection

- Measure the mileage of transit facilities with prevention and protection measures in place (per Federal, state, and local design guidelines) before and after the project is completed.

Outputs: Prevention and Protection

- Share of most critical assets hardened against unauthorized access, illicit activity, attacks, and/or natural events. The definition of "most critical assets" must be defined in the process for assigning a criticality score above.

Inputs: Redundancy and Recovery

- Results of **Network Connectivity and Continuity** calculations, using the process defined in the System Coordination goal area. *For purposes of this analysis, connectivity calculations should be performed for the subset of the system consisting of critical and/or most critical assets, as defined in the intermediate measure above.*
- Extent and redundancy of technology and systems available to provide information to system operators and users.

Evaluation: Redundancy and Recovery

- Using results of before-and-after network connectivity analysis, determine extent to which the project improves connectivity in the designated evacuation route system. *As described in the System Coordination goal area, system connectivity can be defined in terms of several indices and measures. The evaluation here should assess the change that the Transit Expansion project would cause in these indices or measures.*
- Qualitatively compare the extent of information technology available to provide information to system operators and to users during an emergency, system failure, or system disruption, before and after project implementation.

Outputs: Redundancy and Recovery

- Change in System Connectivity for the region's critical and/or most critical transportation assets. *For example, the beta index could change from 1.1 to 1.2 as a result of the project, indicating greater network connectivity and availability of alternative routes in case of a disruption or blockage.*
- Extent to which communication systems are deployed in a redundant fashion to ensure information is available to system operators and users in an emergency, system failure, or system disruption. *For example, "The project provided a diesel generator to power a backup communication system in case of a power failure concurrent with the event or disruption."*

Recommendations for Future Performance Evaluation: Repair/Maintenance/Safety/Security Measures

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 for purposes of transportation security, climate change adaptation, and related uses. NJ TRANSIT, PATH and other transit operators in cooperation with Federal and local governments and other state agencies, have performed an assessment of critical transportation infrastructure. NJ TRANSIT, PATH and other transit operators should continue to work with the 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).

3.6.6 Evaluating Economy Measures

NJTPA Economy Goal - Retain and increase economic activity and competitiveness.

Interdependencies between Data, Analysis Tools, and Performance Measures

The following diagram is a simplification of the interdependencies between Economy measures and the intermediate and ultimate measures discussed in the System Coordination and User Responsiveness sections. No intermediate measures or analysis tools were used in the analysis.

Data Inputs and Sources

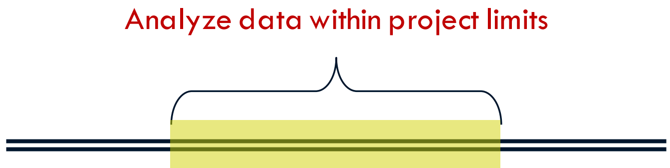
Primary data inputs to the analysis include the following:

Data Inputs	Sources
Estimated "build" and "no-build" travel times by link	Intermediate measure calculated in **System Coordination**; see methodology above
Average value of time	NJTPA Regional Household Travel Survey; NJRTM-E
Net VMT change	Intermediate measure calculated in **User Responsiveness**; see methodology above
Operating costs per passenger vehicle mile	FHWA and NJTPA survey data
Transit vehicle operating cost data	NJ Transit
Net crashes by severity	Output measure of **Repair/Maintenance/Safety/ Security** goal area; see above
Cost per crash, by severity	Exclusive guideways: NJ Transit data Transit services operated on roadways: NJ Transit data and NJDOT and National Highway Traffic Safety Administration (NHTSA)

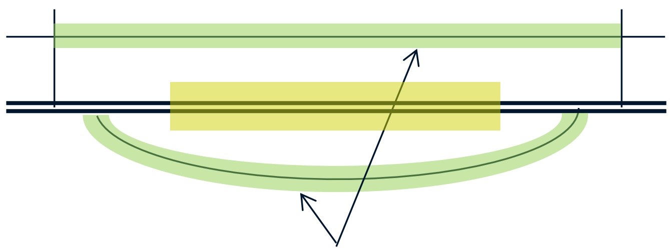
Geographic Scale of Analysis

All measures in the Economy goal area should be evaluated within the project limits. In the case of a project that is expected to generate significant diversions of auto traffic, the analysis area may be expanded to a corridor encompassing multiple facilities, to a county, or to the entire NJTPA region.

CASE 1:
TRANSIT CAPACITY EXPANSION OR SERVICE IMPROVEMENT
with little or no traffic diversion expected



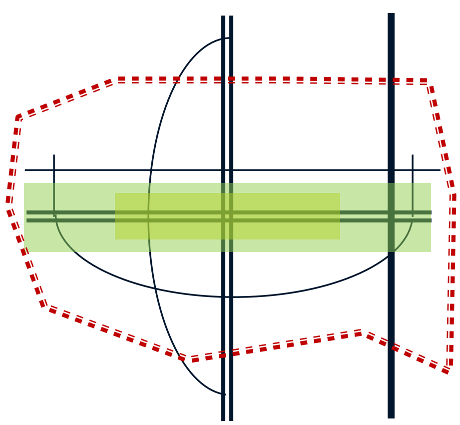
CASE 2:
TRANSIT CAPACITY EXPANSION OR SERVICE IMPROVEMENT
with traffic diversion



…on parallel route(s) and mode(s) within 5 miles that may have been used as alternate(s) or bypass(es). Some impacts of the project may accrue to parallel facilities and modes that saw increases or reductions in traffic.

ALL CASES:
Corridor, Region, and Service Area Comparison

- Compare to data for the entire corridor/route in which the project is located (green).
- Compare to data in the county in which the project is located (red).
- Also compare to entire NJ Transit service area



Improved service(s) — Other services and roads
Extent of improvements — Expanded study area
County boundary

Time Frame of Analysis

The impacts of transit projects as measured in terms of Economy measures may be small or may not be measurable at all shortly after completion of the improvement, because development induced by a transit project will happen gradually over time. However, as years pass many changes as measured by Economy measures may become less pronounced over time. Therefore, it is important to evaluate Economy measures on a continuous basis, using multiple data points from several years before the project and for as many years after the project as data are available.

Analysis Steps

Transportation Costs

Transit-related costs can be quantified in terms of change in monetized travel time costs, change in vehicle operating costs, and change in accident-related costs.

Inputs:

- Estimated "build" and "no-build" travel times between key stations, in minutes. *Include wait time, transfer time, and in-vehicle time.*
- Average value of time for transit passengers, in dollars per minute. *Include wait time, transfer time, and in-vehicle time.*

Calculation:

- Multiply change in travel time by average value of time for users of the facility.

Outputs:

- **Change in travel time costs** associated with the project. *An example is shown in the following table:*

Table 3.6-A: Summary of Estimated Daily Travel Time Savings for illustration purpose only

	Net Change
Daily Person Hours of Travel	-2,000
Value of Time (in 2009 dollars)	$21.00
Estimated Travel Time Savings (Daily)	-$42,000

Inputs:

- Average transit service operating costs, in dollars, before and after project implementation. *For example, a track improvement project that increases train speeds may reduce operating costs on a line by reducing the need for slowing and acceleration through a slow zone. The savings may be difficult to measure on a per-train basis, but over the course of a year the reduced maintenance costs may be evident.*
- Revenue service hours for affected services, before and after project implementation.

Calculation:

- Divide net change in transit operating costs by revenue service hours before and after project implementation.

Outputs:

- **Net change in transit operating costs per revenue service hour** associated with the project. *An example is shown in the following table:*

Table 3.5-B: Sample of Estimated Net Transit Operating Cost Savings
(NOTE: Contains fictional data for illustration purposes only)

	Before	After	Net Change
Estimated Annual Transit Operating Costs (2009 dollars per year)	$600,000	$550,000	$50,000
Revenue service hours	6,000	5,900	100
Estimated Transit Operating Costs per Revenue Service Hour (2009 dollars)	$100.00	$93.22	-$6.78

Inputs:

- Net change in crashes and accidents associated with the project, by severity.
- Average cost of crashes and accidents, by severity.

Calculation:

- Multiply change in crashes and accidents by the average cost of crash and accident for each severity level.

Outputs:

Change in accident-related costs associated with the project. According to NJDOT data from 2009, the *average costs for accidents range from nearly $9,000 for a property-damage-only crash, to around $50,000 for an injury crash, to more than $2 million for a fatal crash. Accident cost savings due to major roadway expansion projects often range in the millions of dollars per year.*

Cost Effectiveness

Cost Effectiveness is independently processed.

Inputs:

- Project capital cost, in dollars.
- Net reduction in transit operating costs, in dollars per year.
- Performance measures from previous calculations (e.g., crashes, travel time savings, and emissions reduction).

Calculations:

- Divide the capital cost by any performance measure to calculate the dollar-weighted impacts of the project. *For example, a million-dollar project that reduces carbon emissions by 1,000 tons has a cost-effectiveness index of $1,000/ton. A project that reduces operating costs by $50,000 per year and reduces carbon emissions by 25 tons has a cost-effectiveness index of $2,000/ton/year.*

Outputs:

- **Cost Effectiveness***, expressed in dollars per unit of benefit per dollar (e.g., dollars per accident reduced; dollar per minute of travel time savings; dollars per ton of reduced carbon emissions).*

NOTE: While cost-effectiveness measures are constituents of a broader benefit-cost analysis approach, many cost-effectiveness measures are not additive. Therefore, extreme caution should be exercised in presenting and explaining results of a project-level cost-effectiveness analysis.

Recommendations for Future Performance Evaluation: Economy Measures

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.

Develop analysis tools and methodologies to calculate property value impacts. Research on the economic impacts of transit investments suggests that new and expanded transit services can have strong positive impacts on property values within ¼-½ mile of transit access points. However, conducting a hedonic price analysis or comparable analysis can be time and labor intensive due to the state of property records (some records are available electronically, others are not), the difficulty in isolating the impacts of the transportation system change from other broader economic impacts (such as changes in interest rates or changes in demand for housing), and the difficulty in finding comparable properties to use as "control" properties. Improved tools for accessing and analyzing property-related data and tools to conduct analyses of property value changes are needed to capture an important element of the economic impacts of transit investments.

3.7 Freight Rail Projects

Freight Rail Facilities: 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 be necessarily applicable to other freight-rail facilities improvements such as terminal and intermodal freight transfer facilities*.

Contents of This Section

Suggested Work Flow for Freight Rail Improvements

The following sequence of goal areas for this project category was developed specifically to enable an ordered evaluation of performance measures. This allowed calculations from earlier intermediate (and final) measures in one goal area to serve as inputs for measures in other goal areas:

1. System Coordination Measures
2. User Responsiveness Measures
3. Environment Measures
4. Repair/Maintenance/Safety/Security Measures
5. Economy Measures

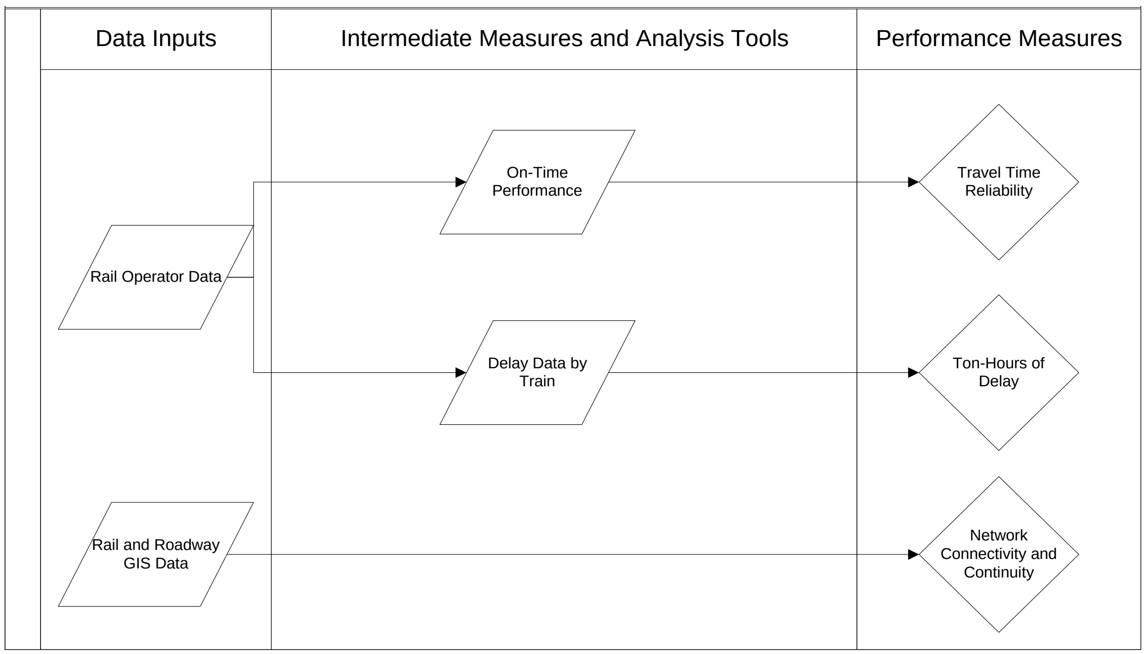
The methodology for calculating each measure is presented in the following sections. Measures in **BOLD** in the table above can be calculated independently. The remaining measures rely on interdependent data, or, in some cases, depend on each other.

3.7.1 Evaluating System Coordination Measures

NJTPA System Coordination Goal - Enhance system coordination, efficiency, and intermodal connectivity.

Interdependencies between Data, Analysis Tools, and Performance Measures

The following diagram is a simplification of the interdependencies between System Coordination measures for rail improvements oriented towards Freight traffic:



Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
On-time performance data	Rail operators
Rail network congestion and delay data	Rail operators
Rail GIS data	NJDOT; Oak Ridge National Laboratory Center for Transportation Analysis Rail Network
Roadway GIS data	NJDOT

Geographic Scale of Analysis

An analysis of System Coordination measures for freight rail projects requires that all affected rail segments be evaluated. Most rail investments affect long-distance rail traffic. Therefore, the appropriate scale of analysis is often an entire rail corridor or the entire NJTPA rail network.

Time Frame of Analysis

The impacts of freight-related rail projects as measured in terms of System Coordination measures are likely to be most pronounced shortly after completion of the improvement. However, as years pass and induced demand and general economic growth lead to traffic growth, many changes as measured by System Coordination measures may diminish over time. Therefore, it is important to evaluate System Coordination measures using multiple data points from several years before the project, during the construction phase, and for as many years after the project as data are available.

Analysis Steps

Travel Time Reliability; Ton-Hours of Delay

Travel time reliability, expressed in terms of train on-time performance, and delay data, expressed as ton-hours of delay, must be obtained from rail operators directly. Due to the competitive nature of the private rail industry, these data may not be available for publication. However, recent applications for Federal TIGER and TIGER II grants submitted by private rail operators did discuss potential benefits of rail investments in terms of freight reliability and delay.

Network Connectivity and Continuity

Inputs:

- Rail network information:
    - Density of nodes (intersections) and segments, in nodes per square mile and segments per square mile.
    - Locations of intermodal rail-to-truck transfer points.
- Roadway network information:
    - Connector roadways between rail-to-truck transfer points and National Highway System.
    - Connector roadways between National Highway System and major ports and other generators of rail freight.

Evaluation:

- For rail network improvements: Use GIS to evaluate connectivity of rail network before and after improvement, comparing the distance a truck would drive between two points compared to the freight rail distance between the same two points. *For example, if a truck can drive between two points in 50 miles and the corresponding rail distance is 70 miles, the ratio is 1.4. The closer the ratio is to 1.0, the more direct the route. Connectivity should be evaluated on a regional scale.*
- For rail access improvements: Use GIS to evaluate the distance between a rail-truck transfer facility and major ports and other generators of rail freight, in miles.
- Connectivity and continuity in the “no-build” condition are simply the conditions that existed before construction.
- Compare route directness analysis for “no-build’ and after conditions.

Recommendations for Future Performance Evaluation: System Coordination Measures

Use simulation models to improve estimates of network-level congestion and delay measures. The methodology presented above assumes rail impacts are expected to be limited to the immediate vicinity of the project. When the analysis involves many links in a network of rail lines, simulation models can be used to calculate all of the System Coordination performance measures on a network scale. Network simulation models have extensive data requirements (for example, they require detailed rail geometry data and operational data). However, network simulation models may produce more accurate estimates of travel speeds and delay when an improvement may lead to major shifts in traffic, for example from one track 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.

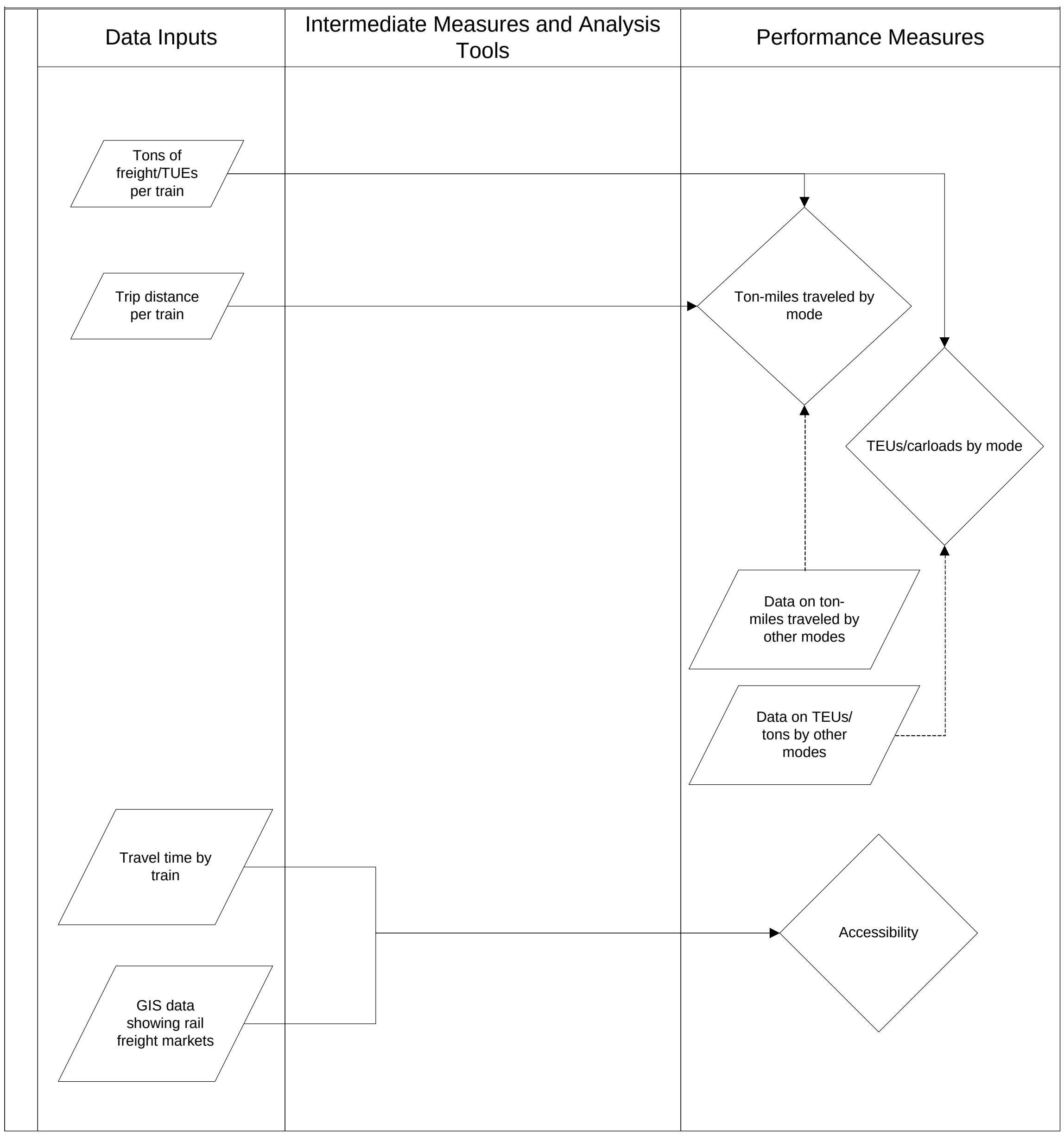
Use the upcoming NJTPA 2040 Freight Forecast Study as a data source for freight movement. The NJTPA 2040 Freight Industry Level Forecasts project will develop a clear, accurate, and comprehensive picture of regional freight activity, both current and future. The end product is to provide an accurate picture of where concentrations of goods movement activity can be expected to occur in the region in the future, the types of commodities that will be moving, and where strategic investments should be made.

3.7.2 Evaluating User Responsiveness Measures

NJTPA User Responsiveness Goal - Provide affordable, accessible, and dynamic transportation systems responsive to current and future customers.

Interdependencies between Data, Analysis Tools, and Performance Measures

The following diagram is a simplification of the interdependencies between User Responsiveness measures. *Note: Customer Satisfaction is independently evaluated and is not included in this diagram. For further information, see page 3.7-10.*



Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Tons of freight and TEUs per train	Commodity flow survey data and related databases (e.g., Transearch) or rail operator data. Note: The commodity flow data is estimated at regional system level which may not be suitable for use at local level. The use of number of trains or the length of the trains may be more appropriate based on data suitability.
Number of trains or the length of the trains	Rail operators
Trip distance per train	Rail Waybill data and rail operators
Travel time by train	Rail operators; can estimate by distance
GIS data showing locations of major regional trading partners (sources of raw materials and inputs; destinations for goods produced in the NJTPA region)	Commodity flow survey data (e.g., Transearch database)
Estimates of ton-miles traveled by other surface modes	Commodity flow survey data (e.g., Transearch database). Note: The commodity flow data is estimated at regional system level which may not be suitable for use at local level. The use of number of trains or the length of the trains may be more appropriate based on data suitability.

Geographic Scale of Analysis

The three User Responsiveness measures are best measured at a regional level or at a corridor level, grouping multiple facilities and modes together to determine the corridor-level or systemwide impacts of any given freight-related rail project.

Time Frame of Analysis

The impacts of freight-related rail projects as measured in terms of User Responsiveness measures may be small or may not be measurable at all shortly after completion of the improvement. However, as years pass many changes as measured by User Responsiveness measures may become more pronounced over time. Therefore, it is important to evaluate User Responsiveness measures on a continuous basis, using multiple data points from several years before the project and for as many years after the project as data are available.

Customer Satisfaction measures are an exception. The reaction to a freight rail project may peak shortly after project completion, but as time goes on, people may not be able to distinguish the project's impacts from other changes that have happened in the mean time (for example, other transportation improvements or economic shifts).

Analysis Steps

Ton-Miles of Travel by Mode or Number of Trains/Train Length by Mode(Mode Choice)

Inputs:

- Ton-miles traveled by rail (from commodity flow data or directly from rail operators) *Note: The commodity flow data is estimated at regional system level which may not be suitable for use at local level. The use of number of trains or the length of the trains may be more appropriate based on data suitability.*
- Estimates of net ton-miles traveled or number of trains/train length by other surface modes.

Analysis:

- Determine mode split before and after construction based on observations of ton-miles traveled or the number of trains/length of the trains by mode from commodity flow data and data directly from rail operators.

Outputs:

- **Net ton-miles of travel by mode or number of trains/length of the trains**

Tons/TEUs by Mode (Mode Choice) or Number of Trains

Inputs:

- Tons of freight per train or number of trains/length of the trains.
- Tons of freight or number of trains/length of the trains moved by other surface modes.

Analysis:

- Determine mode split before and after construction based on observations of ton-miles traveled by mode from commodity flow data and data directly from rail operators. *Note: The commodity flow data is estimated at regional system level which may not be suitable for use at local level. The use of number of trains or the length of the trains may be more appropriate based on data suitability.*

Outputs:

- **Tons and TEUs by mode. Or Number of Trains/Length of the trains.**

Accessibility

Accessibility is a measure of the ability of people to reach opportunities and activities that they undertake in their daily lives, or the ability of businesses to reach their labor force, sources of raw materials and inputs to their production facilities, and the consumer markets for their finished products.

Access to trading partners or **consumer market** refers to the ability of a business to reach consumer markets where their products are sold and sources of inputs and raw materials to their production facilities. Because the trading partners may be outside the NJTPA region, a proxy for trading partners can be county centroids across the U.S.

Inputs:

- Locations of key regional trading partners (Bureau of Economic Analysis data).
- Rail network GIS.

Calculations:

- For period before construction (average of three years) and period after construction (three-year moving average for all available years), calculate the travel time, in minutes, over the rail network between terminals end at Ports Elizabeth or Newark and state border crossings on the regional rail network. *For example, before an improvement, travel time may have been 120 minutes; after the improvement the travel time reduced to 100 minutes, saving 20 minutes per trip.*
- The change in access can be estimated by the difference in travel time before construction and the travel time after construction.

Customer Satisfaction

Customer Satisfaction is a measure that does not depend on inputs from any other performance measure. Customer Satisfaction measures can be obtained from the results of surveys performed by implementing agencies after completion of a project.

Inputs:

- Surveys of freight-rail system users, ideally including information about the relative importance of each system attribute being queried.
- Typical questions on freight-related rail customer satisfaction surveys include:
  - Customer perception of improvement's impacts across NJTPA goal areas: Built and natural environment, congestion, travel speed, access to destinations, safety, user cost or fee, economic impacts.
  - Project's impact on travel behavior: Whether the improvement caused mode shifts ("What was the previous mode used to make the trip?") and destination choice decisions (e.g., enabled a trip between and origin and a destination not previously accessible by rail).
  - Impacts of rail construction: Safety, congestion and delays, access to businesses, environmental impacts during construction.

Recommendations for Future Performance Evaluation: User Responsiveness Measures

Develop GIS tools 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.

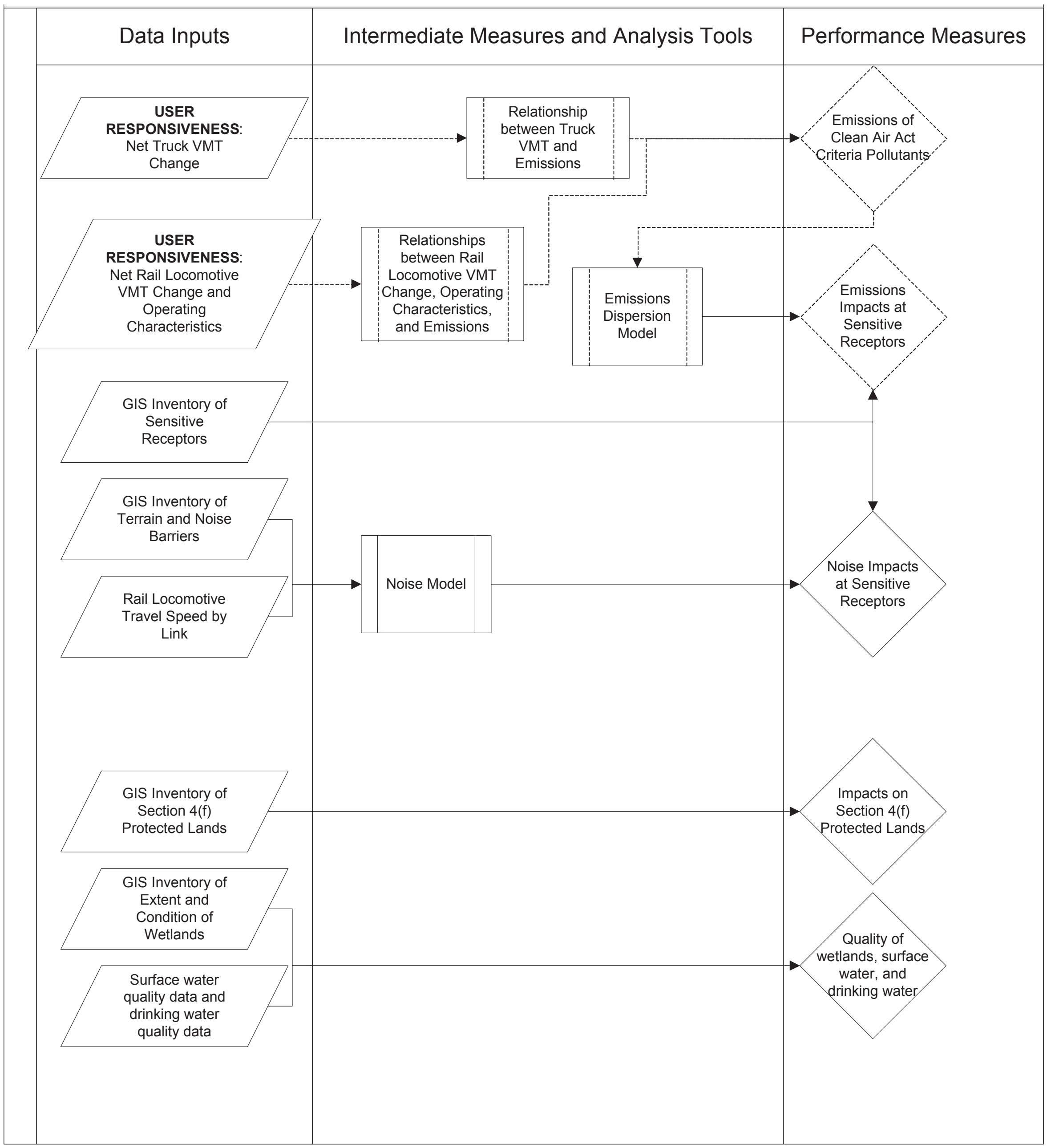
Undertake more customer satisfaction surveys for all modes on a regular basis. Agencies responsible for building, maintaining, and operating the transportation system in the region should undertake regular customer satisfaction surveys to collect a range of qualitative and quantitative data about customer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

3.7.3 Evaluating Environment Measures

NJTPA Environment Goal - Protect and improve the quality of natural ecosystems and human environment.

Interdependencies between Data, Analysis Tools, and Performance Measures

The following diagram is a simplification of the interdependencies between Environmental measures and the intermediate and ultimate measures discussed in the System Coordination and User Responsiveness sections. *Note: Visual aesthetics and context sensitivity is independently evaluated and is not included in this diagram.* For further information, see page 3.7-18.



Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Net Change in Truck VMT and Rail locomotive VMT due to improvement	Intermediate measure calculated in **User Responsiveness** for each respective mode; see methodology above
Emission Factors	NJ DEP for the latest and most appropriate emission factors
Rail locomotive operating characteristics (Speed and idling time are a function of terrain, track layout, horizontal curvature, presence of grade crossings, etc.)	Rail operators
GIS Inventory of Sensitive Receptors	NJDOT and NJDEP GIS; Google Maps and other commercial sources
GIS inventory of terrain and noise barriers	NJDOT and NJDEP GIS; NJDOT Straight Line Diagrams
Rail locomotive travel speeds by link	Rail operators
GIS inventory of Section 4(f) protected lands	NJDEP GIS Wildlife and waterfowl refuges: US Fish and Wildlife Service Historic properties: National Historic Geographic Information System (NHGIS), state historic preservation office (SHPO) and local historical commissions/societies
GIS Inventory of extent and condition of wetlands	NJDEP GIS; US Army Corp of Engineers
Surface and drinking water quality	NJDEP Division of Water Quality; NJDEP Bureau of Safe Drinking Water

Geographic Scale of Analysis

The geographic scale of analysis depends on the measure being assessed. The following table shows the recommended geographic scale of each measure.

Measure	Geographic Scale(s) of Analysis
Emissions of Clean Air Act criteria air pollutants and greenhouse gases	Air quality (AQ) data are collected at the facility level as well as at the regional scale. The regional and statewide travel demand models that are necessary to quantify emissions are based on this state and regional data collection. Transportation-related emissions, for example greenhouse gases, do not respect state and regional boundaries; therefore regional and statewide data are necessary. The Clean Air Act requires regional and project level hotspot analysis. Most non-attainment areas have on the ground monitoring units in set locations. These units are not typically moved to measure emissions for specific projects. Transportation emissions that lead to respiratory conditions and other health impacts should be estimated at sensitive receptors within ¼ mile of project limits.
Transportation-related noise and vibrations at sensitive receptors	Sensitive receptors within ¼ mile of project limits
Quality of wetlands, surface water, and drinking water	Primary/direct impacts (wetlands): Project limits Secondary/cumulative impacts: Project-specific as defined in NEPA Scoping document; could be several miles from project limits; use natural boundaries such as water sheds as study area boundaries
Impacts on Section 4(f) protected lands	Primary/direct impacts: Project limits Secondary/cumulative impacts: Project-specific as defined in NEPA Scoping document; could be several miles from project limits; use natural boundaries such as water sheds as study area boundaries
Visual aesthetics and context sensitivity	Project limits (project-specific design features); adjacent properties; neighborhoods and municipalities in which project is located; architectural and environmental features in view shed

Time Frame of Analysis

The ability to measure the net Environmental impacts of a project over time is directly dependent on the ability to measure net VMT impacts, net changes in truck and rail VMT, net impacts of a project on travel speeds, and net impacts on mode choice decisions. As the quality or reliability of these estimates deteriorates over time, so does the reliability of the results of an environmental impact assessment. Therefore, the time frame of analysis for Environment performance measures should mirror the time frames for System Coordination and User Responsiveness measures: measures should be on a continuous basis if possible, using multiple data points from several years before the project and for as many years after the project as data are available in order to draw valid conclusions about the net impacts of a project.

As indicated in the above graphic, the environmental impacts of rail projects are often measured at a regional scale. Therefore, the net impacts of any one project may be obscured over time by economic growth that generates additional travel demand (in turn affecting emissions and noise), by other development that increases impervious cover and impacts wetlands and water quality, or by changes in the region's socioeconomic and demographic profile that affect public health outcomes. On a project-by-project basis, professional judgment will be necessary to determine the limits of applying the following analysis.

Analysis Steps

Emissions of Criteria Pollutants

Inputs:

- Total change in truck and rail VMT attributable to project (intermediate output measure of **User Responsiveness** analysis for each respective mode).
- Relationship between truck and rail locomotive VMT and emissions (either qualitative or quantitative).

Analysis Tools:

- Apply emissions factor per truck VMT and rail locomotive VMT to calculate emissions by category. *If factors are unknown or if truck VMT and/or rail locomotive VMT estimates are not reliable, a quantitative analysis may not be possible. As an alternative, qualitatively describe whether emissions were likely to increase or decrease as a result of the project.*

Output measures:

- Estimated **change in emissions by criteria pollutant.**

Emissions Impacts at Sensitive Receptors

1. Generate emissions contour maps.

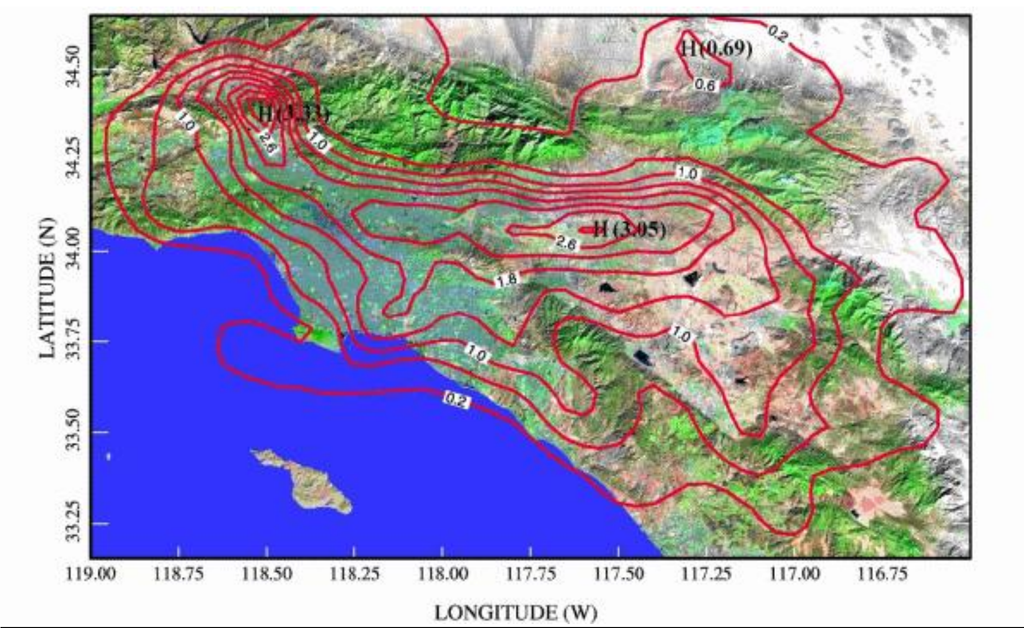
   Inputs:

   - Estimated change in emissions by criteria pollutant.
   - Baseline emissions estimates.
   - Geography-specific climate data (can use defaults built into model).

   Analysis Tools:

   - Use Emissions Dispersion model to allocate emissions to points or subregions in the analysis area. Conduct one run for baseline conditions and a second run for "build" condition.

Figure 3.7-A: Example map of daily emissions of soot in micrograms per cubic meter for Los Angeles Metropolitan Area:



   Outputs:

   - Emissions contour maps showing concentrations by criteria pollutant for baseline condition and for "build" condition.

2. Overlay sensitive receptor points on emissions contour maps.

   Inputs:

   - Emissions contour maps for baseline condition and "build" condition from dispersion model.
   - GIS layer of sensitive receptors in NJTPA region.

Calculations:

Net emissions impact at any given sensitive receptor is the difference between the build condition and the baseline condition. Repeat calculation for each sensitive receptor.

Outputs:

- **Estimated emissions impacts by sensitive receptor.** *For example, "Emissions of particulate matter (PM 2.5) increased from 1.2 micrograms per cubic meter to 1.8 micrograms per cubic meter as a result of the project."*

Noise and Vibration Impacts at Sensitive Receptors

Inputs:

- Average locomotive speed and volume, by link (intermediate output measures of **System Coordination** analysis).
- GIS inventory of terrain type.
- Location and extent of noise barriers (NJDEP GIS).
- GIS inventory of sensitive receptors.
- Archived data on noise levels at sensitive receptors at regional, county level, and/or corridor level.

Calculations:

- Use a Noise Model to generate noise contours and estimated impacts at sensitive receptors. To estimate net impacts, run one scenario with "build" conditions using most recent available data and a second "no-build" scenario with estimated "no-build" inputs. Repeat for each sensitive receptor.
- If enough data are available about changes in decibel levels at sensitive receptors over time, the project-specific impacts also can be compared to regional, county-level, or corridor-level average impacts over the same analysis period as another estimate of what may have happened in the absence of the project.

Outputs:

- **Net noise and vibration impacts at sensitive receptors, in decibels.** *For example, "The hourly equivalent sound level $L_{EQ}(h)$ increased from 60 dB to 75 dB as a result of the project."*

Impacts on Section 4(f) Protected Lands

Inputs:

- GIS inventory of Section 4(f) Protected Lands.

Calculations:

- Compare before and after conditions to determine direct impacts on Section 4(f) Protected Lands. Depending on NEPA scoping effort, may need to expand analysis area to take into account cumulative impacts of the project on Section 4(f) Protected Lands.
- Also compare "after" conditions in project analysis area to regional, county-level, or corridor-level estimates of change in extent of Section 4(f) protected lands over the same analysis period. The percent change in regional extent can be compared to the project-specific impact as one estimate of the net project-specific impact, compared to what would have happened in the project area due to non-transportation-related land consumption.

Outputs:

- Change in **extent and condition of Section 4(f) Protected Lands**. *For example, "5 acres of parks were directly taken for construction of the project and replaced in a 2-for-1 ratio in a new 10-acre park created adjacent to a nearby school."*

Impacts on Wetlands, Surface Water Quality, and Drinking Water Quality

Inputs:

- GIS inventory of wetland extent and condition.
- Surface water quality data within project limits and downstream of project.
- Drinking water quality data within project limits and downstream of project.

Calculations:

- Compare before and after conditions to determine direct impacts on wetlands, surface water quality, and drinking water quality.
- Depending on contents of NEPA scoping effort (if available), may need to expand analysis area to take into account cumulative impacts of the project on wetlands, surface water quality, and drinking water quality. Study area should be consistent with what was used in the original environmental assessment.
- Also compare "after" conditions in project analysis area to regional, county-level, or corridor-level estimates of change in extent of wetlands, and change in condition of wetlands and water quality over the same analysis period. The percent change in regional extent can be compared to the project-specific impact as one estimate of the net project-specific impact, compared to what would have happened in the project area due to non-transportation-related land consumption and runoff.

Outputs:

- Change in **extent and condition of wetlands.** *For example, "20 acres of wetlands were directly taken for construction of the project and replaced in a 2-for-1 ratio in a wetlands mitigation bank maintained by NJDOT in the watershed."*
- Change in **condition of surface water quality and drinking water quality**. *[To be defined in discussions with NJDEP.]*

Visual Aesthetics and Context Sensitivity

Inputs:

- Project purpose and need statement or project description from planning documents, funding applications, etc.
- Photos and project descriptions after project completion.
- Local comprehensive plans and other relevant planning documents for the area in which the project was constructed.
- List of commitments to stakeholders that was developed and maintained during planning and design and/or was incorporated into construction documents prior to beginning construction.
- Results of post-construction surveys of project team members from the implementing agency and consultants.
- Results of post-construction surveys of community stakeholders (residents and businesses) and regulatory agency staff.

Calculations:

Conduct surveys using the following criteria[1]. Score one point for each criterion if 67% or more of implementing agency staff (and/or the agency's project consultants) surveyed respond "yes"; score one additional point for each criterion if 67% or more of community stakeholders and regulatory agency staff surveys respond "yes". Maximum 12 points.

1. The executed project meets the goals and objectives identified in the original purpose and need statement.
2. The project was designed and implemented in a manner that is consistent with local comprehensive plans, the Americans with Disabilities Act, and other relevant planning documents.
3. The implemented project meets or exceeds a list of commitments to stakeholders that was developed and maintained during planning and design, was incorporated into construction documents prior to beginning construction, and is monitored during construction and operation of the completed project.
4. *(If the project is located in a developed area)* Architectural elements were incorporated into the design of the project to make users of all modes feel comfortable and welcome. These elements include, but are not limited to: wayfinding signage for users of all modes for which the facility is designed (including freight and non-motorized users); signage clearly indicating access points to transit services (including park-and-ride lots, bus stops, and fixed guideway transit stations); signage clearly indicating access points and amenities for bicyclists and pedestrians (including signage indicating nearby alternate routes if non-motorized users are prohibited from using the facility); a physical barrier between non-

[1] Adapted from project-level evaluation criteria listed in NCHRP Web-Only Document 69: *Performance Measures for Context Sensitive Solutions- A Guidebook for State DOTs*

motorized traffic (bicyclists and pedestrians) and vehicles or, if a physical barrier was not possible, a defined pavement marking separation; adequate lighting for evening and nighttime use by motorized and non-motorized users; an open view shed into public spaces for people passing by and security officers; and amenities such as artwork and landscaping to enhance the surrounding built and natural environment.

(If the project is located in an undeveloped area) Environmental resources, scenic and historic resources, and aesthetic values, such as architectural styles and landscaping that complement the surrounding environmental, have been maintained or enhanced by the project as completed.

5. Nearby residents and representatives of nearby institutions, schools, and business associations are directly or indirectly (e.g., via an advisory council) involved in the ongoing maintenance and operations of the facility or service.
6. Based on surveys of area residents and businesses, the project appears to have been implemented in a manner that will result in increased economic activity, such as new commercial or residential activity, and it appears to have the potential to create a positive neighborhood impact.

Outputs:

- Qualitative assessment of the degree to which a project improved or detracted from the **visual aesthetics of the built environment**.

Recommendations for Future Performance Evaluation: Environment Measures

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. 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. 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 costs would be incurred if it is discovered that mitigation measures are not successful and additional actions must be undertaken. Monitoring activities, data collection, data clean up, and database maintenance are also time consuming. Agencies are hesitant to encourage monitoring and reporting for political reasons as well. 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 (CEs) 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 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 the 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. 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 project 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 opportunity 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.

3.7.4 Evaluating Repair/Maintenance/Safety/Security Measures

NJTPA Repair/Maintain/Safety/Security Goal - Maintain a safe and reliable transportation system in a state of good repair.

Only safety and security measures are discussed in this section. See Roadway and Bridge Preservation project type for evaluation of Repair and Maintenance-related measures.

Interdependencies between Data, Analysis Tools, and Performance Measures

All data used in the analysis of safety performance measures are drawn from crash databases (e.g., NJDOT Crash Records Database, NJTPA Safety Management System, Plan4Safety), and NJDOT asset management systems. Therefore, for safety measures, there are no interdependencies with previous analyses.

Evaluation of security measures related to resiliency and redundancy use the results of network connectivity and continuity calculations performed under the System Coordination goal area.

Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Crash records at rail grade crossings	NJDOT Crash Records Database; NJDOT Plan4Safety; NJTPA Safety Management System data
VMT data at regional, county, and local level	NJDOT Public Roadway Mileage and Vehicle Miles Traveled, from Highway Performance Monitoring System (HPMS) data
Rail operator safety data	Rail operators
Information on measures taken to prevent or protect against incidents, incursions, attacks, and illicit activity	Facility owner or operator: construction documents and as-built drawings.
Availability of alternate routes	Rail GIS
Daily train traffic, Link capacity (trains per day), and Volume-to-capacity ratio	Rail service operator
Planning studies to identify critical assets and future needs for project development in the study area	State and local governments; NJTPA needs assessments
Network Connectivity and Continuity results	Calculated using methodologies specified in System Coordination goal area
Extent and redundancy of technology and systems available to provide information to system operators and users	Facility owner or operator: construction documents and as-built drawings

Geographic Scale of Analysis

All measures in the Repair/Maintenance/Safety/Security goal area should be evaluated within the project limits. In the case of a project that is expected to generate significant diversions of truck travel, the analysis area may be expanded to a corridor encompassing multiple facilities, to a county, or to the entire NJTPA region. Only safety and security measures are discussed in this section.

Time Frame of Analysis

The project-specific impacts of freight rail projects as measured in terms of Repair/Maintenance/Safety/Security measures are likely to be most pronounced shortly after completion of the improvement. Therefore, it is important to evaluate these measures using multiple data points from several years before the project, during the construction phase, and for as many years after the project as data are available.

Analysis Steps

Intermediate Measures and Analysis Tools

1. Assign a "criticality" index to infrastructure and services in the study area.

   Inputs: (required for each link in the rail network)

   - Facility/service type (Class I or Class III);
   - Whether or not alternate routes are available;
   - Traffic data (trains per day), link capacity (trains per day), and volume-to-capacity ratio, to help establish which facilities and services carry the greatest absolute volumes and which facilities and services have the ability to absorb excess volumes; and
   - Plans and studies done in the study area to identify critical assets and future needs for project development.

   Calculations

   Calculate a composite criticality score or index for each facility.

   Intermediate output measures:

   - Criticality index or score for each facility and service in the network. Facilities should be grouped into broad categories like "most critical", "critical" and "not critical". *Note that this index must be guarded from the public due to the sensitive nature of the information.*

Crashes and Incidents

Inputs:

- Crash data for railroad grade crossings. *For example, the number of crashes for fatality, pedestrian, bicycle, injury, and property-damage-only crashes per year at railroad grade crossings.*

- Safety data for rail facilities. *For example, worker and equipment-related incidents per million vehicle miles.*
- Regional, county-level, and corridor-level aggregate safety statistics.

Calculations:

- Compare project-level changes in absolute number of grade crossing crashes to estimates of regional, county-level, and/or corridor level changes in absolute number of grade crossing crashes as an estimate of what may have happened in the absence of the project. If the project was anticipated to result in significant diversions of traffic to or from other roadways, compile data on absolute numbers of grade crossing crashes on alternate within 5 miles of the improved roadway that could reasonably be expected to accommodate bypass traffic.
- Use operator-provided safety data to determine before-and-after changes in safety of rail operations.

Outputs:

- Absolute number of **crashes and incidents** occurred before and after construction.

Crash Rate

Inputs:

- Absolute number of crashes occurred before and after construction.
- VMT data at regional, county, and local level.
- Regional, county-level, and corridor-level aggregate crash rates.

Calculations:

- Divide grade crossing crashes by VMT in the study area to calculate crash rate in terms of VMT. Also can use AADT on the roadway to normalize grade crossing incident data.
- Compare project-level changes in absolute number of grade crossing crashes to estimates of regional, county-level, and/or corridor level changes in absolute number of grade crossing crashes as an estimate of what may have happened in the absence of the project.
- The net increase or decrease in crash rate attributable to the project can be estimated by subtracting the regional, county-level, or corridor-level crash rate from the observed crash rate after project completion.

Outputs:

- **Crash rate**

Transportation Resiliency

Transportation resiliency is a term that describes the ability of the transportation system to adapt and respond to incidents and disruptions. Transportation resiliency applies to natural threats, such as hurricane storm surges and floods, as well as man-made threats such as terrorist attacks. According to NCHRP Report 525, "Incorporating Security into the Transportation Planning Process", four major categories of security incident countermeasures exist to address threats and vulnerabilities to the nation's transportation infrastructure. These four categories include prevention, protection, redundancy, and recovery. These four measures apply more broadly than security. For example, climate change adaptation strategies often are grouped into similar categories.

Below, the categories "prevention" and "protection" are discussed together below because they both refer to proactive, preventative measures taken in advance of an attack or unauthorized access. Their results are measured in terms of the extent of the system's critical services or pieces of infrastructure from being damaged, destroyed, or used for illicit purposes. Projects addressing "redundancy" and "recovery" address the operations of the system after a major disruption occurs. Their results are measured in terms of how well the system operates (or would operate) after a major disruption.

Inputs: Prevention and Protection

- Measures taken to *prevent or discourage* unauthorized access to a transportation facility or a specific sensitive feature of a transportation facility like a bridge or equipment room, before and after construction; measures taken to prevent or discourage illicit activity in or near a transportation facility; measures taken to prevent or discourage direct and indirect attacks on a facility; and measures taken to protect against the impacts of natural events like extreme weather events. *Examples cited in NCHRP Report 525 include access control systems like fences and locked doors, highly visible closed circuit television (CCTV) systems, and intrusion detection systems such as alarmed entrances and fence-line detection systems. The design of the facility is also important, for example, allowing for open sight lines into a park-and-ride lot from nearby roadways and development, adding lighting to a pedestrian pathway, hardening a facility to prevent physical incursions and/or increase blast resilience, or building a levee and pumping system to protect a roadway from flooding.*
- Criticality index of the facility or service. *Calculated above in intermediate measures and analysis.*

Evaluation: Prevention and Protection

- Measure the mileage of rail facilities with prevention and protection measures in place (per Federal, state, and local design guidelines) before and after the project is completed.

Outputs: Prevention and Protection

- Share of most critical assets hardened against unauthorized access, illicit activity, attacks, and/or natural events. The definition of "most critical assets" must be defined in the process for assigning a criticality score above.

Inputs: Redundancy and Recovery

- Results of **Network Connectivity and Continuity** calculations, using the process defined in the System Coordination goal area. *For purposes of this analysis, connectivity calculations should be performed for the subset of the system consisting of critical and/or most critical assets, as defined in the intermediate measure above.*
- Extent and redundancy of technology and systems available to provide information to system operators and users.

Evaluation: Redundancy and Recovery

- Using results of before-and-after network connectivity analysis, determine extent to which the project improves connectivity in the designated evacuation route system. *As described in the System Coordination goal area, system connectivity can be defined in terms of several indices and measures. The evaluation here should assess the change that the freight rail project would cause in these indices or measures.*
- Qualitatively compare the extent of information technology available to provide information to system operators and to users during an emergency, system failure, or system disruption, before and after project implementation.

Outputs: Redundancy and Recovery

- Change in System Connectivity for the region's critical and/or most critical transportation assets. *For example, the beta index could change from 1.1 to 1.2 as a result of the project, indicating greater network connectivity and availability of alternative routes in case of a disruption or blockage.*
- Extent to which communication systems are deployed in a redundant fashion to ensure information is available to system operators and users in an emergency, system failure, or system disruption. *For example, "The project provided a diesel generator to power a backup communication system in case of a power failure concurrent with the event or disruption."*

Recommendations for Future Performance Evaluation: Repair/Maintenance/Safety/Security Measures

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 for purposes of transportation security, climate change adaptation, and related uses. Rail operators, in cooperation with Federal and local governments and other state agencies, have performed an assessment of critical transportation infrastructure.

NJDOT should continue to work with the 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).

3.7.5 Evaluating Economy Measures

NJTPA Economy Goal - Retain and increase economic activity and competitiveness.

Interdependencies between Data, Analysis Tools, and Performance Measures

All economic performance measures for freight rail projects are derived from proprietary or publicly-available data sets and do not depend on previous calculations.

Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Regional market share data	PIERS global trade data available from Port Authority of New York and New Jersey
Project capital cost	Project implementing agency
Net operating cost reduction	Project implementing agency or service operator

Geographic Scale of Analysis

The scale of the analysis is the entire NJTPA region.

Time Frame of Analysis

The impacts of freight rail projects as measured in terms of Economy measures may be small or may not be measurable at all shortly after completion of the improvement, because development induced by a rail project will happen gradually over time. However, as years pass many changes as measured by Economic measures may become less pronounced over time. Therefore, it is important to evaluate Economy measures on a continuous basis, using multiple data points from several years before the project and for as many years after the project as data are available.

Analysis Steps

Regional Market Share of Imports and Exports

Regional market share refers to the amount of freight imported and exported through the NJTPA region as a percentage of total freight imports and exports in the United States, the East Coast, or other geographic comparison. Compare market share data from before construction to data from after construction. It may be impossible to determine the extent to which a change in market share is attributable to a specific freight project.

Cost Effectiveness

Inputs:

- Project capital cost, in dollars.
- Net reduction in operating costs, in dollars per year.
- Performance measures from previous calculations (e.g., crashes, travel time savings, and emissions reduction).

Calculations:

- Divide the capital cost by any performance measure to calculate the dollar-weighted impacts of the project. *For example, a million-dollar project that reduces carbon emissions by 1,000 tons has a cost-effectiveness index of $1,000/ton. A project that reduces operating costs by $50,000 per year and reduces carbon emissions by 25 tons has a cost-effectiveness index of $2,000/ton/year.*

Outputs:

- **Cost Effectiveness***, expressed in dollars per unit of benefit per dollar (e.g., dollars per accident reduced; dollar per minute of travel time savings; dollars per ton of reduced carbon emissions).*

  NOTE: While cost-effectiveness measures are constituents of a broader benefit-cost analysis approach, many cost-effectiveness measures are not additive. Therefore, extreme caution should be exercised in presenting and explaining results of a project-level cost-effectiveness analysis.

Recommendations for Future Performance Evaluation: Economy Measures

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.

3.8 Freight Roadway Projects

Freight Roadway Facilities: Programs and projects that seek to enhance the availability, accessibility and safety of existing roadway facilities for truck traffic. These include improvements to existing roadway's turning radius, bridge or tunnel clearance, dedicated freight roads (e.g. Portway) and other similar projects.

Contents of This Section

Suggested Work Flow for Freight Roadway Projects

The following sequence of goal areas for this project category was developed specifically to enable an ordered evaluation of performance measures. This allowed calculations from earlier intermediate (and final) measures in one goal area to serve as inputs for measures in other goal areas:

1. System Coordination Measures
2. User Responsiveness Measures
3. Environment Measures
4. Land Use/Transportation Coordination Measures
5. Repair/Maintenance/Safety/Security Measures
6. Economy Measures

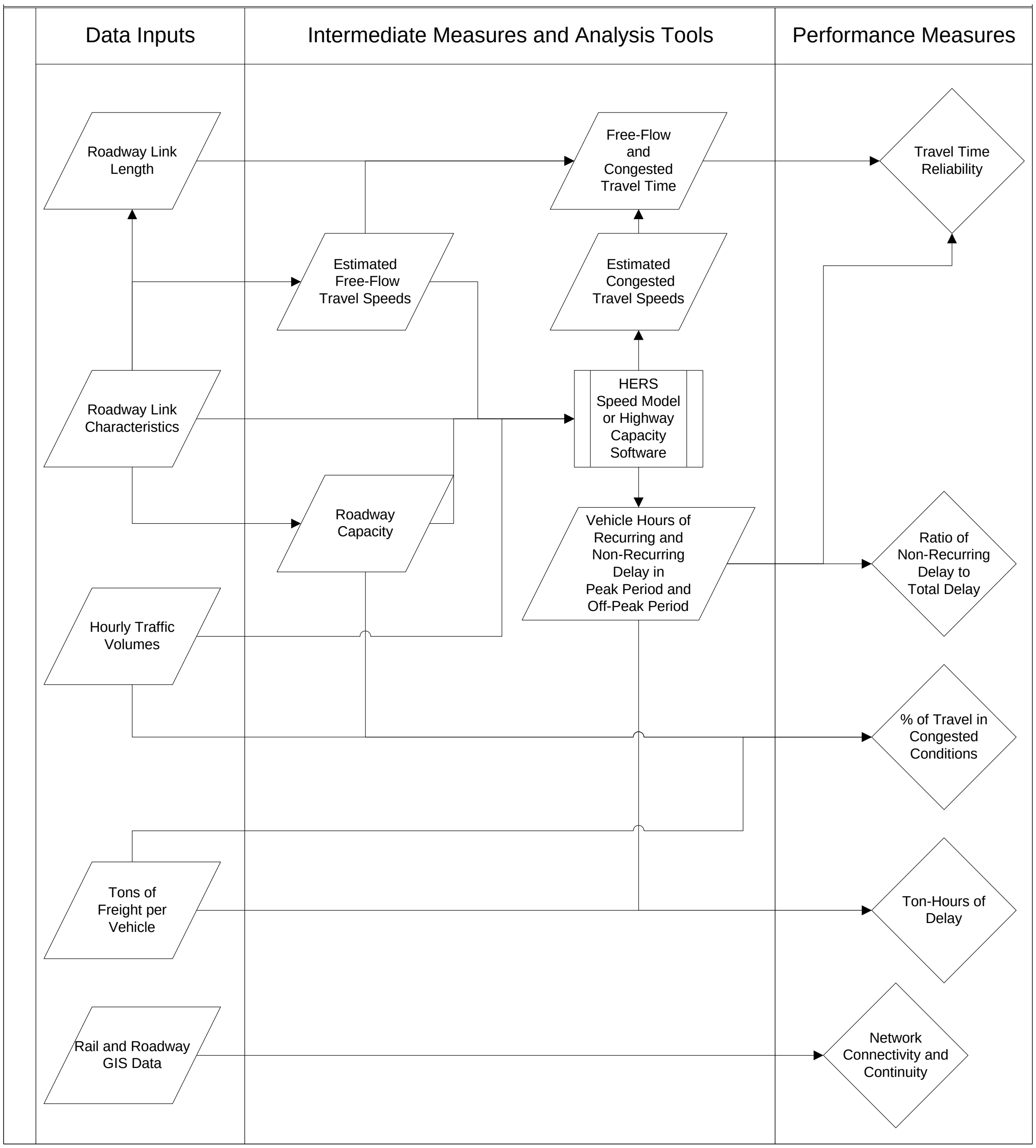
The methodology for calculating each measure is presented in the following sections. Measures in **BOLD** in the table above can be calculated independently. The remaining measures rely on interdependent data, or, in some cases, depend on each other.

3.8.1 Evaluating System Coordination Measures

NJTPA System Coordination Goal - Enhance system coordination, efficiency, and intermodal connectivity.

Interdependencies between Data, Analysis Tools, and Performance Measures

The following diagram is a simplification of the interdependencies between System Coordination measures for roadway improvements oriented towards Freight traffic:



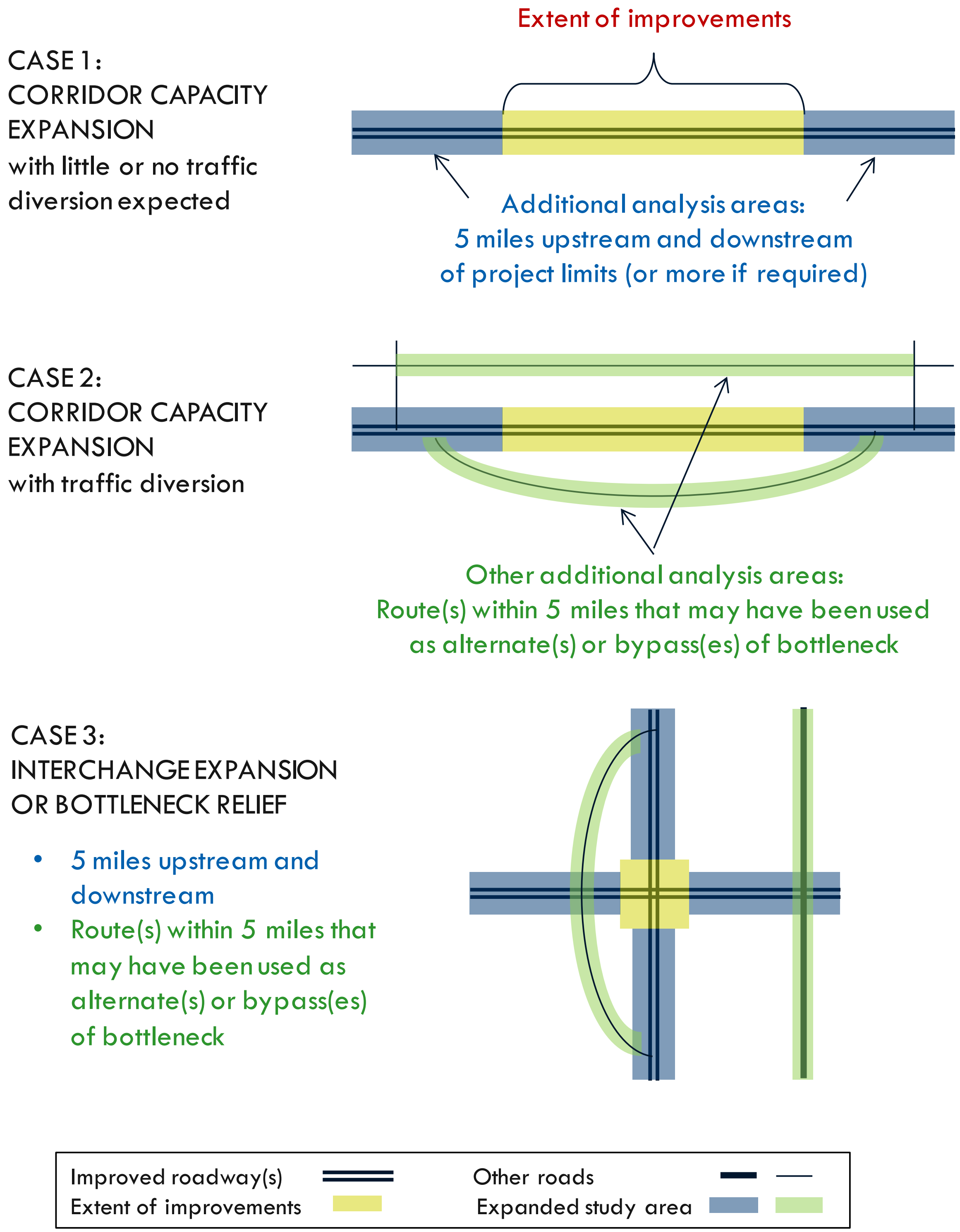
Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Roadway link length	NJDOT Roadway Network File, NJDOT Straight-Line Diagrams, Aerial Photos
Roadway link characteristics: • Roadway functional classification • Number of lanes and lane widths in each travel direction • Number of shoulders and shoulder widths in each travel direction • Terrain type, horizontal and vertical curvature[1] • Vehicle classification and composition (percent trucks and heavy vehicles in traffic flow)[2] • Median type and lateral clearance[2] • Number of access points and bottlenecks per mile[2] • Number of signals and estimated green time for primary flow as a proportion of total cycle length[2]	NJDOT Roadway Network File, NJDOT Straight-Line Diagrams, Aerial Photos Can assume zero grade if terrain information is not available. [2]Default value may be available in software. Also can use average values for roadways of similar functional class in same county or in NJTPA region if link-specific data are not available.
Hourly truck volumes in each direction and directional distribution of peak hour traffic	NJDOT and subregion Traffic Monitoring Systems
Tons of freight and TEUs per vehicle	Commodity flow survey data and related databases (e.g., IHS/Global Insight's Transearch database) *Note: The commodity flow data is estimated at regional system level which may not be suitable for use at local level. The use of number of trucks may be more appropriate based on data suitability.*
Truck VMT on roadways of similar functional classification as improved roadway, in the county in which the project is located	NJDOT Public Roadway Mileage and Vehicle Miles Traveled, from Highway Performance Monitoring System (HPMS) data

Geographic Scale of Analysis

An analysis of System Coordination measures for freight-roadway projects requires that all affected roadways be evaluated. The figure below shows the geographic extent for which data should be analyzed:



Time Frame of Analysis

The impacts of freight-related roadway e projects as measured in terms of System Coordination measures are likely to be most pronounced shortly after completion of the improvement. However, as years pass and induced demand and general economic growth lead to traffic growth, many changes as measured by System Coordination measures may diminish over time. Therefore, it is important to evaluate System Coordination measures using multiple data points from several years before the project, during the construction phase, and for as many years after the project as data are available.

Using delay as an example, compared to pre-construction conditions, delay may increase slightly during construction as lanes are narrowed or closed temporarily, and then decrease as phases of construction are completed. Impacts can be estimated as follows:

- The overall impact of the project can be estimated by comparing delay after the project to delay before the project.
- The net impact can be estimated by comparing delay after the project to delay in a hypothetical "no-build" scenario.
- Finally, delay due to construction can be estimated by comparing delay during construction to delay before and after construction. Or, if enough data are available, delay during construction can be aggregated for the entire construction period and compared to the net impact on delay.

Analysis Steps

Intermediate Measures and Analysis Tools

NOTE: The following steps should be used to estimate free-flow and congested travel times on each roadway link under analysis, where travel time data do not exist. If travel time data are available for the roadway links under analysis, skip these intermediate calculations and begin with estimation of ***Travel Time Reliability*** *below.*

1. Estimate free-flow travel speeds

   Inputs: (required for each link in each direction before, during, and after construction)

   - Observed average overnight travel speeds or 85th percentile overnight travel speeds in miles per hour. *Use actual observed travel speed data if possible. Where data are not available, use posted speed limit as a proxy for free flow travel speed.*

   Intermediate output measures:

   - Actual or estimated **free-flow travel speed** in miles per hour (MPH) by link and by direction before, during and after construction. *Typical range: 25-65 MPH. Typically free-flow travel speed will not vary in the before-construction and after-construction periods, but free-flow speed may vary during construction depending on construction conditions.*
   - **No-build free-flow travel speed** in miles per hour (MPH). *Typical range: 25-65 MPH. Required by link; before, during and after construction. Use pre-construction free-flow travel speed as proxy for no-build free-flow travel speed.*

2. Estimate link capacity

<u>Inputs:</u> (required for each link for each direction before, during, and after construction)

- Number of lanes in each direction of flow.
- Lane widths, *w*, in feet. *Use to calculate adjustment factor f_W. Typical range: 10-12 feet.*
- Percent heavy vehicles in traffic flow, HV. *Use to calculate adjustment factor f_{HV}. Typically 0-25 percent, but may be higher in areas with heavy freight traffic.*
- Peak hour factor, or hourly volume during the maximum-volume hour of the day divided by the peak 15-minute flow rate within the peak hour expressed as an equivalent hourly volume; a measure of traffic demand fluctuations within the peak hour. *In the absence of 15-minute traffic volume data, can assume 0.88 for rural conditions, 0.92 for urban conditions.*
- Effective ratio of green time to cycle length, or g/C ratio. *Range of 0.0-1.0; typically falls between 0.40-0.60. Can use observed values, or assume 0.55 for principal arterials, 0.45 for minor arterials, or 0.40 for collectors.*

<u>Calculation:</u>

- Link Capacity = 1900 *Number of lanes * f_L * f_{HV} * Peak hour factor * g/C ratio
- Lane adjustment factor $f_L = 1 + \frac{w-12}{30}$
- Heavy vehicle factor $f_{HV} = \frac{100}{[100+HV(E_T-1)]}$

Passenger Car Equivalents for Trucks (E_T)

Two-Way Flow Rates	Type of Terrain		
(passenger cars per hour)	Level	Rolling	Mountainous
0-600	1.7	2.5	7.2
>600-1,200	1.2	1.9	7.2
>1,200	1.1	1.5	7.2

- Peak hour factor = hourly volume during the maximum-volume hour of the day divided by the peak 15-minute flow rate within the peak hour. *Default values are 0.92 for urban links and 0.88 for rural links.*
- Ratio of green time to total cycle length = g/C. *Use the minimum g/C ratio if there are multiple signalized intersections in the study area.*

<u>Intermediate output measures:</u>

- **Link capacity** in vehicles per hour by link before, during and after construction. *The maximum capacity for a single lane on a straight, level freeway is around 2,200 vehicles per hour. Calculate link capacity for each link on the study facility (or facilities) for periods before, during, and after construction.*
- **No-build link capacity** in vehicles per hour. *No-build link capacity should reflect conditions that existed before construction.*

3. Estimate congested travel speed and delay for each direction before, during and after construction.

   Inputs: (required for each link before, during, and after construction)

   - Roadway functional classification. *Use standard NJDOT definitions, for example, "urban principal arterial" or "rural collector".*
   - Number of lanes in each travel direction.
   - Lane widths in each travel direction. *Typical range: 10-12 feet.*
   - Number of shoulders and shoulder widths in each travel direction. *Typical range: 0-12 feet.*
   - Terrain type, horizontal and vertical curvature. *Can assume zero grade if terrain information is not available.*
   - Vehicle classification and composition (percent trucks and heavy vehicles in traffic flow). *Default values may be available in software. Also can use average values for roadways of similar functional class in same county or in NJTPA region if link-specific data are not available. As an example, percent trucks may range from 0 to 5 percent on suburban arterials to upwards of 20 percent on major interregional corridors and roads serving ports, rail terminals, and industrial areas.*
   - Median type and lateral clearance. *Default values may be available in software. Also can use average values for roadways of similar functional class in same county or in NJTPA region if link-specific data are not available. For example, many design standards for freeways and expressways call for at least 6-foot left shoulders and 10-foot right shoulders, with center medians and/or median barriers. Local roads and arterials often have painted center medians or no medians or shoulders at all. HERS, HCS, and other software packages assume shoulders at least 6-feet wide provide the maximum benefit to a roadway's capacity, while shoulders less than 6 feet begin to decrease roadway capacity.*
   - Number of access points and bottlenecks per mile. *Default values may be available in software. Also can use average values for roadways of similar functional class in same county or in NJTPA region if link-specific data are not available. For example, in HERS and HCS, the default value for bottlenecks per mile is 0.083.*
   - Number of signals and estimated green time for primary flow as a proportion of total cycle length. *Default values may be available in software. Also can use average values for roadways of similar functional class in same county or in NJTPA region if link-specific data are not available. For example, green time for the primary flow on a major arterial may be 50-60 percent of total cycle length, while the green time for the primary flow at a major intersection of two arterials may be less than 25 percent of the total cycle length, when time devoted to left turn signals, pedestrian walk cycles, and yellow and all-red phases are considered.*
   - Traffic volumes in each direction, in terms of Annual Average Daily Traffic (AADT).
   - Estimated free-flow travel speed, in miles per hour. *Use value from Step 1.*

- Link capacity, in vehicles per hour. *Use value from Step 2. Can use peak hour link capacity or use link capacity for various times of day (AM peak, mid-day, PM peak, and overnight).*

Analysis tools: The main analysis tool required for this analysis is a set of delay equations. These equations are automated into software such as the Speed Model of the Highway Economic Requirements System (HERS) or Highway Capacity Software (HCS). HERS is capable of modeling a single link or an entire network and is applicable for roadway that is classified as rural collector and above, while HCS can be used to analyze a multi-link corridor such as an arterial or freeway.

Intermediate output measures: The outputs of HERS, HCS, or a network simulation model should include the following:

- **Estimated congested travel speed** for determined hour of the day (or for the whole day If resources permit), by link and by direction of travel, in miles per hour. *Typical range: 0-55 MPH. Note that estimated congested travel speeds can be generated for the before, during, and after-construction time periods using data from each respective period. Congested travel speeds may be as low as 20 MPH or lower on extremely congested roadways, and it is possible that a roadway expansion project would increase travel speeds to something approaching free flow speed (55 MPH or higher) in the best case, in the years immediately following completion of an expansion project. Over time, congested travel speeds may begin to decrease as traffic volumes increase, so it is important to monitor speeds for many years following a project's completion.*
- **Vehicle hours of recurring and non-recurring delay** in the peak and off-peak periods, in hours per year. *Vehicle hours of delay on a congested roadway can exceed 1 million hours per year and can drop as low as 10,000 hours per year immediately after construction of a major capacity expansion. Over time, the vehicle hours of both recurring and non-recurring delay will gradually increase if traffic volumes increase, so it is important to monitor travel delay for many years following a project's completion.*

4. Estimate no-build congested travel speed and delay for each link.

Inputs:

- Roadway functional classification. *Use standard NJDOT definitions, for example, "urban principal arterial" or "rural collector".*
- Number of lanes in each travel direction.
- Lane widths in each travel direction. *Typical range: 10-12 feet.*
- Number of shoulders and shoulder widths in each travel direction. *Typical range: 0-12 feet.*
- Terrain type, horizontal and vertical curvature. *Can assume zero grade if terrain information is not available.*
- Vehicle classification and composition (percent trucks and heavy vehicles in traffic flow). *Default values may be available in software. Also can use average values for roadways of similar functional class in same county or in NJTPA region if link-specific data are not available. As an example, percent trucks may range from 0 to 5 percent*

on suburban arterials to upwards of 20 percent on major interregional corridors and roads serving ports, rail terminals, and industrial areas.

- Median type and lateral clearance. *Default values may be available in software. Also can use average values for roadways of similar functional class in same county or in NJTPA region if link-specific data are not available. For example, many design standards for freeways and expressways call for at least 6-foot left shoulders and 10-foot right shoulders, with center medians and/or median barriers. Local roads and arterials often have painted center medians or no medians or shoulders at all. HERS, HCS, and other software packages assume shoulders at least 6-feet wide provide the maximum benefit to a roadway's capacity, while shoulders less than 6 feet begin to decrease roadway capacity.*
- Number of access points and bottlenecks per mile. *Default values may be available in software. Also can use average values for roadways of similar functional class in same county or in NJTPA region if link-specific data are not available. For example, in HERS and HCS, the default value for bottlenecks per mile is 0.083.*
- Number of signals and estimated green time for primary flow as a proportion of total cycle length. *Default values may be available in software. Also can use average values for roadways of similar functional class in same county or in NJTPA region if link-specific data are not available. For example, green time for the primary flow on a major arterial may be 50-60 percent of total cycle length, while the green time for the primary flow at a major intersection of two arterials may be less than 25 percent of the total cycle length, when time devoted to left turn signals, pedestrian walk cycles, and yellow and all-red phases are considered.*
- Traffic volumes in each direction before construction, in terms of Average Annual Daily Traffic (AADT).
- No-build free-flow travel speed, in miles per hour. *Use value from Step 1.*
- No-build link capacity, in vehicles per hour. *Use value from Step 2.*
- Use NJTA I-95, I-80 & I-78 truck growth rates to estimate the background truck traffic growth rate.

<u>Calculation:</u>

- In order to estimate what travel speeds may have been had the improvement not been made (a **"no-build" congested travel speed**), multiply the pre-construction traffic volumes on each link by the growth rate of truck traffic on I-95, I-80 and I-78 (labeled "Major Interstate Highways" in the equation below) as follows:

$$\text{Volume}_{\text{Post-constr.,"No-Build"}} = \text{Volume}_{\text{Pre-constr.}} * \frac{\text{VMT}_{\text{Major Interstate Highways,Post-Constr.}}}{\text{VMT}_{\text{Major Interstate Highways,Pre-Constr.}}}$$

<u>Analysis tools:</u> The main analysis tool required for this analysis is a set of delay equations. These equations are automated into software such as the Speed Model of the Highway Economic Requirements System (HERS) or Highway Capacity Software (HCS). HERS is capable of modeling a single link or an entire network and is applicable for roadway that is classified as

rural collector and above, while HCS can be used to analyze a multi-link corridor such as an arterial or freeway.

Intermediate output measures: The outputs of HERS, HCS, or a network simulation model should include the following:

- **Estimated no-build congested travel speeds** for each hour of the day, by link and by direction of travel, in miles per hour; and
- **No-build vehicle hours of recurring and non-recurring delay** in the peak and off-peak periods, in hours.

5. Calculate congested and free flow travel times for each link, for build and no-build conditions.

Inputs: (required for each link before, during, and after construction)

- Estimated free-flow travel speed, in miles per hour. From Step 1.
- No-build free-flow travel speed, in miles per hour. *From Step 1.*
- Estimated congested travel speed, in miles per hour. *From Step 3.*
- No-build congested travel speed, in miles per hour. From Step 4.
- Length of link to which travel speed estimate applies, in miles.

Calculations: Travel time = Link length / travel speed

Intermediate output measures: (for each link, before, during, and after construction)

- **Free-flow travel time**, in minutes.
- **No-build free-flow travel time**, in minutes.
- **Congested travel time**, in minutes.
- **No-build congested travel time**, in minutes.
- *Travel time values will vary depending on the link length. For shorter links, travel times may be measured in fractions of a minute; for longer links, travel times may be several minutes. As an example, before construction, a 1-mile segment with free-flow travel speed of 60 MPH and a congested travel speed of 30 MPH will have a free-flow travel time of 1 minute and a congested travel time of 2 minutes.*
- *After construction, the free-flow travel speed may increase slightly or stay the same at 60 MPH, but the congested travel speed should increase to something above 30 MPH. Therefore, the after-construction free-flow travel time should be 1 minute or less, and the after-construction congested travel time should ideally reflect some improvement, falling between 2 minutes and 1 minute.*
- *The no-build free-flow travel time can be assumed to be 1 minute (the same as pre-construction conditions), and the no-build congested travel time would likely be greater than 2 minutes, assuming traffic volumes increased between the pre-construction and post-construction periods.*

6. Repeat steps 1-5 for each link, and then aggregate travel times across all links on the roadways being analyzed. The net impact of the project is the difference between after construction conditions and "no-build" conditions.

Travel Time Reliability

Inputs:

- Congested travel times, in minutes. *Ideally, use continuous travel time monitoring data or data aggregated to 15-minute increments, or use estimated congested travel time from calculations above. Required for each roadway before, during, and after construction, ideally for 15-minute increments throughout the day. If estimated congested travel time is used, can use peak-period congested travel time.*
- Free-flow travel times, in minutes. *Ideally, use observed average overnight travel times or 85th percentile overnight travel times, based on continuous travel time monitoring data or data aggregated to 15-minute increments. The 85th percentile speed in free-flow conditions is often used as the basis for setting speed limits in engineering analyses, so the 85th percentile overnight travel time is a suitable proxy for free-flow travel time. Or use estimated free-flow travel time from calculations above. Free-flow travel times may vary throughout the day in cases when signal timing changes by time of day.*

Calculations:

- Using congested travel time data, determine the **95th percentile travel times**. *The 95th percentile travel time represents the peak hour travel time on the two worst traffic days of the month. Note that 95th percentile travel time is a guideline. For trips where reliability is not as important, for example recreational trips, a lower threshold may be used.*
- **Buffer time** = 95th percentile travel time – average travel time. *Buffer time, expressed in minutes, represents the extra time (or time cushion) that travelers must add to their average travel time when planning trips to ensure on-time arrival 95 percent of the time. Typical values for a complete trip range from as low as 5 minutes or less in light congestion to a maximum of 30 minutes or more in heavy congestion. On a shorter roadway segment in a particular study area, buffer time could be measured in seconds.*
- **Buffer index** = (95th percentile travel time – average travel time) / average travel time, expressed as a percentage. *Buffer index values closer to 0% indicate that 90th percentile travel time is close to average travel time, i.e. there is little or no variability in congestion. Buffer index values above 100% indicate severe congestion, i.e. travel time is more than twice as long on the worst traffic days than in average conditions.*
- **Planning time index** = 95th percentile travel time / free-flow travel time. *The planning time index reflects how much total time a traveler should allow to ensure on-time arrival 95 percent of the time (in contrast to buffer index, which represents extra time). For example, a planning time index of 1.60 means that for a trip that takes 15 minutes in light traffic a traveler should budget a total of 24 minutes to ensure on-time arrival 90 percent of the time.*
- For an estimate of **"no-build" reliability indices**, use estimated "no-build" congested travel times. *Continuous or 15-minute congested travel times may not be available for the no-build condition because no-build conditions must necessarily be simulated or calculated. Therefore, use peak hour travel times to estimate the improvement in travel time reliability that is attributable to the project.*

Additional resources on travel time reliability include the following:

- Federal Highway Administration Office of Operations Web site, www.ops.fhwa.dot.gov
- Margiotta, Richard, Taylor, Rich, 2006. "Traffic Congestion and Reliability: Making the Connection with Operations: Part 1: Measuring and Tracking Reliability." Institute of Transportation Engineers. ITE Journal, Feb 2006.
- Federal Highway Administration, 2005. "Traffic Congestion and Reliability: Trends and Advanced Strategies for Congestion Mitigation," prepared by Cambridge Systematics and Texas Transportation Institute.
- SHRP 2 Project L03, 2010. "Analytical Procedures for Determining the Impacts of Reliability Mitigation Strategies," prepared by Cambridge Systematics et al.

Ratio of Non-Recurring Delay to Total Delay

Inputs: (required for each link before, during, and after construction)

- Vehicle hours of recurring and non-recurring delay in the peak and off-peak periods. *See Step 3 in calculations of Intermediate Measures.*
- No-build vehicle hours of recurring and non-recurring delay in the peak and off-peak periods. *See Step 3 in calculations of Intermediate Measures.*

Calculations:

1) Divide non-recurring delay by total delay to determine **ratio of non-recurring delay to total delay** for each link. *The ratio should be between 0.0 and 1.0, where values closer to 0.0 indicate roads with little non-recurring delay (e.g., due to incidents) or roads with large amounts of recurring delay (e.g., congestion due to physical roadway characteristics like bottlenecks). Values closer to 1.0 indicate large amounts of non-recurring delay, and may indicate the need for safety or operational improvements to reduce incidents.*
2) Repeat for all links and calculate **average ratio of non-recurring delay to total delay**, weighted by link length or link traffic volume or both.
3) The net impact attributable to the project is the difference between actual and no-build conditions.

Person-Hours and Ton-Hours of Delay

Inputs: (required for each link before, during, and after construction)

- Vehicle hours of recurring and non-recurring delay in the peak and off-peak periods. *See Step 3 in calculations of Intermediate Measures.*
- Vehicle classification and composition (percent trucks in traffic flow). *Can range from less than 1 percent for local roads to over 20 percent for the busiest highways.*
- Persons per vehicle. *Use 1 for single-occupant vehicles, or up to 50 or more for buses.*
- Tons per truck. *Typical values range from 1 ton for local deliveries up to 25 tons for long-distance trucks transporting ore or building materials. Note: Commodity flow data are estimated at a regional or system level, and may not be suitable for use at local level. The use of observed truck counts may be more appropriate based on data suitability and availability.*
-

Calculations:

1) Multiply vehicle hours of delay by percent heavy vehicles to determine truck hours of delay.
2) Multiply truck hours of delay by tons per truck to determine **ton-hours of delay**. *If value per ton can be assumed, multiply value per ton by ton-hours of delay to estimate impact of delay in dollars per hour of freight. Note: Commodity flow data are estimated at a regional or system level, and may not be suitable for use at local level. The use of observed truck counts may be more appropriate based on data suitability and availability.*
3) Multiply no-build truck hours of delay by tons per truck to determine **no-build ton-hours of delay**. *If value per ton can be assumed, multiply value per ton by ton-hours of delay to estimate impact of delay in dollars per hour of freight.*
4) The net impact attributable to the project is the difference between actual delay for after construction and the no-build estimates of delay.

Table 3.8-A: Sample of Outputs of Ton-hours of Delay Calculation
(NOTE: Contains fictional data for illustration purposes only)

	Before Construction	During Construction	After Construction	No-Build
Link delay (hours per year)	**390,000**	**420,000**	**150,000**	**500,000**
Percent heavy vehicles	8%	8%	8%	8%
Tons per truck	16	16	16	16
Annual ton-hours of delay	**499,200**	**537,600**	**192,000**	**640,000**
Estimated net project impact ("After Construction"-"No Build") Annual ton-hours of delay				**-448,000**

Percent of Travel under Congested Conditions

Inputs: (required for each link before, during, and after construction)

- Hourly traffic volumes, vehicles per hour.
- Roadway capacity, vehicles per hour.
- Tons per truck. *Typical values range from 1 ton for local deliveries up to 25 tons for long-distance trucks transporting ore or building materials.*

Calculations:

- Volume/capacity ratio per hour = Hourly traffic volumes / capacity. *If 15-minute traffic counts or continuous traffic counts are available, calculate V/C ratio at finer level of detail. V/C ratio for the "no-build" condition can be estimated using pre-construction capacity and post-construction traffic volume data.*
- The definition of "congested conditions" must be determined by policy. *A V/C ratio between 0.75 and 1.0 typically indicates a roadway is becoming congested, and a V/C ratio above 1.0 indicates severe congestion.*
- **Percent of ton-hours-traveled under congested conditions** = Hourly traffic volume * percent of trucks in vehicle flow * tons per truck * share of hours during which roadway operates at or above V/C ratios of 0.75 (for moderate congestion) and 1.0 (for severe congestion).

Network Connectivity and Continuity

An analysis of Network Connectivity and Continuity should be conducted for each mode using the roadway network, including automobiles and light trucks; heavy trucks, buses and commercial vehicles; bicycles; and pedestrians. The analysis procedures for bicycle and pedestrian facilities can be found in the Implementation Recommendations for the Bicycle and Pedestrian project category.

Inputs (for automobiles and light trucks; heavy trucks, buses, and commercial vehicles):

- Road network information:
    - Block length or segment length, in feet.
    - Density of nodes (intersections) and segments, per mile.
    - Functional classification. *Use NJDOT functional classifications.*
    - Locations of restrictions on heavy trucks and commercial vehicles (height, width, and/or weight).

Evaluation (automobiles and light trucks; heavy trucks, buses and commercial vehicles): Use GIS to evaluate connectivity of roadway network before and after improvement. Evaluate connectivity on both a local scale and a regional scale. The *Smart Transportation Guidebook*, published in March 2008 through a partnership between Pennsylvania Department of Transportation and the New Jersey Department of Transportation, suggests the following connectivity measures:

- **Internal Connectivity.** Use either of the following two measures:
  - Beta Index — Express as a ratio, a beta index is the number of street links in the study area divided by the number of nodes or link ends. *A higher ratio indicates higher street connectivity. Traditional urban grid networks generally rate above 1.4, while suburban cul-de-sac subdivisions may have beta index values closer to 1.0. A beta index can be calculated for the entire network (all functional classifications), for specific functional classifications (e.g., Interstate Highways, Expressways, and major arterials) or for one functional classification. For heavy trucks, buses, and commercial vehicles the index should take into account any restrictions on vehicle size and weight and restrictions on commercial vehicles.*
  - Intersections per square mile. *Strict grid systems have about 25 intersections per square mile, while conventional branching systems have about one-third to one-half that many.*
- **External Connectivity**
  - The *Smart Transportation Guidebook* recommends that all neighborhoods in the community should be connected to the larger street system at least every ¼ mile. *This measure can be evaluated qualitatively as a "yes/no" indicator.*
- **Route Directness**
  - Route directness measures the distance a truck would drive between two points over the roadway network compared to the straight line (or radial) distance between the same two points. *The closer the ratio is to 1.0, the more direct the route; route directness values of 1.2-1.5 describe reasonably connected truck route networks. Route directness may vary depending on the vehicle type being analyzed, due to restrictions on vehicle size and weight and restrictions on commercial vehicles.*
- Connectivity and continuity in the "no-build" condition are simply the conditions that existed before construction.
- Compare route directness analysis for "no-build' and after conditions.

Additional resources on network connectivity include the following:

- Carlos A. Alba and Edward Beimborn (2005), *Analysis of The Effects of Local Street Connectivity On Arterial Traffic*, Transportation Research Board Annual Meeting (www.trb.org); at www.uwm.edu/Dept/CUTS//lu/conn.pdf.

- Dill, Jennifer (2004). "Measuring Network Connectivity for Bicycling and Walking." Presented at the 83rd Annual Meeting of the Transportation Research Board, Washington, DC.
- Portland Metro (2001), "Street Connectivity Standards," *Planning for Future Streets: Implementing the Regional Transportation Plan*, Portland Metro Regional Services (www.metro-region.org/library_docs/trans/streetconnect.pdf).
- Portland Metro (2004), Street Connectivity: An Evaluation of Case Studies in the Portland Region, Portland Metro (www.metro-region.org/library_docs/trans/connectivityreport.pdf).

Recommendations for Future Performance Evaluation: System Coordination Measures

Improve extent and detail of traffic count data. Truck Traffic count data are currently widely available in the NJTPA region, but if truck 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, delay, and reliability estimation, tools. It would help to improve the quality of Truck VMT data such as Highway Performance Monitoring System (HPMS).

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, Truck GPS-tracking system and other sources, 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, microsimulation 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).

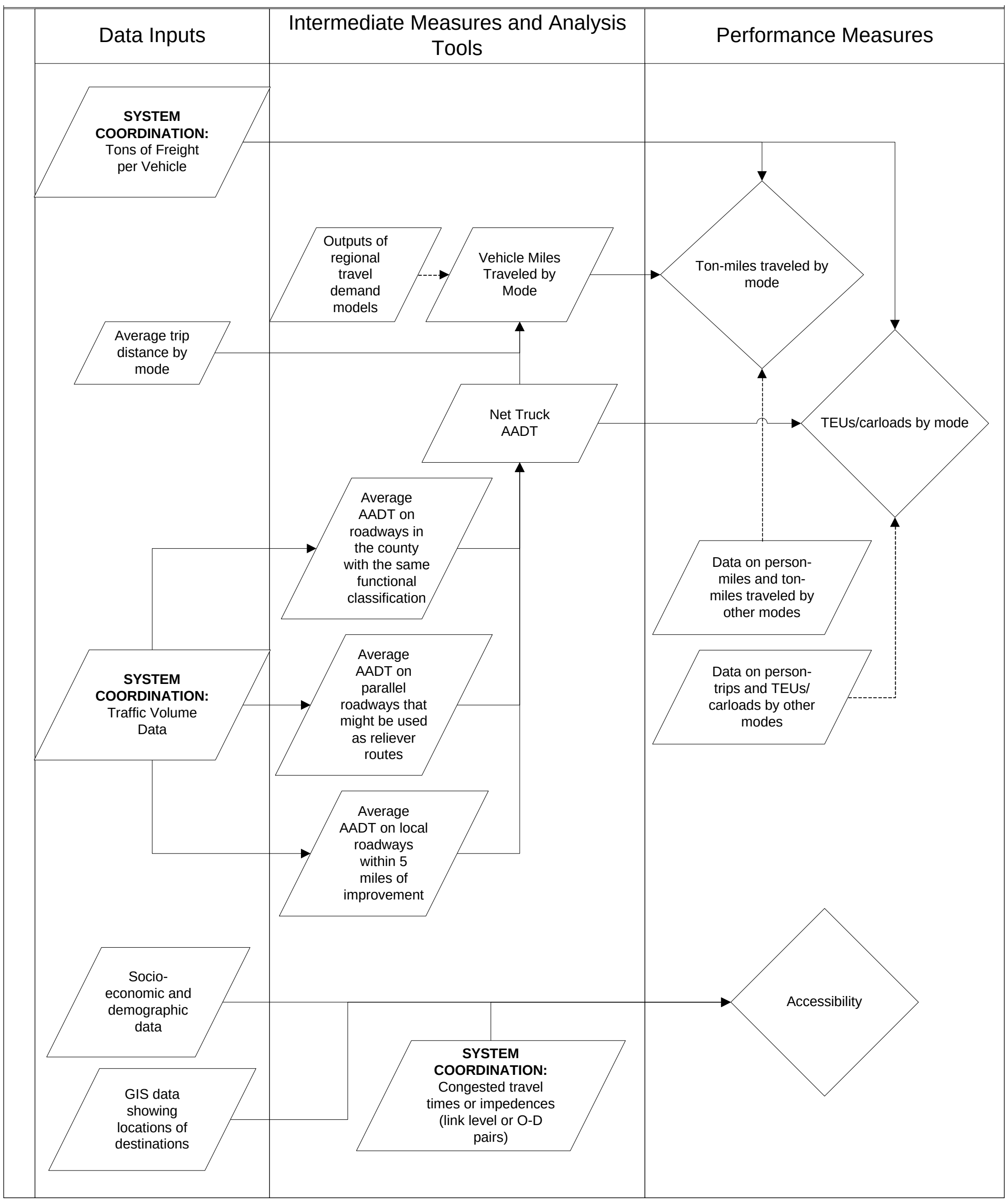
Improve network GIS data, particularly restrictions on oversize/overweight and commercial vehicles. Network connectivity and continuity data could be enhanced with additional information on system condition, facility attributes, and restrictions on use by certain vehicle types.

3.8.2 Evaluating User Responsiveness Measures

NJTPA User Responsiveness Goal - Provide affordable, accessible, and dynamic transportation systems responsive to current and future customers.

Interdependencies between Data, Analysis Tools, and Performance Measures

The following diagram is a simplification of the interdependencies between User Responsiveness and System Coordination measures. *Note: Customer Satisfaction is independently evaluated and is not included in this diagram. For further information, see page 3.8-28.*



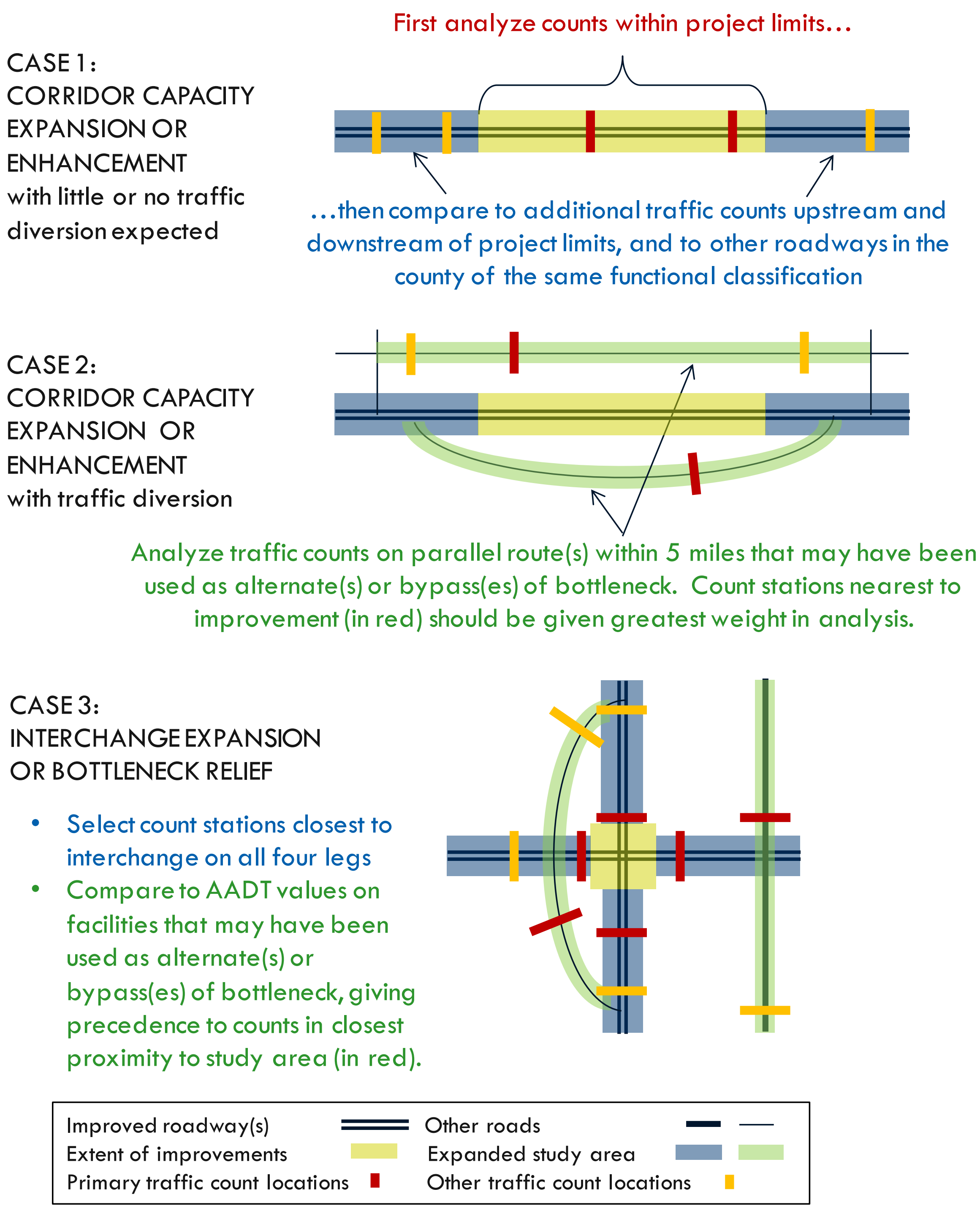
Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Tons of freight and TEUs per vehicle	Commodity flow survey data and related databases (e.g., Transearch). *Note: The commodity flow data is estimated at regional system level which may not be suitable for use at local level. The use of number of trucks may be more appropriate based on data suitability.*
Average truck trip distance	Truck survey data collected by NJTPA , NJDOT, PANYNJ, and other
Hourly traffic volumes in each direction and directional distribution of peak hour traffic	NJDOT Traffic Monitoring System
Socio-economic, demographic, and employment data (Census Block Group, Traffic Analysis Zone (TAZ), or Place level)	U.S. Census Bureau's American Fact Finder; U.S. Census Bureau's American Community Survey 5-year estimates; U.S. Census Bureau's Local Employment-Household Dynamics data, NJTPA. *Note that ACS 5-year estimates should not be compared for overlapping time periods and are mainly intended to be used for population characteristics, not population totals, particularly at smaller geographies (e.g., Census tracts).*
GIS data showing location of local destinations and opportunities (health clinics, grocery stores and sources of fresh food, local parks and playgrounds, elementary and secondary schools, and neighborhood-oriented retail and service establishments like restaurants, bars, dry cleaners, banks, and hardware stores)	Counties and local municipalities, NJDOT, NJDEP, Google Maps, WalkScore.com
GIS data showing locations of regional destinations and opportunities (major hospitals, four-year colleges and universities, major concentrations of retail activity, and recreational and tourist destinations with more than 100 employees, like amusement parks, sports arenas, performing arts venues, museums, and historic sites)	Counties and local municipalities, NJDOT, NJDEP, Google Maps, WalkScore.com
Estimates of ton-miles traveled by rail and other surface modes	Commodity flow survey data (e.g., Transearch database)

Geographic Scale of Analysis

The three User Responsiveness measures are best measured at a regional level or at a corridor level, grouping multiple facilities and modes together to determine the corridor-level or systemwide impacts of any given freight-related roadway project. The figure below shows the geographic extent for which data should be analyzed:



Time Frame of Analysis

The impacts of freight-related roadway projects as measured in terms of User Responsiveness measures may be small or may not be measurable at all shortly after completion of the improvement. However, as years pass many changes as measured by User Responsiveness measures may become more pronounced over time. Therefore, it is important to evaluate User Responsiveness measures on a continuous basis, using multiple data points from several years before the project and for as many years after the project as data are available.

Customer Satisfaction measures are an exception. The reaction to a freight-related roadway project may peak shortly after project completion, but as time goes on, people may not be able to distinguish the project's impacts from other changes that have happened in the mean time (for example, other transportation improvements or economic shifts).

Analysis Steps

Intermediate Measures and Analysis Tools

1. Calculate Net Change in Truck AADT

   Inputs: (Required for each link for the periods before construction and after construction)

   - Truck traffic volumes (expressed in Truck AADT) on roadway(s) within project limits, plus at least five miles upstream and downstream. *On a case-by-case basis, select the extent of roadway for which traffic volumes may have been affected by the project. For major regional bottlenecks, look at a longer segment. For smaller expansion projects with more localized impacts, choose a smaller segment. For example, Truck AADT might range from less than 10 on community streets to over 20,000 on the busiest Interstate Highways in the NJTPA region.*
   - Truck AADT is simply AADT multiplied by percent trucks on the roadway. If facility-specific vehicle classification counts are not available, Truck AADT can be inferred from county-wide data on percent of VMT made up of truck traffic. Truck percentages from other nearby classification count locations also can be used to develop an estimate for the roadway segment under analysis.
   - Average Truck AADT levels on Interstates and freeways in the county in which the project is located. *As above, calculate by dividing total VMT on these facilities by total miles of road. For example, I-78 in Somerset County carried an average of approximately 4,000 trucks per day in 2009.*
   - *Note that continuous traffic counts are preferred because they allow consistent comparison of traffic data in the before- and after-construction periods. In cases in which continuous counts are not available, and only occasional data are collected at the count location, some interpolation or extrapolation of data may be necessary using annual county VMT data as a proxy for general economic conditions that may have affected traffic levels on the link.*

   Calculations:

   - Compare change in Truck AADT (or average change in Truck AADT) on the improved roadway(s) to the average Truck AADT on roadways of the functional classifications

"Interstate" and "Freeway" in the county in which the project is located. To calculate average Truck AADT for a functional class, simply divide VMT by miles of roadway in that functional class in the county.

- The growth in average VMT on Interstates and Freeways, if applied to pre-construction traffic levels on the study facility, is a third way to triangulate what the change in Truck AADT may have been in the absence of the project. The difference between the actual absolute change in Truck AADT on Interstates and Freeways and the actual absolute change in Truck AADT on the study area roadway is a third way to estimate the net Truck AADT impact of the project, assuming that average Truck AADTs on Interstates and Freeways reflect background growth (or decline) due to changing economic conditions. Calculations are as follows:

$$\text{Adjusted AADT}_{\text{Post-constr.,Improved Facility}} = \text{AADT}_{\text{Pre-constr.,Improved Facility}} * \frac{\text{Average AADT}_{\text{Interstates and Freeways,Post-Constr.}}}{\text{Average AADT}_{\text{Interstates and Freeways,Pre-Constr.}}}$$

$$\text{Net AADT Change} = \text{Actual AADT}_{\text{Post-constr.,Improved Road}} - \text{Adjusted AADT}_{\text{Post-constr.,Improved Road}}$$

- *It is important to note if any significant changes occurred on Interstates and Freeways in the county during the analysis period. For example, if a large project was completed or if the study project itself occurred on an Interstate or Freeway, the average Truck AADT estimates for those functional classifications is not a good proxy for regional traffic. In this case, one could substitute the average Truck AADT on all Interstates and Freeways in the NJTPA region as a comparison metric.*

Intermediate output measures:

- Estimated **net change in Truck AADT** attributable to construction of the project, in vehicles per day. *For example, net change in Truck AADT might be 150 trucks per day.*
- If the facility is new, the net Truck AADT may be 100 percent of the traffic observed on the new facility, or some adjustments may be made to account for traffic shifts from parallel roadways.

2. Calculate Net Change in Truck VMT

<u>Inputs:</u>

- Estimated net change in Truck AADT from previous step (for before and after construction).
- Average trip distance for vehicles using the roadways in the analysis (use a single year, perhaps the midpoint of the analysis, so as not to introduce additional error into the calculation). *Trip distance for freight trips varies by trip type. Long-haul trips may be 500 miles or more, while drayage trips to and from a seaport may be 1-5 miles.*
- VMT data and aggregate lengths by roadway functional classification in the county in which the project is located (from HPMS or other source); in the NJTPA region; and in the state (for pre-construction and post-construction years).

<u>Calculations:</u>

a. Convert net Truck AADT estimate to net Truck VMT estimate.

- If truck survey data are available, gather information on average trip distance for the truck using the study area roadways. If survey data are not available, use county-level or regional average trip lengths from Journey to Work data developed by the U.S. Census from both decennial censuses and the American Community Survey.
- Multiply range of net Truck AADT estimates by average trip length to calculate a range of estimated net change in Truck VMT attributable to the project. *For example, a major roadway expansion project may result in a net VMT impact of 50-100 million VMT per year.*

b. Compare the Truck VMT change in the county in which the project is located to the NJTPA region and the State of New Jersey.

- For large projects in particular, Truck VMT impacts may be perceived at a county level. As another point in the "triangulation" process, at this point the range of net Truck VMT estimates produced in the previous step can be compared to the rates of change in Truck VMT at the county, region, and state level. Compare the rate of change in county-level Truck VMT to the rate of change of facility-level Truck AADTs, and also compare the county-level Truck VMT to the rate of change in Truck VMT at the regional and state level. The differences between these respective Truck VMT changes can be used to estimate a range of probable net Truck VMT impacts of the project. *VMT changes could be positive or negative depending on the type of improvement and economic conditions in the study period. Typical VMT impacts range from -30% to +30%.*

c. The result of this approach will be an estimate of net change in VMT. The full range of potential sources of uncertainty should be clearly documented in the report of net change in VMT.

<u>Intermediate output measures:</u>

- **Net change in truck vehicle miles traveled.**

Ton-Miles of Travel by Mode (Mode Choice)

Inputs:

- Net vehicle miles traveled, *from Intermediate Calculations above.*
- Tons per truck. *Typical values range from 1 ton for local deliveries up to 25 tons for long-distance trucks transporting ore or building materials. Note: The commodity flow data is estimated at regional system level which may not be suitable for use at local level. The use of number of trucks may be more appropriate based on data suitability.*
- *Use estimates of freight per truck (use a single year, perhaps the midpoint of the analysis, so as not to introduce additional error into the calculation.*

Calculations:

- Multiply estimates of net vehicle miles traveled by tons of freight per vehicle to determine the net change in ton-miles traveled by truck. *The calculation can be enhanced if vehicle classification data are available along with the traffic counts used to generate Truck AADT values. In this case, vehicle-specific net VMT estimates can be produced, which then will help generate estimates of net ton-miles traveled.*
- *Combined with estimates of ton-miles traveled by other modes (e.g., freight rail or marine highway), this measure can help estimate the impact of the project on mode choice.*

Outputs:

- **Net ton-miles of travel by mode.** *For example, a freight-related roadway project may increase ton-miles of travel by truck by 17 million miles per year and reduce ton-miles of travel by freight rail by 18.5 million miles per year. The discrepancy is explained by the longer distance required by rail trips over a less connected network.*

Tons/TEUs by Mode (Mode Choice)

Inputs:

- Net Truck AADT, *from Intermediate Calculations above.*
- Tons per truck. *Typical values range from 1 ton for local deliveries up to 25 tons for long-distance trucks transporting ore or building materials. Note: The commodity flow data is estimated at regional system level which may not be suitable for use at local level. The use of number of trucks may be more appropriate based on data suitability.*
- *Use estimates of tons per vehicle from a single year, perhaps the midpoint of the analysis, so as not to introduce additional error into the calculation.*

Calculations:

- Multiply estimates of net Truck AADT by tons of freight per vehicle to determine the net change in tons or TEUs by truck.
- Combined with estimates of tons and TEUs moved by other modes (e.g., freight rail or marine highway), this measure can help estimate the impact of the project on mode choice.

Outputs:

- **Net tons and TEUs by mode.** *For example, a freight-related roadway project may increase mode share by truck and reduce mode share by freight rail by a similar share.*

Accessibility

Accessibility is a measure of the ability of people to reach opportunities and activities that they undertake in their daily lives, or the ability of businesses to reach their labor force, sources of raw materials and inputs to their production facilities, and the consumer markets for their finished products.

Access to consumer markets refers to the ability of a business to reach the population where their products are sold and sources of inputs and raw materials to their production facilities. Because consumer markets are likely to be outside the NJTPA region, a proxy for consumer markets can be county centroids.

Inputs:

- Locations of consumer markets (Bureau of Economic Analysis data).
- Peak hour travel speed data for links in the NJRTM-E model network (from INRX or other vehicle probe data).
- NJRTM-E model network link attributes (link length, toll information).

Calculations:

a. Cumulative Opportunity accessibility measure based on travel time

- For period before construction (average of three years) and period after construction (three-year moving average for all available years), use GIS to calculate the shortest travel time between all origins in the regional network and key points of entry on the regional highway network (e.g., Interstate Highway crossings of state borders, seaports, and air cargo facilities).
- Aggregate the number of "opportunities" that lie in the TAZs that can be reached within 5 hours, using average weekday travel time data.
- The relevant equation is:

$$A_i = \sum_{j=1}^{J} B_j O_j$$

where A_i is accessibility measured at point i to potential activities in zone j,

O_j is the opportunities in zone j, and

B_j is a binary value equal to 1 if zone j is within the predetermined threshold and 0 otherwise.

- The change in access is the difference in cumulative opportunities across all TAZ pairs that can be reached in the specified travel time. Cumulative opportunity estimates for each TAZ in a given area can be aggregated using the following equation:

$$A_{Area} = (\Sigma A_i * E_i) / E_{Area}$$

where:

A_i = Accessibility of zone i

E_i = Employment of zone *i*

E_{Area} = Employment of the study area (could be a county or the NJTPA region)

A_{Area} = Accessibility of the region (could be a county or the NJTPA region)

- *For example, before construction, consumer markets containing 2,000,000 people might be accessible within a 5 hour drive of a given location. After construction of a freight-related roadway project, 2,100,000 people might be accessible within 5 hours. The net impact of the project is access to an additional 100,000 people at that location.*

Customer Satisfaction

Customer Satisfaction is a measure that does not depend on inputs from any other performance measure. Customer Satisfaction measures can be obtained from the results of surveys performed by NJDOT or other agencies after completion of a project.

Inputs:

- Surveys of transportation system users such as truck drivers, trucking companies and other road users, ideally including information about the relative importance of each system attribute being queried
- Typical questions on freight -related customer satisfaction surveys include:
  - Customer perception of improvement's impacts across NJTPA goal areas: Built and natural environment, congestion, travel speed, travel fee/cost, if applicable, access to destinations, safety, economic impacts.
  - Project's impact on travel behavior: Whether the improvement caused mode shifts ("What was the previous mode used to make the trip?") and destination choice decisions (e.g., enabled a longer trip to a destination not previously accessible).
  - Impacts of roadway construction: Safety, congestion and delays, access to businesses, traffic impacts during construction.

Recommendations for Future Performance Evaluation: User Responsiveness Measures

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, tons and types of commodities in each vehicle, and modes used before and after project implementation. Research is being conducted into alternatives to travel diaries, 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 long-haul and delivery 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 delivery stop along a route.

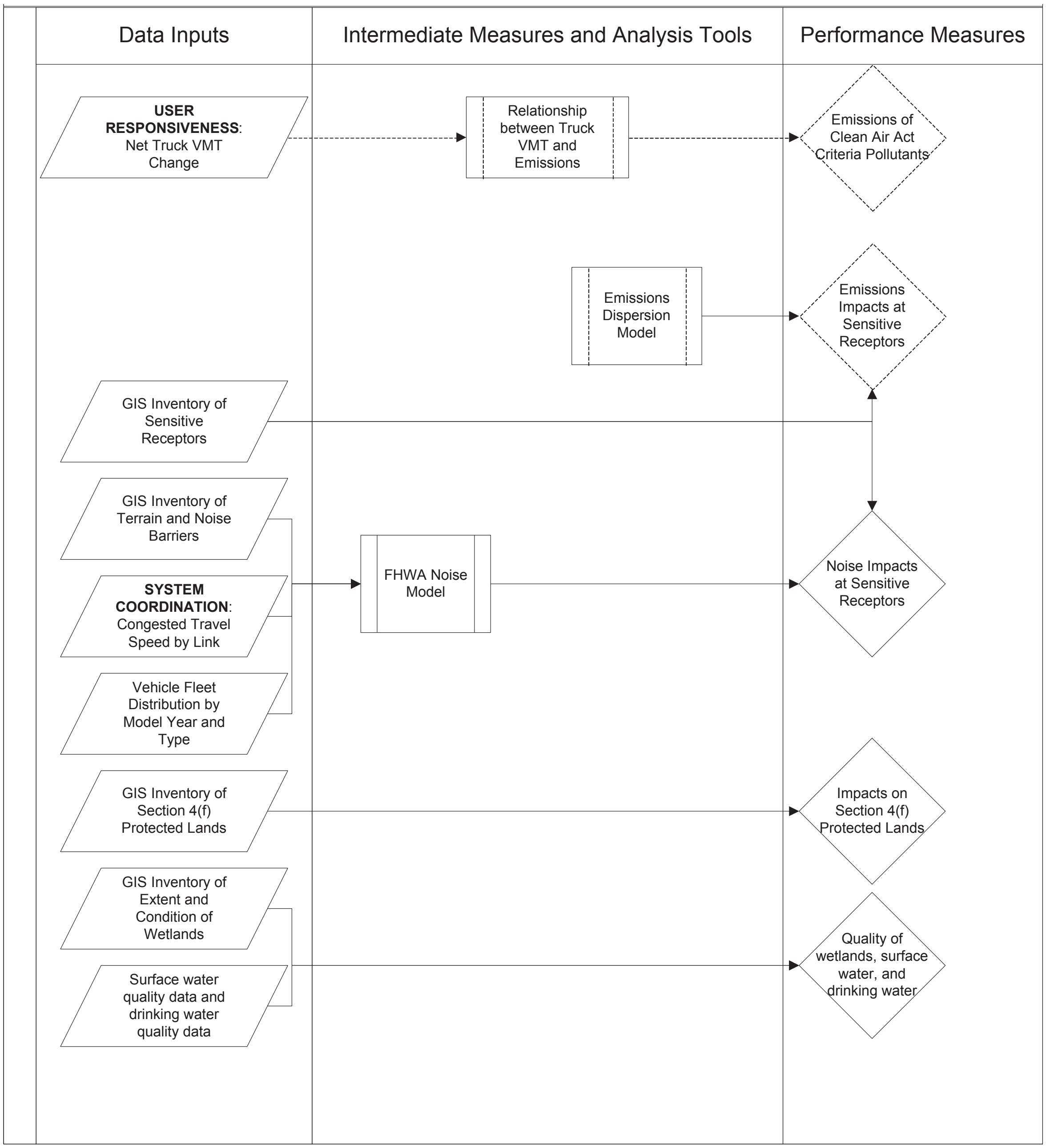
Undertake more customer satisfaction surveys for all modes on a regular basis. Agencies responsible for building, maintaining, and operating the transportation system in the region should undertake regular customer satisfaction surveys to collect a range of qualitative and quantitative data about customer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

3.8.3 Evaluating Environment Measures

NJTPA Environment Goal - Protect and improve the quality of natural ecosystems and human environment.

Interdependencies between Data, Analysis Tools, and Performance Measures

The following diagram is a simplification of the interdependencies between Environmental measures and the intermediate and ultimate measures discussed in the System Coordination and User Responsiveness sections. *Note: Visual aesthetics and context sensitivity is independently evaluated and not included in this diagram. For further information, see page 3.8-45.*



Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Congested Travel Speeds by Link	Intermediate measure calculated in **System Coordination**; see methodology above
Distribution of vehicle trips by time of day	Hourly/15-minute/continuous traffic volume data
Latest Truck Emission Factors	NJDEP
GIS Inventory of Sensitive Receptors	NJDOT and NJDEP GIS; Google Maps and other commercial sources
GIS inventory of terrain and noise barriers	NJDOT and NJDEP GIS; NJDOT Straight Line Diagrams
Congested travel speeds by link	Intermediate measure calculated in **System Coordination**; see methodology above
Vehicle trip distribution by model year and type	NJMVC Registration data; NJDOT vehicle classification count data
GIS inventory of Section 4(f) protected lands	NJDEP GIS Wildlife and waterfowl refuges: US Fish and Wildlife Service Historic properties: National Historic Geographic Information System (NHGIS), state historic preservation office (SHPO) and local historical commissions/societies
GIS Inventory of extent and condition of wetlands	NJDEP GIS; US Army Corp of Engineers
Surface and drinking water quality	NJDEP Division of Water Quality; NJDEP Bureau of Safe Drinking Water

Geographic Scale of Analysis

The geographic scale of analysis depends on the measure being assessed. The following table shows the recommended geographic scale of each measure.

Measure	Geographic Scale(s) of Analysis
Emissions of Clean Air Act criteria air pollutants and greenhouse gases	Air quality (AQ) data are collected at the facility level as well as at the regional scale. The regional and statewide travel demand models that are necessary to quantify emissions are based on this state and regional data collection. Transportation-related emissions, for example greenhouse gases, do not respect state and regional boundaries; therefore regional and statewide data are necessary. The Clean Air Act requires regional and project level hotspot analysis. Most non-attainment areas have on the ground monitoring units in set locations. These units are not typically moved to measure emissions for specific projects. Transportation emissions that lead to respiratory conditions and other health impacts should be estimated at sensitive receptors within ¼ mile of project limits.
Transportation-related noise and vibrations at sensitive receptors	Sensitive receptors within ¼ mile of project limits
Quality of wetlands, surface water, and drinking water	Primary/direct impacts (wetlands): Project limits Secondary/cumulative impacts: Project-specific as defined in NEPA Scoping document; could be several miles from project limits; use natural boundaries such as water sheds as study area boundaries
Impacts on Section 4(f) protected lands	Primary/direct impacts: Project limits Secondary/cumulative impacts: Project-specific as defined in NEPA Scoping document; could be several miles from project limits; use natural boundaries such as water sheds as study area boundaries
Visual aesthetics and context sensitivity	Project limits (project-specific design features); adjacent properties; neighborhoods and municipalities in which project is located; architectural and environmental features in view shed

Time Frame of Analysis

The ability to measure the net Environmental impacts of a project over time is directly dependent on the ability to measure net VMT impacts, net changes in Truck AADT, net impacts on congested travel speeds, and net impacts on mode choice decisions. As the quality or reliability of these estimates deteriorate over time, so does the reliability of the results of an environmental impact assessment. Therefore, the time frame of analysis for Environment performance measures should mirror the time frames for System Coordination and User Responsiveness measures: measures should be on a continuous basis if possible, using multiple data points from several years before the project and for as many years after the project as data are available in order to draw valid conclusions about the net impacts of a project.

As indicated in the above graphic, the environmental impacts of freight-related roadway projects are often measured at a regional scale. Therefore, the net impacts of any one project may be clouded over time by economic growth that generates additional travel demand (in turn affecting emissions and noise), by other development that increases impervious cover and impacts wetlands and water quality, or by changes in the region's socioeconomic and demographic profile that affect public health outcomes. On a project-by-project basis, professional judgment will be necessary to determine the limits applying the following analysis.

Analysis Steps

Emissions of Clean Air Act Criteria Pollutants

Inputs:

- Total change in truck VMT attributable to project (intermediate output measure of **User Responsiveness** analysis).
- Relationship between truck VMT and emissions (either qualitative or quantitative).

Analysis Tools:

- Apply emissions factor per truck VMT to calculate emissions by category. *If factors are unknown or if truck VMT estimate is not reliable, a qualitative analysis may not be possible. As an alternative, qualitatively describe whether emissions were likely to increase or decrease as a result of the project.*

Output measures:

- Estimated **change in emissions by criteria pollutant.**

Emissions Impacts at Sensitive Receptors

1. Generate emissions contour maps.

Inputs:

- Estimated change in emissions by criteria pollutant.
- Baseline emissions estimates.
- Geography-specific climate data. Can use defaults built into models.

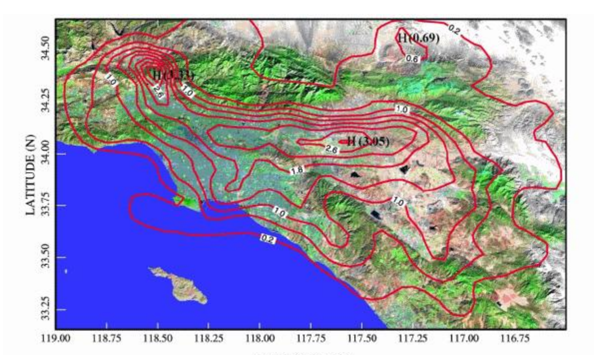
Analysis Tools:

- Use Emissions Dispersion model to allocate emissions to points or subregions in the analysis area. Conduct one run for baseline conditions and a second run for "build" condition.

Outputs:

- Emissions contour maps showing concentrations by criteria pollutant for baseline condition and for "build" condition.

Figure 3.8-A: Example map of daily emissions of soot in micrograms per cubic meter for Los Angeles Metropolitan Area



2. Overlay sensitive receptor points on emissions contour maps.

Inputs:

- Emissions contour maps for baseline condition and "build" condition from dispersion model.
- GIS layer of sensitive receptors in NJTPA region.

Calculations:

Net emissions impact at any given sensitive receptor is the difference between the build condition and the baseline condition. Repeat calculation for each sensitive receptor.

Outputs:

- **Estimated emissions impacts by sensitive receptor.** *For example, "Emissions of particulate matter (PM 2.5) increased from 1.2 micrograms per cubic meter to 1.8 micrograms per cubic meter as a result of the project."*

Noise and Vibration Impacts at Sensitive Receptors

Inputs:

- Peak hour volume and average speed by vehicle type, by link (intermediate output measures of **System Coordination** analysis).
- GIS inventory of terrain type.
- Location and extent of noise barriers (NJDOT GIS and Straight Line Diagrams).
- GIS inventory of sensitive receptors.
- Archived data on noise levels at sensitive receptors at regional, county level, and/or corridor level.

Calculations:

- Use FHWA Noise Model to generate noise contours and estimated impacts at sensitive receptors. To estimate net impacts, run one scenario with "build" conditions using most recent available data and a second "no-build" scenario with estimated "no-build" inputs. Repeat for each sensitive receptor.
- If enough data are available about changes in decibel levels at sensitive receptors over time, the project-specific impacts also can be compared to regional, county-level, or corridor-level average impacts over the same analysis period as another estimate of what may have happened in the absence of the project.

Outputs:

- **Net noise and vibration impacts at sensitive receptors, in decibels.** *For example, "The hourly equivalent sound level $L_{EQ}(h)$ increased from 60 dB to 75 dB as a result of the project."*

Impacts on Section 4(f) Protected Lands

Inputs:

- GIS inventory of Section 4(f) Protected Lands

Calculations:

- Compare before and after conditions to determine direct impacts on Section 4(f) Protected Lands. Depending on NEPA scoping effort, may need to expand analysis area to take into account cumulative impacts of the project on Section 4(f) Protected Lands.
- Also compare "after" conditions in project analysis area to regional, county-level, or corridor-level estimates of change in extent of Section 4(f) protected lands over the same analysis period. The percent change in regional extent can be compared to the project-specific impact as one estimate of the net project-specific impact, compared to what would have happened in the project area due to non-transportation-related land consumption.

Outputs:

- Change in **extent and condition of Section 4(f) Protected Lands**. *For example, "5 acres of parks were directly taken for construction of the project and replaced in a 2-for-1 ratio in a new 10-acre park created adjacent to a nearby school."*

Impacts on Wetlands, Surface Water Quality, and Drinking Water Quality

Inputs:

- GIS inventory of wetland extent and condition.
- Surface water quality data within project limits and downstream of project.
- Drinking water quality data within project limits and downstream of project.

Calculations:

- Compare before and after conditions to determine direct impacts on wetlands, surface water quality, and drinking water quality.
- Depending on contents of NEPA scoping effort (if available), may need to expand analysis area to take into account cumulative impacts of the project on wetlands, surface water quality, and drinking water quality. Study area should be consistent with what was used in the original environmental assessment.
- Also compare "after" conditions in project analysis area to regional, county-level, or corridor-level estimates of change in extent of wetlands, and change in condition of wetlands and water quality over the same analysis period. The percent change in regional extent can be compared to the project-specific impact as one estimate of the net project-specific impact, compared to what would have happened in the project area due to non-transportation-related land consumption and runoff.

Outputs:

- Change in **extent and condition of wetlands.** *For example, "20 acres of wetlands were directly taken for construction of the project and replaced in a 2-for-1 ratio in a wetlands mitigation bank maintained by NJDOT in the watershed."*
- Change in **condition of surface water quality and drinking water quality**. *[To be defined in discussions with NJDEP.]*

Visual Aesthetics and Context Sensitivity

Inputs:

- Project purpose and need statement or project description from planning documents, funding applications, etc.
- Photos and project descriptions after project completion.
- Local comprehensive plans and other relevant planning documents for the area in which the project was constructed.
- List of commitments to stakeholders that was developed and maintained during planning and design and/or was incorporated into construction documents prior to beginning construction.

- Results of post-construction surveys of project team members from the implementing agency and consultants.
- Results of post-construction surveys of community stakeholders (residents and businesses) and regulatory agency staff.

Calculations:

Conduct surveys using the following criteria[1]. Score one point for each criterion if 67% or more of implementing agency staff (and/or the agency's project consultants) surveyed respond "yes"; score one additional point for each criterion if 67% or more of community stakeholders and regulatory agency staff surveys respond "yes". Maximum 12 points.

1. The executed project meets the goals and objectives identified in the original purpose and need statement.
2. The project was designed and implemented in a manner that is consistent with local comprehensive plans, the Americans with Disabilities Act, and other relevant planning documents.
3. The implemented project meets or exceeds a list of commitments to stakeholders that was developed and maintained during planning and design, was incorporated into construction documents prior to beginning construction, and is monitored during construction and operation of the completed project.
4. *(If the project is located in a developed area)* Architectural elements were incorporated into the design of the project to make users of all modes feel comfortable and welcome. These elements include, but are not limited to: wayfinding signage for users of all modes for which the facility is designed (including freight and non-motorized users); signage clearly indicating access points to transit services (including park-and-ride lots, bus stops, and fixed guideway transit stations); signage clearly indicating access points and amenities for bicyclists and pedestrians (including signage indicating nearby alternate routes if non-motorized users are prohibited from using the facility); a physical barrier between non-motorized traffic (bicyclists and pedestrians) and vehicles or, if a physical barrier was not possible, a defined pavement marking separation; adequate lighting for evening and nighttime use by motorized and non-motorized users; an open view shed into public spaces for people passing by and security officers; and amenities such as artwork and landscaping to enhance the surrounding built and natural environment.

   (If the project is located in an undeveloped area) Environmental resources, scenic and historic resources, and aesthetic values, such as architectural styles and landscaping that complement the surrounding environmental, have been maintained or enhanced by the project as completed.
5. Nearby residents and representatives of nearby institutions, schools, and business associations are directly or indirectly (e.g., via an advisory council) involved in the ongoing maintenance and operations of the facility or service.

[1] Adapted from project-level evaluation criteria listed in NCHRP Web-Only Document 69: *Performance Measures for Context Sensitive Solutions- A Guidebook for State DOTs*

6. Based on surveys of area residents and businesses, the project appears to have been implemented in a manner that will result in increased economic activity, such as new commercial or residential activity, and it appears to have the potential to create a positive neighborhood impact.

Outputs:

- Qualitative assessment of the degree to which a project improved or detracted from the **visual aesthetics of the built environment**.

Recommendations for Future Performance Evaluation: Environment Measures

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 emissions, 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
- 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. 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. 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 costs would be incurred if it is discovered that mitigation measures are not successful and additional actions must be undertaken. Monitoring activities, data collection, data clean up and database maintenance are also time consuming. Agencies are hesitant to encourage monitoring and reporting for political reasons as well. 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 (CEs) 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 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. 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 project 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 opportunity 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.

3.8.4 Evaluating Land Use/Transportation Coordination Measures

NJTPA Land Use/Transportation Coordination Goal - Select transportation investments that support the coordination of land use with transportation system.

Interdependencies between Data, Analysis Tools, and Performance Measures

The evaluation of the Land Use/Transportation Coordination measure per capita vehicle miles traveled depends on a calculation of the intermediate measure vehicle miles traveled in the **User Responsiveness** goal area.

Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Net VMT Change	Intermediate measure calculated in **User Responsiveness**; see methodology above
Population	U.S. Census Bureau's American Community Survey 5-year estimates
Employment	U.S. Census Bureau's Local Employment-Household Dynamics data; NJ Labor and Workforce Development, and/or U.S. Bureau of Labor Statistics
Census tract area	U.S. Census Bureau TIGER Line Shape Files

Geographic Scale of Analysis

An analysis of net per capita VMT for roadway projects should be performed on the same scale as the net VMT calculation. Often, this calculation will be performed at a regional scale.

Time Frame of Analysis

The impacts of roadway expansion projects as measured in terms of Land Use/Transportation Coordination measures may be small or may not be measurable at all shortly after completion of the improvement, because development induced by a roadway expansion project will happen gradually over time. However, as years pass many changes as measured by Land Use/Transportation Coordination measures may become less pronounced over time. Therefore, it is important to evaluate Land Use/Transportation Coordination measures on a continuous basis, using multiple data points from several years before the project and for as many years after the project as data are available.

Analysis Steps

Population and Employment Density

<u>Inputs:</u>

- Population in census tracts or census blocks, if available, within 5 miles of project limits, from periods before and after implementation of the transit expansion project. *Use U.S. Census Bureau's American Community Survey (ACS) 5-year Estimates for a rolling annual estimate of census-tract-level population data. Note that the Census Bureau cautions against comparing ACS data from overlapping time periods. ACS is mainly* *intended to be used for population characteristics, not population totals, especially at smaller geographies (e.g., Census tracts).*

- Employment in census tracts within 5 miles of project limits, from periods before and after implementation. *Use U.S. Census Bureau's Longitudinal Employer-Household Dynamics (LEHD) data.*
- Area of census tracts within 5 miles of project limits, in miles, from U.S. Census Bureau's Topologically Integrated Geographic Encoding and Referencing (TIGER) system. *Note that census tract boundaries may change over time, particularly when a new decennial Census is undertaken. It is important to use areas that are as identical as possible for the before and after comparison.*

<u>Calculation:</u>

- Use GIS to aggregate population in census tracts within 5 miles of project limits and divide by aggregate area of those tracts. Calculate population density for periods before implementation and period after implementation.
- Use U.S. Census Bureau's Longitudinal Employer-Household Dynamics online mapping tool, called "OntheMap", to aggregate employment in census tracts within 5 miles of project limits and divide by aggregate area of those tracts. Calculate employment density for periods before implementation and after implementation.
- *The net change in population and employment density cannot be calculated, but a qualitative analysis of the circumstances before and after implementation of the project may provide clues to whether any changes in population and employment density can be attributable to the project. For example, similar to the net new ridership calculation above, population and employment density in the study area can be compared to a "control" area that had conditions similar to the study area before implementation.*

<u>Output:</u>

- **Population density**, in persons per square mile.
- **Employment density**, in jobs per square mile.

<u>Additional resources on population and employment density include the following:</u>

- U.S. Census Bureau Longitudinal Employer-Household Dynamics website, http://lehd.did.census.gov/led/
- U.S. Census Bureau's Topologically Integrated Geographic Encoding and Referencing (TIGER) system website, http://www.census.gov/geo/www/tiger/index.html

Recommendations for Future Performance Evaluation: Land Use/Transportation Coordination Measures

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).

3.8.5 Evaluating Repair/Maintenance/Safety/Security Measures

NJTPA Repair/Maintain/Safety/Security Goal - Maintain a safe and reliable transportation system in a state of good repair.

Only safety and security measures are discussed in this section. See Roadway and Bridge Preservation project type for evaluation of Repair and Maintenance-related measures.

Interdependencies between Data, Analysis Tools, and Performance Measures

All data used in the analysis of safety performance measures are drawn from crash databases (e.g., NJDOT Crash Records Database, NJTPA Safety Management System, Plan4Safety), and NJDOT asset management systems. Evaluation of security measures does not depend on results of previous calculations. Therefore, there are no interdependencies with previous analyses.

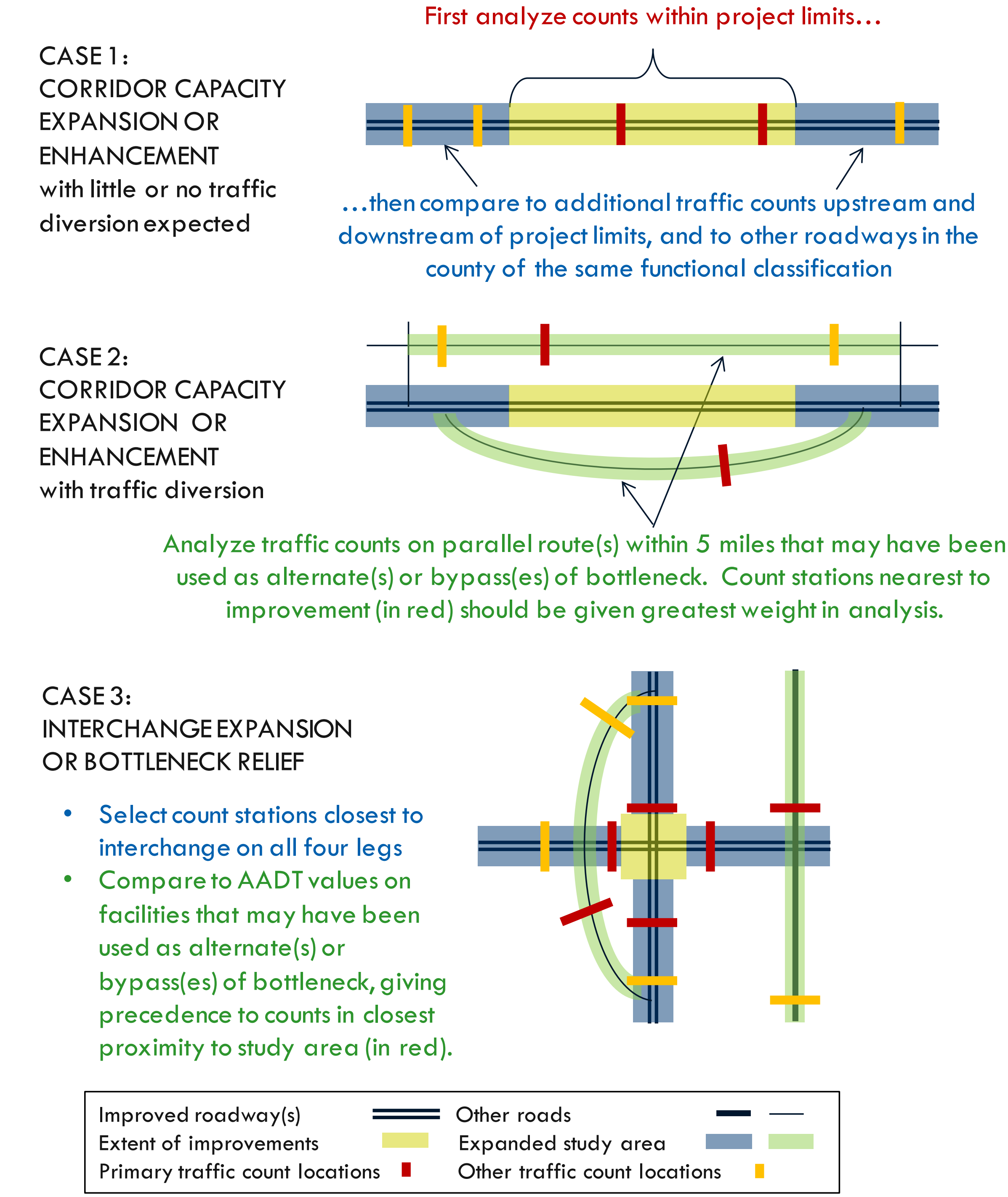
Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Crash records	NJDOT Crash Records Database; Plan4Safety; NJTPA Safety Management System data
VMT data at regional, county, and local level	NJDOT Public Roadway Mileage and Vehicle Miles Traveled, from Highway Performance Monitoring System (HMPS) data
Information on measures taken to prevent or protect against incidents, incursions, attacks, and illicit activity	Facility owner or operator: construction documents and as-built drawings
Facility functional class (Interstate, freeway or expressway, major arterial, or other)	NJDOT Roadway Network File, NJDOT Straight-Line Diagrams
Availability of alternate routes (same or higher functional class/lower functional class/no alternate route)	NJDOT Roadway Network File, NJDOT Straight-Line Diagrams
Traffic volume data (vehicles per day), Link capacity (vehicles per day), and Volume-to-capacity ratio	NJDOT Roadway Network File, NJDOT Straight-Line Diagrams, NJDOT Traffic Monitoring System
Tonnage of freight moved on each link from commodity flow data	IHS Global Insight's TRANSEARCH database or FHWA Freight Analysis Framework 3 (FAF3) data
Facility that are a designated evacuation route	NJDOT Roadway Network File
Planning studies to identify critical assets and future needs for project development in the study area	State and local governments; NJTPA needs assessments
Network Connectivity and Continuity results	Calculated using methodologies specified in System Coordination goal area

Geographic Scale of Analysis

Both safety and security measures should be evaluated within the project limits (in the case of safety improvements) or accommodate significant diversions of auto and truck traffic (in the case of system redundancy projects undertaken for security reasons), the analysis area for safety and security measures may be expanded to a corridor encompassing multiple facilities, to a county, or to the entire NJTPA region.



Time Frame of Analysis

The project-specific impacts of freight-related roadway expansion projects as measured in terms of safety measures are likely to be most pronounced shortly after completion of the improvement. Therefore, it is important to evaluate these measures using multiple data points from several years before the project, during the construction phase, and for as many years after the project as data are available. Security measures, which tend to be discrete improvements whose benefits do not accumulate or diminish over time, should be analyzed for one year before and after implementation of the project. For example, construction of a security fence along a new roadway right of way to prevent unauthorized access would have a one-time benefit to security along that roadway segment; therefore, conditions for the year before construction can simply be compared to conditions in the year following completion of the project.

Analysis Steps

Intermediate Measures and Analysis Tools

1. Assign a "criticality" index to infrastructure and services in the study area.

   Inputs: (required for each link in the highway network)

   - Facility functional class (Interstate, freeway or expressway, major arterial, or other facility type);
   - Whether or not alternate routes are available (same or higher functional class/lower functional class/no alternate route);
   - Traffic volume data (vehicles per day), link capacity (vehicles per day), and volume-to-capacity ratio, to help establish which facilities carry the greatest absolute volumes and which facilities have the ability to absorb excess volumes;
   - Tonnage of freight moved on each link from commodity flow data (TRANSEARCH, FAF), as a proxy of the facility's economic value;
   - Whether or not the facility is a designated evacuation route (yes/no); and
   - Planning and traffic studies done in the study area to identify critical assets and future needs for project development.

   Calculations

   Calculate a composite criticality score or index for each facility. Several analysis tools are available to perform the calculation. For example, the New Jersey Department of Transportation has a license to the Disruption Impact Estimating Tool—Transportation (DIETT), which is a database and spreadsheet-based tool for prioritizing the criticality of transportation choke points.

   Intermediate output measures:

   - Criticality index or score for each facility in the network. Facilities should be grouped into broad categories like "most critical", "critical" and "not critical". *Note that this index must be guarded from the public due to the sensitive nature of the information.*

Crashes

Inputs:

- Facility-specific crash data (minimum 3 years before and after project), preferably indicating involvement of trucks in crashes.
- Regional, county-level, and corridor-level aggregate safety statistics.

Calculations:

- Compare project-level changes in absolute number of crashes to estimates of crashes at the regional and county-level, for corridors of the same functional class, and potentially for specific comparison corridors as an estimate of what may have happened in the absence of the project. If the project was anticipated to result in significant diversions of traffic to or from other roadways, compile data on absolute numbers of crashes on alternate within 5 miles of the improved roadway that could reasonably be expected to accommodate bypass traffic.

Outputs:

- Absolute number of **crashes and number of truck-related crashes** occurred before and after construction. *For example, a project may result in a net reduction of 20 property-damage-only crashes, 5 injury crashes, and 1 fatality per year.*

Crash Rate

Inputs:

- Absolute number of crashes (truck-related) occurred before and after construction.
- VMT data at regional, county, and local level.
- Regional, county-level, and corridor-level aggregate crash rates.

Calculations:

- Divide crashes by VMT in the study area to calculate crash rate per million VMT.
- Compare project-level changes in crash rates to estimates of changes in crash rates at a regional or county-level, for corridors of the same functions class, or in specific comparison corridors as an estimate of what may have happened in the absence of the project.
- The net increase or decrease in crash rate attributable to the project can be estimated by subtracting the regional, county-level, or corridor-level crash rate from the observed crash rate after project completion.

Outputs:

- **Crash rate**, in terms of crashes per million VMT. *In the NJTPA region, crash rates typically range from 0-10 crashes per million VMT, but some roads have higher crash rates.*

Transportation Resiliency

Transportation resiliency is a term that describes the ability of the transportation system to adapt and respond to incidents and disruptions. Transportation resiliency applies to natural threats, such as hurricane storm surges and floods, as well as man-made threats such as terrorist attacks. According to NCHRP Report 525, "Incorporating Security into the Transportation Planning Process", four major categories of security incident countermeasures exist to address threats and vulnerabilities to the nation's transportation infrastructure. These four categories include prevention, protection, redundancy, and recovery. These four measures apply more broadly than security. For example, climate change adaptation strategies often are grouped into similar categories.

Below, the categories "prevention" and "protection" are discussed together below because they both refer to proactive, preventative measures taken in advance of an attack or unauthorized access. Their results are measured in terms of the extent of the system's critical services or pieces of infrastructure from being damaged, destroyed, or used for illicit purposes. Projects addressing "redundancy" and "recovery" address the operations of the system after a major disruption occurs. Their results are measured in terms of how well the system operates (or would operate) after a major disruption.

<u>Inputs: Prevention and Protection</u>

- Measures taken to *prevent or discourage* unauthorized access to a transportation facility or a specific sensitive feature of a transportation facility like a bridge or equipment room, before and after construction; measures taken to prevent or discourage illicit activity in or near a transportation facility; measures taken to prevent or discourage direct and indirect attacks on a facility; and measures taken to protect against the impacts of natural events like extreme weather events. *Examples cited in NCHRP Report 525 include access control systems like fences and locked doors, highly visible closed circuit television (CCTV) systems, and intrusion detection systems such as alarmed entrances and fence-line detection systems. The design of the facility is also important, for example, allowing for open sight lines into a park-and-ride lot from nearby roadways and development, adding lighting to a pedestrian pathway, hardening a facility to prevent physical incursions and/or increase blast resilience, or building a levee and pumping system to protect a roadway from flooding.*
- Criticality index of the facility or service. *Calculated above in intermediate measures and analysis.*

<u>Evaluation: Prevention and Protection</u>

- Measure the mileage of roadways with prevention and protection measures in place (per Federal, state, and local design guidelines) before and after the project is completed.

<u>Outputs: Prevention and Protection</u>

- Share of most critical assets hardened against unauthorized access, illicit activity, attacks, and/or natural events. The definition of "most critical assets" must be defined in the process for assigning a criticality score above.

<u>Inputs: Redundancy and Recovery</u>

- Results of **Network Connectivity and Continuity** calculations, using the process defined in the System Coordination goal area. *For purposes of this analysis, connectivity* *calculations should be performed for the subset of the system consisting of critical and/or most critical assets, as defined in the intermediate measure above.*

- Extent and redundancy of technology and systems available to provide information to system operators and users.

Evaluation: Redundancy and Recovery

- Using results of before-and-after network connectivity analysis, determine extent to which the project improves connectivity in the designated evacuation route system or in the subset of the system consisting of arterials, expressways, and Interstate Highways. *As described in the System Coordination goal area, system connectivity can be defined in terms of several indices and measures. The evaluation here should assess the change that the Roadway Expansion project would cause in these indices or measures.*
- Qualitatively compare the extent of information technology available to provide information to system operators and to users during an emergency, system failure, or system disruption, before and after project implementation.

Outputs: Redundancy and Recovery

- Change in System Connectivity for the region's critical and/or most critical transportation assets. *For example, the beta index could change from 1.1 to 1.2 as a result of the project, indicating greater network connectivity and availability of alternative routes in case of a disruption or blockage.*
- Extent to which communication systems are deployed in a redundant fashion to ensure information is available to system operators and users in an emergency, system failure, or system disruption. *For example, "The project provided a diesel generator to power a backup communication system in case of a power failure concurrent with the event or disruption."*

Recommendations for Future Performance Evaluation: Repair/Maintenance/Safety/Security Measures

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.

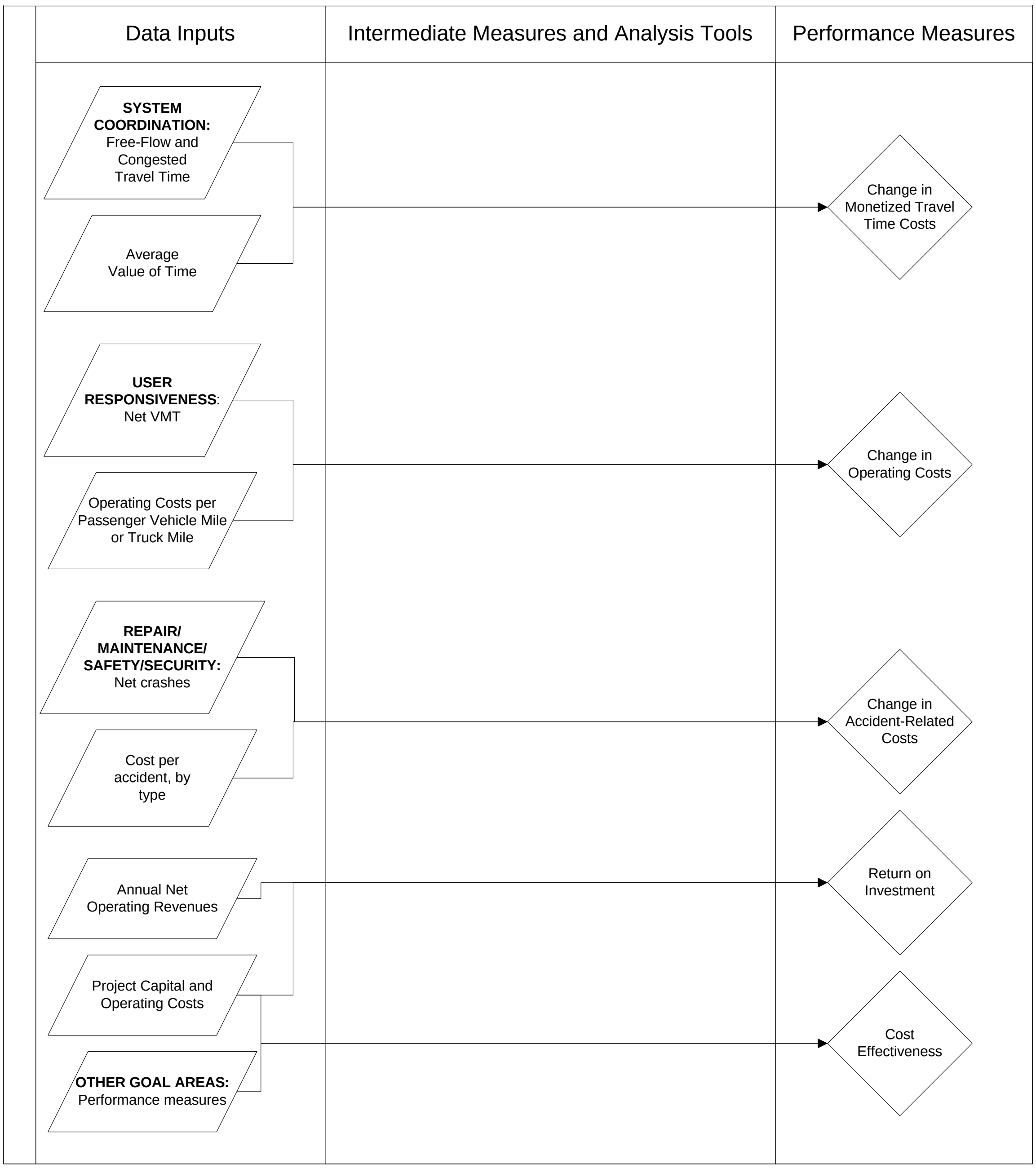
Reassess and periodically update definitions of critical transportation infrastructure and services to support analysis of system resiliency for purposes of transportation security, climate change adaptation, and related uses. NJDOT, in cooperation with Federal and local governments and other state agencies, has performed an assessment of critical transportation infrastructure. NJDOT should continue to work with the 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).

3.8.6 Evaluating Economy Measures

NJTPA Economy Goal - Retain and increase economic activity and competitiveness.

Interdependencies between Data, Analysis Tools, and Performance Measures

The following diagram is a simplification of the interdependencies between Economy measures and the intermediate and ultimate measures discussed in the System Coordination and User Responsiveness sections. No intermediate measures or analysis tools were used in the analysis.



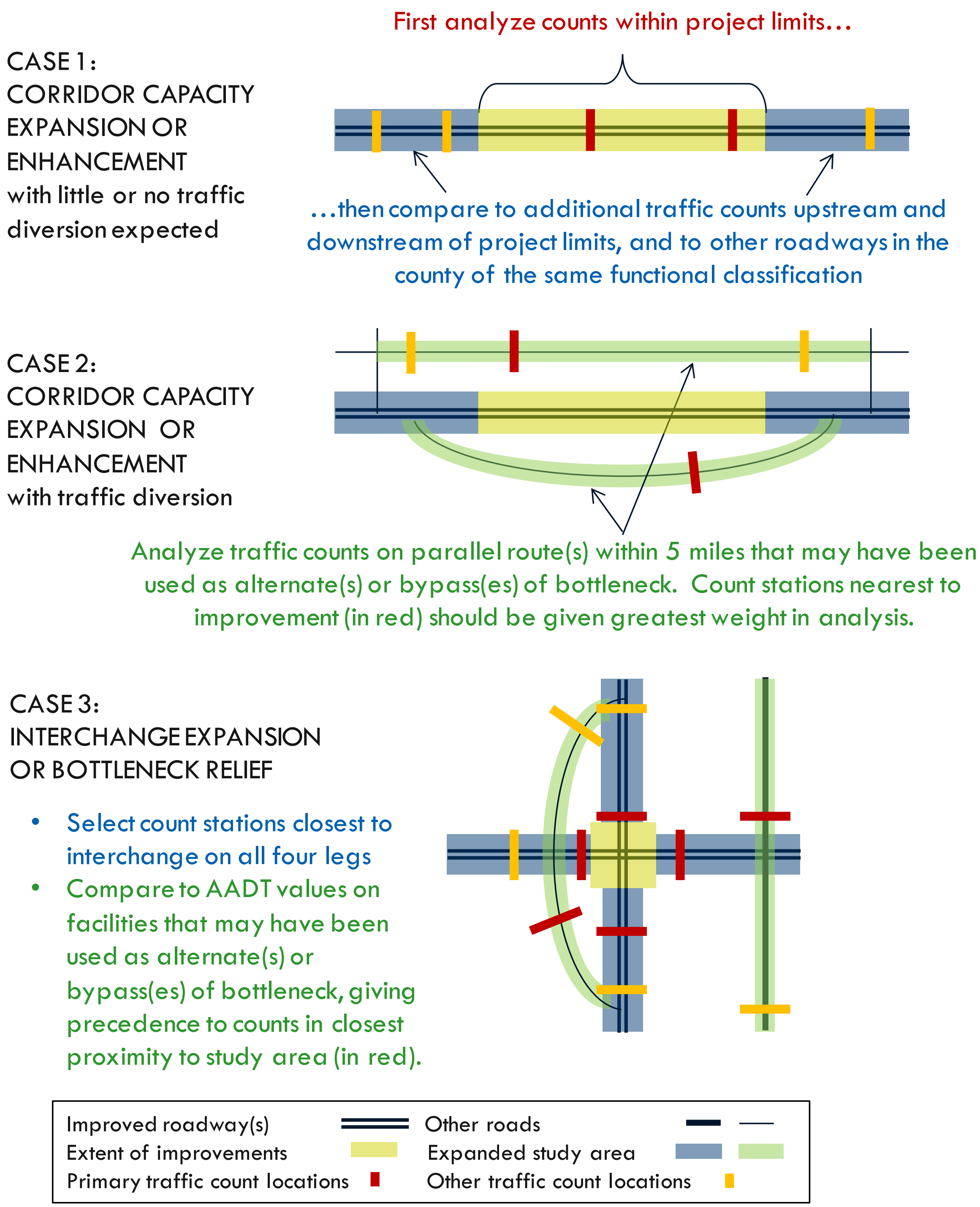
Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Estimated "build" and "no-build" congested travel times by link	Intermediate measure calculated in **System Coordination**; see methodology above
Average truck value of time	NJTRM-E
Net VMT change	Intermediate measure calculated in **User Responsiveness**; see methodology above
Operating costs per truck mile	FHWA and NJTPA survey data
Net crashes by severity	Output measure of **Repair/Maintenance/Safety/ Security** goal area; see above
Cost per crash, by severity	NJDOT and National Highway Traffic Safety Administration (NHTSA)

Geographic Scale of Analysis

All measures in the Economy goal area should be evaluated within the project limits. In the case of a project that is expected to generate significant diversions of auto and truck traffic, the analysis area may be expanded to a corridor encompassing multiple facilities, to a county, or to the entire NJTPA region.



Time Frame of Analysis

The impacts of freight-related roadway project as measured in terms of Economy measures may be small or may not be measurable at all shortly after completion of the improvement, because travel time benefits, operating cost savings, and accident cost reductions generated by a freight-related roadway project will accrue gradually over time. However, as years pass many changes as measured by Economy measures may become less pronounced over time. Therefore, it is important to evaluate Economy measures on a continuous basis, using multiple data points from several years before the project and for as many years after the project as data are available.

Analysis Steps

Transportation Costs

Transportation costs can be quantified in terms of change in monetized travel time costs, change in vehicle operating costs, and change in accident-related costs.

Inputs:

- Estimated "build" and "no-build" congested travel times by link (see diagram above for study area).
- Average value of time, in dollars.

Calculation:

- Multiply change in travel time by average value of time for users of the facility.

Outputs:

- **Net change in travel time costs** associated with the project. *An example is shown in the following table:*

Table 3.8-C: Sample of Estimated Daily Travel Time Savings
(NOTE: Contains fictional data for illustration purposes only)

	Net Change
Daily Truck Hours of Travel	-2,000
Truck Value of Time (in 2009 dollars)	$32.00
Estimated Travel Time Savings (Daily)	-$64,000

Inputs:

- Net change in VMT associated with the project, by vehicle type.
- Average vehicle operating costs for trucks, in dollars.

Calculation:

- Multiply change in VMT by vehicle type by average truck vehicle operating costs by vehicle type.

Outputs:

- **Net change in truck operating costs** associated with the project. *An example is shown in the following table:*

Table 3.8-D: Sample of Estimated Truck Operating Cost Savings
(NOTE: Contains fictional data for illustration purposes only)

Estimated Truck Operating Costs (2009 dollars per mile)	**$8.20**
Estimated Net Daily Truck VMT savings (miles)	160,000
Estimated Net Daily Truck Operating Cost Savings (2009 dollars)	$32,000

Inputs:

- Net change in crashes associated with the project, by severity.
- Average cost of crash, by severity.

Calculation:

- Multiply change in crashes by the average cost of crash for each severity level.

Outputs:

- **Net change in accident-related costs** associated with the project. According to NJDOT year 2009 data, the *average costs for accidents range from nearly $9,000 for a property-damage-only crash, to around $50,000 for an injury crash, to more than $2 million for a fatal crash. Accident cost savings due to major freight-related roadway projects often range in the millions of dollars per year.*

Return on Investment

Inputs:

- Project capital cost and annual operating costs.
- Annual net operating revenue.

Calculations:

- Calculate the net present value of net operating revenue. The net operating revenue is simply revenues from all sources minus operating costs.
- Return on investment is the (Capital Cost minus the Net Present Value of Operating Costs) divided by the Capital Cost. *For example, a transportation project could have a return on investment of 10 percent, meaning the project's annual income exceeds the net present value of its operating costs plus the capital cost.*

Outputs:

- **Return on investment***, expressed as a percentage.*

Cost Effectiveness

Inputs:

- Project capital cost, in dollars.
- Performance measures from previous calculations (e.g., crashes, travel time savings, and emissions reduction).

Calculations:

- Divide the capital cost by any performance measure to calculate the dollar-weighted impacts of the project. *For example, a million-dollar project that reduces carbon emissions by 1,000 tons has a cost-effectiveness index of $1,000/ton.*

Outputs:

- **Cost Effectiveness***, expressed in dollars per unit of benefit per dollar (e.g., dollars per accident reduced; dollar per minute of travel time savings; dollars per ton of reduced carbon emissions).*

  NOTE: While cost-effectiveness measures are constituents of a broader benefit-cost analysis approach, many cost-effectiveness measures are not additive. Therefore, extreme caution should be exercised in presenting and explaining results of a project-level cost-effectiveness analysis.

Recommendations for Future Performance Evaluation: Economy Measures

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.

3.9 Transportation Demand Management Projects

Travel 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 etc. The techniques presented would be applicable to TDM programs such as carpooling, vanpooling, and teleworking often administered by Transportation Management Association.

Contents of This Section

Suggested Work Flow for Travel Demand Management Projects

The following sequence of goal areas for this project category was developed specifically to enable an ordered evaluation of performance measures. This allowed calculations from earlier intermediate (and final) measures in one goal area to serve as inputs for measures in other goal areas:

1. User Responsiveness Measures.

2. Environment Measures.

3. Land Use/Transportation Coordination Measures.

4. Economy Measures.

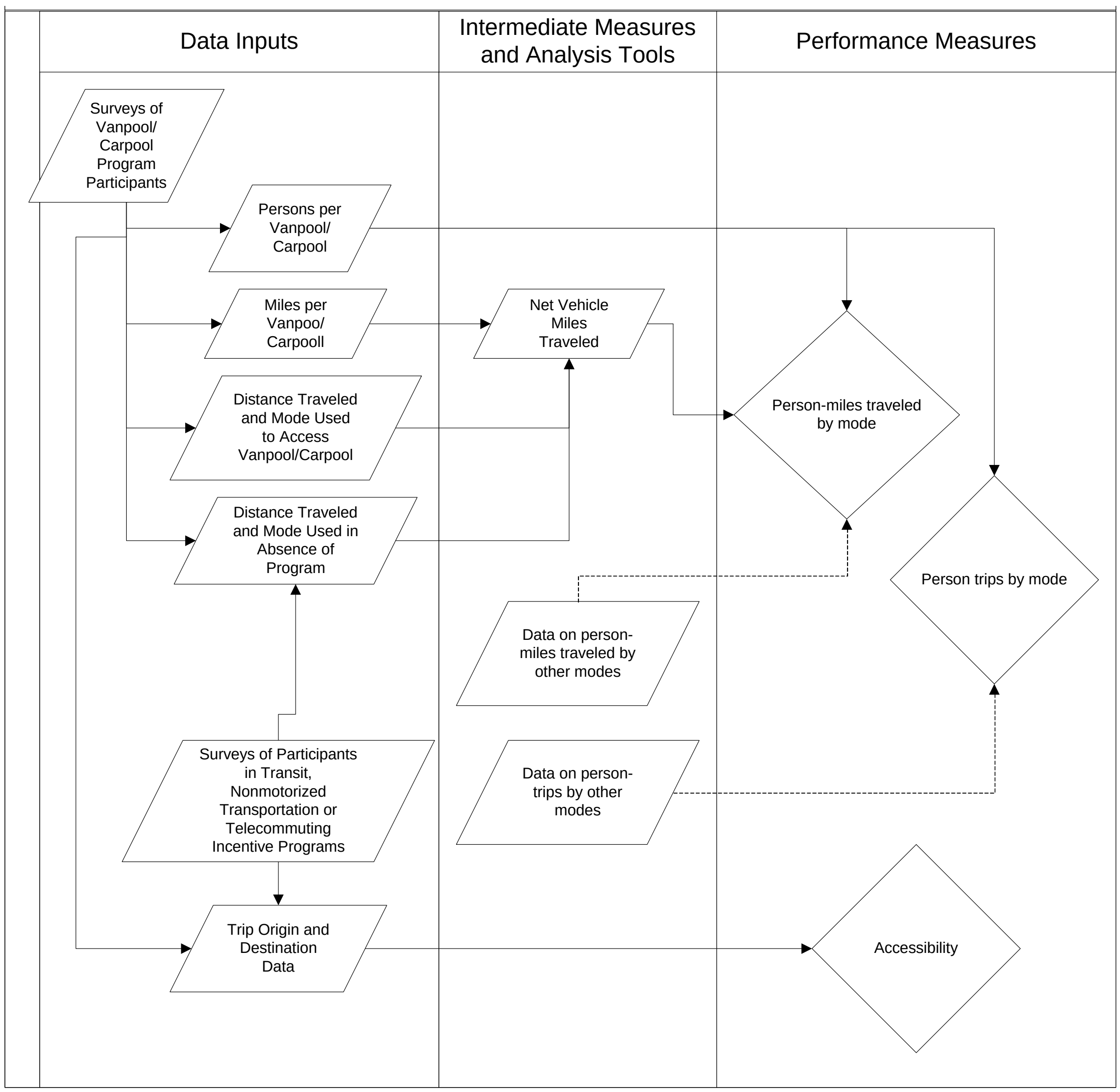
The methodology for calculating each measure is presented in the following sections. Measures in **BOLD** in the table above can be calculated independently. The remaining measures rely on interdependent data, or, in some cases, depend on each other.

3.9.1 Evaluating User Responsiveness Measures

NJTPA User Responsiveness Goal - Provide affordable, accessible and dynamic transportation systems responsive to current and future customers.

Interdependencies between Data, Analysis Tools, and Performance Measures

The following diagram is a simplification of the interdependencies between User Responsiveness and System Coordination measures. *Note: Customer Satisfaction is independently evaluated and not included in this diagram. For further information, see page 3.9-8.*



Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Surveys of users of carpools and vanpools: • Persons per vehicle • Miles traveled per vehicle • Per-person distance traveled to access vehicle • Modes used in absence of carpool/vanpool • Trip origin-destination data	NJTPA Transportation Management Association (TMA), NJ Transit, or other implementing agencies
Surveys of users of transit, nonmotorized transportation, and telecommuting incentive programs	NJ Transit, Transportation Management Associations, or other implementing agencies
Average trip distance	Household travel survey data collected by NJTPA or American Community Survey 5-year average data for work/commute trips in place/county in which link is located
GIS data showing location of local destinations and opportunities (health clinics, grocery stores and sources of fresh food, local parks and playgrounds, elementary and secondary schools, and neighborhood-oriented retail and service establishments like restaurants, bars, dry cleaners, banks, and hardware stores)	Counties and local municipalities, NJDOT, NJDEP, Google Maps, WalkScore.com
GIS data showing locations of regional destinations and opportunities (major hospitals, four-year colleges and universities, major concentrations of retail activity, and recreational and tourist destinations with more than 100 employees, like amusement parks, sports arenas, performing arts venues, museums, and historic sites)	Counties and local municipalities, NJDOT, NJDEP, Google Maps, WalkScore.com

Geographic Scale of Analysis

The three User Responsiveness measures are best measured at a regional level or at a corridor level, grouping multiple facilities and modes together to determine the corridor-level or systemwide impacts of any given TDM initiative.

Time Frame of Analysis

The impacts of TDM projects as measured in terms of User Responsiveness measures may be small or may not be measurable at all shortly after completion of the improvement. However, as years pass many changes as measured by User Responsiveness measures may become more pronounced over time. Therefore, it is important to evaluate User Responsiveness measures on a continuous basis, using multiple data points from several years before the project and for as many years after the project as data are available. For a newly started TDM program, 1 year before the implementation or the year when the new program is implemented and a minimum of 2 years for post-implementation year analysis are required. During the first year implementation of a new TDM program, it is suggested that the program be monitored quarterly for adjustment and improvement purposes. For an existing TDM program, the data should be obtained as far back as possible before implementation.

Customer Satisfaction measures are an exception. A user's perception of a TDM initiative may vary with other exogenous factors such as levels of congestion, cost of other modes, convenience (e.g., directness of route taken by a van pool), and reliability (e.g., on-time performance of transit). Therefore, customer satisfaction should be measured as regularly as possible.

Analysis Steps

Intermediate Measures and Analysis Tools

1. Calculate Net Change in VMT associated with a TDM initiative.

   Inputs:

   - Share of participants who previously drove instead of using the program (or would drive in the absence of the program), and distance that they drove (or would drive in the absence of the program).
   - If user-reported distance information is not reliable or not available, collect data on:
     - Average vehicle occupancy from U.S. Census American Community Survey for the study area, county, or the NJTPA Household Survey *Note: ACS only provides data on work or commuting trip.*
     - Average trip distance via driving for those people who switched from driving to TDM program. Can use average distance traveled to work, or the distance from the home zone to a logical destination with high employment densities, for example.

Calculations:

a. Multiply net VMT associated with each participant by average vehicle occupancy data for the county in which the TDM program is implemented, using most recent available data from the U.S. Census, to produce the average vehicle trips reduced.

b. Separate vehicle trips into destination groups, such as out-of-county and out-of-state trips, based on the proportion of transit trips traveling out-of-state and out-of-county from the U.S. Census Journey to Work data.

c. For each destination group, multiply the number of trips by the average distance to the group destinations to produce the reduction in VMT for out-of-state and out-of-county trips.

d. Convert net program participation estimates to net VMT estimates. *If traveler survey data are available, gather information on average trip distance for the vehicles using roadways in the study area. If survey data are not available, use county-level or regional average trip lengths from U.S. Census American Community Survey or Journey to Work data.*

e. Multiply the net new TDM participants by average trip length to calculate a range of estimated net change in VMT attributable to the project.

Intermediate output measures:

- **Net change in vehicle miles traveled.**

Person-Miles of Travel by Mode (Mode Choice)

Inputs:

- Net vehicle miles traveled*, from calculations above.*
- Persons per vehicle (use a single year, perhaps the midpoint of the analysis, so as not to introduce additional error into the calculation). *For example 1.2 persons per vehicle.*
- Modes used to access transit, and mode share for those access modes.

Calculations:

- Multiply estimates of net vehicle miles traveled by persons per vehicle to determine the net change in person-miles traveled by car.
- Multiply the estimates of net new TDM program participants by average travel distance per participant using transit to access ridesharing opportunity and the percentage of the net new TDM program participant access ridesharing opportunity by transit to determine the net change in person-miles traveled by transit. *For example, 450 net new daily TDM participants * 20 miles average round trip distance * 80 percent of whom previously commuted by car = 7,200 passenger-miles per day. Over 200 annual working days, this translates to 1.44 million net new passenger-miles by transit per year.*
- Estimate the person-miles traveled by other modes. *For example, in the above example, if 80 percent of the net new TDM program participants access r ridesharing opportunity by transit, and the remaining 20 percent walk or bike, with an average trip*

*distance of 1 mile, the average passenger miles traveled by nonmotorized modes is 450 net new daily TDM initiative participants * 20 percent * 1 mile = 90 miles per day or 18,000 miles per year.*

Person-Trips by Mode (Mode Choice)

Inputs:

- Net New TDM Program Participants, *from survey data.*
- Share that previously traveled by car*, from survey data*.
- Share of net new riders who access the expanded transit service by car, other transit modes, or nonmotorized modes.

Calculations:

- *From the above example, there are 450 new person-trips per day by non-Single-occupant-vehicle modes.*
- Multiply estimates of net new TDM program participants by the share who previously drove to determine the net change in person-trips by motor vehicles. *For example, 450 net new daily TDM program participants* 80 percent of whom previously commuted by car = a net reduction of 360 person-trips by car. However, if 80 percent of the net new participants drive to access a transit service or ridesharing activity, the actual net reduction is only 450 * 20 percent = 90 person-trips by car.*
- Calculate the person-trips by other modes. *From the previous step, if 20 percent of net new participants use nonmotorized means to access transit or ridesharing activity, the net increase in nonmotorized trips is 450 * 20 percent = 90 person-trips.*

Accessibility

Accessibility is a measure of the ability of people to reach opportunities and activities that they undertake in their daily lives, or the ability of businesses to reach their labor force, sources of raw materials and inputs to their production facilities, and the consumer markets for their finished products. Most TDM initiatives do not change the distance or travel time to a destination, but rather provide a person with their sole means of accessing that destination when transit service is not available or the transit travel time will take much longer. Unlike other project types, Accessibility for TDM initiatives is typically measured as an all-or-nothing proposition.

Access to jobs refers to the ability of the residents of a given area to access employment opportunities via any mode of transportation. Increased access to jobs is correlated with reduced unemployment rates and improved per capita income.

Access to regional amenities can include the ability to reach major hospitals, universities, major concentrations of retail activity, and recreational and tourist destinations like amusement parks, beaches, sports arenas, performing arts venues, museums, and historic sites. Regional amenities can be screened using employment (only destinations with more than 100 employees, or retail employment density greater than 100 per acre, for example).

Access to community amenities can be defined as the ability to reach destinations that are sources of basic services and daily needs, and may include health clinics, grocery stores and sources of fresh food, local parks and playgrounds, elementary and secondary schools, and neighborhood-oriented retail and service establishments like restaurants, bars, dry cleaners, banks, and hardware stores.

Inputs:

- Survey data regarding means of access in the absence of the TDM initiative. *For example, a question might ask whether a person would be able to make the trip in the absence of a transit voucher or ridesharing opportunity.*

Calculations:

- Based on survey data, determine the absolute number or proportion of TDM program participants who would not be able to make the trip in the absence of the initiative.

Output:

- **Net change in number of people able to access jobs, community amenities, and regional amenities.**

Customer Satisfaction

Customer Satisfaction is a measure that does not depend on inputs from any other performance measure. Customer Satisfaction measures can be obtained from the results of surveys performed by implementing agencies after completion of a project.

Inputs:

- Surveys of TDM participants, ideally including information about the relative importance of each system attribute being queried.
- Typical questions on TDM-related customer satisfaction surveys include:
    - Customer perception of improvement's impacts across NJTPA goal areas: Built and natural environment, travel speed, travel time reliability/on-time performance, waiting time, access to destinations, safety, economic impacts.
    - Program's impact on travel behavior: Whether the improvement caused mode shifts ("What was the previous mode used to make the trip?") and destination choice decisions (e.g., enabled a longer trip to a destination not previously accessible).
    - Impacts of TDM incentives (if any): operating subsidies, guaranteed ride home program, and other incentive programs.

Recommendations for Future Performance Evaluation: User Responsiveness Measures

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 such as GPS type of travel diaries and using TRANSCOM and INRIX data. Older methods include 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.

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.

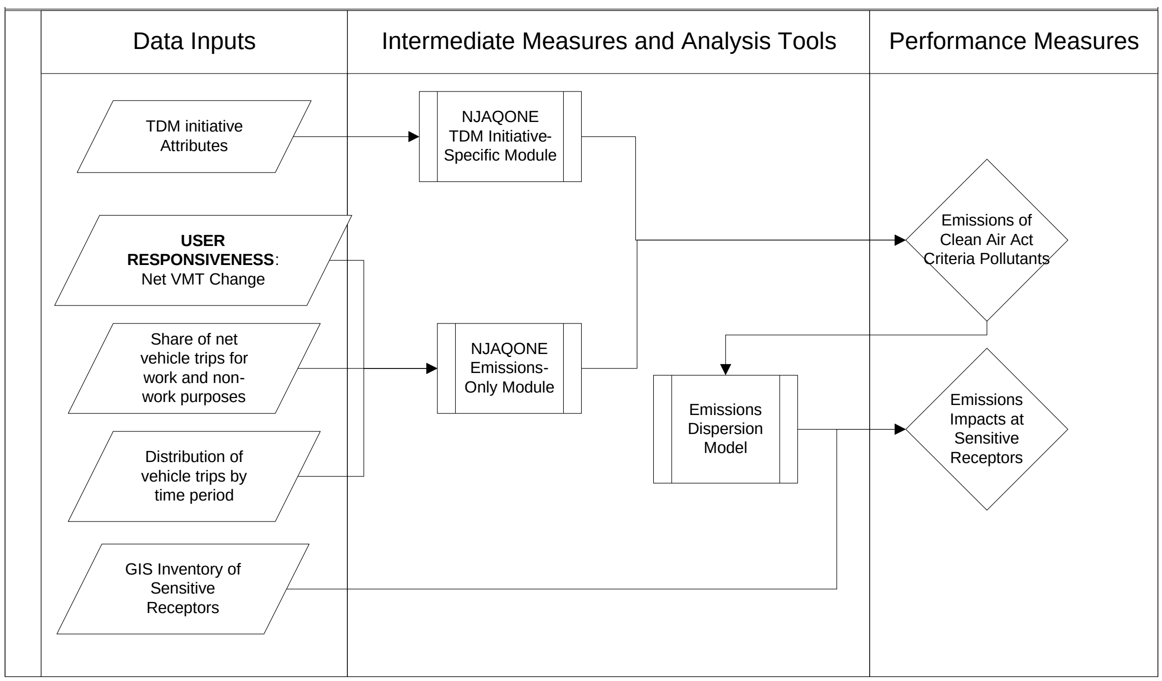
Undertake more customer satisfaction surveys for all modes on a regular. Agencies responsible for building, maintaining, and operating the transportation system in the region should undertake regular customer satisfaction surveys to collect a range of qualitative and quantitative data about customer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

3.9.2 Evaluating Environment Measures

NJTPA Environment Goal - Protect and improve the quality of natural ecosystems and human environment.

Interdependencies between Data, Analysis Tools, and Performance Measures

The following diagram is a simplification of the interdependencies between Environment measures and the intermediate and ultimate measures discussed in the User Responsiveness sections:



Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Net VMT change	Performance measure calculated in **User Responsiveness**; see methodology above
Attributes of TDM Initiatives	NJ Transit, TMA
Age of the vehicle fleet	Sponsoring agencies, NJDEP for emission factors
Share of net vehicle trips for work and non-work purposes	NJTPA household surveys
Distribution of vehicle trips by time period	NJDOT Roadway Network File
GIS Inventory of Sensitive Receptors	NJDOT and NJDEP GIS; Google Maps and other commercial sources
Net person-miles of travel by biking and walking	Performance measure calculated in **User Responsiveness**; see methodology above

Geographic Scale of Analysis

The geographic scale of analysis depends on the measure being assessed. The following table shows the recommended geographic scale of each measure.

Measure	Geographic Scale(s) of Analysis
Emissions of Clean Air Act criteria air pollutants and greenhouse gases	Air quality (AQ) data are collected at the facility level as well as at the regional scale. The regional and statewide travel demand models that are necessary to quantify emissions are based on this state and regional data collection. Transportation-related emissions, for example greenhouse gases, do not respect state and regional boundaries; therefore regional and statewide data are necessary. The Clean Air Act requires regional and project level hotspot analysis. Most non-attainment areas have on the ground monitoring units in set locations. These units are not typically moved to measure emissions for specific projects. Transportation emissions that lead to respiratory conditions and other health impacts should be estimated at sensitive receptors within ¼ mile of project limits.

Time Frame of Analysis

The ability to measure the net Environmental impacts of a project/program over time is directly dependent on the ability to measure net VMT impacts, net changes in AADT, net impacts on congested travel speeds, and net impacts on mode choice decisions. As the quality or reliability of these estimates deteriorate over time, so does the reliability of the results of an environmental impact assessment. Therefore, the time frame of analysis for Environment performance measures should mirror the time frames for User Responsiveness measures: measures should be on a continuous basis if possible, using multiple data points from several years before the project and for as many years after the project as data are available in order to draw valid conclusions about the net impacts of a project.

As indicated in the above graphic, the environmental impacts of transit projects are often measured at a regional scale. Therefore, the net impacts of any one project may be clouded over time by economic growth that generates additional travel demand (in turn affecting emissions and noise), or by changes in the region's socioeconomic and demographic profile that affect public health outcomes. On a project-by-project basis, professional judgment will be necessary to determine the limits of credibility of the following analysis.

Analysis Steps

Emissions of Clean Air Act Criteria Pollutants

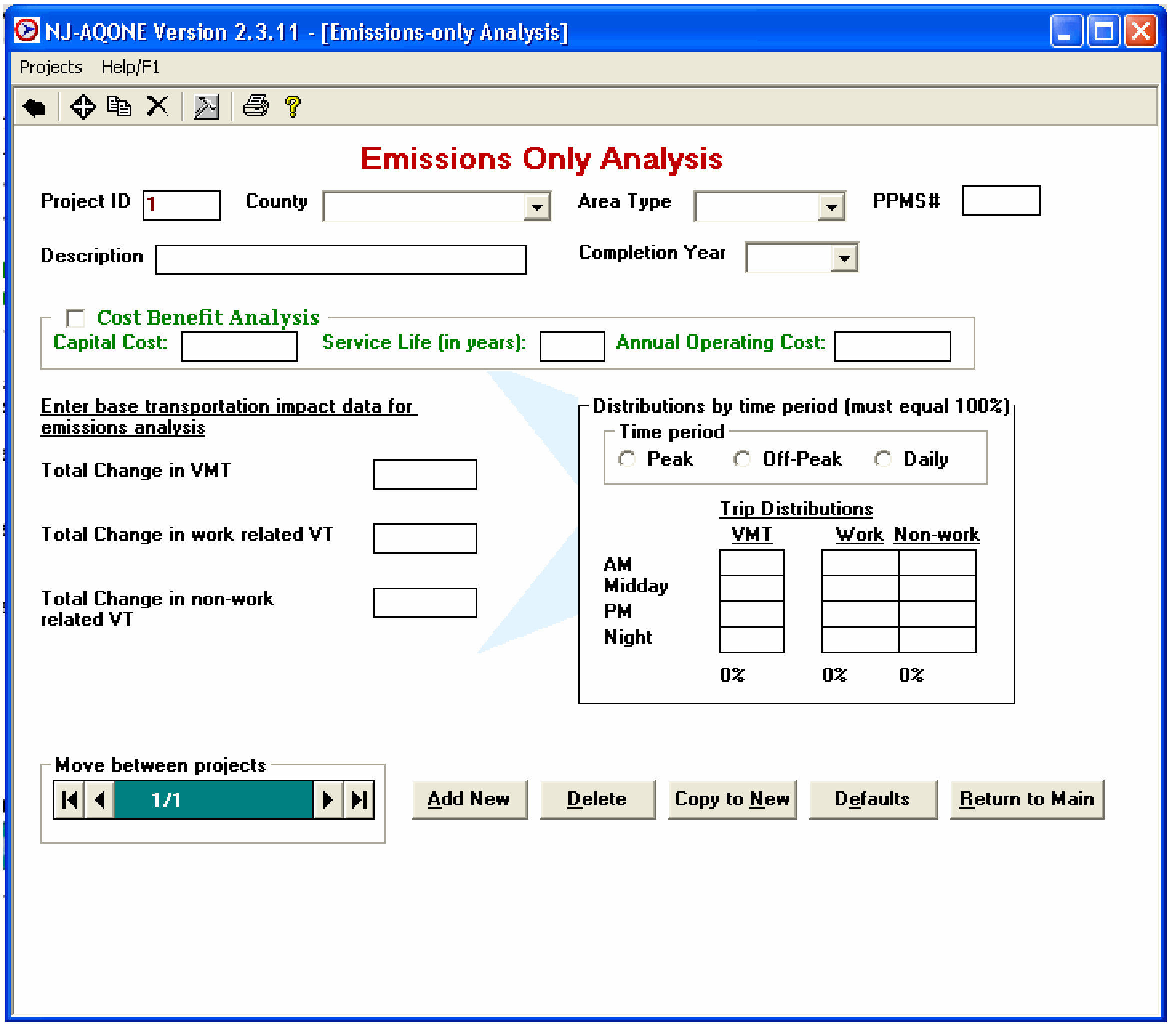
Inputs:

- Total change in VMT attributable to project (intermediate output measure of **User Responsiveness** analysis).
- Total change in work and non-work related vehicle trips attributable to project (from regional household travel surveys).
- Distribution of travel by time period (based on available NJDOT traffic volume data for roadways affected by the project, either hourly, 15-minute, or continuous counts).

Analysis Tools:

- Use NJAQONE Emissions-Only module to estimate emissions in forecast year. Conduct one run for "no-build" condition and a second run for the "build" condition.

Figure 3.9-A: Example Emissions Only Analysis Input Screen from NJAQONE



Output measures:

- Estimated **change in emissions by criteria pollutant.**

1. Generate emissions contour maps.

Inputs:

- Estimated change in emissions by criteria pollutant, from NJAQONE or MOVES.
- Baseline emissions estimates, from NJAQONE or MOVES baseline data.
- Geography-specific climate data. Can use defaults built into models.

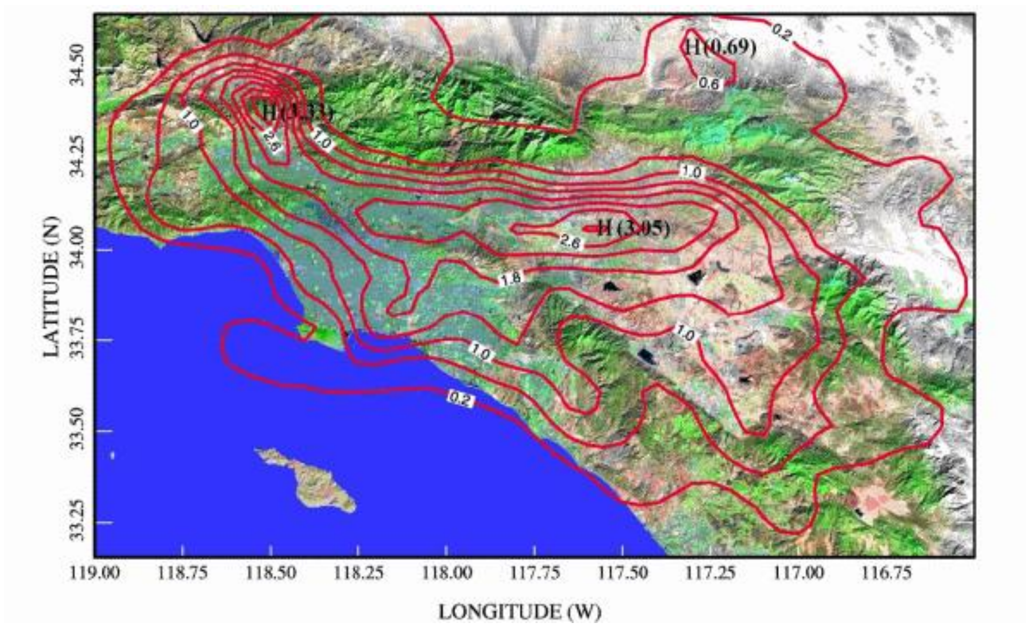
Analysis Tools:

- Use Emissions Dispersion model to allocate emissions to points or subregions in the analysis area. Conduct one run for baseline conditions and a second run for "build" condition.

Outputs:

- Emissions contour maps showing concentrations by criteria pollutant for baseline condition and for "build" condition.

Figure 3.9-B: Example map of daily emissions of soot in micrograms per cubic meter for Los Angeles Metropolitan Area



2. Overlay sensitive receptor points on emissions contour maps.

Inputs:

- Emissions contour maps for baseline condition and "build" condition from dispersion model.
- GIS layer of sensitive receptors in NJTPA region.

Calculations:

Net emissions impact at any given sensitive receptor is the difference between the build condition and the baseline condition. Repeat calculation for each sensitive receptor.

Outputs:

- **Estimated emissions impacts by sensitive receptor.** *For example, "Emissions of particulate matter (PM 2.5) increased from 1.2 micrograms per cubic meter to 1.8 micrograms per cubic meter as a result of the project."*

Recommendations for Future Performance Evaluation: Environment Measures

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 emissions, 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.
- 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 in Roadway section).
- 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/

Recommendations for Future Performance Evaluation: Environment Measures

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, they 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 opportunity 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.

3.9.3 Evaluating Land Use/Transportation Coordination Measures

NJTPA Land Use/Transportation Coordination Goal - Select transportation investments that support the coordination of land use with transportation system.

Interdependencies between Data, Analysis Tools, and Performance Measures

The evaluation of the Land Use/Transportation Coordination measure per capita vehicle miles traveled depends on a calculation of the intermediate measure vehicle miles traveled in the **User Responsiveness** goal area.

Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Net VMT Change	Intermediate measure calculated in **User Responsiveness**; see methodology above
Population	U.S. Census Bureau's American Community Survey 5-year estimates
Employment	U.S. Census Bureau's Local Employment-Household Dynamics data; NJ Labor and Workforce Development, and/or U.S. Bureau of Labor Statistics
Census tract area	U.S. Census Bureau TIGER Line Shape Files

Geographic Scale of Analysis

An analysis of net per capita VMT for TDM program should be performed on the same scale as the net VMT calculation. Often, this calculation will be performed at a regional scale.

Time Frame of Analysis

The impacts of TDM initiatives as measured in terms of Land Use/Transportation Coordination measures may be small or may not be measurable at all shortly after completion of the improvement, because development induced by a TDM program will happen gradually over time. However, as years pass many changes as measured by Land Use/Transportation Coordination measures may become less pronounced over time. Therefore, it is important to evaluate Land Use/Transportation Coordination measures on a continuous basis, using multiple data points from several years before the program and for as many years after the project as data are available.

Analysis Steps

Population and Employment Density

Inputs:

- For discrete, corridor-oriented projects, obtain data on population in census tracts within ¼ mile of program limits, from periods before and after implementation of the travel demand management program. For projects with a subregional or regional focus, collect data on population at the municipal or county level. *Use U.S. Census Bureau's American Community Survey (ACS) 5-year Estimates for a rolling annual estimate of census-tract-level population data. Note: The U.S. Census Bureau cautions against comparing ACS data from overlapping time periods. ACS is mainly intended to be used for population characteristics, not population totals, especially at smaller geographies (e.g., Census tracts).*

- For discrete, corridor-oriented projects, obtain data on employment in census tracts within ¼ mile of program limits, from periods before and after implementation. For projects with a subregional or regional focus, collect employment data at the municipal or county level. *Use U.S. Census Bureau's Longitudinal Employer-Household Dynamics (LEHD) data.*

- Area of census tracts within ¼ mile of program limits, in miles, from U.S. Census Bureau's Topologically Integrated Geographic Encoding and Referencing (TIGER) system. *Note that census tract boundaries may change over time, particularly when a new decennial Census is undertaken. It is important to use areas that are as identical as possible for the before and after comparison.*

Calculation:

- Use GIS to aggregate population in census tracts within ¼ mile of program limits and divide by aggregate area of those tracts. Calculate population density for period before implementation and period after implementation.

- Use U.S. Census Bureau's Longitudinal Employer-Household Dynamics online mapping tool, called "OntheMap", to aggregate employment in census tracts within ¼ mile of project limits and divide by aggregate area of those tracts. Calculate employment density for periods before implementation and after implementation.

- *The net change in population and employment density cannot be calculated, but a qualitative analysis of the circumstances before and after implementation of the program may provide clues to whether any changes in population and employment density can be attributable to the program. For example, similar to the net new participant calculation in "User Responsiveness" section, population and employment density in the study area can be compared to a "control" area that had conditions similar to the study area before implementation.*

Output:

- **Population density**, in persons per square mile.
- **Employment density**, in jobs per square mile.

Additional resources on population and employment density include the following:

- U.S. Census Bureau Longitudinal Employer-Household Dynamics website, http://lehd.did.census.gov/led/.
- U.S. Census Bureau's Topologically Integrated Geographic Encoding and Referencing (TIGER) system website, http://www.census.gov/geo/www/tiger/index.html.

Per Capita Vehicle Miles Traveled

Inputs:

- Net regionwide vehicle miles of travel attributable to the program.
- Regional population data from before and after program implementation.

Calculation:

- Divide regionwide vehicle miles of travel before construction by population before construction, perform the same calculation for the period after construction, and subtract the two values to calculate an estimate of net change in per capita vehicle miles traveled.

Output:

- **Daily per capita vehicle miles traveled.** *The daily VMT per capita in the NJTPA region is around 13.8 miles per capita according to recent survey results.*

Recommendations for Future Performance Evaluation: Land Use/Transportation Coordination Measures

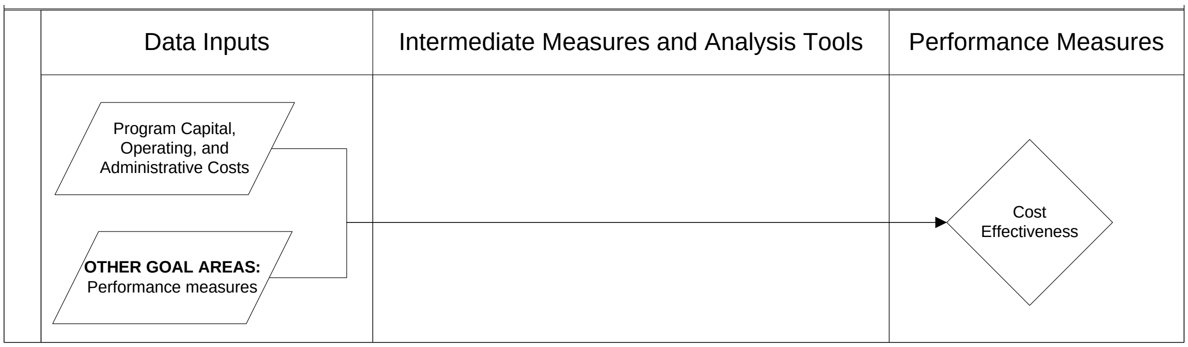
Improve availability and archiving of parcel-level land use data. Population and employment density can provide potential proxies for actual land use changes that occur in response to transportation investments and policy changes. However, it is currently difficult to gather historical and sometimes 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).

3.9.4 Evaluating Economy Measures

NJTPA Economy Goal - Retain and increase economic activity and competitiveness.

Interdependencies between Data, Analysis Tools, and Performance Measures

The following diagram is a simplification of the interdependencies between Economy measures and the intermediate and ultimate measures discussed in the User Responsiveness section. No intermediate measures or analysis tools were used in the analysis.



Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Program capital, operating, and administrative costs	Sponsoring agencies or transit operators
Performance measures to be used as denominators for cost effectiveness calculations	Calculations in other goal areas

Geographic Scale of Analysis

All measures in the Economy goal area should be evaluated within the project limits for discrete projects, or for the entire region for programs that have a regional emphasis.

Time Frame of Analysis

The impacts of TDM program as measured in terms of Economy measures may be small or may not be measurable at all shortly after program implementation or after significant revision of an existing program, because participant induced by a TDM program will happen gradually over time. However, as years pass many changes as measured by Economy measures may become less pronounced over time. Therefore, it is important to evaluate Economy measures on a continuous basis, using multiple data points from several years before the project and for as many years after the project as data are available.

Analysis Steps

Cost Effectiveness

<u>Inputs:</u>

- Program capital costs plus ongoing operating and administrative costs, in dollars.
- Performance measures from previous calculations (e.g., operating cost savings, and emissions reduction).

<u>Calculations:</u>

- Divide the combined capital, operating, and administrative cost by any performance measure to calculate the dollar-weighted impacts of the program. *For example, program with an annualized capital cost of $25,000/year over the useful life of the improvements that reduces operating costs by $50,000 per year yields a net savings of $25,000 per year. If the project reduces carbon emissions by 25 tons per year, it has a cost-effectiveness index of $1,000/ton/year.*

<u>Outputs:</u>

- **Cost Effectiveness***, expressed in dollars per unit of benefit per dollar (e.g., dollars per accident reduced; dollar per minute of travel time savings; dollars per ton of reduced carbon emissions).*

NOTE: While cost-effectiveness measures are constituents of a broader benefit-cost analysis approach, many cost-effectiveness measures are not additive. Therefore, extreme caution should be exercised in presenting and explaining results of a project-level cost-effectiveness analysis.

Recommendations for Future Performance Evaluation: Economy Measures

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 program'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.

3.10 Bicycle and Pedestrian Projects

Bicycle and Pedestrian Facilities: 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 projects.

Contents of This Section

Suggested Work Flow for Bicycle and Pedestrian Projects

The following sequence of goal areas for this project category was developed specifically to enable an ordered evaluation of performance measures. This allowed calculations from earlier intermediate (and final) measures in one goal area to serve as inputs for measures in other goal areas:

1. System Coordination Measures
2. User Responsiveness Measures
3. Environment Measures
4. Land Use/Transportation Coordination Measures
5. Repair/Maintenance/Safety/Security Measures
6. Economy Measures

The methodology for calculating each measure is presented in the following sections. Measures in **BOLD** in the table above can be calculated independently.

3.10.1 Evaluating System Coordination Measures

NJTPA System Coordination Goal - Enhance system coordination, efficiency, and intermodal connectivity

Interdependencies between Data, Analysis Tools, and Performance Measures

The only applicable System Coordination measure is “Network Connectivity and Continuity by Mode”, which can be evaluated independently.

Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Bicycle network characteristics: • Presence and type of bike lanes in each direction (physically separated path, marked and signed lane, shared and signed lane, no bike facility) • Density of nodes (intersections) and segments in the bike network • Condition of bike lanes (e.g., pavement condition, shoulder width, obstacles like double-parked cars) • Presence of bicycle-specific pavement markings, signage, and signals (if appropriate) at intersections	Roadway GIS data, NJDOT Straight-Line Diagrams, Aerial Photos, field observations
Pedestrian network characteristics: • Presence or absence of sidewalks on each side of roadway • Sidewalk width • Barriers within sidewalk width (e.g., trees, signage, light posts that reduce effective width below minimum acceptable standard) • Physical separation from adjacent roadway • ADA accessibility at curb cuts and on sidewalk (slopes, pavement condition) • Number of driveways and curb cuts per mile • Presence of pedestrian-specific pavement markings (including crosswalks), signage, signals (if appropriate), and pedestrian refuges (if appropriate) at intersections • Length of pedestrian crossings at major intersections and corresponding pedestrian signal green time • Presence or absence of pedestrian amenities like landscaping, benches, pedestrian-scale lighting, art, special paving • Adjacent land use: Building setbacks, uses, percent of frontage dedicated to automobile driveways and parking, presence or absence of sidewalk entrances, and display windows	Roadway GIS data, NJDOT Straight-Line Diagrams, Aerial Photos, field observations

Data Inputs	Sources
Roadway link characteristics: • Roadway functional classification • Number of lanes and lane widths in each travel direction • Number of shoulders and shoulder widths in each travel direction • Terrain type, horizontal curvature (blind curves), and vertical curvature (hills) • Vehicle classification and composition (percent trucks and heavy vehicles in traffic flow) • Median type and lateral clearance • Number of driveways and curb cuts per mile	
Roadway and multi-use path link lengths and number of intersections per square mile	Roadway GIS data, NJDOT Straight-Line Diagrams, Aerial Photos

Geographic Scale of Analysis

An analysis of System Coordination measures for Bicycle and Pedestrian projects should be conducted for the project limits. In some cases, the analysis should extend up to ½ mile beyond the project limits to streets surrounding the project to provide better context for the network connectivity and continuity analysis.

Time Frame of Analysis

Bicycle and pedestrian projects should have lasting benefits which may occur in both the short and long term. Therefore, an analysis should take into account conditions before and after implementation, using the best data available.

Analysis Steps

Intermediate Measures and Analysis Tools

An analysis of bicycle and pedestrian networks needs to include a quality-of-service component to enable an analysis by facility "functional classification." Both quantitative, objective criteria and qualitative, subjective criteria should be considered. There are many methodologies available for calculating bicycle and pedestrian level of service. Two examples for bicycle level of service and one example for pedestrians are provided below.

Example Calculation Methodology #1: As one example, the following scoring system is used by the City of Gainesville, Florida, and has been adapted for use by the Florida Department of Transportation:

Bicycle and Pedestrian Level-of-Service Performance-Measure Point System[1]

BICYCLE			PEDESTRIAN		
CATEGORY	CRITERION	POINTS	CATEGORY	CRITERION	POINTS
BICYCLE FACILITY PROVIDED	Outside Lane 3.66m (12')	0	PEDESTRIAN FACILITY PROVIDED	Not Continuous or Non-existent	0
(Max Value = 10)	Outside Lane >3.66m-4.27m (>12'-14')	5	(Max Value = 10)	Continuous on One Side	4
	Outside Lane >4.27m (>14')	6		Continuous on Both Sides	6
	Off-Street / Parallel Alternative Facility	4		Min. 1.53m (5') Wide & Barrier Free	2
				Sidewalk Width >1.53m (5')	1
				Off-Street / Parallel Alternative Facility	1
CONFLICTS	Driveways & Sidestreets	1	CONFLICTS	Driveways & Sidestreets	1
(Max Value = 4)	Barrier Free	0.5	(Max Value = 4)	Ped Signal Delay 40 Sec. or Less	0.5
	No On-Street Parking	1		Reduced Turn Conflict Implementation	0.5
	Medians Present	0.5		Crossing Width 18.3m (60') or Less	0.5
	Unrestricted Sight Distance	0.5		Posted Speed	0.5
	Intersection Implementation	0.5		Medians Present	1
SPEED DIFFERENTIAL	>48 KPH (>30 MPH)	0	AMENITIES	Buffer Not Less Than 1m (3.5')	1
(Max Value = 2)	40-48 KPH (25-30 MPH)	1	(Max Value = 2)	Benches or Pedestrian Scale Lighting	0.5
	24-32 KPH (15-20 MPH)	2		Shade Trees	0.5
MOTOR VEHICLE LOS	LOS = E, F, OR 6 or More Travel Lanes	0	MOTOR VEHICLE LOS	LOS = E, F, OR 6 or More Travel Lanes	0
(Max Value = 2)	LOS = D and < 6 Travel Lanes	1	(Max Value = 2)	LOS = D and < 6 Travel Lanes	1
	LOS = A, B, C, and < 6 Travel Lanes	2		LOS = A, B, C, and < 6 Travel Lanes	2
MAINTENANCE	Major or Frequent Problems	-1	MAINTENANCE	Major or Frequent Problems	-1
(Max Value = 2)	Minor or Infrequent Problems	0	(Max Value = 2)	Minor or Infrequent Problems	0
	No Problems	2		No Problems	2
TDM / MULTI-MODAL	No Support	0	TDM / MULTI-MODAL	No Support	0
(Max Value = 1)	Support Exists	1	(Max Value = 1)	Support Exists	1
CALCULATIONS	Segment Score [1]	21	CALCULATIONS	Segment Score [1]	21
	Segment Weight [2]	1		Segment Weight [2]	1
	Adjusted Segment Score [3]	21		Adjusted Segment Score [3]	21
	Corridor Score [4]	21 = LOS A		Corridor Score [4]	21 = LOS A

[1] Segment Score = sum of points in the six categories
[2] Segment Weight = segment length / corridor length
[3] Adjusted Segment Score = Segment Score x Segment Weight
[4] Corridor Score = sum of the Adjusted Segment Scores in the corridor

[1] Source: Dixon, Linda, 1996. "Bicycle and Pedestrian Level-of-Service Performance Measures and Standards for Congestion Management Systems." *Transportation Research Record 1538*, Transportation Research Board, Washington, D.C.

The methodology for evaluating each measure and calculating a bicycle and pedestrian level of service can be found in the "Bicycle and Pedestrian Level-of-Service Performance Measures and Standards for Congestion Management Systems." By Transportation Research Record 1538, Transportation Research Board, Washington, D.C. Note that the score can be calculated on a corridor level as well as segment-by-segment level. In addition to the criteria in the above table, the following additional factors may be considered in an analysis of pedestrian level of service:

- Sidewalk and crosswalk design: use of special pavements, colors, and textures to delineate pedestrian areas.
- Adjacent land use and development characteristics:
  - Building setbacks (structure built up to sidewalk vs. set back behind landscaping vs. set back behind parking lot);
  - Land uses (auto-oriented uses like car dealers, repair shops, gas stations vs. residential, retail, institutional, office, and other pedestrian destinations);
  - Percent of frontage dedicated to automobile driveways and parking;
  - Presence or absence of sidewalk entrances and display windows on street (vs. entrances facing parking lots).

Table 3.10-A: Bicycle and Pedestrian Level of Service Score Ranges Using Calculation Methodology #1

Score Range	17.1-21	14.1-17	11.1-14	7.1-11	3.1-7	0-3
LOS Level or Grade	A	B	C	D	E	F

Example Calculation Methodology #2: As an alternative to the above calculation, a second methodology for calculating bicycle level of service (BLOS) is as follows. A statistically-calibrated equation for bicycle level of service, similar to those found in the Highway Capacity Manual, was developed by Landis et. al:[2][3]

$$\text{Bicycle LOS} = 0.507 \ln(Vol_{15}/L_n) + 0.199\, SP_t(1+10.38HV)^2 + 7.066(1/PR_5)^2 - 0.005\, W_e^2 + 0.760$$

where:

Vol_{15} = volume of directional traffic in 15 minutes = (ADT * D * K_d) / (4 * PHF)

ADT = Average Daily Traffic on the segment

D = Directional Factor

K_d = Peak to Daily Factor

PHF = Peak Hour Factor

L_n = number of directional through lanes

SP_t = effective speed limit = $1.1199 \ln(SP_p-20) + 0.8103$, where SP_p is the posted speed limit

HV = percentage of heavy vehicles

PR_5 = FHWA's 5-point pavement surface condition rating (5=best)

W_e = average effective width of outside through lane:

$W_e = W_v - (10' * OSPA)$, where $W_1 = 0$

$W_e = W_v + W_1 (1 - 2 * OSPA)$ where $W_1 > 0$ & $W_{ps} = 0$

$W_e = Wv + W_1 - 2 (10' * OSPA)$ where $W_1 > 0$, $W_{ps} > 0$, and a bike lane exists.

W_t = total width of outside lane (and shoulder) pavement

OSPA = fraction of segment with occupied on-street parking

W_1 = width of paving between outside lane stripe and edge of pavement

W_{ps} = width of pavement striped for on-street parking

W_v = effective width as a function of traffic volume

$W_v = W_t$ if ADT>4000 veh/day

$W_v = W_t (2 - (ADT/4000))$ if ADT<4000 and road is undivided and unstriped.

For Pedestrian Level of Service, the following equation is used:

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[2] Landis, Bruce (1997). "Real-Time Human Perceptions: Toward a Bicycle Level of Service," *Transportation Research Record 1578*, Transportation Research Board, Washington DC.

[3] See also: Sprinkle Consulting, Inc. (2007). "Bicycle Level of Service Applied Model." Available from the Florida Department of Transportation at: http://www.dot.state.fl.us/planning/systems/sm/los/pdfs/bikelosmod.pdf

$$\text{Pedestrian LOS} = -1.227 \ln(W_{ol} + W_l + f_P \times \%OSP + f_b \times W_b + f_{SW} \times W_S) + 0.009\,(Vol_{15}/L) + 0.0004\,SPD^2 + 6.046$$

where:

W_{ol}= width of outside lane

W_l= width from outside lane stripe to pavement edge (shoulder, parking, bike lanes)

f_P= on-street parking effect coefficient

%OSP = percent of segment with on-street parking

f_b= buffer area barrier coefficient

W_b= buffer width (between edge of pavement and sidewalk)

f_{SW}= sidewalk presence coefficient

W_S= width of sidewalk

Vol_{15}= volume of directional traffic in 15 minute time period

L = total number of through lanes

SPD = average running speed of traffic

Bicycle and Pedestrian Level of Service ranges and associated level of service designations, based on the above equations, are as follows.

Table 3.10-B. Bicycle and Pedestrian Level of Service Score Ranges Using Calculation Methodology #2

Level of Service Score Range	< 1.50	1.51-2.50	2.51-3.50	3.51-4.50	4.51-5.50	> 5.50
LOS Level or Grade	A	B	C	D	E	F

A level of service calculator that uses the above equations is available online at:
http://www.bikelib.org/roads/blos/losform.htm

BLOS/PLOS Calculator Form

Bicycle Level of Service (BLOS) and Pedestrian Level of Service (PLOS) are two nationally-used measures of user comfort level as a function of a road corridor's geometry and traffic conditions. (Note that BLOS only measures ***on-road*** bicyclist comfort level.) The League of Illinois Bicyclists (LIB) created this calculator for the formulas, which were published by Sprinkle Consulting.

To calculate BLOS and PLOS of a particular roadway section, fill out the following for the typical cross-section. Results will pop up in a new window. Default values will be used for any fields left empty.

Some details on the BLOS input fields and their ranges are below. Further information and references on these measures are here.

Through lanes per direction: (Default = 1)	1
Width of outside lane, to outside stripe, in ft: (Default = 12)	12
Paved shoulder, bike lane, OR marked parking area - outside lane stripe to pavement edge, in ft: (Def=0)	0
Bi-directional Traffic Volume, in ADT: (Default = 12000)	12000
Posted speed limit in mph: (Default = 40)	40
Percentage of heavy vehicles: (Default = 2)	2
FHWA's pavement condition rating: (5 = Best, 1 = Worst; Default = 4)	4
Percentage of road segment with occupied on-street parking: (Default = 0)	0
Percentage of segment with sidewalks: (0 - 100, default = 100)	100
Sidewalk width, in ft: (Default = 5)	5
Sidewalk buffer/parkway width, in ft: (Default = 10)	10
Buffer/parkway average tree spacing, in ft: (Default = 80, 0 for no trees)	80

Calculate Reset

Inputs and calculations: See tables and calculations above and source documents.

Intermediate output measures: **Bicycle and pedestrian level of service**.

Network Connectivity and Continuity Analysis

Inputs:

- Bicycle network information:
  - Presence and type of bike facilities in each direction.
  - Bicycle level of service (LOS) by link and corridor (see above).
  - Density of nodes (intersections) and segments in the bike network, in intersections per square mile and segments per square mile.
- Pedestrian network information:
  - Presence and type of pedestrian facilities.
  - Pedestrian level of service (LOS) by link and corridor (see above).
  - ADA accessibility at curb cuts and on sidewalk (slopes, pavement condition).

Evaluation: Use GIS to evaluate connectivity of bicycle and pedestrian networks before and after improvement. Evaluate connectivity on both a local scale and a regional scale. The *Smart Transportation Guidebook*, published in March 2008 through a partnership between the Pennsylvania Department of Transportation and the New Jersey Department of Transportation, suggests the bicycle and pedestrian connectivity measures:

- **Internal Connectivity.** Use either of the following two measures:
  - Calculate the Beta Index, which is the number of links divided by the number of nodes or link ends. *A higher ratio indicates higher street connectivity.*
  - Calculate the number of intersections per square mile. S*trict grid systems have about 25 intersections per square mile, while conventional branching systems have about one-third to one-half that many.*
- **External Connectivity**
  - Ideally, all major generators of pedestrian activity should be directly connected to the bicycle and pedestrian network. Schools, universities, fixed guideway transit stations, and other major generators should be linked to a fully connected and continuous pedestrian network within a ½ mile radius and to a bike network within a 5 mile radius.
- **Route Directness**
  - This measures the distance a pedestrian would walk or a cyclist would ride between two points compared to the straight line (or radial) distance between the same two points. *The closer the ratio is to 1.0, the more direct the route; route directness values of 1.2-1.5 describe reasonably connected walkable and bikable networks.*
- Connectivity and continuity in the “no-build” condition are simply the conditions that existed before construction.
- Compare route directness analysis for “no-build’ and after conditions.

Additional resources on Network Connectivity and Continuity Analysis include the following:

- Carlos A. Alba and Edward Beimborn (2005), *Analysis Of The Effects Of Local Street Connectivity On Arterial Traffic*, Transportation Research Board Annual Meeting (www.trb.org); at www.uwm.edu/Dept/CUTS//lu/conn.pdf.
- Dill, Jennifer (2004). "Measuring Network Connectivity for Bicycling and Walking." Presented at the 83rd Annual Meeting of the Transportation Research Board, Washington, DC.
- New York City Department of Planning, Transportation Division (2006). "Pedestrian Level of Service Study - Phase I," available at: http://www.nyc.gov/html/dcp/html/transportation/td_ped_level_serv.shtml.
- Portland Metro (2001), "Street Connectivity Standards," *Planning for Future Streets: Implementing the Regional Transportation Plan*, Portland Metro Regional Services (www.metro-region.org/library_docs/trans/streetconnect.pdf).
- Portland Metro (2004), Street Connectivity: An Evaluation of Case Studies in the Portland Region, Portland Metro (http://library.oregonmetro.gov/files/connectivityreport.pdf).
- San Francisco Metropolitan Transportation Council (MTC) procedures for pedestrian and bicycle network analysis: (http://www.mtc.ca.gov/planning/smart_growth/stars/Appendix_G_GIS_Analysis_Procedures.pdf).

Recommendations for Future Performance Evaluation for System Coordination

Improve network GIS data, particularly pedestrian and bicycle system attributes. Bicycle and pedestrian level of service values could be assigned to each link in the network given improved information on presence or absence of bicycle and pedestrian facilities, and, where facilities do exist, attributes such as facility geometry, signage, markings, pavement type and condition, and level of amenities.

3.10.2 Evaluating User Responsiveness Measures

NJTPA User Responsiveness Goal - Provide affordable, accessible, and dynamic transportation systems responsive to current and future customers.

Interdependencies between Data, Analysis Tools, and Performance Measures

All three of the User Responsiveness measures are independently evaluated.

Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	**Sources**
Average trip distance	Household travel survey data collected by NJTPA or American Community Survey 5-year average data for commute/work trips for place/county in which link is located.
Socio-economic, demographic, and employment data (Census Block Group, Traffic Analysis Zone (TAZ), or Place level)	U.S. Census Bureau- Population, U.S. Census' Longitudinal Employer- Household Dynamic, NJTPA . *Note that ACS data focus on work/commute trips, and therefore the data may need to be adjusted to account for all trip types using the facility.*
GIS data showing location of local destinations and opportunities (health clinics, grocery stores and sources of fresh food, local parks and playgrounds, elementary and secondary schools, and neighborhood-oriented retail and service establishments like restaurants, bars, dry cleaners, banks, and hardware stores)	Counties and local municipalities, NJDOT, NJDEP, Google Maps, WalkScore.com
GIS data showing locations of regional destinations and opportunities (major hospitals, four-year colleges and universities, major concentrations of retail activity, and recreational and tourist destinations with more than 100 employees, like amusement parks, sports arenas, performing arts venues, museums, and historic sites)	Counties and local municipalities, NJDOT, NJDEP, Google Maps, WalkScore.com

Geographic Scale of Analysis

Accessibility level should be measured at a local level. The effect of any one project on mode choice decisions may not be detectable at the local level, but multiple bicycle and pedestrian projects working together may affect mode choice at a corridor or subregional level. Customer satisfaction should be measured in the immediate area surrounding the project limits.

Time Frame of Analysis

Accessibility should be measured shortly after a project's completion, because as other network improvements are made, the impacts of an individual project may not be discernable. **Mode choice** impacts may be small or may not be measurable at all shortly after completion of the improvement. However, mode choice impacts of any given project may become more pronounced over time as people change their travel behavior and even location decisions in response to the transportation network improvement. Therefore, it is important to evaluate User Responsiveness measures on a continuous basis, using multiple data points from several years before the project and for as many years after the project as data are available. Initial **Customer satisfaction** surveys should be performed within one year of project completion. Customer satisfaction surveys should also be conducted on the project immediately after other bicycle and pedestrian projects that are designed as a complement to the original project are implemented. Long term customer satisfaction surveys relating on the original project should be conducted on a multiple year interval basis.

Analysis Steps

Person-Miles of Travel by Mode and Person-Trips by Mode (Mode Choice)

Inputs:

- Results of traveler surveys, asking a sample of the population in the area of the project to what extent the project affected their mode choice decisions for various trip purposes, and how long their average trip was before and after the project was completed. *For example, a bicyclist may have driven 5 miles to work previously and now bikes 5 miles to complete the trip.*
- Data from the Decennial Census and the American Community Survey on mode choice for work trips and average trip length. *Use data from census tracts in which the project is located. Typical bicycle and pedestrian projects will not, on their own, typically affect mode choice even at the census tract level, but in combination with other bicycle and pedestrian network improvements, over time mode share may increase measurably.*

Calculations:

- Using available traveler survey data, compare travel distance by walking before and after the project was completed. Combined with survey info on mode choice, estimate person miles of travel by non-motorized transportation. *For example, surveys may indicate that 5 percent of people who previously drove have switched to walking and biking due to completion of a linear multi-use path. If their average round trip length is 10 miles and there are 15 such people, the person-miles of travel by non-motorized* *transportation can be estimated to be 150 miles per day. For 200 working days per year, this translates to 30,000 person-miles of travel by nonmotorized modes each year.*

- The net impact of the project can be estimated by asking travelers to what extent the project affected their mode choice decisions. *In the above example, the net impact is 30,000 person-miles of travel because there were no walkers or bike riders before the project existed.*
- Combined with estimates of person-miles of travel and person-trips by other modes (e.g., driving), this measure can help estimate the impact of the project on mode choice. See the Roadway Expansion and Roadway Enhancement sections for guidance on how to calculate person-trips by driving.

Accessibility

Accessibility is a measure of the ability of people to reach opportunities and activities that they undertake in their daily lives, or the ability of businesses to reach their labor force, sources of raw materials and inputs to their production facilities, and the consumer markets for their finished products.

Access to jobs refers to the ability of the residents of a given area to access employment opportunities via any mode of transportation. Increased access to jobs is correlated with reduced unemployment rates and improved per capita income.

Access to labor force refers to the ability of businesses to access a pool of labor in a given market area. Increased access to labor force makes a business more competitive as more people with the skills necessary to do a job can compete for the same job opening.

Access to regional amenities can include the ability to reach major hospitals, universities, major concentrations of retail activity, and recreational and tourist destinations like amusement parks, beaches, sports arenas, performing arts venues, museums, and historic sites. Regional amenities can be screened using employment (only destinations with more than 100 employees, or retail employment density greater than 100 per acre, for example).

Access to community amenities can be defined as the ability to reach destinations that are sources of basic services and daily needs, and may include health clinics, grocery stores and sources of fresh food, local parks and playgrounds, elementary and secondary schools, and neighborhood-oriented retail and service establishments like restaurants, bars, dry cleaners, banks, and hardware stores.

The key to calculating accessibility change for bicycle and pedestrian projects is determining which destinations are newly accessible by biking and walking that otherwise may not be accessible to a certain population segment. For example, if a transit station has limited parking or no parking, and a new pedestrian or bicycle connection (e.g., over a river or a freeway) provides access to a new area, that area’s access to transit and all the destinations (and origins) served by transit has improved. There may be environmental justice issues to consider if the newly-served area is transportation disadvantaged.

<u>Inputs:</u>

- Locations of working-age population (U.S. Census Bureau) aggregated to traffic analysis zones (TAZs).
- Locations of jobs (from U.S. Census Bureau, Center for Economic Studies, Longitudinal Employer-Household Dynamics Program) aggregated to TAZs.
- Locations of regional amenities (from GIS database of regional amenities).
- Locations of local amenities (from GIS database of local amenities).
- Peak hour travel speed data for links in the NJRTM-E model network (from INRX or other vehicle probe data).
- NJRTM-E model network link attributes (link length, toll information).

Calculations:

a. Access to Community Amenities: Distance-Based Cumulative Opportunity accessibility measure

- For local amenities, a distance-based threshold may be the only option. *If travel times by walking, biking, and competing modes are known, one of the other accessibility measures mentioned in this section can be used instead of the following procedure.*
- Using GIS, in an area within a ½-mile radius of the project limits, calculate the number of local amenities that can be reached within a ½-mile walk before and after construction of the bicycle or pedestrian enhancement project. The change in access to local amenities is the difference in cumulative opportunities that can be reached before and after construction. *For example, before construction of a trail connection across a major highway, there may be one grocery stores within a ½-mile walk, and after construction of the overpass there may be two.*
- *Access to community amenities should be evaluated at as fine-grained a geographic scale as possible (e.g., Census blocks or block groups), because many TAZs may be more than ½-mile across.*
- *If no sub-TAZ data are available, access to community amenities can be evaluated qualitatively using maps showing before-and-after local street network, sidewalk network, and bike network connectivity.*

b. For all destinations other than community amenities: Travel-time-based Cumulative Opportunity accessibility measure

- For period before construction (average of three years) and period after construction (three-year moving average for all available years), use GIS to calculate the shortest travel time between all O-D pairs in the regional transportation network. Bicycle and pedestrian projects may improve transit accessibility, which in turn allows some trips to be made by transit that formerly could not be made.
- Aggregate the number of "opportunities" that lie in the TAZs that can be reached within the following time thresholds:
  - Jobs: 60 minutes (using peak hour travel times).
  - Labor force: 60 minutes (using peak hour travel times).
  - Regional amenities: 90 minutes (using average weekend day travel time).
- The relevant equation is:

$$A_i = \sum_{j=1}^{J} B_j O_j$$

where A_i is accessibility measured at point i to potential activities in zone j,

O_j is the opportunities in zone j, and

B_j is a binary value equal to 1 if zone j is within the predetermined threshold and 0 otherwise.

- The change in access is the difference in cumulative opportunities across all TAZ pairs that can be reached in the specified travel time. Cumulative opportunity estimates for each TAZ in a given area can be aggregated using the following equation:

  $$A_{Area} = (\Sigma A_i * P_i) / P_{Area}$$

  where:

  A_i = Accessibility of zone *i*

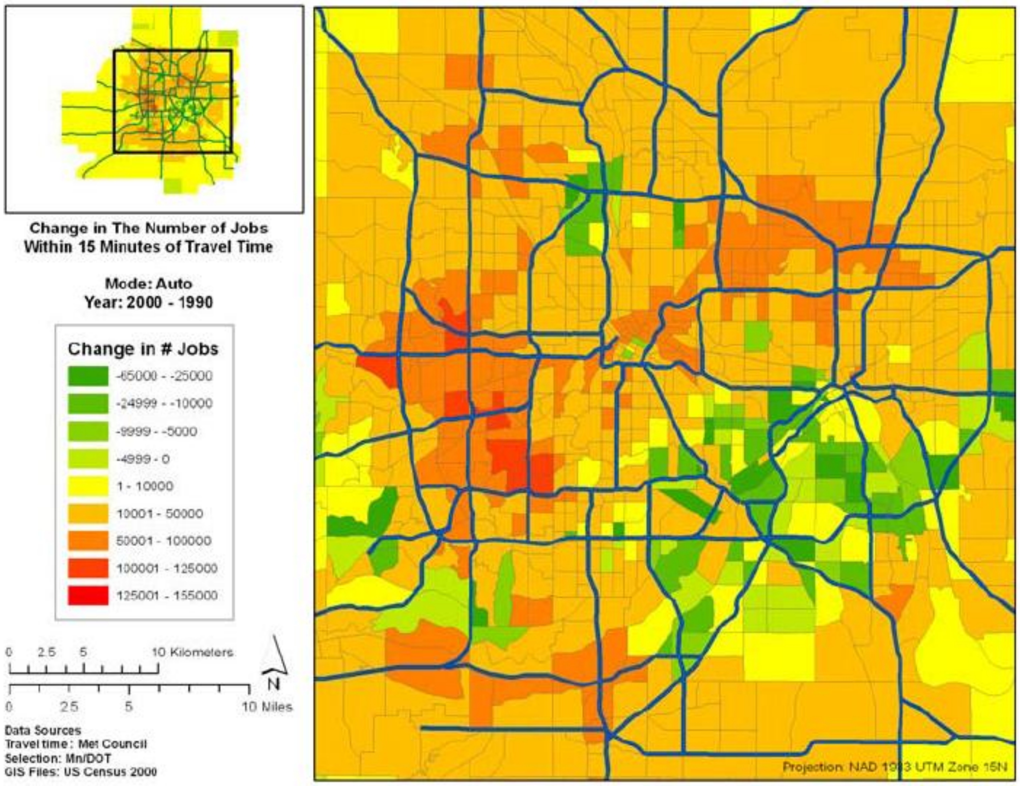
  P_i = Population of zone *i*

  P_{Area} = Population of the study area (could be a county or the NJTPA region)

  A_{Area} = Accessibility of the region (could be a county or the NJTPA region)

- *For example, before construction of a multi-use trail overpass across a major highway, 100 jobs might be accessible within a 20-minute bike ride of a given location. After construction of the overpass, 500 jobs might be accessible within 20 minutes. The net impact of the project is access to an additional 400 jobs at that location. The net impacts for each TAZ or analysis area can be plotted on a map to determine where the biggest net accessibility benefits accrue, as in the example below from the Minneapolis-St. Paul metro area.*

Figure 3.10-A: Example of a Map of Regional Accessibility Change



Source: El-Geneidy, A and D. Levinson, 2005. "Place Rank: A New Accessibility Measure," Nexus (Networks, Economics, and Urban Systems) Research Group, Department of Civil Engineering, University of Minnesota.

- *Note that population is not necessarily the most appropriate weighting factor. Employment could be used in place of population for access to employment and access to labor force, for example.*
- *A cumulative opportunity measure of accessibility is perhaps the simplest way to measure accessibility, but this measure requires the use of an arbitrary radius that, for example, attributes no value to jobs 61 minutes from an origin or regional amenities 91 minutes away. Because the measure is being used to compare before and after conditions, rather than rank the accessibility of individual zones, choosing an arbitrary threshold is not as problematic. A sensitivity analysis could be employed by varying the time threshold by +/- 10 minutes to see if the results change significantly.*

<u>Additional resources on accessibility measures include the following:</u>

- El-Geneidy, A and D. Levinson, 2005. "Place Rank: A New Accessibility Measure," Nexus (Networks, Economics, and Urban Systems) Research Group, Department of Civil Engineering, University of Minnesota. El-Geneidy and Levinson propose the use of a so-called "Place Rank" accessibility measure that uses actual information about origins and destinations by trip purpose and takes into account the relative attractiveness of each zone in calculating accessibility. The Place Rank accessibility calculation is an iterative process that uses the following equations:

$$R_{j,t} = \sum_{i=1}^{I} E_{ij} * P_{it-1}$$

$$P_{it-1} = [E_j * [R_{j,t-1} / E_i]]$$

Where:

- $R_{j,t}$ The *place rank* of *j* in iteration *t*
- *I* The total number of *i* zones that are linked to zone *j*
- E_{ij} The number of people leaving *i* to reach an activity in *j*
- P_{it-1} The power of each person leaving *i* in the previous iteration
- E_j The original number of people destined for *j* *Ej* = $\sum_{i} ij$
- $R_{j,t-1}$ The *place rank*ing of *j* from the previous iteration
- E_i The original number of people residing in zone *i*: *Ei* = $\sum_{j} ij$

Customer Satisfaction

Customer Satisfaction is a measure that does not depend on inputs from any other performance measure. Customer Satisfaction measures can be obtained from the results of surveys performed by NJDOT, the local implementing agency, or other agencies after completion of a project.

Inputs:

- Surveys of transportation system users, ideally including information about the relative importance of each system attribute being queried.
- Typical questions on customer satisfaction surveys for non-motorized users include:
  - Customer perception of improvement's impacts across NJTPA goal areas: Built and natural environment, congestion, travel speed, access to destinations, safety, economic impacts.
  - Project's impact on travel behavior: Whether the improvement caused mode shifts ("What was the previous mode used to make the trip?") and destination choice decisions (e.g., enabled a longer trip to a destination not previously accessible).
  - Impacts of construction: Safety, congestion and delays, access to businesses, environmental impacts during construction.

Recommendations for Future Performance Evaluation: User Responsiveness Measures

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, such as the map shown above in Figure 3.10-A, 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.

3.10.3 Evaluating Environment Measures

NJTPA Environment Goal - Protect and improve the quality of natural ecosystems and human environment.

Interdependencies between Data, Analysis Tools, and Performance Measures

The User Responsiveness measure "Visual Aesthetics and Context Sensitivity" can be evaluated independently.

Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Project purpose and need statement or project description from planning documents, funding applications, etc	Implementing agency; county or local municipality in which project is located
Photos and project descriptions after project completion	Implementing agency; county or local municipality in which project is located
Local comprehensive plans and other relevant planning documents for the area in which the project was constructed	County or local municipality in which project is located
List of commitments to stakeholders that was developed and maintained during planning and design and/or was incorporated into construction documents prior to beginning construction	Implementing agency; county or local municipality in which project is located
Results of post-implementation surveys of project team members from the implementing agency and consultants	Post-implementation surveys
Results of post-implementation surveys of community stakeholders (residents and businesses) and regulatory agency staff	Post-implementation surveys

Geographic Scale of Analysis

The geographic scale of analysis depends on the measure being assessed. The following table shows the recommended geographic scale of each measure.

Measure	Geographic Scale(s) of Analysis
Visual aesthetics and context sensitivity	Project limits (project-specific design features); adjacent properties; neighborhoods and municipalities in which project is located; architectural and environmental features in view shed

Time Frame of Analysis

The time frame of analysis for visual aesthetics and context sensitivity should be a short time before and after completion of the project.

Analysis Steps

Visual Aesthetics and Context Sensitivity

Inputs:

- Project purpose and need statement or project description from planning documents, funding applications, etc.
- Photos and project descriptions after project completion.
- Local comprehensive plans and other relevant planning documents for the area in which the project was constructed.
- List of commitments to stakeholders that was developed and maintained during planning and design and/or was incorporated into construction documents prior to beginning construction.
- Results of post-construction surveys of project team members from the implementing agency and consultants.
- Results of post-construction surveys of community stakeholders (residents and businesses) and regulatory agency staff.

Calculations:

Conduct surveys using the following criteria[4]. Score one point for each criterion if 67% or more of implementing agency staff (and/or the agency's project consultants) surveyed respond "yes"; score one additional point for each criterion if 67% or more of community stakeholders and regulatory agency staff surveys respond "yes". Maximum 12 points.

[4] Adapted from project-level evaluation criteria listed in NCHRP Web-Only Document 69: *Performance Measures for Context Sensitive Solutions- A Guidebook for State DOTs*

1. The executed project meets the goals and objectives identified in the original purpose and need statement.
2. The project was designed and implemented in a manner that is consistent with local comprehensive plans, the Americans with Disabilities Act, and other relevant planning documents.
3. The implemented project meets or exceeds a list of commitments to stakeholders that was developed and maintained during planning and design, was incorporated into construction documents prior to beginning construction, and is monitored during construction and operation of the completed project.
4. *(If the project is located in a developed area)* Architectural elements were incorporated into the design of the project to make users of all modes feel comfortable and welcome. These elements include, but are not limited to: wayfinding signage for users of all modes for which the facility is designed; signage clearly indicating access points to transit services (including park-and-ride lots, bus stops, and fixed guideway transit stations); signage clearly indicating access points and amenities for bicyclists and pedestrians (including signage indicating nearby alternate routes if non-motorized users are prohibited from using nearby facilities); a physical barrier between non-motorized traffic (bicyclists and pedestrians) and vehicles or, if a physical barrier was not possible, a defined pavement marking separation; adequate lighting for evening and nighttime use by motorized and non-motorized users; an open view shed into public spaces for people passing by and security officers; and amenities such as artwork and landscaping to enhance the surrounding built and natural environment.

   (If the project is located in an undeveloped area) Environmental resources, scenic and historic resources, and aesthetic values, such as architectural styles and landscaping that complement the surrounding environmental, have been maintained or enhanced by the project as completed.
5. Nearby residents and representatives of nearby institutions, schools, and business associations are directly or indirectly (e.g., via an advisory council) involved in the ongoing maintenance and operations of the facility or service.
6. Based on surveys of area residents and businesses, the project appears to have been implemented in a manner that will result in increased economic activity, such as new commercial or residential activity, and it appears to have the potential to create a positive neighborhood impact.

Outputs:

- Qualitative assessment of the degree to which a project improved or detracted from the **visual aesthetics of the built environment**.

Recommendations for Future Performance Evaluation: Environment Measures

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 opportunity 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.

3.10.4 Evaluating Land Use/Transportation Coordination Measures

NJTPA Land Use/Transportation Coordination Goal - Select transportation investments that support the coordination of land use with transportation system.

Interdependencies between Data, Analysis Tools, and Performance Measures

There are no interdependencies in the data evaluated in the Land Use/Transportation Coordination goal area.

Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Population	U.S. Census Bureau's American Community Survey 5-year estimates
Employment	U.S. Census Bureau's Local Employment-Household Dynamics data; NJ Labor and Workforce Development, and/or U.S. Bureau of Labor Statistics
Census tract area	U.S. Census Bureau TIGER Line Shape Files

Geographic Scale of Analysis

An analysis of population and employment changes for bicycle and pedestrian projects should be performed for areas within 5 miles of the project limits.

Time Frame of Analysis

The impacts of bicycle and pedestrian projects as measured in terms of Land Use/Transportation Coordination measures may be small or may not be measurable at all shortly after completion of the improvement, because development induced by a bicycle and pedestrian project will happen gradually over time. However, as years pass many changes as measured by Land Use/Transportation Coordination measures may become less pronounced over time. Therefore, it is important to evaluate Land Use/Transportation coordination measures on a continuous basis, using multiple data points from several years before the project and for as many years after the project as data are available.

Analysis Steps

Population and Employment Density

Inputs:

- Population in census tracts within ½ mile of project limits, from periods before and after implementation of the project. *Use U.S. Census Bureau's American Community Survey (ACS) 5-year Estimates for a rolling annual estimate of census-tract-level population data. Note: The U.S. Census Bureau cautions against comparing ACS data from overlapping time periods. ACS is mainly intended to be used for population characteristics, not population totals, especially at smaller geographies (e.g., Census tracts).*
- Employment in census tracts within ½ mile of project limits, from periods before and after implementation. *Use U.S. Census Bureau's Longitudinal Employer-Household Dynamics (LEHD) data.*
- Area of census tracts within ½ mile of project limits, in miles, from U.S. Census Bureau's Topologically Integrated Geographic Encoding and Referencing (TIGER) system. *Note that census tract boundaries may change over time, particularly when a new decennial Census is undertaken. It is important to use areas that are as identical as possible for the before and after comparison.*

Calculation:

- Use GIS to aggregate population in census tracts within ½ mile of project limits and divide by aggregate area of those tracts. Calculate population density for periods before implementation and period after implementation.
- Use U.S. Census Bureau's Longitudinal Employer-Household Dynamics online mapping tool, called "OntheMap", to aggregate employment in census tracts within 5 miles of project limits and divide by aggregate area of those tracts. Calculate employment density for periods before implementation and after implementation.
- *The net change in population and employment density cannot be calculated, but a qualitative analysis of the circumstances before and after implementation of the project may provide clues to whether any changes in population and employment density can be attributable to the project.*

Output:

- **Population density**, in persons per square mile.
- **Employment density**, in jobs per square mile.

Additional resources on population and employment density include the following:

- U.S. Census Bureau Longitudinal Employer-Household Dynamics website, http://lehd.did.census.gov/led/
- U.S. Census Bureau's Topologically Integrated Geographic Encoding and Referencing (TIGER) system website, http://www.census.gov/geo/www/tiger/index.html

Recommendations for Future Performance Evaluation: Land Use/Transportation Coordination Measures

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).

3.10.5 Evaluating Repair/Maintenance/Safety/Security Measures

NJPTA Repair/Maintain/Safety/Security Goal - Maintain a safe and reliable transportation system in a state of good repair.

Only safety and security measures are discussed in this section. See Roadway and Bridge Preservation project type for evaluation of Repair and Maintenance-related measures.

Interdependencies between Data, Analysis Tools, and Performance Measures

All data used in the analysis of safety performance measures are drawn from crash databases (e.g., NJDOT Crash Records Database, NJTPA Safety Management System, Plan4Safety), and NJDOT asset management systems. Evaluation of security measures does not depend on results of previous calculations. Therefore, there are no interdependencies with previous analyses.

Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Crash records	NJDOT Crash Records Database; Plan4Safety; NJTPA Safety Management System data
VMT data at regional, county, and local level	NJDOT
Information on measures taken to prevent or protect against illicit activity	Facility owner or operator: construction documents and as-built drawings

Geographic Scale of Analysis

All measures in the Repair/Maintenance/Safety/Security goal area should be evaluated within the project limits, but comparisons may be made to crash data for comparison facilities elsewhere in the region, at a corridor level, or at a regional level.

Time Frame of Analysis

The project-specific impacts of bicycle and pedestrian projects as measured in terms of Repair/Maintenance/Safety/Security measures are likely to be most pronounced shortly after completion of the improvement. Therefore, it is important to evaluate these measures using multiple data points from several years before the project, during the construction phase, and for as many years after the project as data are available.

Analysis Steps

Crashes

Inputs:

- Facility-specific crash data (minimum 3 years before and after project), preferably with an indication of whether a pedestrian or bicyclist was involved.
- Regional, county-level, and corridor-level aggregate safety statistics.

Calculations:

- Compare project-level changes in absolute number of crashes to estimates of regional, county-level, and/or changes in absolute number of crashes in specific comparison corridors as an estimate of what may have happened in the absence of the project.
- *Data on bicycle and pedestrian crashes was not collected regionwide until recently. There may be significant problems with crash data, including inaccurate reporting of crash locations and crash categorizations that would prevent any project-level analysis from being trustworthy. NJTPA Plan4Safety program provides crashes categorizations by gender, age, crash types, vehicle types, injury level, seatbelt use, and other categories. Extreme caution should be used in drawing any conclusions from before-and-after analyses of transit and highway safety data.*

Outputs:

- Absolute number of bicycle and pedestrian related **crashes** occurred before and after construction. For example, there may have been 12 crashes per year before implementation and 2 crashes per year after.

Crash Rate

Inputs:

- Absolute number of bicycle and pedestrian related crashes occurred before and after construction.
- VMT data at regional, county, and local level.

- Regional, county-level, and corridor-level aggregate crash rates.

<u>Calculations:</u>

- Divide crashes by VMT in the study area to calculate crash rate in terms of VMT.
- Compare project-level changes in absolute number of crashes to estimates of regional, county-level, and/or changes in absolute number of crashes in specific comparison corridors as an estimate of what may have happened in the absence of the project.
- The net increase or decrease in crash rate attributable to the project can be estimated by subtracting the regional, county-level, or corridor-level crash rate from the observed crash rate after project completion.

<u>Outputs:</u>

- **Crash rate**, in crashes per million vehicle miles traveled.

Perception of Security

<u>Inputs:</u>

- Information on measures taken to prevent or protect against illicit activity.

<u>Analysis:</u>

- Conduct a qualitative analysis of the extent to which the project increased perception of safety and security for users of the facility. For example, installation of lighting, installation of closed-circuit security cameras, or improvement of visibility and sightlines from nearby streets and populated areas.

<u>Outputs:</u>

- **Change in perception of security** for non-motorized users.

Recommendations for Future Performance Evaluation: Repair/Maintenance/Safety/Security Measures

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. 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.

3.10.6 Evaluating Economy Measures

NJPTA Economy Goal - Retain and increase economic activity and competitiveness.

Interdependencies between Data, Analysis Tools, and Performance Measures

No intermediate measures or analysis tools were used in the analysis.

Data Inputs and Sources

Primary data inputs to the analysis include the following:

Data Inputs	Sources
Estimated “build” and “no-build” congested travel times by link	Intermediate measure calculated in **System Coordination**; see methodology above
Average value of time	NJTPA Regional Household Travel Survey
Net crashes by severity	Output measure of **Repair/Maintenance/Safety/ Security** goal area; see above
Cost per crash, by severity	NJDOT and National Highway Traffic Safety Administration (NHTSA)

Geographic Scale of Analysis

All measures in the Economy goal area should be evaluated within the project limits.

Time Frame of Analysis

The impacts of bicycle and pedestrian projects as measured in terms of Economy measures may be small or may not be measurable at all shortly after completion of the improvement, because travel time benefits, operating cost savings, and accident cost reductions generated by a bicycle or pedestrian project will accrue gradually over time. However, as years pass many changes as measured by Economy measures may become less pronounced over time. Therefore, it is important to evaluate Economy measures on a continuous basis, using multiple data points from several years before the project and for as many years after the project as data are available.

Analysis Steps

Cost Effectiveness

Inputs:

- Project capital cost, in dollars.
- Performance measures from previous calculations (e.g., crashes, travel time savings, and emissions reduction).

Calculations:

- Divide the capital cost by any performance measure to calculate the dollar-weighted impacts of the project. *For example, a million-dollar project that reduces carbon emissions by 1,000 tons has a cost-effectiveness index of $1,000/ton.*

Outputs:

- **Cost Effectiveness***, expressed in dollars per unit of benefit per dollar (e.g., dollars per accident reduced; dollar per minute of travel time savings; dollars per ton of reduced carbon emissions).*

NOTE: While cost-effectiveness measures are constituents of a broader benefit-cost analysis approach, many cost-effectiveness measures are not additive. Therefore, extreme caution should be exercised in presenting and explaining results of a project-level cost-effectiveness analysis.

Recommendations for Future Performance Evaluation: Economy Measures

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.