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16. Abstract

This report estimates both the *one-time* and the *on-going* economic and fiscal benefits from transportation investments. The report provides NJDOT with two general software programs to enable both types of benefits to be estimated for specific highway transportation projects. These programs can assist NJDOT in its planning and economic analysis. The report uses past NJDOT highway transportation projects to identify the myriad inputs used in highway projects and the expenditures made on these inputs for 40 project types and locations (e.g., bridge replacement, road widening, intersection improvements, *etc.* in North and South New Jersey). Using the R/ECON™ Input-Output Model, estimates of the *one-time* benefits of each project type/location are made and a general- use software program is developed. This Transportation Investment Impact Estimator is applied to NJDOT's Ten-Year Capital Plan. The analysis indicates that over 95,000 job-years, an additional $7.9 billion in gross domestic product, and an additional $6 billion in compensation (income) will be generated in New Jersey from the estimated $10.7 billion in investment expenditures of the Ten-Year Capital Plan. In addition, a similar analysis is conducted for the $832 million in state and local highway projects that will receive the first-round of support from the American Recovery and Reinvestment Act. These projects will generate over eight thousand job-years, $627 million in additional gross domestic product, and $480 million in additional income for New Jersey. The report proceeds to analyze the reductions in recurring costs (due to congestion, traffic accidents, environmental damages, vehicle operation, and maintenance) that result from improvements in transportation capacity. The North Jersey Regional Transportation Model is used together with cost functions (CUBE) developed specifically for New Jersey. Cost-benefit analysis is conducted for five past highway projects that increased transportation capacity. The analysis indicates that each of the projects was economically efficient; i.e., the present value of the future stream of economic benefits (reduced costs) generated by the project exceeds (by significant margins) the present value of the investment costs of the project. A software program is developed that allows NJDOT to conduct such cost-benefit analyses for any past, current, or future projects that increase transportation capacity in north New Jersey.

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EXECUTIVE SUMMARY

This report estimates both the one-time and the recurring economic and fiscal benefits from investments in highway transportation infrastructure in New Jersey.

One-time benefits occur because expenditures are made on labor, materials, and other inputs. These expenditures generate further effects as the personal income and business revenues they directly create are spent, in turn, on other goods and services. The benefits are one-time because they end when the transportation investment expenditures cease.

Recurring benefits occur because of the reduction in costs due to increases in transportation capacity that result from the investments. These benefits consist of reduced congestion costs, reduced accident costs, avoided environmental costs (e.g., air quality and noise level improvements), reduced vehicle operating costs, and reduced highway maintenance costs.

An accessible software program, the Transportation Investment Impact Estimator (TIIE) is developed for NJDOT using detailed cost data from 741 awarded NJDOT bids from 2000 to 2007 (Chapter II). The analysis integrates highly detailed project cost data with the R/ECON™ Input-Output Model for 48 project types, locations (North and South New Jersey), and sizes (dollars invested). The TIIE program enables NJDOT to estimate the *one-time economic and fiscal benefits* in any of these 48 project categories for any specific past, current, or future project.

The TIIE program is used to estimate the one-time economic and fiscal benefits of the expenditures required to implement the Ten-Year Capital Plan of NJDOT (Chapter III). The TIIE is applied to 208 projects representing 55% of the value ($10.7 billion) of all the highway projects in the Plan. The analysis indicates that these projects will generate over 95,000 job-years, an additional $7.9 billion in state gross domestic product, and $6 billion in additional income in New Jersey.

In addition, the TIIE program is used to estimate the one-time economic and fiscal benefits of the state and local highway projects that will receive the initial round of financial support from the American Recovery and Reinvestment Act (Chapter III). The total investment of $832 million in 119 projects, of which ARRA will provide approximately 67%, will generate over 8,000 job-years, $627 million in additional state gross domestic product, and $480 million in additional income in New Jersey.

The *recurring benefits* of highway investments are estimated using traffic flow analyses of the North Jersey Regional Transportation Model in conjunction with cost reduction functions (for congestion, accidents, environmental damages, vehicle costs, and highway maintenance) specific to New Jersey. Using this methodology, a cost-benefit analysis is conducted on five NJDOT projects that increase highway capacity (Chapter IV). The results indicate that all five projects will yield lifetime economic benefits significantly in excess of their costs. This analysis allows NJDOT to conduct similar cost-benefit studies for any future project that expands highway capacity in north New Jersey.

A software program, NJCOST, is a second key deliverable of this report and provides NJDOT with the ability to estimate reductions in the recurring costs attributable to highway capacity increases in north New Jersey. Complete user instructions and an explanation of the output of NJCOST are provided in Chapter V.

Transportation services are a highly important input to New Jersey businesses. Using the R/ECON™ Input-Output Model, an analysis of the *intensity* of use of transportation services by type of industry is done (Chapter VI). Industries are ranked by their transportation intensity (*expenditures on transportation inputs per* *dollar of industry output*) along with their respective shares in New Jersey's total output and employment. Industries are also ranked by their *total transportation service purchases.*

The benefits analyzed above – both one time and recurring – are specific to individual highway projects. A broader measure of *additional* potential benefits of highway investments is made using the R/ECON^{TM} econometric forecasting model of New Jersey (Chapter VII). The model is used to simulate the economic impact of a 10 minute per-day reduction in commuting time for all workers in New Jersey. While such a reduction is ambitious for the entire workforce of the state, the simulation indicates that, depending on how the saved commuting time is used (for additional leisure and/or for additional work) significant economic benefits would result.

The report recommends that NJDOT consider routinely estimating the one-time and the recurring economic benefits of its highway projects to inform and guide its decisions on project selection and priorities (Chapter VIII). Such analyses can inform both decision makers and the general public with concise summaries, measured in the commonly understood metrics of jobs, income, tax revenues, and dollar benefits of investments in the highway infrastructure of the state.

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CHAPTER I: INTRODUCTION

The decision of the New Jersey Department of Transportation to systematically examine the economic benefits of transportation investments could not have been more timely, nor more appropriate. The focus of this research contract is to provide comprehensive estimates of the *one-time* economic benefits that accompany the construction phase of transportation projects *and* the *on-going annual* economic benefits of the projects. Transportation investment deeply affects the economic competitiveness of a state's economy and the welfare, well-being, and safety of its citizens.[1] In addition, over the last year, transportation investment has assumed a major role in both the federal and New Jersey fiscal efforts to blunt the severity and duration of the current deep economic recession that has enveloped the nation.

Accordingly, this NJDOT research contract presciently anticipated the need for a rigorous analysis of the economic benefits of transportation investments. An additional and important goal of the contract is to provide NJDOT with user-friendly tools to estimate the economic impacts of transportation investment on an on-going basis. This capability permits an objective evaluation across individual projects using common economic metrics. Such a capability can inform NJDOT decisions as to prioritizing projects

Organization of the Report

The report is organized into eight chapters as described briefly below. Chapter II uses input-output analysis to estimate the one-time (i.e., the construction phase) economic impacts of transportation investments. Projects are organized by type (bridge repair, road widening, road re-surfacing, etc.). The economic impacts are measured using the R/ECON™ Input-Output model of the state's

[1] See, e.g., "A Transportation-Driven World Class Economy: New Jersey at Risk" J.W. Hughes and J. J. Seneca, *Rutgers Regional Report*, No. 23, April, 2005.

economy developed and maintained by Professor Michael Lahr of the Center for Urban Policy Research at the Bloustein School of Planning and Public Policy at Rutgers University. The analysis yields estimates of the increase in employment (by business sector) caused *directly* (by the construction phase expenditures) and *indirectly* (through the multiplier process whereby initial transportation construction expenditures generate incomes which are spent and, in turn, generate further economic impacts). The effects on income, gross domestic product, and local and state tax revenues are also estimated by the analysis. In addition, the analysis estimates these impacts for Northern and Southern New Jersey by project type and project size (in dollars).

Chapter II also provides NJDOT with a Transportation Infrastructure Impact Estimator (TIIE) software program that can be used to estimate the one-time economic and fiscal impacts of planned transportation projects by project type. It provides a careful and thorough narrative of the procedures behind how TIIE was developed from an intensive analysis of past transportation projects. The analysis of large numbers of past projects enables the estimation of a set of general relationships between the economic impacts in terms of employment, income, and output and the underlying transportation expenditures that generate these effects. These relationships are estimated for a portfolio of different project types.

Chapter III uses the TIIE software program to provide estimates of the economic and fiscal impacts of a significant share of the approximately $30 billion NJDOT Ten Year Capital Plan (2009 to 2018). In addition, the TIIE is applied to state and local projects eligible for the initial round of federal support from the American Recovery and Reinvestment Act.

Chapter IV provides estimates of the *on-going* benefits of transportation investments to complement the analysis that estimates the one-time, or short-term, construction spending impacts of the proceeding chapter. Thus, transportation projects can yield recurring annual benefits in the form of reductions in congestion, time savings in commuter costs, lower vehicle maintenance costs, air quality improvements, fewer traffic accidents (and accompanying declines in fatalities and injuries), and savings in business costs. These outputs, in fact, are the core benefits and main objectives of transportation investments since they persist year after year. Such benefits are over and above the short term boost to the economy caused by the immediate spending on the labor, materials, and resources needed to execute the project. It is these on-going benefits that should be evaluated relative to the total costs of the project in order to inform decisions as to the economic viability of the investment.

Accordingly, Chapter IV employs a model (NJCOST) developed and maintained by Professor Kaan Ozbay of the Department of Civil and Mechanical Engineering of the Rutgers School of Engineering. That model provides estimates of the on-going benefits of transportation projects. The analysis also uses a transportation planning model (CUBE) that distributes by origin and destination the total vehicle trips in a given geographic region before and after a transportation project.[2] Together these two models provide estimates of the on-going benefits of transportation investments by project type. Traffic flows that result from a transportation project in terms of volume and quality (time) are estimated by the CUBE model. The on-going economic impacts of these changes in traffic volume and time are then estimated by the NJCOST model. Benefits are then measured with respect to the resulting changes in six measures of output (reductions in costs) that are generated by the transportation project - vehicle operating costs, congestion costs, accident costs, air quality costs, noise costs, and road maintenance costs.

[2] The CUBE model also accommodates the growth in total trips over time in response to general economic and population changes. Thus, the distribution of trips by origin and destination with and without a specific transportation project (e.g., lane additions) accounts for overall growth in vehicle trips and isolates the effects on trip time and routes attributable to the presence (or absence) of the specific project.

Chapter IV provides a careful explanation of the use of these models with a series of applications to specific NJDOT projects. The economic value of the recurring benefits listed above are discussed and compared to project costs to obtain cost-benefit ratios for selected projects. A generalized software program (NJCOST) is provided to enable NJDOT to estimate the recurring annual benefits for several types of transportation projects.

Chapter V presents the NJCOST software program developed to estimate these recurring benefits for any significant transportation infrastructure investment that increases transportation capacity. It provides accessible and clear instructions on how to use the program and the options available within it. It represents a powerful key deliverable of the project.

Chapter VI provides an analysis of the *transportation intensity* of New Jersey businesses – i.e., what is the role of transportation inputs, relative to the other inputs, and relative to output across New Jersey business sectors. It identifies and ranks those New Jersey industries that are heavily dependent on transportation services as inputs into their business and relates that to the role of these industries into the overall economy of the state.

Chapter VII estimates several additional potential benefits of transportation investments over and above the economic impacts analyzed in the previous chapters. These potential *macroeconomic* benefits consist of possible impacts on the overall state economy that result from *gains in leisure, worker productivity, and additional output* because of savings in travel time. Thus, depending on the scale and extent of travel time reductions attributable to transportation investments, worker productivity could improve because more time could (potentially) be spent at work rather than in commuting. Any such gains due to productivity increases are additive to the benefits of the previous chapters. Thus, Chapter VII uses the R/ECON Econometric Forecasting Model developed and maintained by Dr. Nancy Mantell of the Center for Urban Policy Research at the Bloustein School of Rutgers University to estimate these benefits.

The model is used to simulate the effects of a 10 minute daily reduction in the commuting time for *all* New Jersey workers (regardless of the mode of transportation used by workers to get to work). Chapter VII carefully explains the possible alternative scenarios for the use of the savings in worker travel time (increased work time and increased output, with or without additional compensation paid to the workers, or increased leisure time for workers). The model then estimates the macroeconomic impacts on the state's economy under each of these scenarios.

Chapter VIII provides a brief summary and conclusions to the report.

CHAPTER II ECONOMIC IMPACTS OF TRANSPORTATION INFRASTRUCTURE CONSTRUCTION SPENDING

Introduction

This chapter describes the Excel-based Transportation Infrastructure Impact Estimator (TIIE) developed for use by NJDOT to measure the *one-time, or short-term* economic impacts of transportation infrastructure project expenditures. The chapter also provides an explanation of the methodology used to create this key project deliverable. In the next chapter, the TIIE is applied to the spending associated with NJDOT's 2009-2018 Ten-Year Capital Plan.

The key criterion in selecting among various transportation infrastructure projects for possible implementation should be the extent of the *ongoing, or recurring,,* economic benefits. However, there are several compelling reasons why it is also important to examine the *one-time economic impacts* of such projects. An immediate reason is to ensure that New Jersey receives an equitable share of the federal government's infrastructure-based economic stimulus funding commensurate with the state's share of the nation's population and employment. Accordingly, the ability to demonstrate, in a rigorous and comprehensive manner, that New Jersey has a portfolio of transportation infrastructure projects that can produce significant immediate short-term economic benefits, is useful in making the case for federal support. This is true both for the funds now available under the American Recovery and Reinvestment Act, but also for ongoing federal transportation allocations. In addition, a second important reason for estimating the one-time economic impacts is to assist the state in its evaluation of projects, especially of similar type projects when available resources do not allow all such projects to be funded.

Therefore, to assist NJDOT in evaluating the one-time economic impacts of projects as they arise in the future, we have developed an easy-to-use, accessible Excel-based Transportation Infrastructure Investment Estimator. This program will allow NJDOT to readily generate statewide economic impact estimates for a wide variety of project types, according to each project's size and location within the state.

This chapter is organized as follows: First, we provide a brief overview of *input-output analysis* – the core methodology used to estimate the one-time economic impacts of the transportation construction expenditures. This includes a description the R/ECON™ Input-Output Model used to create the economic impact estimating program. Next, there is a description of how construction cost data from past NJDOT projects was used to develop the inputs for the input-output analysis. This is followed by a description of the Excel-based estimating program, TIIE.

Input-Output Analysis

Input-output analysis is a technique which allows economists to estimate the impacts of expenditures made in one sector of an economy on all other sectors throughout the economy. Expenditures made on transportation infrastructure, for example, generate direct and indirect economic impacts in the form of employment, income, gross domestic product, and tax revenues for the state. These impacts can be estimated using the state-of-the-art *R/ECON™ Input-Output Model* at the Center for Urban Policy Research at the Bloustein School of Planning and Public Policy. The R/ECON™ model consists of *517 individual sectors* of the New Jersey economy and measures the effect of changes in expenditures in any one of these industries on economic activity in all other industries. For example, expenditures on materials (asphalt, steel, etc.) and services (construction labor, design services, communications, etc.) for a transportation infrastructure project have both *direct* economic effects as those expenditures become incomes for construction workers and revenues for providers of materials and services to the project, and subsequent *indirect* effects as those employees and businesses, in turn, spend those incomes and revenues on consumer goods, business investments, etc. These expenditures, in turn, become income for other workers and businesses, and these incomes are further spent, and so on. The model is able to trace the effects of changes in one part of the economy on all other parts of the economy (both within and outside of New Jersey). It also accounts for the division of expenditures between those that are made within the state and those that “leak” outside the state.

In summary, the R/ECON™ model estimates both the *direct* economic effects of the initial expenditures (in terms of jobs and income) and the *indirect* (or multiplier) effects (in additional jobs and income) of the subsequent economic activity that occurs following the initial expenditures. The model also estimates the tax revenues (state and local) generated by the combined direct and indirect new economic activity caused by the initial spending.

Preparation of Transportation Infrastructure Production Functions Using NJDOT Cost Data

On its website, the New Jersey Department of Transportation provides detailed breakdowns of awarded bids for transportation infrastructure projects from 2000 through 2008. While these bid-sheets represent initial cost estimates and do not reflect later cost revisions, they are the best available estimates of construction cost breakdowns for a *wide variety of project types in New Jersey*. For purposes of our analysis we accessed a total of *741 awarded bids* from 2000 through 2007.

Once the project cost breakdowns had been obtained, the next step was to standardize the breakdown of the expenditures reported in the bid-sheets for each project. This made the projects comparable in terms of content, and also prepared them for use in the R/ECON™ Input-Output Model.

The R/ECON™ Input-Output Model is highly detailed, with 517 service/labor and material categories into which any given item in the cost breakdowns can be assigned. Items such as concrete, steel, various types of construction labor, streetlamps, asphalt, structural assemblies, electronic components, sheet metal and other key items appearing in any typical transportation infrastructure project were assigned to a specific Standard Industrial Classification (SIC) sector. To classify the thousands of cost items appearing in the bid sheets, all 741 project bid sheets were first imported into the database program Filemaker Pro. Then, when any given item in a single project was assigned to the appropriate SIC sector, the item would be assigned to that same sector in *all* projects in which it appears.

Because many components of infrastructure construction are subcontracted, and the subcontracted items are not disaggregated into their labor and material components in the NJDOT bid sheets, each item listed in a project's cost breakdown was *first* assigned to *two* of the SIC codes that define the relationships between sectors in the model – one code indicating the type of material associated with the item, and one indicating the type of labor. Thus, *all cost items* were assigned to both a labor *and* a material category, so that both labor *and* material costs, if totaled, would equal the full cost of the project.

Once all construction inputs had been assigned to the appropriate SIC sectors, a list of *14 project types* was created into which projects could be classified (a description of each project type is provided in Appendix I). The key rationale is that the project types were selected *to match as many project types as possible from NJDOT's current Ten-Year Capital Plan*. Projects were then drawn from the database of 741 past projects and classified into the appropriate project types (see Table 1).[1]

[1] Not all 741 projects were used. In all, a total of 391 projects were included in the analysis. The NJDOT DP numbers of the projects used in the analysis are listed by project type and size in Appendix I. Only construction expenditures in each project were allocated to SIC sectors. Design and other non-construction costs were not included in the analysis

Table 1 - Transportation Infrastructure Project Types

1	Bridge Rehab/Repair
2	Bridge Construction/Replacement
3	Bridge Painting
4	Drainage Improvements
5	Drainage Restoration
6	Interchange Improvements
7	Intersection Improvements
8	Resurfacing
9	Resurfacing Maintenance Contracts
10	Road Construction and Widening
11	Roadway Repair
12	Bridge Deck Replacement
13	Pavement Repair
14	Pavement Marking

Because ongoing maintenance constitutes a large portion of NJDOT's annual capital budget, in addition to project types prevalent in the Capital Plan, certain recurring contracts for basic maintenance work (e.g., road resurfacing and bridge painting) were also included in the analysis.

A taxonomy of project types was created so that the cost structures (i.e., *production functions, or the relation between inputs and outputs*) of similar projects types could be averaged in order to minimize the effect of any anomalous expenditures appearing in any single project. In other words, *typical production functions* were created for each type of the fourteen project types within a given size (i.e., dollar) range. Thus, once the expenditures for each project had been assigned to the appropriate service/labor and material SIC sectors, the total costs allocated to each SIC sector were summed, and the dollar breakdowns were then expressed as percentages of the total project cost. This allowed the cost breakdowns of *similar projects of similar dollar size* to be *averaged together into typical production functions.*[2]

[2] It is important to note that even projects of similar description can vary significantly in the composition of their material and labor inputs. It is therefore important to stress again that the impact estimators presented here for use by NJDOT are intended as *general* models for assessing and comparing the projected impacts

The number of dollar size categories chosen for any of the fourteen project types was determined by averaging together the cost breakdowns of similar dollar sized projects and then examining the resulting cost functions to see if they differed significantly from one another. Where notable differences were found, the dollar size divisions were retained. If no significant differences were evident in the production functions for projects of different sizes, all projects were averaged into a single function.

As previously noted, projects within each type and size category were also initially classified by their location (county) within the state. However, an examination of the production functions for similar projects in different regions of the state (i.e., North and South Jersey) did not reveal significant differences in cost structure. Thus, it was determined that any differential in the economic impacts of similar projects implemented in different regions in the state would result only from the differences in wage rates in the North and South regions of the state. These differences are addressed when the impacts of the expenditures are estimated, and this process is described later in this section.

Finally, to prepare the typical functions for use in the R/ECON™ Input-Output Model, it was necessary to divide the various cost items (now aggregated into the appropriate SIC sectors) into their labor/service and material components (note that each production function at this stage still totaled 200%, with 100% of costs allocated in full to both labor/service sectors and material sectors). In order to estimate the division between the labor and material component of any given expenditure category (i.e., SIC sector), we used data from the Construction Industry Division of the 2002 Economic Census. This data provides the material and labor shares of net value added for a range of construction and construction-related activities, including highway, street and bridge construction; other heavy

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of the construction spending on projects, but are not designed to give precise estimates of the impacts of any single project.

construction; electrical contracting; painting contractors; etc. The share of material in net value added ranged from approximately 27% for painting contractors to 42% for highway and street construction. Thus, for example, if 20% of a given project type's costs were allocated to asphalt, that 20% would have initially been allocated in full to the SIC sectors for both asphalt and for highway and street construction. The next step in the process in this case then allocates 42% of this 20% total to the SIC code for asphalt, and assigns the remaining 58% to the SIC code for highway and street construction (i.e., to the labor associated with the asphalt). This process was repeated for each of the labor/service and material SIC codes in each typical production function. In cases where a given SIC material code was unlikely to have an associated labor/service component, or where a particular SIC service code (i.e., telecommunications) was not likely to have any significant material component, these allocations were retained in full.[3] Through this allocation process, each typical production function was transformed so that its cost structure totaled 100%, with the appropriate allocations to labor/services and materials.

Description of Final Production Functions

The full set of 24 final production functions and a listing (by DP number and date) of the past projects used in deriving them is included in Appendix II. The number of NJDOT past projects used in creating the final production functions ranged from one to 110. For those project type/size classifications for which very few projects were available for analysis, NJDOT staff were asked to examine the original project bid sheet to determine whether the project was indeed typical of its type and size. While it would be desirable to have a large number of projects averaged together for each classification in order to avoid the use of single (or very few) projects as models for analysis of future projects, none of the projects

[3] Additional small adjustments were made to each production function in order to embody, as accurately as possible, the full range of industry sectors involved in any given infrastructure project. In most cases, this entailed the assignment of a small portion (approximately one-sixth) of the total material allocations to the SIC sectors for wholesale trade in order to reflect those sectors' role in the provision of construction materials.

examined by NJDOT were found to be anomalous, and thus the production functions derived from single projects are included in the analysis.

The number of dollar size classifications for the 14 project types ranged from one, in the case of roadway repair, bridge painting, pavement marking, resurfacing, and resurfacing maintenance contracts, to three, in the case of bridge rehabilitation/repair and interchange improvements. The list of project types is repeated in Table 2, along with the size classifications and ranges for each type and the number of past project cost breakdowns used in developing each average production function. There are 24 project/size classifications.

Table 2 - Project Types and Size Classifications

Type/Size	Range	Number of Projects
Bridge Replacements		
Small	<30	24
Large	>30	3
Drainage Restoration		
Small	<1	22
Large	>1	2
Drainage Improvements		
Small	<3	2
Large	>3	5
Resurfacing Maintenance Contracts		
All	>0	7
Resurfacing Projects		
All	>0	22
Intersection Improvements		
Small	<1	8
Large	>1	18
Road Construction/Widening		
Small/Medium	<90	60
Large	>90	2
Roadway Repair/Improvements		
All	>0	110
Interchange Improvements		
Small	<7.5	1
Medium	7.5 - 45	7
Large	>45	1
Bridge Repair/Rehabilitation		
Small	<10	7
Medium	10 - 25	2
Large	>25	3
Bridge Painting Contracts		
All	>0	27
Pavement Repair		
All	>0	25
Bridge Deck Replacement		
Small	<20	10
Large	>20	1
Pavement Marking		
All	>0	22

While the mix of types of labor/services and types of materials differs from project type/size to project type/size, the final allocation for each project type/size is typically about 65-70% labor/services and 35-40% materials. This is consistent with past experience in the analysis of public infrastructure and other construction projects. It is also consistent with the division between labor and materials reflected in the Economic Census data on construction. In addition, examination of certain final production functions revealed them to be consistent with our initial expectations. For example, the expectation that the final allocation of bridge painting projects would skew the division toward a heavier labor share compared to other project types is confirmed by the data. The labor share for bridge painting is 78%, while the average labor share for all other project types/sizes is 66%.[4]

Economic Impact Analysis Using the R/ECON™ Input-Output Model

The 24 typical production functions in Table 2 became the basis of the analysis for the R/ECON™ Input-Output Model. The purpose of this analysis was to estimate *specific New Jersey construction multipliers* expressed as the economic impacts of one million dollars in expenditures for each of the 24 project type/size categories. Thus, each production function was used to allocate one million dollars in transportation infrastructure spending across the various SIC industry categories underlying the R/ECON™ Model. The model was then used to estimate the economic impact of that one million dollars. For the first run, the underlying data in the model reflected the construction labor salaries of counties in North and Central New Jersey, while for the second run, the construction labor salaries were adjusted to reflect the average wage levels for the same jobs in South Jersey. Thus, a total of 48 runs were conducted using the R/ECON™ Model, with each run generating the estimated economic impacts of one million dollars in expenditures for a specific project type, size, and location in the state.

[4] A notable exception to the typical labor-material division is the case of pavement marking contracts, where over 50% of the expenditures are allocated to materials. This reflects the fact that these contracts often include funds for the lease and/or purchase of trucks used for the installation of pavement markers.

For most of the construction employment in question – that is, construction work associated specifically with roads and bridges – the wage levels in the South are 17% - 20% lower than those in the North. For other sectors, such as electrical contracting and painting, the wage rates in the South are only slightly lower than those of the North, and in some cases (e.g., masonry), average wage rates in the South exceed those in the North. Generally, however, the key wage rates associated with transportation construction are significantly higher in the North of the state than in the South, and thus similar projects in the South are likely to have greater *direct employment impacts* than those in the North *on a per-million-dollar basis*. However, because of the lower wage rates in the South, similar projects are likely to have lower overall costs, and this will be reflected in the overall economic impacts of the project investment.

The economic impacts estimated by the R/ECON™ Model include employment (in job-years[5]), gross domestic product, income (compensation), and state and local tax revenues. The model also provides a breakdown of the employment generated by industry sector. The next step was to make all this data readily accessible to NJDOT users seeking to estimate the economic impacts of a proposed project. To do this, we took the per-million-dollar economic impacts estimated with the R/ECON ™ Model and developed the Excel-based Transportation Infrastructure Investment Estimator (TIIE). This program is described in the next section.

Excel-based Transportation Infrastructure Investment Estimator

The Excel-based TIIE is a key deliverable of the study. TIIE is intended to assist NJDOT in evaluating projects for implementation. As previously noted, the on-going, or long-term, impacts of any given transportation infrastructure investment should be the paramount consideration when ranking and selecting projects. However, particularly in light of the federal infrastructure stimulus package and

[5] Measured as one job lasting one year.

the need for immediate job-creation initiatives, the one-time, short- and medium-term, economic impacts of transportation infrastructure investments also warrant consideration when evaluating and prioritizing projects for implementation.

The economic impact estimating tool was designed to provide NJDOT with an accessible and easy-to-use program to estimate the economic impacts of various projects. By choosing a project's type, size and location from drop-down menus, and entering the project's (dollar) size, a user can generate an economic impact statement providing both the total and the per-million-dollar impacts of a project in terms of employment, gross state product, income (compensation), and state and local tax revenues. These impacts are also disaggregated into their direct and indirect components. The *direct impacts* are those immediately generated by the expenditures made on the project (e.g., employment of construction workers and their associated compensation, and the purchases of construction materials from manufacturers and wholesalers). The *indirect impacts* are those resulting from the multiplier effects of the initial expenditures (e.g., the project's construction workers and suppliers spend their income, resulting in sales, business revenue, and additional employment in other sectors, and so on). In addition, the economic impact statement also provides an *industry breakdown* of the total employment generated by the project, along with the associated total compensation and average compensation per job-year for each industry.

Figure 1 provides a screenshot of the input interface for the TIIE program. There are six input categories: Project Number, Project Name, Project Type, Project Size (e.g., small, medium, large), Location (County) and Investment (in dollars).

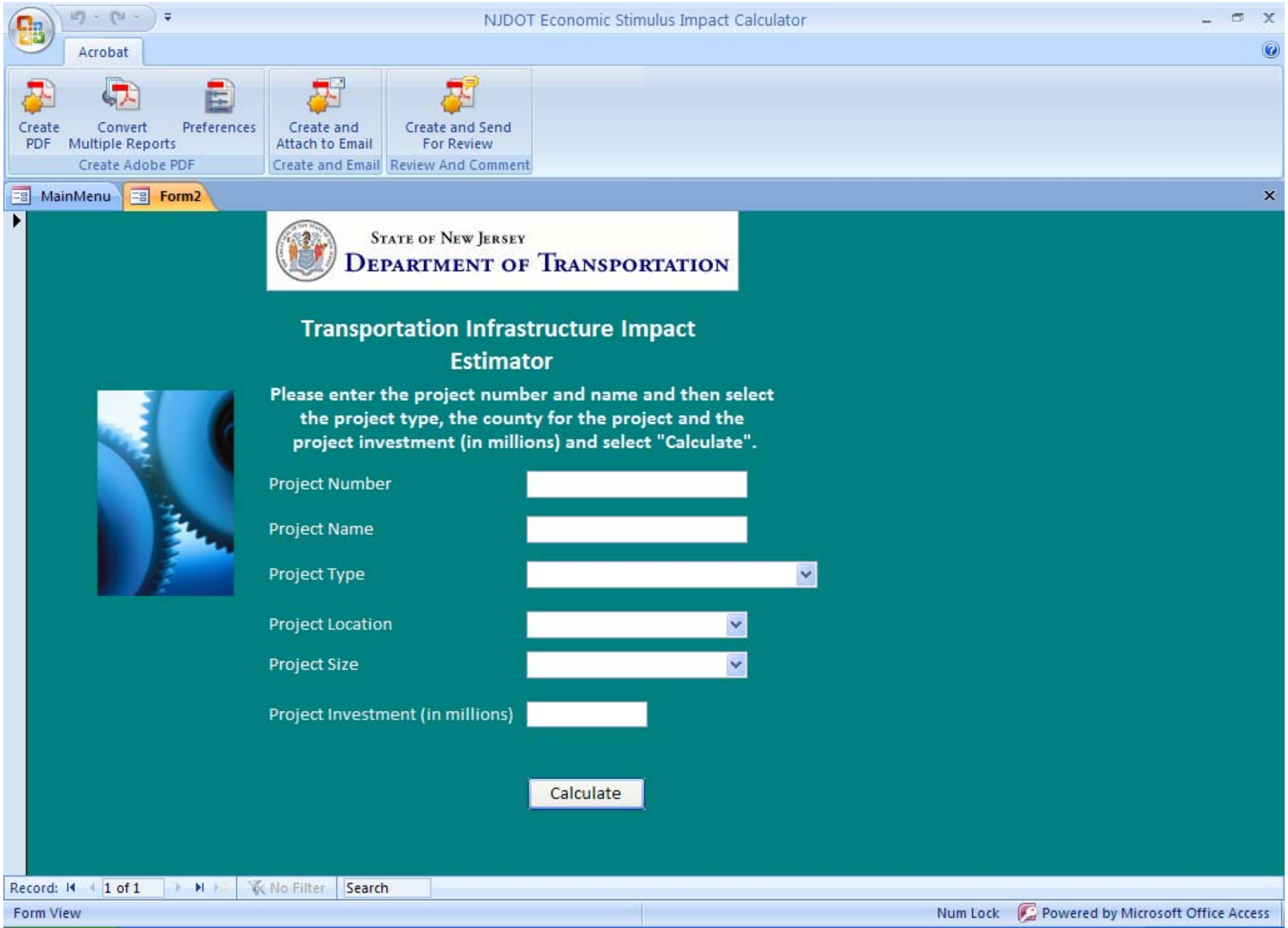

Figure 1. Input Interface for the TIIE Program

The project number and project name are entered by the user in the cells where indicated. Next, when the user mouse-clicks on the word Project Type, a drop-down menu appears listing the fourteen project types available for analysis. After selecting the appropriate project type, the user then clicks on Project Size, and a drop-down menu appears listing the range of project sizes available for that project type. The sizes are indicated by name (e.g., small, medium, large) and by the corresponding cost range in millions of dollars (e.g., $0 - $10). The size ranges for each project type are provided in Table 2 above. The size classification is particularly important when estimating impacts at the program level, as demonstrated in the next section.

The user next selects one of the state's 21 counties from the Location drop-down menu. Because the model is region-specific (North vs. South), rather than county-specific, if the project is a multi-county project confined to a single region, it is sufficient to choose only one of the counties in order to generate the economic impact statement. The counties in each region are listed in Table 3.

Table 3 - NJ Counties by Region

North Counties
Bergen
Essex
Hudson
Hunterdon
Mercer
Middlesex
Monmouth
Morris
Ocean
Passaic
Somerset
Sussex
Union
Warren
South Counties
Atlantic
Burlington
Camden
Cape May
Cumberland
Gloucester
Salem

If the project is a multi-county project occurring across the two regions, the user can enter estimates of the expenditures for the North and South regions separately, and the outcomes of the two resulting impact estimates can be summed.[6]

[6] Note that while the *total* impacts of different projects or project components can be summed, the *per-million* impacts are not additive.

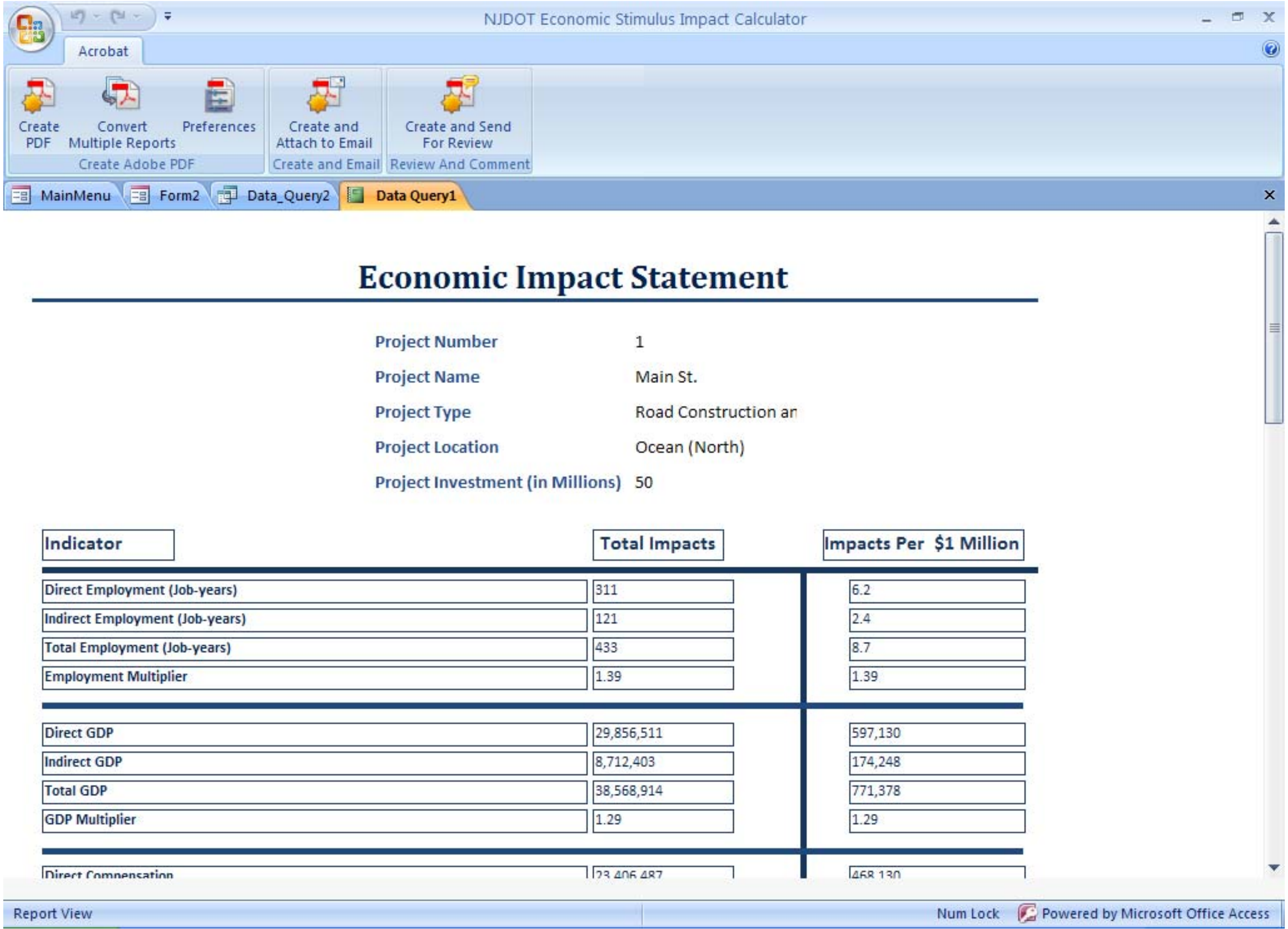

Figure 2. Economic Impact Statement Screenshot

Finally, the user enters the total estimated expenditures for the project in the Investment cell where indicated, and clicks on the Generate Report button below the input interfaces. This will generate a new spreadsheet containing the Economic Impact Statement for the project, including both total and per-million-dollar economic impacts, as shown in the screenshot in Figure 2.

The project name, number, type, size classification, county/region, and total investment amount are listed in the header of the Economic Impact Statement. The left panel of the statement provides the total economic impacts estimated for the project, while the right panel shows the impacts per-million dollars of expenditures. Thus, the values reported in the left panel are effectively those in the right, *multiplied* by the total investment in millions of dollars. The top panel of each side of the impact statement provides the aggregate economic impacts for the project expenditures (or per million dollars), while the bottom panel provides industry detail for the total employment and associated compensation generated by the project.

Following is a brief description of each of the impacts generated by the TIIE program.

Employment

Employment is measured in job-years. Each job-year represents one full-time job lasting one year. Direct employment consists of those jobs immediately associated with the project, including construction, engineering, and some manufacturing jobs, while indirect employment consists of those jobs generated via the multiplier effects of the project as the initial expenditures ripple through the economy. The same is true of the direct/indirect division for all the indicators described here. The multiplier is calculated as the total impact (here, in terms of employment) divided by the direct impact, and indicates the total number of job-years (or GDP, or compensation) generated for each direct job-year (or dollar of GDP or compensation) generated by the project.

Gross Domestic Product (by State)

The U.S. Bureau of Economic Analysis defines Gross Domestic Product (by State) as follows: "A measurement of a state's output; it is the sum of value added from all industries in the state. GDP by state is the state counterpart to the Nation's gross domestic product (GDP). Gross domestic product (GDP) is the market value of goods and services produced by labor and property in the United States, regardless of nationality."

Compensation

Compensation consists of workers' wages plus employer contributions to pension funds, insurance funds, and government social insurance.

State Tax Revenues

State tax revenues generated by a given project consist primarily of the state income taxes paid by the workers in the jobs generated both directly and indirectly by the project expenditures, as well as the sales taxes paid both on the purchases of materials for the project and on the expenditures generated indirectly through payment of wages and further business expenditures generated via the multiplier effect.

Local Tax Revenues

Local tax revenues represent a *long-run* estimate of property tax revenues generated by payment of residential and commercial property taxes from the personal and business incomes generated by the project and/or resulting from improvements made to property caused by the increased economic activity generated by the project.

Employment and Compensation by Industry

The bottom panel provides total employment and compensation and average compensation per job-year by industry. Most of the industry sectors are self-explanatory, with the exception of Services. This is a broad category encompassing such industries as business services, health services, legal services, educational services, engineering services and others.

Ranges of Estimated Economic Impacts

The per-million-dollar economic impact estimates range widely across projects and between the North and South regions. The employment impacts per million dollars will generally be higher for the south due to the lower wage rates for direct employment. However, this difference will also be reflected in lower total project costs for projects in the South compared to similar projects in the North. Total employment estimates range from a low of 5.4 job-years per million dollars of expenditures for pavement marking projects in the North to 13.2 job-years per million for bridge painting projects in the South. Total compensation per million dollars of expenditures ranges from a low of $356,066 for pavement marking projects in the North to $647,292 for bridge painting projects in the North, and total GDP generated per million dollars of expenditure ranges from $473,125 for large drainage restoration projects in the South to $842,723 for bridge painting projects in the North. Again, it is important to note that these are impacts *per million dollars* of expenditure based on the size and region of the project, but that the total impacts of any given project will be determined by the magnitude of its total expenditures.

The next chapter provides an application of the TIIE to NJDOT's 10-Year Capital Plan.[7]

[7] Presentations and consultations will also be provided to NJDOT staff in the use and application of the estimating tool.

CHAPTER III USING THE TIIE TO ESTIMATE THE ECONOMIC IMPACTS OF NJDOT'S TEN-YEAR CAPITAL PLAN FOR 2009-2018

The purpose of this chapter is to provide a second key deliverable of the study, namely, an estimate of the one-time economic and fiscal impacts of NJDOT's Ten-Year Capital Plan for 2009-2018. The chapter is organized as follows; Section I provides the background on how the projects of the Ten-Year Capital Plan were organized for the analysis. Section II describes how the Transportation Infrastructure Impact Estimator (TIIE) was applied to 208 projects from the Capital Plan. Section III provides the economic and fiscal estimates generated by the TIIE for the Capital Plan. Section IV provides an additional application of the TIIE for the highway projects within the Capital Plan that are scheduled to receive initial federal funds from the American Recovery and Reinvestment Act. Section V provides a brief conclusion.

Background

As noted in Chapter II, the project types selected for analysis with respect to their one-time impacts were chosen primarily based on two factors – the project types should be those found in the Ten-Year Capital Plan, and second, that similar project types are found in the NJDOT database of previously awarded projects. Given these criteria, it was possible to assign 208 of the Capital Plan's projects to the 14 project types used in the analysis. These projects account for $10.7 billion, or approximately 55% of the value of the NJDOT projects in the Capital Plan, and 32% of the value of all projects in the Capital Plan when NJ Transit projects are also included.[1]

[1] Due to lack of detailed cost information, NJ Transit projects were not included in the analysis. The NJDOT projects not included in the analysis included those for which it was not possible to separate construction and design costs from right-of-way costs, and those which did not include significant transportation infrastructure expenditures (e.g., ITS projects), and those for which no previously awarded projects were available to develop production functions (i.e., relations between costs and outputs) for the given project type.

From this point, there are two ways to use the TIIE program. One is to estimate the impacts of each *project individually*. This can be done by entering each project's type, location and planned expenditure into the input interface of the TIIE and generating economic and fiscal impact estimates for each individual project. This would be the appropriate approach if the goal were, for example, to compare the impacts of several of the projects. However, since the objective in this case is to evaluate the *aggregate* impacts of the Capital Plan, a second approach is used.

Thus, in this case, the impacts of each *project type/size/region group* as a whole are analyzed. This first required that the 208 projects, now sorted by project type, also be sorted by (expenditure) size and location. In order to aggregate groups of projects by size, it is first necessary to know the range of values for each of the expenditure size classifications for each project type. These ranges were determined during the production function estimation process described earlier. They are included in Appendix II with each of the production functions, and are provided separately in Table 2 in the preceding chapter. The expenditure ranges also appear next to the size classifications for each project type listed in the Project Size drop-down menu in the user interface. When it is necessary to aggregate projects for purposes of impact estimation at the program level, their values should be aggregated based on their type, size ranges and regions (which are defined by county in Table 3 in the preceding chapter).

Applying the TIIE to the Capital Plan

Once the Capital Plan projects were grouped according to their type, size and location, the values of all the projects in each type/size/region classification were then summed to produce an aggregate expenditure value for each. The 208 Capital Plan projects were assigned to 40 of the 48 possible type/size/region classifications. The projects assigned to each classification are listed in

Appendix III (projects are indicated by their DB numbers). For some projects, where the total expenditures were known to include design costs, the total costs were reduced by 10%, with the remaining 90% allocated to construction and thus included in the analysis. In addition, for aggregate projects, in which funds are allocated to future expenditures on projects throughout the state but the locations of the projects have not yet been determined, 2/3 of the available funds were allocated to the North, and 1/3 to the South.

Thus, "aggregate" projects are listed under multiple classifications. In most cases, within each region, the distribution of the *individual* projects by size for the given project type was used as the basis for allocation of the aggregate funds by project size. However, in some cases where few or no individual projects were available for analysis and/or the project description indicated small or low-cost projects, the funds were allocated to small project sizes.

The next step was to take the aggregate expenditures value for each type/size/location group and apply the TIIE. Here, the Project Size selector in the TIIE plays an important role and must be carefully used. If, for example, the Project Size applicable to the *aggregate value* of the expenditure was selected, the wrong set of per-million impacts might be applied to this total value. For example, if the *aggregate value* of the *small* projects for a given project type and location falls in the value range for *individual* medium or large projects, selecting the medium or large value range in this case would be inappropriate. Thus, it is important to select the size classification appropriate to the cost of the *individual* projects (even those that have been aggregated into a single expenditure value).

Economic and Fiscal Impacts of the Capital Plan

Using the approach described above, the TIIE generated an economic impact statement for each of the 40 type/size/region classifications.[2] These individual impact statements were then summed to estimate the total economic and fiscal impacts for all 208 projects. The summary impact statement provided in Table 4 lists the total economic and fiscal impacts of each group of projects classified by type, size and region. It is important to note, as discussed in Chapter II, that the economic and fiscal impacts are expressed in constant 2009 dollars. Thus, to obtain these impacts, there is an implicit assumption that the annual outlays for the projects over time are increased to accommodate any inflation that occurs in order to achieve the desired project outcomes in terms of engineering objectives.[3]

The individual economic and fiscal impact statements for each of the 40 type/size/region groups are provided in Appendix IV.

[2] In this case, any of the counties in a given region can be chosen since the impacts are region-specific, rather than county specific.

[3] It is useful to note that in times of recession there may actually be a deflation in construction industry prices, allowing a given amount of spending on transportation projects to purchase more infrastructure output, or to purchase the same infrastructure output at lower total costs and thus free resources to be used on additional infrastructure investments.

Table 4 - Summary Economic Impact Statement: 2009 – 2018 Capital Plan

Project Type	Project Size	Project Location	Investment (millions)	Total Employment (Job-years)	Total GDP (millions)	Total Compensation (millions)	Total State Tax Revenue (millions)	Total Local Tax Revenue (millions)
Bridge Painting	Any	North	113.3	1,371	95.48	73.34	2.04	2.48
Bridge Painting	Any	South	56.7	750	46.87	35.98	0.94	1.15
Bridge Deck Replacement	Small	North	256.8	2,199	192.62	148.85	4.40	5.64
Bridge Deck Replacement	Small	South	128.4	1,366	96.61	74.66	2.12	2.72
Bridge Rehab & Repair	Large	North	1,293.6	11,260	995.50	758.16	21.44	27.17
Bridge Rehab & Repair	Large	South	116.1	1,230	90.14	68.72	1.87	2.37
Bridge Rehab & Repair	Medium	North	203.5	1,957	164.66	126.82	3.59	4.57
Bridge Rehab & Repair	Medium	South	81.7	908	65.42	50.50	1.36	1.73
Bridge Rehab & Repair	Small	North	406.7	3,538	313.43	237.02	6.81	8.64
Bridge Rehab & Repair	Small	South	205.7	2,198	160.27	121.17	3.33	4.25
Bridge Construction/Replacement	Large	North	1,480.4	12,383	1,117.08	851.63	24.50	31.23
Bridge Construction/Replacement	Large	South	613.6	6,282	466.63	355.57	9.85	12.61
Bridge Construction/Replacement	Small	North	767.7	6,726	600.57	457.44	13.08	16.65
Bridge Construction/Replacement	Small	South	245.1	2,633	192.84	146.89	4.02	5.14
Drainage Improvements	Large	North	50.5	433	37.44	28.79	0.85	1.08
Drainage Improvements	Large	South	36.5	394	27.54	21.21	0.60	0.77
Drainage Improvements	Small	North	16.7	141	12.59	9.53	0.28	0.36
Drainage Improvements	Small	South	6.0	63	4.56	3.45	0.10	0.13
Drainage Restoration	Small	North	18.0	128	11.66	8.85	0.26	0.33
Drainage Restoration	Small	South	9.0	76	5.90	4.49	0.12	0.16
Interchange Improvements	Large	North	385.3	3,334	298.93	228.19	6.46	8.20
Interchange Improvements	Large	South	564.3	6,057	444.55	339.35	9.17	11.71
Interchange Improvements	Medium	North	95.9	820	73.62	55.97	1.62	2.06
Interchange Improvements	Medium	South	82.9	871	64.20	48.82	1.35	1.73
Interchange Improvements	Small	North	35.1	302	27.40	20.71	0.61	0.78
Interchange Improvements	Small	South	22.5	243	17.73	13.40	0.38	0.49
Intersection Improvements	Large	North	156.3	1,320	117.53	89.47	2.61	3.33
Intersection Improvements	Large	South	75.9	791	57.59	43.88	1.23	1.57
Intersection Improvements	Small	North	5.3	44	3.86	2.96	0.09	0.11
Roadway Repair/Improvements	Any	North	60.0	481	41.91	32.18	0.98	1.25
Roadway Repair/Improvements	Any	South	30.0	300	21.15	16.24	0.47	0.61
Pavement Repair	Any	North	184.4	1,491	129.43	99.49	3.04	3.89
Pavement Repair	Any	South	140.7	1,425	99.35	76.34	2.24	2.88
Pavement Marking	Any	North	541.5	2,923	256.20	192.81	6.71	8.66
Pavement Marking	Any	South	276.3	1,890	137.40	103.26	3.49	4.51
Resurfacing	Any	North	478.3	3,830	330.91	255.58	7.76	9.93
Resurfacing	Any	South	174.8	1,759	122.14	94.23	2.75	3.53
Road Construction & Widening	Large	North	977.6	8,476	754.28	576.40	16.63	21.21
Road Construction & Widening	Small	North	265.8	2,301	205.03	156.15	4.49	5.73
Road Construction & Widening	Small	South	64.1	679	49.73	37.86	1.04	1.34
TOTAL	All	All	10,723.0	95,373	7,950.74	6,066.35	174.67	222.68

Based on the results of the TIIE as shown in Table 4 the following one-time economic and fiscal impacts are estimated to be generated by the $10.7 billion in Capital Plan expenditures for the 208 projects analyzed:

- 95,388 job-years, including both direct and indirect employment. This is an average of approximately 9 job-years per million dollars of expenditure. For perspective, over the best years of this decade in terms of job growth (2004-2007), New Jersey added an average of approximately 18,900 private-sector jobs annually. Thus, the additional 95,000 job-years estimated to be created by the implementation of the Capital Plan are a significant source of job growth for the state.

- Almost $8 billion in additional gross domestic product for New Jersey.

- $6.1 billion in additional income (compensation).

- $175 million in additional state tax revenue.

- $223 million in additional local tax revenue.

Projects Eligible for funding from American Recovery and Reinvestment Act

Thirty-one state highway projects included in NJDOT's Ten-Year Capital Plan are eligible for the initial component of federal stimulus funding under the American Recovery and Reinvestment Act (ARRA).[4] These state highway projects have an estimated total expenditure of $679.5 million, of which approximately 66% will be financed by the ARRA. In addition, there are numerous local highway projects that will receive ARRA funds.[5]

A TIIE analysis was conducted on the *state projects* scheduled to receive ARRA funds and the impact estimates are listed in Table 5. The $679.5 million in expenditures on the ARRA-supported state projects will generate an estimated 6,745 job years, $516 million in additional state GDP, and $395 million in additional compensation (income). Also, state tax revenues will increase by $11.2 million and local tax revenues will rise by $14.2 million. The single largest state project in the ARRA supported list is a $298.9 million bridge and causeway construction on Route 52 in Somers Point, in Ocean and Atlantic Counties. Federal ARRA funds will provide approximately 23% of the total costs of this project.

Project size is measured in dollars and the thresholds (large vs. small) vary by project type depending on detectible differences in the production function for each project type. See the TIIE tool menu for size for the specific thresholds by project type.

[4] Design projects, right of way purchases, and cross-median projects are not included in the TIIE analysis. However, the TIIE analysis reported here covers approximately 94% of the total expenditures on ARRA supported state projects ($725 million). For ease of estimation, the 31 state projects were aligned into 15 project types (e.g., similar projects, such as resurfacing, were aggregated into a single project type). The results of the TIIE analysis of the 15 project types are reported in Table 5.

[5] For a list of both the state and local projects see: http://www.nj.gov/transportation/capital/stimulus/pdf/NJDOTARRAstatewideprojects.pdf

Table 5 - Summary Economic Impact Statement ARRA Supported State Projects – 2009

Project Type	Project Size	Project Location	Investment (millions)	Total Employment (Job-years)	Total GDP (millions)	Total Compensation (millions)	Total State Tax Revenue (millions)	Total Local Tax Revenue (millions)
Bridge Painting	Any	North	65.3	790	55.03	42.27	1.17	1.43
Bridge Painting	Any	South	6.0	79	4.96	3.81	0.10	0.12
Bridge Deck Replacement (Agg)	Small	North	42.1	361	31.58	24.40	0.72	0.92
Bridge Deck Replacement	Small	South	1.9	20	1.43	1.10	0.03	0.04
Bridge Deck Replacement	Large	North	26.7	230	20.40	15.62	0.45	0.57
Bridge Deck Replacement	Large	South	56.0	598	43.15	33.08	0.91	1.16
Bridge Construction/Replacement	Large	North	32.4	271	24.45	18.64	0.54	0.68
Bridge Construction/Replacement	Large	South	298.9	3,060	227.31	173.21	4.80	6.14
Drainage Improvements	Small	North	1.1	9	0.83	0.63	0.02	0.02
Drainage Improvements	Large	North	16.2	139	12.01	9.24	0.27	0.35
Drainage Improvements	Large	South	13.0	140	9.81	7.56	0.21	0.27
Pavement Repair	Any	South	28.0	284	19.77	15.19	0.45	0.57
Resurfacing	Any	North	60.9	488	42.13	32.54	0.99	1.26
Resurfacing	Any	South	6.0	60	4.19	3.23	0.09	0.12
Road Construction & Widening	Small	North	25.0	216	19.28	14.69	0.42	0.54
TOTAL	Any	Any	679.5	6745	516.33	395.21	11.17	14.22

The TIIE analysis was also done for the 91 *local projects* that will receive initial ARRA funds.[6] There is $152.2 million in planned expenditures on these local highway projects, representing 93% of all the ARRA supported expenditures on local highway projects.[7] All of the costs of the local projects will be paid by ARRA funds. Table 6 lists the one-time economic and fiscal impacts of this expenditure as estimated by the TIIE.

- 1,338 job-years, including both direct and indirect employment
- $110.5 million in additional New Jersey Gross Domestic Product
- Nearly $85 million in additional compensation (income)

[6] Most of these local projects are road resurfacing and bridge repairs. The 91 projects were aligned into 16 project types for the TIIE analysis listed in Table 6.
[7] Several guardrail projects were excluded from the TIIE analysis.

- $2.5 million in additional state tax revenues
- $3.2 million in additional local tax revenues

Table 6 - Summary Economic Impact Statement-ARRA Supported Local Projects - 2009

Project Type	Project Size	Project Location	Investment (millions)	Total Employment (Job-years)	Total GDP (millions)	Total Compensation (millions)	Total State Tax Revenue (millions)	Total Local Tax Revenue (millions)
Bridge Painting	Any	North	0.575	7	0.485	0.372	0.010	0.013
Bridge Painting	Any	South	3.95	52	3.265	2.506	0.066	0.080
Bridge Rehab & Repair	Small	North	3.246	28	2.502	1.892	0.054	0.069
Bridge Rehab & Repair	Medium	North	16.788	161	13.584	10.462	0.296	0.377
Bridge Construction/Replacement	Small	North	7.206	63	5.637	4.294	0.123	0.156
Interchange Improvements	Small	North	0.15	1	0.117	0.088	0.003	0.003
Intersection Improvements	Small	North	4.56	38	3.320	2.543	0.074	0.095
Intersection Improvements	Small	South	1.25	12	0.907	0.694	0.019	0.025
Intersection Improvements	Large	North	12.75	108	9.587	7.298	0.213	0.272
Intersection Improvements	Large	South	5.5	57	4.173	3.180	0.089	0.114
Roadway Repair/Improvements	Any	North	4.588	37	3.205	2.461	0.075	0.095
Roadway Repair/Improvements	Any	South	1.069	11	0.754	0.579	0.017	0.022
Pavement Repair	Any	North	4.92	40	3.453	2.654	0.081	0.104
Resurfacing	Any	North	67.529	541	46.720	36.084	1.096	1.402
Resurfacing	Any	South	17.153	173	11.985	9.247	0.270	0.347
Road Construction & Widening	Small	North	1	9	0.771	0.587	0.017	0.022
TOTAL	Any	Any	152.234	1338	110.464	84.942	2.503	3.194

The combined *state and local* ARRA-supported projects, with an estimated $831.7 million in investment expenditures, will result in the following total impacts as given in Table 7.

Table 7 - Economic Impacts of Combined State and Local ARRA Supported Projects - 2009

	Total
Investment	$831.7 million
Job Years	8083
GDP	$626.8 million
Compensation	$480.15 million
State Tax Revenues	$13.67 million
Local Tax Revenues	$17.41 million

Conclusion

This chapter has demonstrated the useful application of the Transportation Infrastructure Impact Estimator (TIIE). This accessible and user-friendly software program is based on extensive historical NJDOT project experience and can estimated economic and fiscal impacts for 42 separate project categories.

Two informative applications of TIIE are conducted here. The first provides estimates of the economic impacts of the NJDOT Ten-Year Capital Plan and indicates the extensive positive one-time economic benefits of the $10.7 billion in transportation investments. Of particular note, is the sizeable increase in employment, over 95,000 job-years will be generated. The second application estimates the economic and fiscal impacts of the state and local highway projects that will receive support from the initial phases of the federal stimulus program for transportation.

In general, the TIIE program enables NJDOT to estimate for any past or future project, or group of projects, the expected one-time economic and fiscal impacts on the state's economy. It is a robust and highly usable addition to the planning and economic analysis capabilities of NJDOT.

CHAPTER IV RECURRING BENEFITS OF TRANSPORTATION INVESTMENT

The purpose of this chapter is to present the analysis of the on-going, recurring benefits of investments in transportation infrastructure. It is a complement to the analysis of Chapters II and III which use input-output analysis to estimate the one-time economic impacts generated by the expenditures on transportation infrastructure. These benefits represent the core value of such investments and occur annually over the life of the project. This Chapter is organized as follows. The first section provides an introduction to the role of transportation in economic growth and its historical importance in New Jersey.   Next there is a description of the analysis and defines the measures of the output of transportation investments.   There is then a review the literature of the impact of transportation investments on employment and the economy, and a discussion of a cost-benefit approach to evaluate capital investments. A methodology section presents the evaluation framework used in our analysis. The next section reviews the cost savings categories that are included in evaluating highway capital investments. A case studies section applies the techniques to five major highway projects recently undertaken in New Jersey and presents the cost-benefit findings for each project. Finally, a conclusion section presents the findings of this study.

Background and Introduction

New Jersey has been called the corridor state, a consequence of its perceived role in, and proximity to, the strong markets and high employment and income concentrations in New York City, Philadelphia and the Boston-Washington Northeast Corridor. Rapid growth of the port complex, both air and ship, at Newark and Elizabeth; expansion of the high technology and medical and life-science industries near Princeton and New Brunswick; proposed sustained development of the Meadowlands, making it far more that a sports complex; and the large growth in commercial office space along the Hudson River, all attest to the importance of New Jersey and its economic role in the Northeast Region, the nation, and the world. However, in order to maintain the competitiveness of its economy, the state's transportation system must continuously evolve through increased efficiency and connectivity. This need confronts a series of thorny technical and policy problems.

Solutions to the ubiquitous traffic congestion problems of many areas of the state, for example, are often difficult to identify and implement. Capital-intensive solutions such as capacity expansion by building new roads, while sometimes desirable and appropriate, are always expensive and frequently can have major, negative impacts on the environment and on quality of life. In order to alleviate congestion, state and local authorities must achieve a balance between the construction of key, new transportation facilities and the use of advanced technology and demand management policies. Other related strategies include smart growth initiatives and improved land-use planning.

Over the years, the traffic congestion problems across the nation have been addressed through a variety of measures. These have consisted of:

- **Improving Roadway Infrastructure:** Building new highways and increasing the capacity of the in-place networks by constructing additional lanes has been favored for many years. However, it has also been argued that infrastructure development alone cannot keep up with the increase in vehicle ownership and use.

- **Taxation on fuel use**: It seems plausible to assert that increasing fuel taxes can cut back highway travel [(1)]. However, the net effect of fuel taxation in terms of reduced congestion is unclear, since the fuel tax remains only a small fraction of vehicle ownership costs. Congestion is location and time oriented, whereas fuel taxes are an average cost pricing instrument that does not differentiate between differing cost-inducing circumstances (e.g., time of day driving). Rather, all use is charged the same [(1)]. In addition, higher fuel taxes raise issues such as how the increased tax revenues are used and the equity impacts of such taxation.

- **Improving / Expanding Public Transport**: This policy portfolio includes subsidies to public transport, the improvement of current service levels and expansion of the existing infrastructure, thereby inducing demand shifts from motor vehicles to transit. Well-known problems with such measures occur when they are employed inefficiently (e.g., cost overruns, the need for continual revenue increases, ever higher operation and labor costs). These adversely affect the costs of transportation operations and may become capitalized in user costs and hence may hinder incentives for major modal change in consumer and business behaviors [(3, 4)].

- **Congestion Pricing**: This policy makes users pay for the full social costs of their travel, i.e., the congestion costs that they impose on other users. It discourages users from trip making during peak hours by charging a toll at the margin of the costs imposed by the peak users. While this policy is theoretically sound, it raises a number of technical problems and political acceptability issues. Richardson and Bae [(5)] lists several possible effects of congestion pricing: no significant change in travel behavior (users pay the charges, but do not reduce use or switch modes); changing travel behavior with the same level of trip making by changing the time of departure, or route); and changes in location decisions (i.e. changing the residence, workplace, business, shopping destinations, etc)[1].

- Application of the option of congestion pricing is now becoming more extensive with the development of sophisticated technologies, such as electronic toll collection, billing and enforcement all done at highway speeds.

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[1] For a detailed explanation of the political and social feasibility of congestion pricing, see Jones [(6)].

- **Traffic Control Management**: This option involves various policies and adaptations ranging from the use of advanced technology, e.g., the optimization of traffic signals, ramp metering and variable message signs to allocating lanes for buses and car–pools, to the use of communication devices.

- **Non-traffic policy means**: These include parking charges, vehicle license fees, land use planning, and improved telematics, etc [(4)].

Despite these efforts, none of these approaches alone has been able to fully overcome the congestion problem.

Objectives

This chapter aims at providing an economic evaluation framework of the recurring, long-term benefits of highway capital investments. The proposed framework recognizes that investments must be studied in a number of dimensions, including the extent to which they impact the overall transportation system that realistically adjusts to the dynamics of traffic flow. It utilizes the most important and recurring technique of the public investments evaluation, namely, *cost-benefit analysis*. Cost-benefit analysis is the most commonly used approach in evaluating highway transportation projects. It requires the quantification and comparison of the various benefits and costs generated by a project over time. The effects from the project are first enumerated and classified as benefits and costs. Then, each effect is quantified and expressed in monetary terms using appropriate conversion factors [(7)].

It is well known that in the case of transportation investments, the identification of costs and benefits requires a complex analysis due to the multidimensional impacts of a given transportation project. The prevailing goal of a transportation investment is the improvement of travel conditions which can be defined in multiple dimensions (access, time, safety, reliability, etc.). There are, however, additional and broader benefits of transportation projects. Highway transportation offers direct benefits to businesses (e.g., cost reductions in trade, manufacturing, agriculture and increased tourism), and indirectly generates and supports economic growth.

The ultimate goal of any publicly-funded project is to allocate society's resources efficiently. Therefore, to ensure that any proposed project promises to return to society in value more than it costs. Accordingly, cost-benefit analysis is used to identify which projects that have positive net social benefits and which do not.

Decisions about public investments, of course, are made in a political process, and cost-benefit analysis does not replace these political decisions. It does inform those decisions and makes the tradeoffs involved in using scarce and finite public resources more transparent [(9)].

In this Chapter cost-benefit analyses are performed on five past highway projects in New Jersey using a comprehensive evaluation framework that measures the dollar value of the output of these projects in a multiple dimensional manner.

Literature Review: Transportation Investment and Economic Growth

Over the last decade numerous studies have examined the impact of transportation infrastructure development on economic growth. The major objectives of these studies have been to estimate the returns of transportation investments by type (e.g., highway or public transit) and by geographical level (e.g., national, state). The most common approach is to develop a production function model in which transportation infrastructure is treated as a public capital input, which like other inputs (mainly private capital and labor), determine output (e.g., GDP). Longitudinal and pooled databases have been used to estimate output elasticities (the quantitative relationship between inputs and outputs) as well as the productivity of labor and private and public capital.

Numerous empirical studies have expanded upon the seminal work of Aschauer [27] on the relationship between transportation capital investment and economic development. The key policy results from these studies pertain to the elasticity of output with respect to transportation capital. The output elasticity results vary widely ranging from a very high 0.39-0.56, [27] or 0.33, [28] to a very low 0.04, [29] or 0.08 [30]. (An estimate of .39, for example, means a 10% increase in transportation capital leads to a 3.9% increase in output).This wide dispersion of output elasticity estimates is probably the result of differences among studies relative to the spatial level of analysis, the definition of capital stock as well as underlying models and estimating techniques.

Most of the previous studies have used a production function model with a common structure. Eakin [31] for instance, has applied a production function to state level data consisting of output, labor, private capital and state and local government capital. The study concluded that the elasticity of private output with respect to public sector capital is relatively large (0.23). Munnell [32] examined spillover effects by hypothesizing that highway public capital creates positive cross-state spillovers. She argued that this could occur when infrastructure investments in one state benefit economic activity in others. Eakin and Schwartz [33] have studied similar effects and measured the indirect effect of highway capital investment on neighboring states. However, they have rejected the hypothesis that highway capital has positive output spillovers. In fact, in some of their specifications, the spillover parameter was statistically significant and negative. Theoretically, indirect effects from highway capital investment are the net result of the two offsetting factors. These are: the relocation of economic activity (e.g., Forkenbrock and Foster [34]), and the spillover effect (Munnell [32]). Boarnet [35] has examined how highway investments redistribute economic activity by dividing the economic impacts of transportation infrastructure into a direct effect (impact near a street or a highway) and an indirect effect (any impact that occurs at locations more distant from the highway corridor). He concluded that the direct and indirect effects were equal in magnitude, but with opposite signs. Berechman *et al*. [36] investigated the relationships between transportation capital development and economic activity at the state, county and municipality level. Their analysis of longitudinal state, county and municipal level data indicated that private and public capital have positive impacts on output at the state and county levels. However, the magnitude of the impact of public capital declines as the geographical scale becomes smaller due to more pronounced spillover effects. They found output elasticities with respect to highway capital of 0.37, 0.34 and -0.01 for state, county and municipality levels, respectively.

On the question of the relationships between public capital investment and private economic activity, Munnell [28] has estimated a model in which public capital affects output, employment growth, and private investment at the state and regional levels. The dependent variable was state product (GDP), while the independent variables were the level of technology, private capital stock, labor and the stock of public capital. The regression results revealed, at the state level, that public capital has a significant positive impact on the level of output, disregarding possible spillover effects. The elasticity for private capital in the equation was 0.31, whereas that of public capital was 0.15, both were highly significant. Haughwout [37] proposed a spatial general equilibrium model of an economy with non-traded, localized public goods like infrastructure. The results show that infrastructure provides significant productivity and consumption benefits to both sectors firms and households. The elasticity for public capital was positive, but small.

Accessibility and Employment Growth

One of the key factors affecting a state or region's economic competitiveness and performance is a reliable and efficient transportation infrastructure. A well-developed, efficient, reliable and safe transportation system provides adequate 'access' to the region and business and household confidence, which in turn, are necessary conditions for the efficient operation of manufacturing, service, labor and housing markets as well as the international flow of exports and imports.

The literature shows that there is a linkage between accessibility (transportation) and economic development. This key finding has emerged as a consensus of previous studies. Clay *et al.* [(38)], for instance, examined several counties in North Carolina and focused on changes in employment and highway expenditures. The authors concluded that highway investment is central to economic development, detecting that extensive spending on highways has led to rapid employment growth in North Carolina's metropolitan areas. Isserman *et al.* [(39)] used a quasi-experimental approach to investigate the effect of highways on smaller communities and rural areas. They examined income growth rates during 1969-1984 for 231 small rural cities, some with highway access, and others without. It was found that the cities located near highways had faster economic growth.

Although most of the previous studies identified a positive relationship between highway investment and local economic development, there are several studies that indicate that there is little or no effect of transportation investment on local economic growth. The major point of these studies is that the economic growth that would have occurred anyway is located near highways, but local economic growth is not created and stimulated by transportation investment. As an example, Stephanedes and Eagle [(40)] used a time series approach to investigate the relationship between state highway expenditures and changes in employment levels in 30 non-metropolitan Minnesota counties between 1964 and 1982. Grouping all 87 Minnesota counties, the authors found no overall relationship between highway expenditures and changes in employment levels. For a subgroup of regional centers, however, highway expenditures did appear to engender job growth.

Ozbay *et al.* [41] examined the effect of improved accessibility from transport investments on the local employment in the New York / New Jersey metropolitan area. Their analysis indicated that changes in accessibility costs had a detectable effect on employment. Accessibility was found to be affected more by private car travel times, rather than public transit travel times. The magnitude of the estimated net employment effect was modest, namely, a 10% increase in accessibility results in a 0.54% increase in new employment.

Cost-Benefit Analysis

Even though most transportation policies are local, their influence often spreads out beyond the area of implementation. Responding to road changes, traffic will shift from the impacted part of the network to other areas, and the intensity of the shift will depend on several factors, such as road characteristics, demand structure, and network configuration [42]. Thus, quantification of the likely changes in transportation benefits and costs associated with the capacity expansion is crucial for policy planners in order to determine the net benefits from capacity expansion projects. Such information can be used in the process to select the projects that are most likely to generate highest return to society.

Several approaches have been developed by researchers and practitioners to evaluate and compare potential transportation improvement projects. The existing methodologies range from single-criteria cost-benefit analysis (COBA) to multiple criteria models and total cost analysis methods.

COBA method is an economic approach that evaluates the benefits and costs of projects in dollar values and compares the benefit cost ratio [43, 44, 45, 46, 47]. Even though this method has several advantages, COBA has rarely been used by urban transportation decision makers due to decision makers' unfamiliarity with this concept, and the complexity of placing monetary values on some of the benefits and costs of transportation projects (e.g., accident reductions, commuting time saved, temporary disruptions).[48, 49]. To address some of these concerns DeCorda-Souza *et al*. [48] proposed a total cost analysis to compare alternatives across modes, which may be more useful for decision-makers. This analysis includes travel time, vehicle operating and accident costs.

Multiple criteria methods developed to select the most beneficial projects draw upon several approaches. One approach, the scoring method, ranks projects with respect to different objectives, where each objective is assigned a weight and each project is scored with respect to each of the objectives. Then each project is then ranked by score [50, 51, 52]. The main drawbacks of this method are the inability to explicitly address resource constraints and compensatory bias [49]. A second approach applies mathematical programming models, such as multi-attribute/objective decision making, goal programming and analytical hierarchy process. In this approach, a variety of objectives and resource restrictions are considered simultaneously [49, 53, 54, 55, 56]. The main discrepancy of this approach is the need for crisp data to get meaningful results. Given the high level of uncertainty associated with transportation projects, decision makers typically refrain from such complex techniques [49]. A third approach, Analytical Hierarchy Process, was developed to include criteria that are not measurable in an absolute sense. In this approach, subjective judgments enter into the evaluation process [57, 58, 59]. This approach is most suitable when optimization is not pursued, resources are not restricted, and interdependencies do not exist.

In economic evaluation of projects, there are several commonly used economic indicators that can be placed in a final comparable format: the Net Present Value (NPV), the Cost-Benefit ratio (B/C), the Equivalent Uniform Annual Costs (EUAC), and Internal Rate of Return (IRR). The choice of the appropriate indicator depends largely on the level and context of the analysis. It may also depend on the degree of uncertainty for some parameters. For example, when projects are evaluated in developing countries where the discount rate is uncertain, the IRR format is the preferred format. Or, when the analysis period of the project is unknown, or when the project is expected to last indefinitely, then EUAC is considered to be the better final format. This is because EUAC equations are derived under the explicit assumption that the project will last indefinitely.

The formulas for each of these formats are presented in Table 8.

Table 8 - Equations of economic indicators

Eq. No	**Indicator**	**Abbreviation**	**Equation**
1	Net Present Value	NPV	$NPV = \sum_{t=0}^{T} \frac{B_t - C_t}{(1+d)^t}$
2	Benefit-Cost Ratio	B/C	$\frac{PVB}{PVC} = \sum_{t=0}^{T} \frac{B_t / (1+d)^t}{C_t / (1+d)^t}$
3	Equivalent Uniform Annual Costs	EUAC	$EUAC = NPV \left[\frac{1(1+d)^t}{(1+d)^t - 1} \right]$
4	Internal Rate of Return	IRR	$\sum_{t=0}^{T} \frac{B_t - C_t}{(1+IRR)^t} = 0$
NPV = Net present value of future costs and benefits, IRR = Internal Rate of Return, B/C = Benefit/Cost PVB = Present value of future benefits, PVC = Present value of future costs d = Discount Rate , t = time of incurrence (year), T = Lifetime of the project or Analysis period (years)			

Life Cycle Cost Analysis (LCCA) is one of the most widely used techniques applied for decision-making in transportation. LCCA is a systematic process for evaluating public projects that generate various impacts over long periods of time. The process is performed by summing up the monetary values of all benefits and costs at their respective time of occurrence throughout the analysis period. These are then converted into a common time dimension so that different alternatives can be compared with respect to a common metric.

The Life Cycle Cost Analysis approach consists of the following steps [60, 61, 62, 63]:

1. Define project's alternatives
2. Decide on a probabilistic or deterministic outcome
3. Choose the general economic parameters: discount rate, analysis period
4. Establish expenditure stream for each alternative
    a. Design rehabilitation strategies and their timings
    b. Estimate agency costs
    c. Estimate user costs
    d. Estimate societal costs
5. Compute Net Present Value for each alternative
6. Compare and interpret results
7. Re-evaluate design strategies if needed

Sections below describe these individual steps in detail.

Defining Project's Alternatives

Experts and experienced professionals suggest strategies that might be potential options for the project. For example, in a pavement project, each strategy specifies an initial design and its performance, time-dependent rehabilitation/treatment activities, and the timings and respective performances of these. Common costs across different strategies can be identified and addressed, for example, in evaluating new pavement projects, right-of-way costs are common to all alternatives and thus can be expressed as such in the analysis. Costs, especially those occurring in the future, can be significant with respect to the total value of the project, thus it is helpful to identify such costs beforehand.

Decide on a Probabilistic vs. Deterministic Approach

Deciding the approach should be based on information and data available for the LCCA model parameters. In all cases, most of the LCCA parameters are uncertain and, therefore, it is generally recommended that the probabilistic approach be adopted.

Choose General Economic Parameters

General economic parameters are the discount rate and the analysis periods. Both parameters should be the same for the analysis of all options.

Establish Expenditure Stream

An expenditure stream diagram can be constructed (see, e.g., Figure 3)

1. Set the design strategies, including scope and timing of each activity.
2. Compute agency costs (in real dollars) for each year of the analysis period.
3. Computer user costs (real dollars) for each year.
4. Compute societal costs (real dollars) for each year.

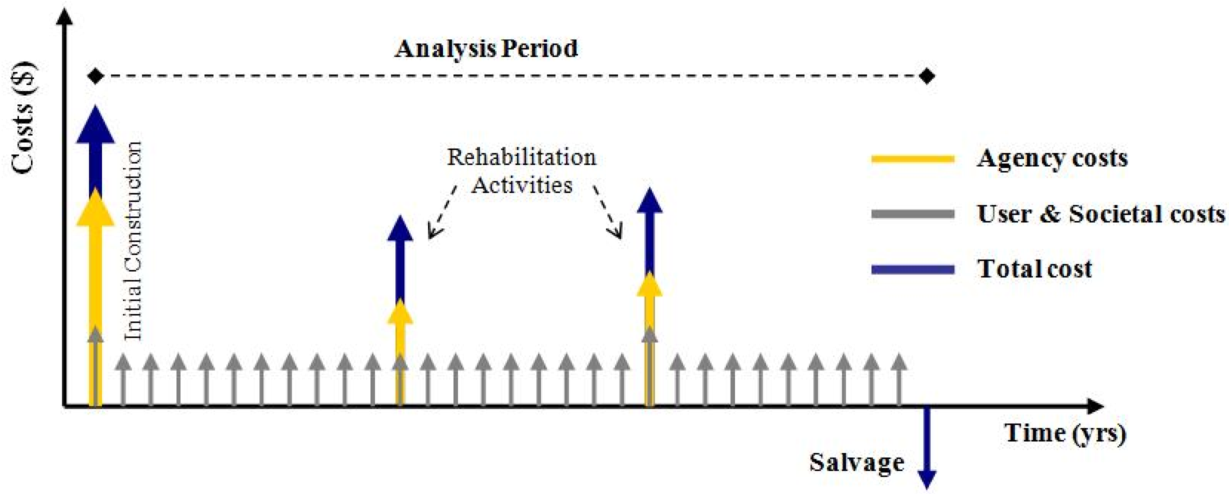

Figure 3. Conceptual Cash Flow Diagram of a Project [61]

Compute the Net Present Value

After constructing the expenditure stream, compute the Net Present Value of each alternative via equation 1 in Table 8. Compute agency, user, and society costs separately before computing the total value of the project in order to better understand the contribution of each cost category to the total.

Compare and Interpret results/ Sensitivity Analysis

Generally, an alternative is preferred if its NPV is more than 10% lower than the NPV of other competing alternatives. If the difference between NPV of alternatives is less than 10%, then such alternatives are considered similar or equivalent. If the deterministic approach is adopted in the analysis, sensitivity analysis should be conducted. The sensitivity analysis should examine the effects of variability of the main parameters on the overall results. This is done by performing the analysis over a range of possible values of a given parameter while holding all other parameters constant. This analysis can provide the decision-maker with a better relative representation of alternatives and, to some extent, it can rule out bias toward certain alternatives.

The most significant parameters in the analysis that should be tested for sensitivity are:

1. Discount rate
2. Timing of future rehabilitation activities
3. Traffic growth rate
4. Unit costs of the major construction components.

Re-evaluate Design Strategies

Presenting and analyzing results assist the process of re-assessing design strategies, whether in scope, timing or other factors. Sometimes minor alterations of the design strategies can lead to a better choice for the project.

Methodology

A major challenge in analyzing the impacts of, for example, new roadway construction, major reconstruction of roadways and roadway widening is the limitations on estimates of the project's effects on traffic patterns. The purpose of these projects is to improve the traffic flow at the specific highway section. Accordingly, it is necessary to predict the modified traffic flow in order to estimate benefits.

The question is then how to accurately evaluate the impact of capacity improvements on traffic flow. The traditional economic models make use of "static traffic assignment" to assess the impact of "capacity expansion." Although these models do not consider the time-dependent dynamics of traffic flow and demand, they are superior to alternatives such as traffic simulation tools and spreadsheet models due to their ability to estimate the changes in network flow characteristics as a result of capacity improvements, i.e. *induced demand*.

The North Jersey Regional Transportation Model (NJRTM) is used to estimate the changes in traffic flows that occur on both local and network levels as a result of capacity improvements. NJRTM is currently used by the North Jersey Transportation Planning Authority (NJTPA).

The NJRTM network, shown in Figure 4, is a standard four-step transportation model that uses CUBE, Fortran and TP+ software. The model area consists of the thirteen county North Jersey region; external stations are used to represent travel to and from places outside the region including New York City. The model is a tool that is used to help with analyzing projects, developing the long-range plan, and determining compliance with air quality conformity standards. The model was largely developed in the late 1980’s by the New Jersey Department of Transportation (NJDOT) and subsequently enhanced by the NJTPA and NJDOT in various stages since then. The NJRTM network has 1377 traffic analysis zones and 74 external stations (64).

The highway network includes most arterials (major and minor), but does not include many local roads. The model was revalidated in April 2006 using observed traffic data from 2000 (including traffic counts and travel time) and socioeconomic data. This network has undergone major improvements in the last year, and now it has more traffic information and GIS-based capabilities than its previous version.

The NJRTM model was improved and the North Jersey Regional Transportation Model - Enhanced (NJRTM-E) by NJTPA and its consultants to produce a fully functioning transportation forecasting tool that is comprehensive and powerful enough to fulfill the regional modeling needs of all major transportation agencies in the region.

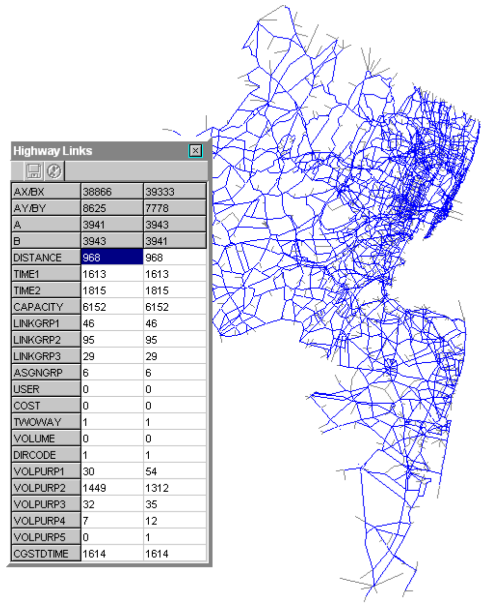

Figure 4. North Jersey Regional Transportation Model (NJRTM)

"In 2008, NJTPA completed a major upgrade to the region's travel demand model. The result is the North Jersey Regional Transportation Model-Enhanced (NJRTM-E). This model was developed with the participation of NJDOT and NJ Transit and fully incorporates the multi-modal nature of the transportation issues facing northern New Jersey. The model is comprehensive and sufficiently powerful to be used by all major transportation agencies in the region. It runs on Citilabs software products CUBE (as an interface), and Voyager with additional FORTRAN programs used for mode choice and reporting elements" [(65)].

"Cube, the main tool used for NJRTM-E model, is a powerful and comprehensive software developed by Citilabs. A Cube modeling module, Cube Voyager combines the latest in Citilabs' technologies for the forecasting of personal travel. Cube Voyager uses a modular and script-based structure allowing the incorporation of any model methodology ranging from standard four-step models, to discrete choice to activity-based approaches. Advanced methodologies provide junction-based capacity restraint for highway analysis and discrete choice multipath transit path building and assignment. Cube Voyager includes highly flexible network and matrix calculators for the calculation of travel demand and for the detailed comparison of scenarios.” (66)

The user interface of the NJRTM-E model in CUBE can be seen in Figure 5. The NJRTM-E is a standard four-step transportation model. The four steps are (64):

Trip generation, where the number of trip origins and destinations are estimated;
Trip distribution, where trip origins are matched with trip destinations;
Mode choice, where a travel mode (e.g., single occupant vehicle, transit) is assigned to each trip; and
Trip assignment, where the route that each trip takes from origin to destination is estimated.

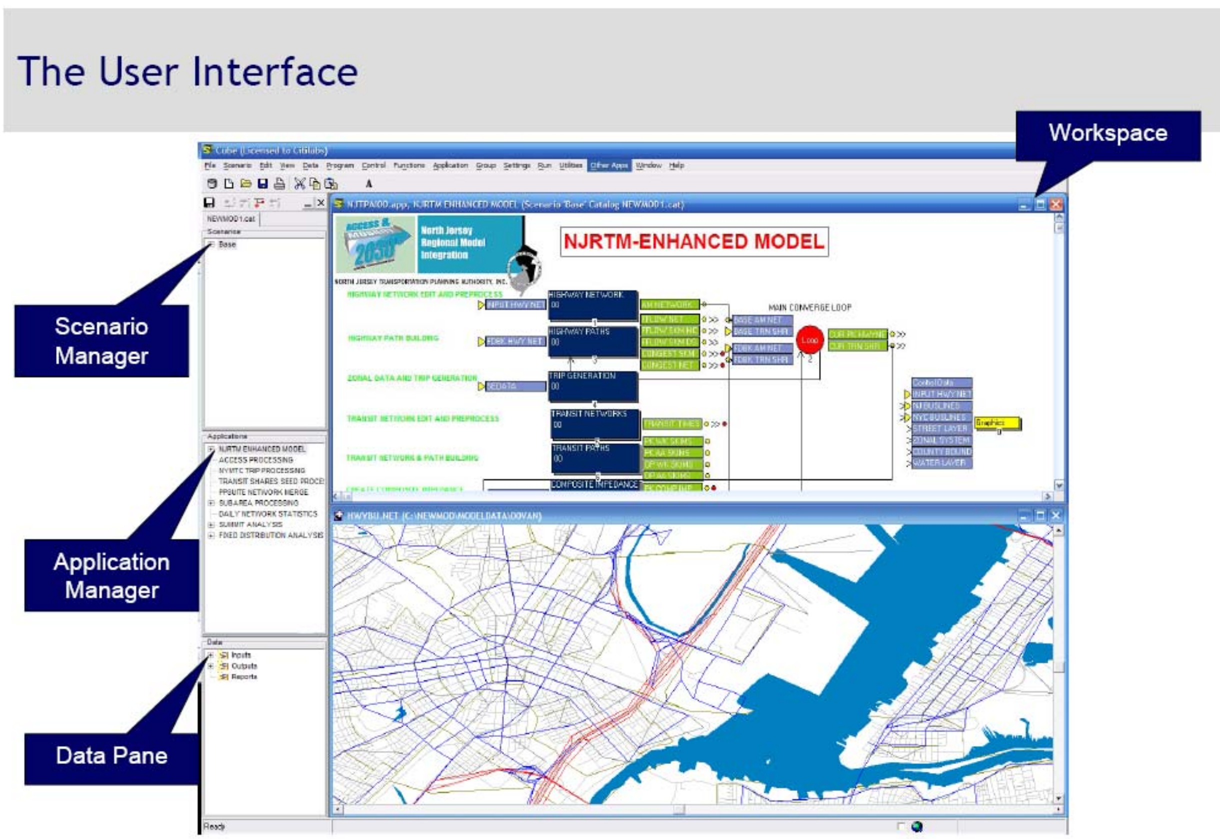

Figure 5. User Interface of NJRTM-E Model (65)

“The new NJRTM-E model's includes trips to the NY area as well, which provides more realistic picture of the commuting trends in the region. The NJRTM-E model now includes a detailed highway network with 6.5 million residents and 23,000 miles of highway network in CUBE (see Figure 6)”.

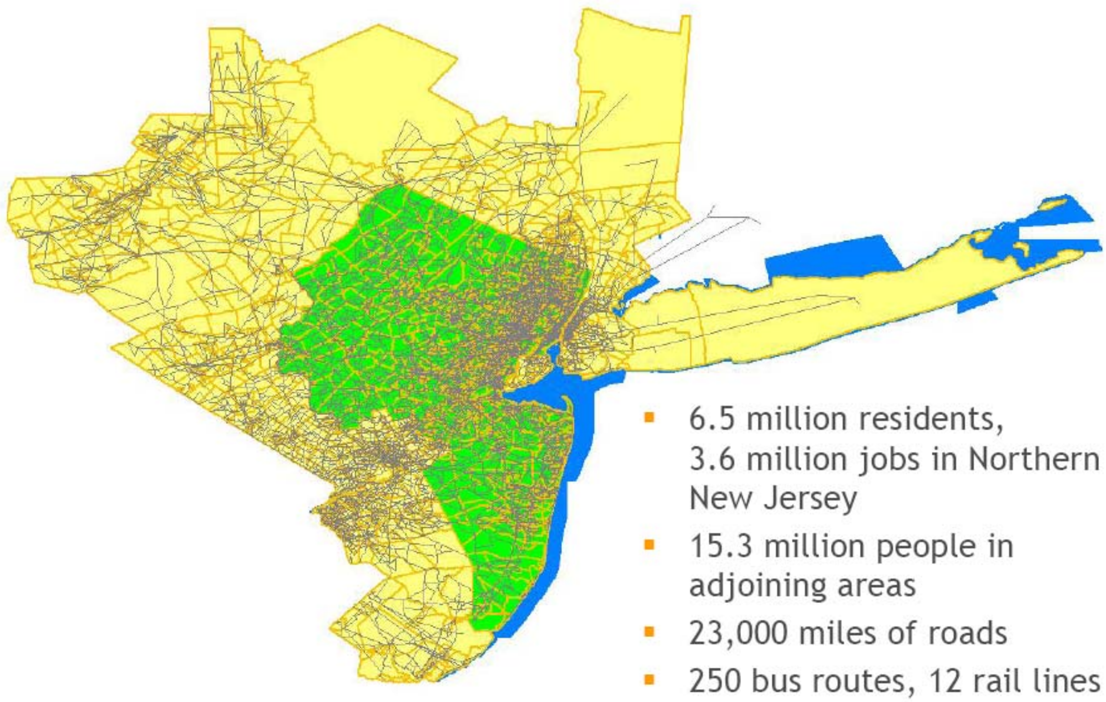

Figure 6. NJRTM-E Region in Cube [65]

The proposed evaluation framework for our analysis is presented in

Figure 7. For each selected past highway capital improvement project, the capacity improvement is reflected in the NJRTM-E CUBE model by increasing the capacity of the link where the project took place. It is, however in most cases, difficult to quantify the impact of a construction project on roadway capacity. Roadway capacity can be improved by not only increasing the number of lanes, but through other means such as increasing shoulder length, removing guardrails, increasing the lane width and changing the roadway geometry (vertical and horizontal alignment). Therefore, the capacity improvement factor, denoted by α_{cap} in this study, is subject to sensitivity analysis.

The NJRTM-E network is run *with and without the capacity improvements*, and the network traffic flows are obtained from CUBE. Using the before and after network results, the benefits of the project are estimated by the reductions in various cost categories, such as congestion, vehicle operating, accident, air pollution, noise and maintenance costs at network level. Accordingly, the proposed methodology combines sound economic theory with the output of a highly detailed transportation demand model for estimating the costs and benefits of selected highway projects.

The NJRTM-E network is based on 2000 traffic levels. For projects that were undertaken after year 2000, an annual traffic growth rate of 1 percent is used to populate the origin-destination (OD) demand for future years.

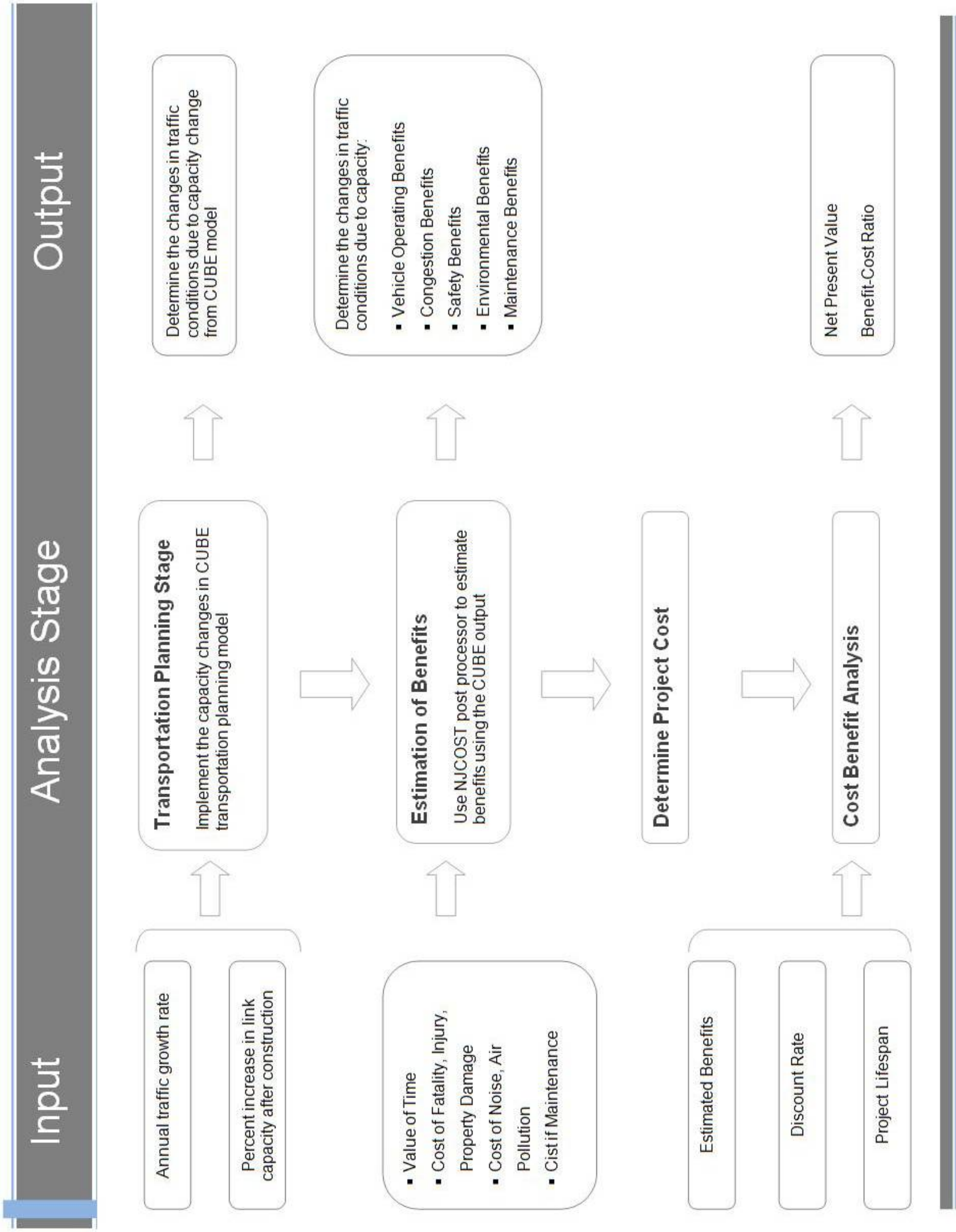

Figure 7. Proposed project evaluation framework

Since we are dealing with completed projects, we know definite cost of construction. Given the cost of the project, and then also given that the benefits are estimated, the net present value of the project can be calculated. A discount rate is used to convert future costs and benefits to present values. Various discount rates recommended by the U.S. Office of Management and Budget (USOMB) are shown in Table 9.

Table 9 - Real discount rates to be used for cost-benefit analysis [10]

3-Year	5-Year	7-Year	10-Year	20-Year	30-Year
0.9	1.6	1.9	2.4	2.9	2.7

The results of NJRTM-E network runs with and without capacity improvements obtained in CUBE are then processed in the NJCOST program developed for this project.

NJCOST employs ArcGIS in the Visual Basic .NET environment. It calculates costs using the output database files obtained from the CUBE runs. NJCOST can calculate link based or O-D based costs. O-D based cost is calculated using the constrained k-shortest path algorithm that uses C programming language. Link-based costs are calculated for a selected region (e.g. county) or network-wide. In comparing the cost reduction due to the selected projects, we employ link-based cost functionality of NJCOST to calculate total network costs before and after project implementation.

A detailed explanation of NJCOST, its capabilities and its user manual is given in Chapter V.

Cost Functions

The cost reduction categories used in this study are (1) vehicle-operating, (2) travel time and congestion, (3) accident, (4) air-pollution, (5) noise, and (6) maintenance costs.

Reductions in each cost category attributable to a project were estimated using data obtained from NJDOT and other state and national sources. Data on vehicle operating costs, accident costs, and infrastructure costs are NJ-specific. STATA software is used to estimate the parameters of each cost function. Congestion and environmental costs, however, were based on relevant studies in the literature. The parameters of the cost functions were modified to reflect NJ-specific conditions. The individual cost reduction functions are discussed below.

Vehicle Operating Costs

Vehicle operating costs are directly borne by drivers. These costs are affected by many factors, such as road design, type of the vehicle, environmental conditions, and flow speed of traffic. In this study, vehicle operating costs depend on depreciation cost, cost of fuel, oil, tires, insurance, and parking/tolls. Depreciation cost is itself a function of mileage and vehicle age; other costs are unit costs per mile. In this study, we employed the depreciation cost function estimated by Ozbay *et al*. [(15)], shown in Table 15.

The other cost categories, namely, cost of fuel, oil, tires, insurance, parking and tolls are obtained from appropriate AAA report [(18)] and USDOT report [(19)]. The unit operating costs given in Table 10 are in 2005 dollars.

Table 10 - Operating costs (in 2005 dollars) [18,19]

Operating Expenses	Unit Costs
Gas & oil	0.087 ($/mile)
Maintenance	0.056 ($/mile)
Tires	0.0064 ($/mile)
Insurance Cost	1,370($/year)
Parking and Tolls	0.021 ($/mile)

Congestion Costs

Congestion cost is defined as the time-loss due to traffic conditions and drivers' discomfort, both of which are a function of increasing volume to capacity ratios. Specifically,

- **Time loss** can be determined through the use of a travel time function. Its value depends on the distance between any OD pairs (*d*), traffic volume (*Q*) and roadway capacity (*C*).

- **Users' characteristics:** Users traveling in a highway network are not homogeneous with respect to their value of time.

Since all these cost categories are directly related to travel time, the monetary value of time (VOT) is a crucial determinant of cost changes. Depending on the mode used by the traveler, travel time costs may include time devoted to waiting, accessing vehicles, as well as actual travel.

In a study of congestion costs in Boston and Portland areas, Apogee Research estimated congestion costs using VOT values based on 50% of the average wage rate for work trips and 25% for other trip purposes [72]. Based on a review of international studies, K. Gwilliam [67] concluded that work travel time should be valued at 100% wage rate, whereas non-work travel time should be valued at 30% of the hourly wage rate, given the absence of superior local data. Similarly, the USDOT [68] suggests VOT values between 50% and 100% of the hourly wage rate depending on travel type (personal, business). In these studies, user characteristics, mode of travel, or time of day choices are not included in the VOT estimation. To address these issues, stated preference surveys are conducted in some studies to estimate VOT for different modes and trip types [69,70, 71].

In this study, we adopt the VOT ranges based on average hourly wages as recommended by the USDOT [68]. Following the USDOT [68], we assume two vehicle types: passenger cars and trucks. For passenger cars, the VOT range, based on the hourly wage, is assumed to be between 80% and 120% of the average hourly wage within peak period, and between 35% and 60% of the average hourly wage within off-peak periods, respectively. For trucks, the VOT range, based on the hourly wage, is assumed to be 100% within both off-peak and peak periods.

U.S. Department of Labor [73] reported average hourly wages for all occupations in New Jersey. The report indicates that, in 2007, the average hourly wage for all occupations was $22.64 per hour. The hourly wage in trucking was $19.90 per hour.

Table 11 shows the VOT ranges, as suggested by the USDOT [68], used in our analysis.

Table 11 - Value of Time Ranges

Time Period	Passenger Cars	Trucks
Peak	$18.1 - $27.2	$19.9
Off- Peak	$7.9 - $13.6	$19.9

The Bureau of Public Roads travel time function was used to calculate time loss. Thus, the total cost of congestion between a given OD pair can be calculated by the time loss of one driver along the route, multiplied by total traffic volume (*Q*) and the average value of time (VOT).

Table 16 presents the congestion cost formula.

Accident Costs

Accident costs are the economic value of damages caused by vehicle accidents/incidents. These costs can be classified in two major groups: (1) cost of foregone production and consumption, which can be converted into monetary values, and (2) life-injury damages, which involves more complex techniques to convert into monetary values. Costs associated with these two categories are given in 12.

The accident cost function estimates the number of accidents that occur over a period of time, and converts the estimated number of accidents into a dollar value by multiplying the number of accidents by their unit cost values. The cost of any specific accident varies of course with individual circumstances. However, similar accidents typically have costs that fall within the same range.

Table 12 - Accident Cost Categories

Pure Economic Costs	
Major costs	Description
Medically related costs	Hospital, Physician, Rehabilitation, Prescription
Emergency services costs	Police, Fire, ambulance, helicopter services, incident management services
Administrative and legal costs	Vehicle repair and replacement, damage to the transportation infrastructure
Life Injury Costs	
Employer costs	Wages paid to co-workers and supervisors to recruit and train replacement for disabled workers, repair damaged company vehicles, productivity losses due to inefficient start-up of substitute workers
Lost productivity costs	Wages, fringes, household work, earnings lost by family and friends caring for the injured
Quality of life costs	Costs due to pain, suffering, death and injury
Travel delay costs	Productivity loss by people stuck in crash related traffic jams

Accidents were categorized as fatal, injury and property damage accidents. Accident occurrence rate functions for each accident type were developed using the traffic accident database of New Jersey.

Historical data obtained from NJDOT show that annual accident rates, by accident type, are closely related to traffic volume and roadway geometry.

Traffic volume is represented by the average annual daily traffic. The **roadway geometry** of a highway section is based on its engineering design. There are various features of a roadway geometric design that closely affect the likelihood of an accident occurrence. However, these variables are too detailed to be considered in a given function. Thus, highways were classified on the basis of their functional type, namely Interstate, freeway-expressway and local-arterial-collector**.** It was assumed that each highway type has its unique roadway design features. This classification makes it possible to work with only two variables: **road length** and **number of lanes**[2]. There are three accident occurrence rate functions for each accident type for each of the three highway functional types. Hence, nine different functions were developed. Regression analysis was used to estimate these functions. The available data consists of detailed accident summaries for the years 1991 to 1995 in New Jersey. For each highway functional type, the number of accidents in a given year is reported.

The unit cost of each type of accident directly affects the cost estimates. The National Safety Council (75) reported the average unit cost per person for three accident types, as shown in Table 13. These values are comprehensive costs that include a measure of the value of lost quality of life which was obtained through empirical studies based on observed willingness to pay by individuals to reduce safety and health risks.

Table 13 - Average Comprehensive Cost per person by accident type (75)

Accident Type	Cost
Death	$4,100,000
Incapacitating Injury	$208,500
Nonincapacitating Injury	$53,200
Possible Injury	$25,300
Property Damage	$2,300

Accident cost estimation is not exact, it can only be approximated. The studies in the relevant literature show varying unit costs for accidents. A NHTSA study (76) reports the lifetime economic cost of each fatality as $977,000. Over 80% of this

[2] This approach is also consistent with previous studies e.g., Mayeres et al. (12)

amount is attributable to lost workplace and household productivity. The same study reports that the cost of each critically injured survivor is $1.1 million [76].

A study by FHWA [77] reported the comprehensive cost of each accident by severity, as shown in Table 14.

Table 14 - Average comprehensive cost by accident type [77]

Accident Type	Cost
Fatal	$3,673,732
Incapacitating	$254,335
Evident	$50,867
Possible	$26,847
Property Damage	$2,826

Note: All costs are in 2008 dollars, converted from 1994 values using 2.5% discount rate.

A recent poll conducted by AASHTO [78] reported accident costs by severity. The reported figures shown in Table 15 reflect the average accident costs used by 24 states for prioritizing safety projects.

Table 15 - Average cost by accident type [78]

Accident Type	Cost
Fatality	$2,435,134
Major Injury	$483,667
Incapacitating Injury	$245,815
Minor Injury	$64,400
Nonincapacitating Evident Injury	$46,328
Injury	$59,898
Possible or Unknown injury	$23,837
Property Damage	$6,142

In our analysis, we use the unit accident costs reported by the FHWA [77] (see Table 13). In order to align the cost estimates based on the accident types available in NJDOT accident database, we regroup accident types in FHWA [77] into fatality, injury (incapacitating) and property damage accidents.

The accident cost functions are presented in Table 16. These functions are based on unit accident cost for each accident type. The accident cost functions used in this study were first developed by Ozbay *et al*. [13], and later improved by Ozbay *et al*. [14,15] with a new accident database. The statistical results of the estimation of accident occurrence rate functions can be found in Ozbay *et al*. [15].

Environmental Costs

Environmental costs due to highway transportation are categorized as air pollution and noise pollution costs.

Air Pollution Costs

Highway transportation accounts for the air pollution due to the release of pollutants during motor vehicle operations. This occurs either through the direct emission of the pollutants from the vehicles, or the resulting chemical reactions of the emitted pollutants with each other and/or with the existent materials in the atmosphere. The pollutants included in estimating air pollution costs in this study are volatile organic compounds (VOC), carbon monoxide (CO), nitrogen oxide (NO_x), and particulate matters (PM_{10}).

Estimating the costs attributable to highway air pollution is not a straightforward task, since there are no reliable methods to precisely identify and quantify the origins of the existing air pollution levels. The constraints for estimating the costs attributable to air pollution are listed as follows:

Air pollution can be *local*, *trans-boundary* or *global*. As the range of its influence broadens, the cost generated increases, and after a certain point the full cost impact becomes difficult to estimate.

Air pollution effects are typically chronic in nature. Namely, unless the pollution level is at toxic levels, the damage imposed on human health, agricultural products and materials may be detectable only after years of exposure.

Even if the influence of specific sources of air pollution could be isolated with precision, quantifying the contribution of highway transportation requires several assumptions. Emission rates depend on multiple factors, such as topographical and climatic conditions of the region, vehicle properties, vehicle speed, acceleration and deceleration, fuel type, *etc*. The widely used estimation model is available in US MOBILE software, which requires, as inputs, the above listed factors. Based on the input values, the program estimates emissions of each pollutant. However, the accuracy of this specific model and the other current models is, as noted, imprecise (see Small, *et al.* [79]).

Cost values attributable to differing levels of air pollution require a detailed investigation and an evaluation of people's preferences and their willingness to pay in order to mitigate or avoid these adverse effects.

There is an extensive literature that attempts to measure the costs of air pollution (e.g., Small [80], Small and Kazimi al.[79], Mayeres et al. [69]). There are three ways of estimating the costs of air pollution: *Direct estimation of damages*, *hedonic price measurement* (relates price changes, demand, and air quality levels) and *preference of policymakers* (pollution costs are inferred from the costs of meeting pollution regulations), (Small and Kazimi [79]).

Small and Kazimi [79] adopt the direct estimation of damages method to measure the unit costs of each pollutant. The study differentiates the resulting damages in three categories: *mortality from particulates*, *morbidity from particulates* and *morbidity from ozone*. It is assumed that human health costs are the dominant portion of costs due to air pollution rather than the damage to agriculture or materials. *Particulate Matter* (PM_{10}) which is both directly emitted and indirectly generated by the chemical reaction of *VOC*, NO_x, and SO_x, is assumed to be the major cause of health damage costs. Ozone (O_3) formation is attributed to the chemical reaction between *VOC* and NO_x. In this study, we adopt the unit cost values suggested by Small and Kazimi [79]. The air pollution cost function is given in Table 16.

<u>Noise Costs</u>

The external costs of noise are most commonly estimated as the rate of depreciation in the value of residential units located at various distances from highways. Presumably, the closer a house to the highway the more the disamentity of noise will be capitalized in the value of that house. While there are many other factors that are also capitalized in housing values, “closeness” is most often utilized as the major variable explaining the effect of noise levels. The Noise Depreciation Sensitivity Index (*NDSI*) as given in Nelson [17] is defined as the ratio of the percentage reduction in housing value due to a unit change in the noise level. Nelson [17] suggests the value of *0.40*% for *NDSI*.

The noise cost function is given in Table 16. The function indicates that whenever the ambient noise level at a certain distance from the highway exceeds 50 decibels, it causes a reduction in home values of houses. Thus, the change in total noise cost depends both on the noise level and on the house value. Detailed information is presented in Ozbay *et al.* [13].

Maintenance Costs

Roadway infrastructure costs are equated in this analysis with resurfacing costs. A total of 61 resurfacing projects in New Jersey, between 2005 and 2006 were considered. The data consisted of average number of lanes, length in miles and total project costs. This data did not include roadway traffic volume. Therefore, a simple resurfacing cost function based on number of lanes and length was developed. Table 16 shows the infrastructure cost function of roadway maintenance (resurfacing).

Table 16 - Cost Functions [14,15]

Cost	Total Cost Function	Variable Definition	Data Sources
Vehicle Operating	C_{opr} = 7208.73 + 0.12(m/a) + 2783.3a + 0.143m	a: Vehicle age (years)	AAA [18], USDOT [19], KBB [20]
Congestion	$C_{cong} = \begin{cases} Q.\frac{d_{a,b}}{V_o}.\left(1+0.15\left(\frac{Q}{C}\right)^4\right).VOT & \text{if } Q \le C \\ Q.\frac{d_{a,b}}{V_o}.\left(1+0.15\left(\frac{Q}{C}\right)^4\right).VOT+Q.\left(\frac{Q}{C}-1\right).\frac{VOT}{2} & \text{if } Q > C \end{cases}$	Q = Volume (veh/hr) d = Distance (mile) C = Capacity (veh/hr) VOT = Value of time ($/hr) V_o = Free flow speed (mph)	Mun [21] Small and Chu [22]
Accident	*Category 1*: Interstate-freeway $C_{acc} = 127.5Q^{0.77}.M^{0.76}.L^{0.53} + 114.75Q^{0.85}.M^{0.75}.L^{0.49} + 198{,}900Q^{0.17}.M^{0.42}.L^{0.45}$	Q = Volume (veh/day) M = Path length (miles) L = no of lanes	FHWA [23] USDOT [24]
	Category 2: principal arterial $C_{acc} = 178.5Q^{0.58}.M^{0.69}.L^{0.43} + 18{,}359Q^{0.45}.M^{0.63}.L^{0.47}$		
	Category 3: arterial-collector-local road $C_{acc} = 229.5Q^{0.58}.M^{0.77}.L^{0.77} + 9{,}179.96Q^{0.74}.M^{0.81}.L^{0.75}$		
Air pollution	$TC_{air} = Q(0.01094 + 0.2155F)$ where; $F = 0.0723 - 0.00312V + 5.403x10^{-5}V^2$	F = Fuel consumption at cruising speed (gl/mile) V = Average speed (mph) Q = Volume (veh/hr)	EPA [25]
Noise	$C_{noise} = 2\int_{r_1=50}^{r_2=r_{max}} (L_{eq} - 50) DW_{avg} \frac{RD}{5280} dr$ where; $K = K_{car} + K_{truck}$ $K = \frac{F_c}{V_c}\left(V_c^{4.174}.10^{0.115} + 10^{5.03F_{ac}+(1-F_{ac})6.7}\right) + \frac{F_{tr}}{V_{tr}}\left(V_{tr}^{3.588}.10^{2.102} + 10^{7.43F_{atr}+(1-F_{atr})7.4}\right)$ $L_{eq} = 10\log(Q) + 10\log(K) - 10\log(r) + 1.14$	Q = Volume (veh/day) r = distance to highway K = Noise-energy emis. K_{car} = Auto emission K_{truck} = Truck emission F_c = % of autos, F_{tr} = % of trucks F_{ac} =% const. speed autos F_{atr}=% of const. speed tr. V_c = Auto Speed (mph) V_{tr} = Truck Speed (mph)	Delucchi and Hsu [26]
Maint.	$C_M = 800{,}950N^{0.384}L^{0.403}$	N: Number of lanes L: Length of project (miles) T: Time between each resurfacing cycles (hour) t: Travel time of one additional vehicle (hour)	Ozbay et al. [13]

Case Studies: Applying the Methodology

Transportation agencies, given finite resources, are routinely faced with the problem of efficiently selecting a subset of transportation projects for implementation from a much larger portfolio of potential projects. One of the major difficulties in project selection is the quantification of the value of time, the value of human life, and the value of various environmental impacts [(81)]. With the use of the methodology presented here, this study provides a comprehensive and consistent approach to quantify all transportation costs with respect to different O-D pairs and road sections.

Using the available transportation network of northern NJ, it is possible to estimate the transportation costs for original and modified (i.e., capacity enhanced) network conditions.

In this section, the cost reduction impacts of real-world highway capacity investments on several routes are estimated. Five major roadway widening projects, completed between 2004 and 2009 in Northern NJ, were selected for our analysis. Table 17 summarizes the details of the selected projects.

Table 17 - The selected widening projects in northern New Jersey

Route	**Location**	**Length**	**Work Type**	**Cost**
Route 17	Bergen County	0.50 miles	Roadway Widening & Bridge Reconstruction	$84.4 million
Route 18	Middlesex County	1.54 miles	Roadway Widening & Extension	$82 million
Route 35	Middlesex Country	1.38 miles	Roadway Widening & Bridge Reconstruction	$129.6 million
Route 1&9	Union County	n/a	Bridge Reconstruction	$72 million
Route 1	Middlesex County	2.92 miles	Roadway Widening & Bridge Reconstruction	$59 million

Figure 8 shows the location of the road sections for which the possible impacts of capacity investment are assessed using the proposed methodology.

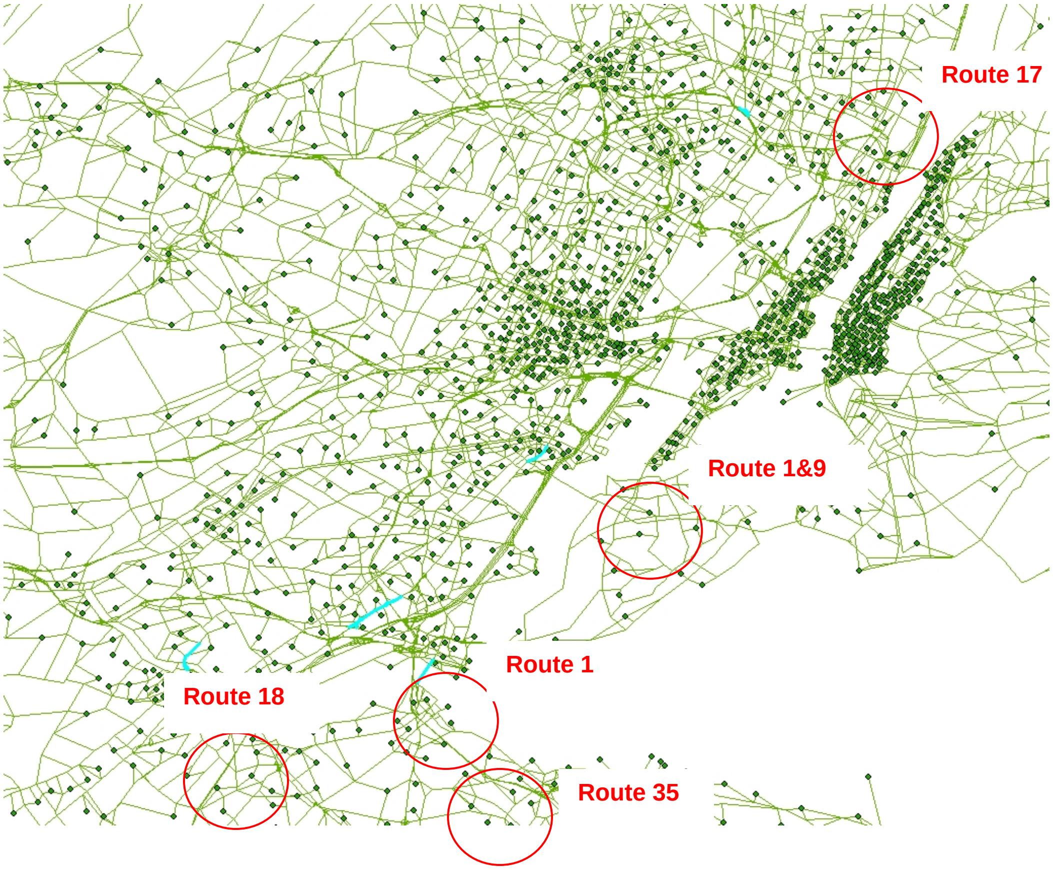

Figure 8. Locations of the selected roadway projects

After increasing the capacity of these road sections, traffic is reassigned onto the modified network. The output information obtained from the traffic assignment is used for comparison of before-after costs. The difference is the benefits (i.e., the reduction in costs) attributable to the project. It should be noted that impacts of each capacity investment are investigated separately, i.e. five different modified networks are created for the five different capacity investments. The changes in costs are calculated using the developed GIS tool.

Route 17 Project

This project replaced the existing deficient structure of four-lane Essex Street Bridge with a new, wider structure of six lanes that is compatible with the planned future improvements on route 17. The demolished bridge was 76 years old. The construction of the new bridge and the improvements at the ramps to route 17 were completed in the summer of 2008.[(82)]

The allocated funds for this project are shown in Table 18. The total construction cost is calculated for the year 2008 by compounding the costs using 1.6% interest rate.

Table 18 - Allocated funds for Route 17 project [82)]

	2004	2005	2006	2007	2008	Total
Funds Allocated (in millions)	$1.924	$15.38	$13.9	$34.55	$15.6	$83.2

The link corresponding to the Essex Bridge was modified in the NJRTM-E model in accordance with the widening specifications. The O-D matrix for the transportation network from year 2000 was populated for year 2008 using 1% annual traffic growth. The transportation network was run with the original (existing) bridge capacity and with the modified bridge capacity. The GIS program developed by Ozbay *et al.* [(15)] was used to calculate the total cost for the original and the modified network. The results are shown in Table 19.

Table 19 - Estimated total daily cost for original and modified networks ($)

Morning Peak							
	Vehicle Operating	**Congestion**	**Accident**	**Air Pollution**	**Noise**	**Maintenance**	**Total**
Original	12,269,130	39,133,860	3,090,104	1,866,980	42,316.2	688,671.8	57,091,062
Modified	12,201,810	37,791,990	3,054,356	1,865,848	42,233.3	731,113.8	55,687,351.1
Benefit	**67,320**	**1,341,870**	**35,748**	**1,132**	**82.9**	**-42,442**	**1,403,710.98**
Midday Off-peak							
Original	13,290,220	14,092,140	4,131,658	2,538,840	65,369.9	1,584,298	35,702,525.9
Modified	13,290,210	14,091,140	4,131,628	2,538,710	65,327.9	1,584,178	35,701,193.9
Benefit	**10.0**	**1,000**	**30.0**	**130.0**	**42.0**	**120.0**	**1,332**
Afternoon Peak							
Original	13,737,490	45,214,080	3,422,373	2,054,029	45,853.5	740,909.6	65,214,735.1
Modified	13,705,500	44,701,830	3,407,008	2,052,287	45,835.8	741,083.9	64,653,544.7
Benefit	**31,990**	**512,250**	**15,365**	**1,742**	**17.73**	**-174.3**	**561,190.4**
Night Off-peak							
Original	9,350,579	9,712,229	3,744,627	1,805,579	46,189	2,293,476	26,952,679
Modified	9,335,390	9,562,083	3,726,513	1,799,889	45,673.3	2,303,998	26,773,546.3
Benefit	**15,189**	**150,146**	**18,114**	**5,690**	**515.7**	**-10,522**	**179,132.7**
Total Daily Benefit							**$2,145,366.1**

It should be noted that the congestion costs shown in Table 19 are estimated based on the lower bound of the VOT assumption as shown in Table 11. Based on the results shown in Table 19, the total daily benefit within the NJRTM-E network due to capacity improvement at the Essex Bridge is estimated as $2.15 million. It should be noted that this value represents an estimated average benefit of the capacity expansion on a given work-day. Annual benefit of this project can be calculated by multiplying the daily benefit by 250 workdays, which equals $536.34 million. The annual benefit does not include benefits that accrue on weekends; therefore it reflects a lower, conservative bound of the benefits of this project.

The annual benefits of this project will not remain constant in the future, given that the bridge life-time is likely to be over 50 years. Due to expected traffic growth in the future, the benefit of this project will diminish over the years. We assume that the estimated benefit becomes zero after 25 years due to increased levels of traffic[3]. Based on this assumption the net present value of benefits in 2008 is $5.67 billion, assuming a discount rate of 2.8% for 25 years[4].

Since the net present value of the benefits outweighs the net present value of construction costs, this project is socially efficient, i.e., it promises to return more to society than it costs. The conservative benefit-cost ratio of this project is 68.08 ($5,665.08m/$83.2m).

Route 18 Extension Project

Route 18 links the New Brunswick area with the north-central New Jersey shore communities. It serves as an east-west route through Middlesex and Monmouth Counties to fill a gap in the existing expressway grid, it provides an alternate route for trucks along the Garden State Parkway Corridor and it also provides an overload route for peak recreational traffic to North Jersey shore resorts. (82)

In 2001, the NJDOT approved a reconstruction as part of its five-year capital program. The four-lane extension follows the route originally proposed in 1962, along the Metlars Lane-Hoes Lane alignment. (82)

The project was completed in 2004 replacing an existing two-lane roadway with a new four-lane limited access highway. One important objective of the new highway was to eliminate the bottleneck of Metlars Lane and provide the missing link in Route 18 with grade-separated interchanges with River Road, the Rutgers Busch Campus, Metlars lane/Davidson Road and the Rutgers Livingston Campus. The Route 18 extension now feeds into Hoes Lane, a four-lane divided road.

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[3] We assume that within 25 years the benefits linearly reduce to zero.
[4] The discount rate for 25 years is assumed to be 2.8%, interpolated using the discount rates for 20 years and 30 years as shown in Table 9.

The allocated fund for this project was $75.6 million in 2002. The total construction cost is calculated as $83.2 million in 2008 by compounding the costs using a 1.6% interest rate.

The links corresponding to Route 18 in the NJRTM-E model were modified in accordance with the widening specifications. The O-D matrix for the transportation network from year 2000 was populated for year 2008 using 1% annual traffic growth. The transportation network was run with the original (existing) and the expanded roadway capacity. The GIS program developed by Ozbay et al. [15] was used to calculate the total cost for the original and the modified network. The results are shown in Table 20.

Table 20 - Estimated total daily cost for original and modified networks ($)

Morning Peak							
	Vehicle Operating	**Congestion**	**Accident**	**Air Pollution**	**Noise**	**Maintenance**	**Total**
Original	12,269,130	39,133,860	3,090,104	1,866,980	42,316.2	688,671.8	57,091,062
Modified	12,181,890	37,494,590	3,045,857	1,864,648	42,199.3	731,733.3	55,360,917.6
Benefit	**87,240**	**1,639,270**	**44,247**	**2,332**	**116.9**	**-43,061.5**	**1,730,144.4**
Midday Off-peak							
Original	13,290,220	14,092,140	4,131,657	2,538,840	65,369.9	1,584,298	35,702,524.9
Modified	13,290,190	14,091,990	4,131,689	2,538,826	65,369.4	1,584,272	35,702,336.4
Benefit	**30.0**	**150.0**	**-32.0**	**14.0**	**0.45**	**26.0**	**188.4**
Afternoon Peak							
Original	13,737,490	45,214,080	3,422,373	2,054,029	45,853.5	740,909.6	65,214,735
Modified	13,734,350	45,176,190	3,421,061	2,054,931	45,900.4	740,835.8	65,173,268.2
Benefit	**3,140**	**37,890**	**1,312**	**-902.0**	**-46.9**	**73.8**	**41,466.9**
Night Off-peak							
Original	9,350,579	9,712,229	3,744,627	1,805,579	46,189	2,293,476	26,952,679
Modified	9,335,382	9,562,021	3,726,508	1,799,894	45,673.7	2,303,998	26,773,476.7
Benefit	15,197	150,208	18,119	5,685	515.4	-10,522	179,202.4
Total Daily Benefit							**$1,951,002**

VOT congestion costs shown in Table 20 are estimated based on the lower bound of the values shown in Table 11. Based on the results shown in Table 20, the network-wide daily benefit of the Route 18 extension project was estimated at $1.95 million. The annual benefit of this project is calculated by multiplying this times 250 workdays, or $487.75 million. As mentioned earlier, the calculated annual benefit does not include benefits accruing on the weekends, and therefore it is a conservative lower bound of the benefits of this project.

It is assumed that the annual benefits of this project will not remain constant in the future. If we assume conservatively that the lifetime of the new roadway is 25 years, the benefit of this project will diminish over the years due to expected traffic growth in the future. We assume that the estimated benefit becomes zero after 25 years due to increased levels of traffic. Based on this assumption, the estimated net present value of the benefits is $5.15 billion, assuming a discount rate of 2.8% for 25 years. Since the net present value of the benefits is less than the net present value of construction costs, the roadway expansion was economically efficient based on our assumptions. The benefit cost ratio of this project is 58.95 ($5,151.85m/$87.4m).

Route 35 Victory Bridge Project

The Victory Bridge in New Jersey carries Route 35 over the Raritan River, connecting Perth Amboy and Sayreville. The new bridge replaced a bridge constructed in 1926. The old bridge carried four 9.5-foot travel lanes with no shoulders. The objective of the new bridge was to boost the regional economy and significantly alleviate congestion and improve safety. [82]

The new bridge consists of twin structures (northbound and southbound) each carrying two 12-foot lanes, a 10-foot bike lane/outside shoulder and a three foot shoulder. The bridge was designed with a 440-foot main span. The project also involved the construction of an access road that is a continuation of a connector roadway from Perth Amboy to the Victory Bridge. The construction was completed in December 2005. The adjusted cost of the project in 2008 dollars was $129.6 million. (82)

The links corresponding to the Victory Bridge in the NJRTM-E model were modified in accordance with the widening specifications. The O-D matrix for the transportation network from year 2000 was populated for year 2008 using 1% annual traffic growth. The transportation network was run with the original (existing) and the expanded roadway capacity. The GIS program developed by Ozbay *et al.* (15) was used to calculate the total cost for the original and the modified network. The results are shown in Table 21.

Table 21 - Estimated total daily cost for original and modified networks ($)

Morning Peak							
	Vehicle Operating	**Congestion**	**Accident**	**Air Pollution**	**Noise**	**Maintenance**	**Total**
Original	12,269,130	39,133,860	3,090,104	1,866,980	42,316.2	688,671.8	57,091,062
Modified	12,202,720	37,776,420	3,055,329	1,865,782	42,235.1	731,017.6	55,673,503.7
Benefit	**66,410**	**1,357,440**	**34,775**	**1,198**	**81.1**	**-42,345.8**	**1,417,558.3**
Midday Off-peak							
Original	13,290,220	14,092,140	4,131,657	2,538,840	65,369.9	1,584,298	35,702,524.9
Modified	13,290,120	14,091,140	4,131,627	2,538,840	65,364.9	1,584,298	35,701,389.9
Benefit	**100.0**	**1,000**	**30.0**	**0.0**	**5.0**	**0.0**	**1,135**
Afternoon Peak							
Original	13,737,490	45,214,080	3,422,373	2,054,029	45,853.5	740,909.6	65,214,735.1
Modified	13,740,870	45,187,420	3,420,469	2,054,826	45,889.4	740,848.1	65,190,322.5
Benefit	**-3,380**	**26,660**	**1,904**	**-797.0**	**-35.9**	**61.5**	**24,412.6**
Night Off-peak							
Original	9,350,579	9,712,229	3,744,627	1,805,579	46,189	2,293,476	26,952,679
Modified	9,335,390	9,562,163	3,726,513	1,799,889	45,673.3	2,303,998	26,773,626.3
Benefit	**15,189**	**150,066**	**18,114**	**5,690**	**515.7**	**-10,522**	**179,052.9**
Total Daily Benefit							**$1,622,158**

In Table 21, the estimated congestion costs are based on the lower bound of the VOT ranges as shown in Table11. Based on the results shown in Table 21, the daily benefit of the Victory Bridge reconstruction project was estimated at $1.62 million. The annual benefit of this project can be calculated by multiplying the estimate by 250 workdays, which equals $405.53 million. The calculated annual benefit does not include benefits that accrue on weekends, and therefore reflects a conservative, lower bound of the benefits of this project.

As mentioned in the previous analyses, it is assumed that the annual benefits of this project will not remain constant in the future. Assuming that the bridge life-time is over 50 years, it is assumed that the benefit of this project will diminish over the years due to expected traffic growth. We assume that the estimated benefit becomes zero after 25 years due to increased levels of traffic. Based on this assumption the net present value of benefits in 2008 is $4.28 billion, assuming a discount rate of 2.8%.

Since the net present value of the benefits outweighs the net present value of construction costs, the reconstruction of the Bridge with higher roadway capacity is economically efficient. The benefit cost ratio of this project is 33.05 ($4,283.40m/$129.6m).

Route 1 & 9 Viaduct Project

The Route 1&9 project involved the staged erection of two bridges (northbound and southbound) to replace the historic Elizabeth Viaduct constructed in 1929 over the Elizabeth River and the downtown marketplace. The old bridge carried two 10-foot travel lanes with no shoulders. Each constructed bridge is 1,870-foot long and 53-foot wide allowing for 3-lanes with one full width and one partial width shoulder for both north and southbound traffic. [(82)]

Route 1&9 in Elizabeth, NJ serves as one of the region's most critical arteries. The project was undertaken to improve safety and congestion, as well improving the local economy by creating new jobs. [82]

The allocation for this construction project was $10.5 million, $36 million and $25.5 million for the fiscal years 2004, 2005 and 2006, respectively. The compounded cost for the year 2008, assuming a 1.6% interest rate is $75.3 million.

The links corresponding to Route 1&9 over the Elizabeth River in the NJRTM-E model were modified in accordance with the widening specifications. The O-D matrix for the transportation network from year 2000 was populated for year 2008 using 1% annual traffic growth. The transportation network was run with the original (existing) and the expanded roadway capacity. The GIS program developed by Ozbay *et al*. [15] was used to calculate the total cost for the original and the modified network. The results are shown in Table 22.

Table 22 - Estimated total daily cost for original and modified networks ($)

Morning Peak							
	Vehicle Operating	**Congestion**	**Accident**	**Air Pollution**	**Noise**	**Maintenance**	**Total**
Original	12,269,130	39,133,860	3,090,104	1,866,980	42,316.2	688,671.8	57,091,062
Modified	12,192,470	37,574,730	3,050,254	1,865,515	42,223.5	731,008.7	55,456,201.2
Benefit	**76,660**	**1,559,130**	**39,850**	**1,465**	**92.7**	**-42,336.9**	**1,634,860.8**
Midday Off-peak							
Original	13,290,220	14,092,140	4,131,657	2,538,840	65,369.86	1,584,298	35,702,524.86
Modified	13,290,210	14,092,130	4,131,658	2,538,837	65,369.91	1,584,270	35,702,474.91
Benefit	**10.0**	**10.0**	**-1.0**	**3.0**	**-0.05**	**28.0**	**49.95**
Afternoon Peak							
Original	13,737,490	45,214,080	3,422,373	2,054,029	45,853.5	740,909.6	65,214,735.1
Modified	13,707,520	44,685,900	3,408,057	2,052,300	45,816.5	741,074.0	64,640,667.5
Benefit	**29,970**	**528,180**	**14,316**	**1,729**	**37.0**	**-164.4**	**574,067.6**
Night Off-peak							
Original	9,350,579	9,712,229	3,744,627	1,805,579	46,189	2,293,476	26,952,679.0
Modified	9,335,391	9,562,033	3,726,508	1,799,890	45,673.4	2,303,995	26,773,490.4
Benefit	**15,188**	**150,196**	**18,119**	**5,689**	**515.6**	**-10,519**	**179,188.6**
Total Daily Benefit							**$2,388,167**

The estimated congestion costs in Table 22 are based on the lower bound of the VOT ranges given in Table 11. Based on the given in Table 22, the daily benefit of the viaduct reconstruction project was estimated as $2.39 million. The annual benefit of this project can be calculated by multiplying this estimate by 250 workdays, which equals $597.04 million. As with the previous projects, we assume that the estimated benefit will diminish over the years due to expected traffic increase. Assuming that the benefit will linearly decrease to zero at the end of 25 years, the net present value of the total benefits is calculated as $6.36 billion in 2008 dollars, assuming a 2.8% discount rate. Therefore, the benefit-cost ratio of this project is 83.75 ($6,306.23m/$75.3m), and the project is economically efficient.

Route 1 Widening Project

The Route 1 widening project will provide three 12-foot lanes with a 3-foot inside shoulder and a 12-foot outside shoulder, or 13-foot auxiliary lane in each direction. Entrance and exit ramps will be added at Pierson Avenue, Grandview Avenue, Parsonage Road and Ford Avenue to aid in the smoothing of traffic. The bridge over Amboy Avenue will be replaced and the exiting ramps will be upgraded. The bridge over the Conrail South Amboy line will be replaced. (82)

The allocated funds for this project were compounded for 2008 by using a 1.6% interest rate, and equal $61.1 million. (82)

The links corresponding to the nearly 3-mile construction on Route 1 in the NJRTM-E model were modified in accordance with the widening specifications. The O-D matrix for the transportation network from year 2000 was populated for year 2008 using 1% annual traffic growth. The transportation network was run with the original (existing) and the expanded roadway capacity. The GIS program developed by Ozbay *et al.* (15) was used to calculate the total cost for the original and the modified network. The results are shown in Table 23.

Table 23 - Estimated total daily cost of original and modified networks ($)

Morning Peak							
	Vehicle Operating	**Congestion**	**Accident**	**Air Pollution**	**Noise**	**Maintenance**	**Total**
Original	12,269,130	39,133,860	3,090,104	1,866,980	42,316.23	688,671.8	57,091,062.03
Modified	12,192,460	37,634,050	3,048,894	1,865,091	42,197.50	731,246.3	55,513,938.80
Benefit	**76,670**	**1,499,810**	**41,210**	**1,889**	**118.73**	**-42,574.5**	**1,577,123.23**
Midday Off-peak							
Original	13,290,220	14,092,140	4,131,657	2,538,840	65,369.86	1,584,298	35,702,524.86
Modified	13,290,090	14,092,020	4,131,995	2,538,691	65,363.08	1,584,134	35,702,293.08
Benefit	**130.0**	**120.0**	**-338.0**	**149.0**	**6.78**	**164.0**	**231.78**
Afternoon Peak							
Original	13,737,490	45,214,080	3,422,373	2,054,029	45,853.54	740,909.6	65,214,735.14
Modified	13,737,660	45,209,970	3,419,410	2,054,795	45,891.86	740,106.3	65,207,833.16
Benefit	**-170.0**	**4,110**	**2,963**	**-766.0**	**-38.32**	**803.3**	**6,901.98**
Night Off-peak							
Original	9,350,579	9,712,229	3,744,627	1,805,579	46,189.01	2,293,476	26,952,679.01
Modified	9,335,402	9,561,970	3,726,421	1,799,884	45,673.55	2,303,973	26,773,323.55
Benefit	**15,177**	**150,259**	**18,206**	**5,695**	**515.46**	**-10,497**	**179,355.46**
Total Daily Benefit							**$1,763,612.45**

As mentioned earlier, the congestion costs given in Table 23 are estimated based on the lower bound of the VOT assumption in Table 11. The daily benefit of the Route 1 widening project was estimated at $1.76 million. The annual benefits of this project can be calculated by multiplying this estimate by 250 workdays, and equal $440.90 million. Again assuming that the estimated benefit will diminish over the years due to expected traffic increase and that the benefit will linearly decrease to zero at the end of 25 years, the net present value of the total benefits is calculated as $4.65 billion in 2008 dollars, assuming a 2.8% discount rate. Therefore, the benefit cost ratio of this project is 76.21 ($4,657.0m/$61.1m), and the project is economically efficient based on our assumptions.

Sensitivity Analysis

In this section we investigate the variation in the benefit-cost ratio of the selected project with respect to our assumptions in calculating benefits. The variables that are subject to the sensitivity analysis are the value-of-time (VOT) and the level of capacity increase.

The VOT ranges for passenger cars and trucks during peak and off-peak hours are shown in Table 11. The benefit-cost ratios for each project presented in the previous section were based on the low VOT range.

The increase in capacity due to each project was reflected in the NJRTM-E CUBE model by multiplying the base capacity by a factor that is estimated based on the project specifications such as the increase in number of lanes and addition of shoulders. The benefit cost ratios presented in the previous section were based on these assumptions of capacity increase (high capacity results). For sensitivity analysis, we investigate the variation in benefit cost ratios assuming a lower increase in capacity than initially assumed. Therefore, the factors that were used to increase capacity for each project were lowered in half in the CUBE model, and new results were obtained accordingly (low capacity). For example, if the base capacity is 3,000 veh/hr, and our initial assumption of the new capacity is 4,000 veh/hr, then the lower bound of capacity is assumed as 3,500 veh/hr in the sensitivity analysis.

The benefit-cost ratio of each project based on various ranges of VOT and the level of capacity are presented in Table 24. It should be noted that the benefits are converted to 2008 dollars using the discount rates shown in Table 9.

Table 24 – Benefit-cost ratios of sensitivity analyses

	High Capacity		**Low Capacity**	
	Low VOT	*High VOT*	*Low VOT*	*High VOT*
Route 17	35.8	52.3	35.4	51.9
Route 18	1.68	2.60	22.0	32.3
Route 35	28.8	42.2	38.9	56.9
Route 1&9	1.20	1.73	1.75	2.66
Route 1	65.9	96.6	39.3	57.8

It can be seen from the results presented in the previous section that the majority of the benefits are due to reduction in congestion costs. Therefore, the VOT assumption significantly affects the benefit-cost ratios shown in Table 24. Except for the Route 18 and Route 1&9 projects (which still remain economically efficient), the results of our analyses show high benefit-cost ratios.

Summary and Conclusions

The purpose of this chapter is to present the analysis of the ongoing benefits of investments due to the improvements of transportation infrastructure. Identifying the benefits of roadway expansion projects is difficult due to the complexity of highway transportation networks.

A careful analysis of the effects of any highway infrastructure improvement requires the investigation of several key issues.

First, the estimation of how a specific roadway expansion project affects the traffic patterns throughout the network has to be investigated. Predicting the network impacts of such projects is a difficult task. A capacity expansion project can improve the travel conditions on a specific roadway, but its effects on the travel patterns of the rest of the network is not often easily predictable without using a complete transportation network model. Therefore, in our analyses the North Jersey Regional Transportation Model (NJRTM-E) was used to estimate the traffic flow changes that are expected to occur on both local and network levels as a result of capacity improvements. NJRTM-E is currently used by the North Jersey Transportation Planning Authority (NJTPA). Detailed information about the NJRTM-E is presented in the Methodology section.

Second, benefits of capacity expansion projects are not solely due to reduced travel times, but also due to reduced accident costs, vehicle operating, maintenance and environmental costs (e.g. noise and air pollution). In our analyses, reductions in each cost category attributable to each project were estimated using data obtained from NJDOT and other state and national sources. The parameters of the cost functions were modified to reflect NJ-specific conditions. The individual cost functions are discussed in Cost Functions section of this Chapter.

Cost-benefit analyses are performed for five past highway projects in New Jersey using a comprehensive evaluation framework that measures the impact of these projects. Each selected project as shown in Table 17 involves capacity improvements. For each selected past highway capital improvement project, the capacity improvement is incorporated in the NJRTM-E CUBE model by increasing the capacity of the link where the project took place.

The NJRTM-E network is run *with and without the capacity improvements*, and the network-wide traffic flows are obtained from CUBE. The results obtained from the CUBE runs are compiled and analyzed using the NJCOST tool customized for this project. Using the before and after results, the benefits of each project are estimated as reductions in various cost categories, such as congestion, vehicle operating, accident, air pollution, noise and maintenance costs. Accordingly, the proposed methodology combines sound economic theory with the output of a highly detailed transportation demand model for estimating the costs and benefits of selected highway projects.

The impacts of each capacity investment are investigated separately, i.e. five different modified networks are created for the five different capacity investments.

It should be noted that the year 2000 is the base year for the current NJRTM-E. We investigate the impact of each project for 2008. Therefore, the traffic demand of 2000 is updated for 2008 using one percent annual traffic growth rate. It is clear that the traffic demand growth is rarely uniform for all origin-destination pairs. Some origin-destination pairs are expected to increase at a higher rate than others. Also, one could argue that within eight years there have been numerous other projects that have been completed within the network that could have changed the traffic patterns. However, incorporating all these changes within the network is out of the scope of this project. Our results presented in the previous section do not include these capacity changes due to other projects. However, NJRTM-E model is the most up-to date network model for the study area and it was released in 2008 [(65)]. Thus, it contains the best information that is available about network and demand conditions for the study area.

Benefit cost ratio of each selected project is presented in the Case Studies section. Sensitivity analyses are also conducted with respect to two variables, namely capacity increase and value-of-time. The results show that with three projects show high benefit cost ratios; whereas the other two projects show moderate benefit-cost ratios. The results presented in Tables 19 through 23 indicate that the majority of benefits accrue through reduced travel times. Therefore, the benefits vary with high margins with respect to value-of-time assumptions. Table 24 presents a summary of all benefit-cost ratios for different scenarios. As seen from these results, network-wide benefits are not always easily predictable. They tend to change for different scenarios. Thus, more research is needed to better explain the reasons behind these changes in terms of network-wide benefits. Also, more research is needed to conduct the same analyses for different geographical scopes with respect to the actual location of the studied project. Finally, trip based benefit estimations should be performed. However, for a large network, this task becomes computationally very expensive if all the OD pairs have to be considered. On the other hand, average costs can be estimated using a sample of OD pairs. The relationship between these methods in terms of accuracy of the estimates is also an important topic for further research.

CHAPTER V: NJ COST SOFTWARE TOOL

This chapter describes NJCost, a GIS-based Full Cost Estimation tool that can, among its other capabilities, be used to estimate the *recurring annual benefits* of transportation projects. The chapter also provides easily accessible instructions on how to use this tool and describes the powerful additional outputs of NJCost now available to NJDOT.

NJCost has been developed to estimate the reductions in various costs of highway transportation in (north) New Jersey due to capacity enhancements from individual transportation projects. It is the complement to the Transportation Investment Impact Estimator (TIIE) presented in Chapter II which can be used to estimate the *one-time economic and fiscal impacts* of transportation investments. A key strength of NJCost is that it uses cost reduction models specific to New Jersey.

The chapter is organized as follows. Section I provides an overview of the NJCost tool, its capabilities, and its advantages. Section II describes user options within the capacities of the NJCost tool. Section III discusses the linkage of the NJCost tool to the NJTRME model and its output. Section IV provides a brief conclusion. A series of appendices provide the detailed installation and user instructions and output options for NJCost.

Section I: Overview

The NJCost tool employs ArcGIS in the Visual Basic .NET environment. The costs of a trip between a selected Origin-Destination (O-D) pair is calculated using the constrained k-shortest path algorithm that uses C programming language. In the developed GIS-based NJCost tool, the origin and/or destination of a trip can be any of the following options:

a. Single node.
b. User-defined set of nodes within Traffic Analysis Zones (TAZ) or one TAZ for each origin and destination.
c. County-to-County selection, i.e. user-defined set of nodes within each county (one county for each origin and destination).
d. Intra-County selection i.e. user-defined set of nodes within a county (same county for the origin and destination).
e. Network-wide selection - user-defined set of nodes within the whole network at hand.

Accordingly, the NJCost tool has the following advantages:

1. With the full cost estimation on traffic analysis zone (TAZ) level and county level, users can observe the changes in trip-based costs among different O-D pairs in a given area. Moreover, the network-wide selection helps users to observe the distribution of trip-based full cost throughout the entire highway network.

2. The NJCost tool not only estimates the differences in full cost between selected O-D pairs, but can also compare two different networks, and estimate the short-term impacts of network changes (e.g., lane and/or link additions, etc.) on trip costs.

Figure 9 shows the flowchart of the GIS-based Multiple-path full cost estimation tool. In the first step, the user is prompted to select whether s/he wants to estimate the full cost between two O-D locations, or to observe the short-term impacts of network changes on the full cost of different trips. Then, the user selects the origin and destination of the trip for which s/he wants to calculate the full trip cost.

If the user wants to analyze a specific O-D pair, the following steps are taken:

1. The user manually selects the origin node and the destination node from the network.
2. C-program finds all feasible paths between that particular O-D pair.
3. For each path found, the total, marginal and average costs are calculated, and stored to a folder.
4. Estimated costs and their weighted average for each O-D pair are displayed in a tabular format.

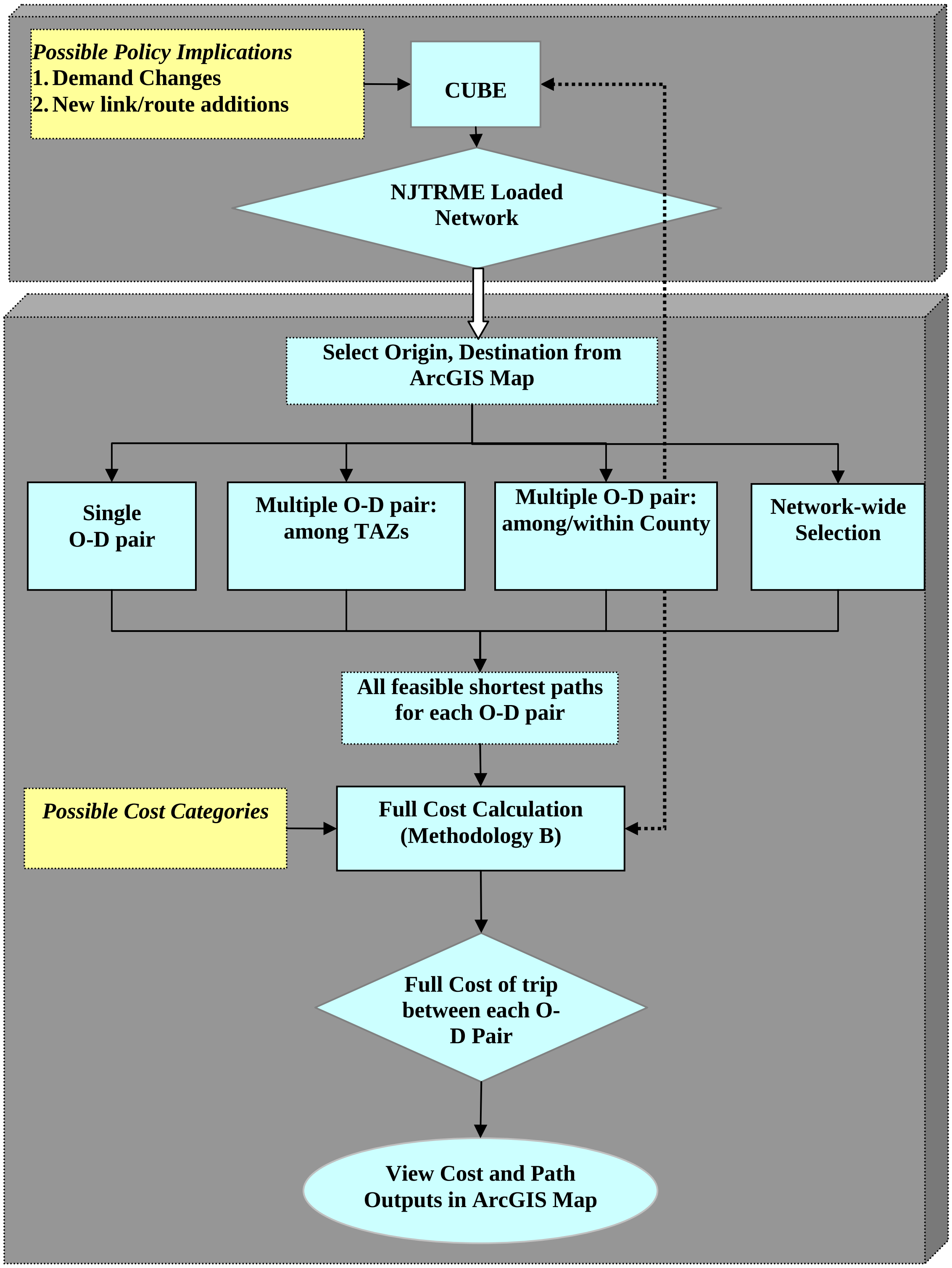

Figure 9. Flow chart for the Calculations of Full Cost of Transportation

Section II: User Options

The available user options for multiple O-D pair analysis are:

- TAZ-to-TAZ analysis: The user manually selects two different TAZs for origin and destination locations. The program automatically saves the whole origin and destination nodes located within the selected TAZs.
- County-to-county analysis: The user can select two different counties for origin and destination locations from the dropdown list. The program automatically saves the whole origin and destination nodes located within the selected counties.
- Intra-county analysis: The user can select only one county for both origin and destination locations from the dropdown list. The program automatically saves the whole origin and destination nodes located within the selected county.

For network-wide selection, the user does not need to specify any O-D location. Instead, the program automatically saves the whole origin and destination nodes located within the entire network. After specifying the type of the multiple O-D pair selection, the following steps are conducted:

1. The user is prompted to specify the number of O-D pairs to be analyzed.
2. Then, the C-program randomly samples the user-defined number of O-D pairs between the selected TAZs, counties, or the network.
3. For each O-D pair, all the feasible paths are calculated in the C-Program, and the weighted average of the total, marginal and average of each cost category are calculated.
4. After the calculations are completed for each O-D pair, the sampled O-D pair ID numbers, and corresponding cost values are displayed in a tabular format in the .NET environment on the ArcView map of the network.
5. By selecting the row of a path in the cost output form, the shortest path of that particular O-D pair is highlighted on the map.

If the user does not wish to conduct any comparison analysis, the tool is ready to rerun the estimation process for *different O-D pairs* after displaying the full cost values for the selected O-D pair. However, if the user wishes to compare two different networks (e.g., a before and after scenario), then after displaying the results for the first network, the user specifies the second network. Then, the C-program reruns for this new modified network, and displays the full cost values for the same set of O-D pairs. Finally, in another output table, *the changes* in the full cost values of each O-D pair are displayed. The ability to examine changes (or differences) in cost outcomes across alternative network capabilities is one key capability provided by the tool. The details of the installation and operation of the software are provided in Appendix V.

Section III Linkage of NJCOST to NJTRME

The developed GIS-based full cost estimation tool enables planners to efficiently identify areas of interest, to observe the short-term impacts of network changes, and to visualize results on the study network by taking advantage of powerful graphical capabilities of ArcGIS combined with the algorithm developed in this study for NJDOT.

The *input* for the NJCost tool is the output of the NJTRME. This output is generated by the four-step planning process performed in either TP+/VIPER or alternately CUBE. Once highway assignment is completed in NJTRME, four time-period specific database files are produced. These four files are the data files that are connected to the geographic files in CUBE to produce loaded networks for analysis. Each one of these files contains predicted values for traffic on all the links of the network. They also include basic information about all the links carried over from the input networks that enable sorting and filtration based on their characteristics; for example, a sort can be conducted by all links within a certain state or county, or by all highway links. The databases in use for the O-D trip analysis are shown in Table 25.

Table 25 - Database created from NJTRME Output used in NJCOST Analysis

Field Name	Description
ID	Link ID
A	Node ID of starting node
B	Node ID of ending node
LENGTH	Link Length
COUNTY	County Index
LANESAM	Lanes for AM period
LANESPM	Lanes for PM period
LANESOP	Lanes for off-peak period
CAPACITY	Capacity of the link
T_0	Freeflow travel time
TIME_1	Congested travel time
SPEED	Congested Speed
V_1	Congested Volume
AT	Area Type for the link
FT	Road Type for the link

The calculation of travel times, full costs, and travel paths can be performed for manually selected O-D zones. This is facilitated by the built-in “Select Features” tool in NJCost. The O-D zones selection can be performed for zones located within a county by selecting the county from a drop-down list. The same process can be performed for trips between origin and destination zones located within different counties or on a network-wide level.

For the intra-county, county-to-county and network-wide analysis options, since the number of possible origin and destination pairs is very huge, it is possible – albeit through a time-consuming process – to perform the calculation for all the pairs. Hence, the user is prompted to enter a sample size for the number of O-D pairs for which the analysis is intended to be performed. The O-D pairs are randomly chosen from the complete set of possible O-D pairs.

In addition to the three functionalities described above, the output of visualization and analysis can be saved and stored in the form of Microsoft Excel worksheets. The set of operations performed each time can be stored in a session and the user can selectively save the output from those operations that are deemed appropriate for subsequent analysis.

Section IV. Conclusion

NJCOST provides powerful capabilities to NJDOT to analyze policy changes and/or highway investment projects that alter transportation capacities. These capacity increases result in traffic changes as measured by the NJTRME model. NJCOST then takes these traffic flow changes and estimates the benefits (i.e., the reductions in costs) that are attributable to the capacity improvements. Estimates of these cost reductions are derived from specific New Jersey relationships as described previously in Chapter IV. These benefits occur annually over the life of the project and consist of all the components presented in the benefit-cost applications of the previous chapter. Thus, with NJCOST, the NJDOT has the capability to estimate the recurring benefits of highway investments, to observe the short-term impacts of network changes, and to visualize results on the network affected by the investment. The appendices to this chapter provide detailed instructions and illustrations of how to use NJCOST.

CHAPTER VI: MEASURING THE RELIANCE OF NEW JERSEY INDUSTRIES ON TRANSPORTATION SERVICES

New Jersey's location has provided an enormous and sustained competitive advantage for its businesses since Colonial times. While the nature of the state's economy has shifted dramatically across the centuries – from agriculture to manufacturing to services, the state's central location in an ever expanding, ever more densely populated, and high income and high wealth market has been a cornerstone of the prosperity of its economy. Throughout New Jersey's history this advantage of location has been best leveraged into economic success by the presence of a complementary efficient and effective transportation system.[1] Thus, transportation has been a key requirement for sustaining the on-going competitive operation of New Jersey's businesses.

Accordingly, this chapter uses input-output analysis to provide comprehensive measures of the importance of transportation as an *input* to the current profile of New Jersey's industries. The analysis begins by measuring the *transportation intensity* of each industry in New Jersey. Transportation intensity is defined as the share of transportation industry purchases (in dollars) of each industry's total output. Thus, transportation intensity is an indication of the degree to which each industry is reliant on the services provided by the transportation sector.

Using national input-output tables, we measure the percentage of each industry's output that is spent on services from the transportation industry. Table 26 ranks sixty industries according to their transportation intensity. Table 26 also indicates each industry's amount and share of New Jersey's gross domestic product (GDP) and its total employment in 2005. These later two measures reflect both the absolute and relative importance of each industry in the state's overall economy.

[1] See "A Transportation-Driven World-Class Economy: New Jersey at Risk" J.W. Hughes and J.J. Seneca. *Rutgers Regional Report*, No. 23, April, 2005.

If the public sector (i.e., federal government) and the transportation industries themselves (e.g. water, truck, air, and rail) are excluded, the top 15 transportation-intensive private-sector industries account for almost 27% of transportation services purchased in New Jersey.[2] These industries also generate over 10% of the state's GDP and employ nearly 278,000 people, or 5.5% of the state's total employment.

Thus, key New Jersey industries are highly reliant on the transportation sector and are responsible for significant contributions to the state economy. As such, transportation infrastructure investments which reduce (or lower the increase of) transportation costs (e.g., investments which lower travel times, result in lower vehicle maintenance, and lower other business costs) will generate substantial benefits throughout the New Jersey economy. This is because some of New Jersey's largest business sectors are highly transportation intensive in their operations.

Table 27 ranks the same industries by their *total transportation service purchases* in New Jersey. This ranking identifies the industries that are the largest buyers (in absolute dollar amount) of transportation services in the state. Because of the sheer volume of their use of transportation services, these industries would likely be the greatest *absolute* beneficiaries of any reductions, or lower rates of cost increases, in transportation services. Together, the top eight industries accounted for over 50% of transportation industry purchases in New Jersey and for nearly 35% of the state's GDP and almost 33% of the state's employment in 2005.

The top seven non-transportation private-sector industries[3] – chemical products; professional scientific and technical services; wholesale trade; construction; food,

[2] The top 15 industries (exclusive of the transportation industries and public sector) consist of those in block outline in Table 26.
[3] That is, excluding the Truck and Water transportation industries in Table 27.

beverage and tobacco manufacturing, and retail trade – comprise 39% of private sector transportation expenditures, 40.3% of private sector GDP, and 42.8% of private sector employment in New Jersey.

Finally, the relative and absolute measures reported in Tables 26 and 27 examine business reliance on transportation services in order to conduct their operations. They do not reflect, of course, the additional critical dependence of businesses being able to have their workforce reliably, efficiently, and safely get to and from work each day, a topic we examine in the following chapter.

Table 26 - National Transportation Intensity and New Jersey Transportation Expenditures, GDP and Employment by Sector Ranked by Transportation Intensity

			NJ Expenditures		NJ GDP		NJ Employment	
Rank	Sector	Intensity	Amount	Share	Amount	Share	Amount	Share
1	Water transportation	20.4	431	3.4	525	0.1	2,809	0.1
2	Truck transportation	18.3	1,445	11.3	3,766	0.9	56,629	1.1
3	**Primary metals**	**9.5**	**248**	**1.9**	**1,057**	**0.2**	**7,255**	**0.1**
4	**Nonmetallic mineral products**	**8.8**	**307**	**2.4**	**1,553**	**0.4**	**14,466**	**0.3**
5	Air transportation	8.7	336	2.6	1,351	0.3	16,419	0.3
6	Rail transportation	7.8	28	0.2	147	0.0	1,282	0.0
7	Transit and ground passenger transportation	5.5	110	0.9	1,108	0.3	39,245	0.8
8	**Paper products**	**5.4**	**263**	**2.0**	**1,265**	**0.3**	**14,577**	**0.3**
9	**Mining, except oil and gas**	**5.3**	**22**	**0.2**	**236**	**0.1**	**1,730**	**0.0**
10	Other transportation and support activities	5.2	286	2.2	4,039	0.9	54,092	1.1
11	**Wood products**	**3.8**	**39**	**0.3**	**339**	**0.1**	**5,815**	**0.1**
12	**Textile mills and textile product mills**	**3.3**	**65**	**0.5**	**614**	**0.1**	**8,416**	**0.2**
13	Federal government	3.2	379	3.0	7384	1.7	86,421	1.7
14	**Rental and leasing services and lessors of intangible assets**	**3.0**	**242**	**1.9**	**5,640**	**1.3**	**21,642**	**0.4**
15	**Plastics and rubber products**	**2.8**	**150**	**1.2**	**1,651**	**0.4**	**21,087**	**0.4**
16	**Food and beverage and tobacco products**	**2.7**	**438**	**3.4**	**3,541**	**0.8**	**34,384**	**0.7**
17	**Printing and related support activities**	**2.6**	**115**	**0.9**	**2,005**	**0.5**	**25,414**	**0.5**
18	**Chemical products**	**2.4**	**1,409**	**11.0**	**14,792**	**3.5**	**71,558**	**1.4**
19	**Waste management and remediation services**	**2.1**	**51**	**0.4**	**1,157**	**0.3**	**11,756**	**0.2**
20	**Furniture and related products**	**2.1**	**29**	**0.2**	**582**	**0.1**	**8,123**	**0.2**
21	**Utilities**	**2.1**	**294**	**2.3**	**8,432**	**2.0**	**14,536**	**0.3**
22	**Farms**	**2.0**	**48**	**0.4**	**494**	**0.1**	**17,111**	**0.3**
23	Information and data processing services	1.7	79	0.6	2,303	0.5	19,973	0.4
24	Apparel and leather and allied products	1.6	26	0.2	694	0.2	9,406	0.2
25	Miscellaneous manufacturing	1.6	107	0.8	2,503	0.6	23,875	0.5
26	Fabricated metal products	1.6	84	0.7	2,425	0.6	28,266	0.6
27	Support activities for mining	1.6	1	0.0	8	0.0	175	0.0
28	Construction	1.6	500	3.9	18,164	4.2	256,115	5.1
29	Hospitals and nursing and residential care facilities	1.5	319	2.5	11,804	2.8	223,899	4.5
30	Food services and drinking places	1.4	174	1.4	6,006	1.4	229,374	4.6
31	Professional, scientific and technical services	1.4	846	6.6	35,861	8.4	411,803	8.2
32	Machinery	1.4	65	0.5	1,489	0.3	17,825	0.4
33	Administrative and support services	1.4	282	2.2	12,566	2.9	301,361	6.0
34	Motor vehicles, bodies and trailers, and parts, and other	1.4	28	0.2	467	0.1	7,374	0.1

Rank	Sector	Intensity	Expenditures Amount	Expenditures Share	NJ GDP Amount	NJ GDP Share	NJ Employment Amount	NJ Employment Share
35	Wholesale trade	1.3	598	4.7	35,452	8.3	255,080	5.1
36	Electrical equipment, appliances, and components	1.3	27	0.2	789	0.2	8,308	0.2
37	Securities, commodity contracts, and investments	1.2	185	1.4	8,793	2.1	100,784	2.0
38	State and local government	1.3	804	6.3	36,791	8.6	569,576	11.3
39	Other services, except government	1.1	201	1.6	8,753	2.0	254,799	5.1
40	Publishing industries (includes software)	1.1	106	0.8	6,057	1.4	35,998	0.7
41	Accommodation	1.1	102	0.8	4,564	1.1	74,070	1.5
42	Retail trade	1.0	427	3.3	27,577	6.4	554,105	11.0
43	Federal Reserve banks, credit intermediation, and related	1.0	220	1.7	14,376	3.4	86,470	1.7
44	Educational services	1.0	59	0.5	3,771	0.9	108,479	2.2
45	Social assistance	0.9	39	0.3	2,478	0.6	95,797	1.9
46	Warehousing and storage	0.9	21	0.2	1,612	0.4	26,620	0.5
47	Petroleum and coal products	0.8	94	0.7	1,253	0.3	3,631	0.1
48	Computer and electronic products	0.8	68	0.5	1,900	0.4	31,506	0.6
49	Motion picture and sound recording industries	0.7	8	0.1	482	0.1	9,319	0.2
50	Ambulatory health care services	0.7	167	1.3	16,051	3.8	214,114	4.3
51	Forestry, fishing, and related activities	0.7	2	0.0	152	0.0	6,464	0.1
52	Amusements, gambling, and recreation industries	0.7	19	0.1	2,337	0.5	50,652	1.0
53	Broadcasting and telecommunications	0.6	151	1.2	11,398	2.7	48,297	1.0
54	Pipeline transportation	0.6	1	0.0	53	0.0	328	0.0
55	Performing arts, spectator sports, museums, and related	0.5	9	0.1	1,337	0.3	45,510	0.9
56	Funds, trusts, and other financial vehicles	0.4	8	0.1	551	0.1	9,709	0.2
57	Insurance carriers and related activities	0.3	87	0.7	10,643	2.5	93,401	1.9
58	Oil and gas extraction	0.3	0	0.0	18	0.0	1,101	0.0
59	Real estate	0.3	174	1.4	64,982	15.2	207,383	4.1
60	Management of companies and enterprises	0.1	19	0.1	9,515	2.2	69,600	1.4
	Total		**12,842**	**100.0**	**427,653**	**100.0**	**5,025,314**	**100.0**
State and local government		1.3	804	6.3	36,791	8.6	569,576	11.3

Table 27 - New Jersey Transportation Expenditures, GDP and Employment by Industry

Ran k	Name	Trans. ($ millions	Cum. Shar	GDP, 2005 ($ millions	Cum. Share	Employment, Jobs	Cum. Shar
1	Truck transportation	1,445	23.5	3,766	9.5	56,629	12.5
2	Chemical products	1,409	33.7	14,792	12.9	71,558	13.9
3	Professional, scientific and	846	39.8	35,861	21.3	411,803	22.1
4	State and local government	804	6.3	36,791	8.6	569,576	11.3
5	Wholesale trade	598	44.1	35,452	29.6	255,080	27.2
6	Construction	500	47.7	18,164	33.9	256,115	32.3
7	Food and beverage and tobacco	438	50.9	3,541	34.7	34,384	32.9
8	Water transportation	431	54.0	525	34.8	2,809	33.0
9	Retail trade	427	57.1	27,577	41.3	554,105	44.0
10	Federal government	379	59.8	7384	43.0	86,421	45.7
11	Air transportation	336	62.2	1,351	43.3	16,419	46.1
12	Hospitals and nursing and	319	64.5	11,804	46.1	223,899	50.5
13	Nonmetallic mineral products	307	66.7	1,553	46.4	14,466	50.8
14	Utilities	294	68.9	8,432	48.4	14,536	51.1
15	Other transportation and support	286	70.9	4,039	49.3	54,092	52.2
16	Administrative and support	282	73.0	12,566	52.3	301,361	58.2
17	Paper products	263	74.9	1,265	52.6	14,577	58.5
18	Primary metals	248	76.7	1,057	52.8	7,255	58.6
19	Rental and leasing services and	242	78.4	5,640	54.1	21,642	59.0
20	Federal Reserve banks, credit	220	80.0	14,376	57.5	86,470	60.8
21	Other services, except government	201	81.5	8,753	59.6	254,799	65.8
22	Securities, commodity contracts,	185	82.8	8,793	61.6	100,784	67.8
23	Food services and drinking places	174	84.0	6,006	63.0	229,374	72.4
24	Real estate	174	85.3	64,982	78.2	207,383	76.5
25	Ambulatory health care services	167	86.5	16,051	82.0	214,114	80.8
26	Broadcasting and	151	87.6	11,398	84.6	48,297	81.7
27	Plastics and rubber products	150	88.7	1,651	85.0	21,087	82.2
28	Printing and related support	115	89.5	2,005	85.5	25,414	82.7
29	Transit and ground passenger	110	90.3	1,108	85.7	39,245	83.5
30	Miscellaneous manufacturing	107	91.1	2,503	86.3	23,875	83.9
31	Publishing industries (includes	106	91.8	6,057	87.7	35,998	84.6
32	Accommodation	102	92.6	4,564	88.8	74,070	86.1
33	Petroleum and coal products	94	93.3	1,253	89.1	3,631	86.2
34	Insurance carriers and related	87	93.9	10,643	91.6	93,401	88.0
35	Fabricated metal products	84	94.5	2,425	92.2	28,266	88.6
36	Information and data processing	79	95.1	2,303	92.7	19,973	89.0
37	Computer and electronic products	68	95.6	1,900	93.1	31,506	89.6
38	Textile mills and textile product	65	96.0	614	93.3	8,416	89.8
39	Machinery	65	96.5	1,489	93.6	17,825	90.2
40	Educational services	59	96.9	3,771	94.5	108,479	92.3
41	Waste management and	51	97.3	1,157	94.8	11,756	92.5
42	Farms	48	97.6	494	94.9	17,111	92.9
43	Social assistance	39	97.9	2,478	95.5	95,797	94.8
44	Wood products	39	98.2	339	95.6	5,815	94.9
45	Furniture and related products	29	98.4	582	95.7	8,123	95.1
46	Rail transportation	28	98.6	147	95.7	1,282	95.1
47	Motor vehicles, bodies and	28	98.8	467	95.8	7,374	95.2
48	Electrical equipment, appliances,	27	99.0	789	96.0	8,308	95.4
49	Apparel and leather and allied	26	99.2	694	96.2	9,406	95.6
50	Mining, except oil and gas	22	99.4	236	96.2	1,730	95.6
51	Warehousing and storage	21	99.5	1,612	96.6	26,620	96.2
52	Management of companies and	19	99.6	9,515	98.8	69,600	97.5
53	Amusements, gambling, and	19	99.8	2,337	99.4	50,652	98.6
54	Performing arts, spectator sports,	9	99.9	1,337	99.7	45,510	99.5
55	Motion picture and sound	8	99.9	482	99.8	9,319	99.6
56	Funds, trusts, and other financial	8	100.0	551	99.9	9,709	99.8
57	Forestry, fishing, and related	2	100.0	152	100.0	6,464	100.0
58	Pipeline transportation	1	100.0	53	100.0	328	100.0
59	Support activities for mining	1	100.0	8	100.0	175	100.0
60	Oil and gas extraction	0	100.0	18	100.0	1,101	100.0
	Total	**13,848**		**427,653**		**5,025,31**	

Source: U.S. Bureau of Economic Analysis; Rutgers calculations.

CHAPTER VII ECONOMIC IMPACT OF REDUCTIONS IN COMMUTING TIME

This chapter provides an analysis of a major component of the *on-going* benefits of transportation investment, namely the reduction in commuting time that can result from improvements to transportation infrastructure.[1] Congestion costs are ubiquitous throughout the country and periodic studies indicate that New Jersey is significantly and negatively affected by the delays, congestion, and lost work time experienced by motorists.[2] In addition to the time costs that congestion imposes on employees, congestion results in significant costs on businesses in terms of shipment delays, overtime payments, missed deadlines, and disruptions to time sensitive business transactions and flows.

The analysis of this chapter consists of a simulation at the *aggregate state level.* As a result, it provides an assessment of the scale of the potential benefits from a comprehensive transportation investment program sustained over time across the entire state. Alternatively, the one-time and recurring benefits of specific transportation investment projects (at smaller scales of geographic impact) can be estimated via the TIIE and the GIS-based NJCOST programs

The simulation uses the following baseline metrics and assumptions:

1. The average one-way commute by car in New Jersey is 30 minutes.[3]
2. The average employee in New Jersey works 250 days per year.[4]
3. The average hourly wage paid in New Jersey (across all industries) is $27.67.[5]

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[1] Improvements in travel delays can also consist of reductions in the rate of increase in congestion.
[2] The annual Urban Mobility Reports of the Texas Transportation Institute indicate that the NY- Newark, NY-NJ-CT urban area and the Philadelphia, PA-NJ-DE-MD urban area consistently rank among the top 25 urban areas in the nation in terms of travel time delays and congestion.
[3] This estimate is based on the 2000 U.S. Census.
[4] The average employee is assumed to work 50 weeks each year at 5 work days per week with 10 vacation (i.e., non-commuting) days.
[5] This estimate is based on wage and salary income and employment for New Jersey in 2006 (Bureau of Economic Analysis, U.S. Department of Commerce).

4. As a result of systematic and sustained transportation infrastructure improvements, all New Jersey workers experience a 10 minute decrease in commuting time per day (i.e., round-trip commuting time declines by 10 minutes per work day).[6]

The simulation further assumes that there are three possible ways to evaluate (i.e., place a monetary value upon) the economic impacts of the reduction in commuting time.[7] These are given below.

1. A worker would use all the commuting time saved to provide additional work on the job and not receive additional compensation. This has the effect of raising the productivity of the business (i.e., total hours worked increase, but labor costs do not).
2. A worker would use all the commuting time saved to provide additional work on the job and receive additional compensation for the additional time worked. In this case, both the output and the (labor) costs of the business would increase.
3. A worker would use all the time saved for leisure (i.e., non-working purposes). In this case, the opportunity cost of leisure (i.e., valued, for example, by the hourly wage of the worker, or some fraction thereof) would be the entire benefit of the commuting time saved. That is, there would be no direct economic effect on the employer (as occurs in the first two scenarios above).

The R/ECON econometric model of New Jersey is used to simulate the effects on the New Jersey economy of these three scenarios. The model consists of over 300 equations describing the state's economy in terms of 18 business

[6] Such an effect achieved for all workers in New Jersey is of enormous scale (there are over 4 million payroll jobs in New Jersey) and unrealistic in terms of the actual reductions that are likely to be achieved by policy. It is assumed that all workers commute and that the same time savings per worker (10 minutes per day) occurs across all commuting travel modes – rail, bus, and motor vehicle.

[7] Each assumption represents an extreme case in terms of how the additional time saved in commuting will be re-deployed. The actual economic impacts experienced by the economy will be somewhere within these extremes.

sectors, total employment, consumer prices, total personal income, and tax revenues among other variables. The R/ECON econometric model is used regularly to forecast economic conditions in New Jersey and these forecasts are publicly released semi-annually. The model's simulations in this analysis examine the effects of each of the three scenarios described above *relative* to the model's long-run baseline forecast for the New Jersey economy to 2015.[8]

Table 28 summarizes the impact on hours worked, commuting time, and leisure time under the three scenarios relative to the baseline forecast for 2015 (assuming that commuter time savings begin in 2010). Thus, in the baseline estimate (i.e., before the transportation investment), each employee in New Jersey works 1,875 hours and commutes 250 hours per year for a total of 2,125 working and commuting hours per worker per year.

In scenarios one and two, all the time savings (41.7 hours per year per worker) are assumed to be used to work additional hours, and thus work time increases one hour for each hour of reduced travel time.[9] This results in a 2.2 % increase in annual hours worked per worker (41.7 hours) from the baseline of 1,875 hours to 1,916.7 hours for both scenarios 1 and 2, and a decrease in annual commuting time per worker to 208.3 hours, or by 16.7%. In scenario 3, annual commuting time also declines by 41.7 hours, but there is no change in total work time. Instead, all of the 41.7 travel hours saved per worker per year are devoted to additional leisure.

Table 29 provides the estimates of the *economic* impact of the commuting time saved relative to the baseline forecast for 2015. Only the first two scenarios generate additional economic impacts. This is because in each of these situations, there is additional time worked and that additional time results in

[8] Thus, the key point of the analysis is that given the long-run baseline forecast the comparison with each of the three alternative scenarios for the use of the commuting time savings provides an indication of the *change* in the forecast. Thus, even if the baseline forecast changes (as it inevitably will) over time, the simulation isolates the impact of each of the three different time savings scenarios.

[9] The 41.7 hours results from saving ten minutes in travel time per day for 250 work days per year.

increase output. In the third scenario, all of the commuting time saved is devoted to leisure and hence there is no direct impact on economic activity. However, that leisure time has value to the individuals and this value can be expressed in monetary terms. For example, in many studies of the value of time saved, the value of leisure time can be approximated by the hourly wage of a worker. Thus, a savings of 41.7 hours per worker in commuting time per year *if valued at the average hourly wage* of all New Jersey workers ($27.67 in 2006) times the number of workers affected (approximately 4 million) yields an estimate of $4.8 billion per year as the value of the additional leisure time to New Jersey workers.

In scenario 1, Table 29 indicates that the additional output generates an increase in total personal income of $2.4 billion annually in 2015. It also increases employment by 31,400 jobs, lowers the unemployment rate by .5 percentage points, and increases inflation-adjusted GDP by $9.7 billion annually relative to the 2015 baseline. While these increases are relatively small in percentage terms, they are sizeable absolute gains. The economic factors behind these results are that in scenario 1, the increase in output occurs without an accompanying increase in labor costs since workers work more hours but are not compensated in wages for that work. Higher output results in higher business revenues which can be used to expand employment and output further and hence personal income, employment and GDP also rise as the effects the initial increase in output disseminate through the economy.

In scenario 2, the additional hours worked due to the travel time saved is compensated by additional wages paid for that time. Thus, personal income increases more in scenario 2 ($5.4 billion) compared to scenario 1 ($2.4 billion). However, while output increases by the same amount as in scenario 1, labor costs also rise and hence reduce the net resources available to businesses to expand output and employment further relative to what occurs in scenario 1. Hence, many fewer jobs are added (3,700 vs. 31,400) and the increase in GDP is also much less ($743 million vs. $9.7 billion).

In scenario 3 there are no direct economic effects since the commuting time savings are all taken in the form of additional leisure. This leisure, as noted above, if valued at the prevailing hourly wage, implies a total additional value of the leisure time *to the commuting workers* of $4.8 billion per year.[10]

Table 28 - Annual Work Hours, Commuting Hours, and Change in Leisure Time (Percent changes shown in parentheses)

Indicator	**Baseline**	**Scenario 1** **Increased Productivity**	**Scenario 2** **Compensated Work**	**Scenario 3** **All Leisure**
Annual Work Time per Worker (Hours)	1,875	1,916.7 (2.2%)	1,916.7 (2.2%)	1,875 (0%)
Annual Commuting Time per Worker (Hours)	250	208.3 (-16.7%)	208.3 (-16.7%)	208.3 (-16.7%)
Change in Leisure Time per Worker (Hours)	0	0	0	41.7

[10] Note that there are other methods of valuing an hour of commuting time saved that would yield different estimates.

Table 29 - Change in Key Economic Indicators Relative to Baseline Forecast: 2015

(Percent changes shown in parentheses)

Economic Indicator	Baseline	Scenario 1 Increased Productivity	Scenario 2 Compensated Work	Scenario 3 All Leisure
Personal Income ($Billion)[11]	$625.2	$2.4 (0.4%)	$5.4 (0.9%)	-
Employment (Thousands)[12]	4,333.1	31.4 (0.7%)	3.7 (0.1%)	-
Unemployment Rate (Change)[13]	5.3%	- 0.05%	- 0.008%	-
Gross Domestic Product ($Billions, 2000)[14]	$469.4	$9.7 (2.1%)	$.743 (0.2%)	-

[11] "Personal Income" is the income that is received by all persons from all sources. It is calculated as the sum of wage and salary disbursements, supplements to wages and salaries, proprietors' income with inventory valuation and capital consumption adjustments, rental income of persons with capital consumption adjustment, personal dividend income, personal interest income, and personal current transfer receipts, less contributions for government social insurance. (U.S. Bureau of Economic Analysis)

[12] "Employment" refers to non-agricultural payroll jobs located in New Jersey.

[13] "Unemployment Rate" is the number of unemployed people as a percentage of the labor force. (U.S. Bureau of Labor Statistics)

[14] "Gross Domestic Product" is the value added in production by the labor and capital located in the state. GDP is derived as the sum of the gross domestic product originating in all industries in the state. In concept, an industry's GDP, referred to as its "value added", is equivalent to its gross output (sales or receipts and other operating income, commodity taxes, and inventory change) minus its intermediate inputs (consumption of goods and services purchased from other U.S. industries or imported). Thus, GDP for a single state is the state counterpart of the nation's gross domestic product (GDP), BEA's featured measure of U.S. output. (U.S. Bureau of Economic Analysis)

CHAPTER VIII CONCLUSIONS AND RECOMMENDATIONS

When this research contract began in January 2008, the country had just entered what has now turned out to be the most severe economic recession in the post - World War II era. The National Bureau of Economic Research, the official arbiter of the nation's business cycle, has determined that the United States economy fell into recession in December 2007.[1] The recession gathered strength of the course of 2008, starting with the earlier bursting of the housing bubble and then the collapse of the stock market bubble, an ensuing complex and dire financial crisis, enormous employment losses, and a spreading global economic downturn. The federal authorities responded with increasingly aggressive monetary and fiscal policies in an attempt to restore financial market stability and blunt the severity and duration of the downturn.

A centerpiece of that federal response is the massive $787 billion American Recovery and Reinvestment Act enacted by Congress and signed by President Obama in January 2009. One key objective of that Act was to provide large injections of federal spending for transportation and other infrastructure in order to jump start the economy. The goal was an immediate fiscal stimulus to generate employment, income, spending, and fiscal benefits for states and the country as a whole. New Jersey, facing the spreading economic weakness in the autumn of 2007, announced, in advance of the federal initiative, its own economic stimulus program which included significant transportation spending,

Thus, New Jersey Department of Transportation's decision to proceed with an economic impact study of investment in transportation could not have been more prescient, nor more timely. A central output of this research has been the development of a generalized methodology to estimate the immediate, one-time economic impacts of transportation investment based on extensive NJDOT

[1] The NBER waited a full year, until December 2008, to make its determination on the starting date of the recession.

project experience in combination with an analysis using the R/ECON Input-Output Model as described in Chapter II. This methodology has resulted in the Transportation Investment Impact Estimator (TIIE) provided in this report to NJDOT. The Impact Estimator allows NJDOT to estimate the one-time economic benefits of the total expenditures for any given project for 14 project types. It provides economic impact estimates tailored to the scale of the project and to its location within the state. It is a robust and powerful tool that provides the NJDOT with the capacity to generate state economic impact estimates for specific projects, groups of projects, and large system-wide transportation plans. Such estimates are provided in this report, for example, for the existing Ten Year Capital Plan (see Chapter II).

The immediate and justifiable focus, given the severity of the current economic recession, of both the federal and state stimulus policies in transportation is to promptly boost overall economic activity. The resulting impacts are measured by employment, income, gross domestic product, and tax revenues. These impacts, as noted throughout this report, are one-time, or short-run impacts. They persist as long as the expenditures last and they stop with the end of the expenditures.

However, beyond the immediate recession-induced objective of invigorating a moribund economy, the fundamental purpose of transportation infrastructure investment is to enhance the competiveness of the nation and the state and its businesses, provide for the efficient, safe, and reliable movement of people and goods, and improve the quality of life of individuals and families. These are the permanent, on-going goals of infrastructure investment and their achievement over time has resulted in enormous benefits to American society in how we live and how well we live.

Thus, the key criterion for transportation investments is whether a project achieves these objectives – i.e., whether it generates sustained, annual impacts over the life of the investment and whether these impacts, when expressed in terms of money, exceed the costs of the project. This is the efficiency test of economics and it is typically expressed in a cost-benefit analysis. Decisions to allocate scarce resources among alternative possible transportation investments are continually being made. Therefore, it is vital for NJDOT to have the capacity to ask, and answer, the core efficiency question of public economics, namely; Does a specific transportation project promise to return to society more than it costs?

Accordingly, Chapter IV develops a methodology and the accompanying NJCOST tool that permits NJDOT to make an assessment of the on-going benefits of many transportation investment project types. This capacity complements the estimates of the one-time economic impacts provided by the TIIE tool that result from the direct construction expenditures for the project. This additional capacity for the NJDOT has two powerful outcomes.

First, it provides the NJDOT with a rigorous, standardized method to inform its decisions on how scarce resources should be spent across the many potential transportation projects (specifically, among those projects that increase transportation capacity). The ability to rank projects in terms of their monetary benefits versus their costs by evaluating a project’s on-going outcomes can improve the efficacy of the Department’s decisions and increase net public benefits.

The second outcome is that NJDOT will have the ability to provide an economic rationale for transportation investment. For example, in the allocation of federal funds, New Jersey will be able, via an objective and independent methodology, to demonstrate the efficiency of its proposed transportation projects in north New Jersey. While the one-time economic impacts are important, especially in the current deeply constrained economic environment, the rationale for public investments should properly rest on whether these investments are efficient over the course of a project’s life. Therefore, having the ability to determine whether a given project is efficient (i.e., do the anticipated benefits to society exceed the project's costs to society?) and to determine a project's relative rate of return per dollar spent (i.e., its benefit to cost ratio) is a potent tool to justify allocating scarce public resources (state and federal) to transportation investments.

Recommendations

NJDOT should consider, as a general policy, using the TIIE program to estimate the one-time economic impacts of each transportation project initiated in a given year and report the cumulative impacts of all such projects in the annual accountability process of the Department. This will provide the public and the Department with a concise and accessible summary, measured in the common metrics of jobs and dollars, of the immediate economic effects of the Department's investment expenditures.

This analysis should also be periodically done for the Capital Plan as anticipated projects change in number, scope, and location, and as the overall Capital Plan evolves over time.

NJDOT should consider using the NJCOST program, where applicable, to routinely provide an economic rationale for its use of public resources and to support its requests for federal transportation resources.

NJDOT should consider using NJCOST to routinely prioritize and rank potential transportation projects according to their net economic benefit. This information can be an additional and important factor, within the Department's existing decision making protocols, to inform its decision on the allocation of scarce public resources among competing uses.

REFERENCES

1. Proost, S., Van Dender, K. (1998). “Variabilization of Car Taxes and Externalities.” In, *Road Pricing, Traffic Congestion and the Environment*: Issues of Efficiency and Social Feasibility, Button K., Verhoef E. (eds.). Northampton, MA: Edward Elgar Publishing.

2. Puget Sound Regional Council (PRSC), Issue Paper No.1 (2002), “Transportation Pricing Options and Approaches” Internet Source: http://www.prsc.org/projects/pricing.

3. Berechman J., (1993), Public Transit Economics and Deregulation Policy, North-Holland.

4. Button, K. (1998) “Road pricing and the alternatives for controlling road traffic congestion.” In *Road Pricing, Traffic Congestion and the Environment*: Issues of Efficiency and Social Feasibility (K.J. Button and E.T. Verhoef, eds.), pp. 263-284. Northampton, MA: Edward Elgar Publishing.

5. Richardson, H. W., & Bae, C. C. (1998). “The equity impacts of road congestion pricing. InButton K. J., and Verhof E. T. (Eds.), *Road Pricing, Traffic Congestion and the Environmen*t: Issues of Efficiency and Social Feasibility. Northampton, MA: Edward Elgar Publishing. pp. 39-78.

6. Jones, P. (1998). “Urban road pricing: public acceptability and barriers to implementation.” In Road Pricing, Traffic Congestion and the Environment: Issues of Efficiency and Social Feasibility (K.J. Button and E.T. Verhoef, eds.), pp. 263-284. Northampton, MA: Edward Elgar Publishing.

7. Banister, D. and Berechman, J. (2000) “Transport Investment and Economic Development” University College London Press.

8. Ozbay, K., Ertekin D., and Berechman, J. “Empirical Analysis of the Relationship Between Accessibility and Economic Development,” Forthcoming in the ASCE Journal of Urban Planning and Development, June, 2003.

9. Small, K. (1999). “Project Evaluation,” in *Transportation Policy and Economics*, Brookings. Available at www.uctc.net/papers/379.pdf.

10. U.S. Office of Management and Budget (2008). "Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs". Circular No: A-94. Appendix C.

11. Ozbay, K., Bartin, B. O., Berechman, J. (2000). *Full Costs of Highway Transportation in New Jersey*, New Jersey Department of Transportation Project Report.

12. Mayeres I., Ochelen, S. and Proost, S., 1996. The Marginal External Costs of Urban Transport. *Transportation Research D*, Vol. 1, No. 2, pp.111-130.

13. Ozbay, K., Bartin, B. and Berechman, J. (2001). "Estimation and Evaluation of Full Marginal Costs of Highway Transportation in New Jersey", Journal of Transportation and Statistics, Vol. 4, No.1, April 2001. (With Ozbay, K. and Berechman, J.)

14. Ozbay, K., Bartin, B., Yanmaz-Tuzel, O., Berechman, J. (2008) "Alternative Methods for Estimating Full Marginal Costs of Highway Transportation", Transportation Research A, Vol. 41, pp. 768-786.

15. Ozbay, K., Yanmaz-Tuzel O., Mudigonda S., Bartin B., and Berechman J. Cost of Transporting People in New Jersey-Phase II. *New Jersey Department of Transportation Final Report*, Report No FHWA/NJ-2007-003, 2007.

16. Federal Highway Administration (FHWA). *Motor Vehicle Accident Costs*, 2005, Available online at http://www.fhwa.dot.gov/legsregs/directives/techadvs/t75702

17. Nelson, J. P., May 1982. Highway Noise and Property Values: A Survey of Recent Evidence. *Journal of Transport Economics and Policy*, pp. 117-138.

18. American Automobile Association, Your Driving Costs 2003, American Automobile Association (www.ouraaa .com), 2003. Based on Runzheimer International data.

19. US Department of Transportation. Cost of Owning and Operating Automobiles, Vans and Light Trucks, 1999.

20. Kelly Blue Book Website, 2006. Available online at http://www.kbb.com/.

21. Mun, Se-IL. Traffic Jams and Congestion Tolls. *Transportation Research B*, Vol. 28, 1994, pp. 365-375.

22. Small K., and X. Chu. Hypercongestion. *Journal of Transport Economics and Policy*, Vol. 37, 2003, pp. 319-352.

23. Federal Highway Administration (FHWA). *Motor Vehicle Accident Costs*, 2005, Available online at http://www.fhwa.dot.gov/legsregs/directives/techadvs/t75702

24. US Department of Transportation. *Crash Records*, 2005, Available online at http://www. state.nj.us/transportation/refdata/accident/rawdata01-03.shtm

25. Environmental Protection Agency Publications. *National Emission Trends*. 1995.

26. Delucchi, M., and S. Hsu. The External Damage Cost of Noise Emitted from Motor Vehicles. *Journal of Transportation and Statistics*, Vol. 1, 1998, pp. 1-24.

27. Aschauer, A.D. (1989). "Is public expenditure productive?" *Journal of Monetary Economics*. 23(2), pp. 177-200.

28. Munnell, A.H. (1990). "How does public infrastructure affect regional economic performance?" *New England Economic Review*. Sept.-Oct, pp. 11-32.

29. Garcia-Milla, T. and McGuire, T.J. (1992). "The contribution of publicly provided inputs to States' economies." *Regional Science and Urban Economics*. Vol. 22, pp. 229-241.

30. Waters, W.G.II. (2004). "Empirical studies of infrastructure investment and economic activity: evidence from Canada." World Conference on Transport Research, Istanbul.

31. Eakin, D.H. (1994). "Public sector capital and productivity puzzle." *The Review of Economics and Statistics*. Vol. 76 (1), pp. 12-21.

32. Munnell, A.H. (1992). "Policy watch: infrastructure investment and economic growth." *Journal of Economic Perspectives*. 6(4), pp. 189-198.

33. Eakin, D.H. and Schwartz, A.E. (1995) "Spatial productivity spillovers from public infrastructure: evidence from state highways." *International Tax and Public Finance.*

34. Forkenbrock, D.J. and Foster, N.S.J. (1990). "Economic benefits of a corridor highway investment." *Transportation Research* 24A (4), pp. 303-312.

35. Boarnet, M.G. (1996). "The direct and indirect economic effects of transportation infrastructure Working Paper No. 340". The Transportation Center, University of California, Berkeley, CA

36. Berechman, J., Ozmen, D. and Ozbay, K. (2006). "Empirical analysis of transportation investment and economic development at state, county and municipality levels." *Transportation*. Vol. 33, 537-551.

37. Haughwout, A.F. (2000). "Public infrastructure investments, productivity and welfare in fixed geographic areas." Federal Reserve Bank of New York, Staff Report 104, May 2000.

38. Clay, J. W., Stuart, A.W. and Walcott, W.A. (1988). "Jobs, highways and regional development in North Carolina." Charlotte, NC: Institute for Transportation Research and Education.

39. Isserman, A.M., Rephann, T. and Sorenson, D.J. (1989). "Highways and rural economic development: results from quasi-experimental approaches." Presented in the Seminar on Transportation Networks and Regional Development, Leningrad, USSR.

40. Stephanedes, Y. and Eagle, D.M. (1986). "Time series analysis of interactions between transportation and manufacturing and retail Employment". *Transportation Research Record.* (1074), 16-24.

41. Ozbay, K., Ozmen, D. and Berechman, J. (2006). "Modeling and analysis of the link between accessibility and employment growth." Journal of Transportation Engineering. May, pp. 385-393.

42. Safirova, E., K. Gillingham, S. Houde. Measuring Marginal Congestion Costs of Urban Transportation: Do Networks Matter? *Transportation Research A*, Vol. 41, 2007, pp. 734-749.

43. Tevfik, N. *Cost-Benefit Analysis: Theory and Application*. Newbury Park, CA: Sage, 1996.

44. Cambridge Systematics and Bernardin Lochmueller. *Indiana Guide. Major Corridor Investment-Benefit Analysis System*. Indiana Department of Transportation Technical Report, 1996.

45. Lewis, D. *NCHRP 342: Primer on Transportation, Productivity and Economic Development*. National Cooperative Highway Research Program, Aug. 1996.

46. Hahn, R.W. Government Analysis of the Benefits and Costs of Regulation. *Journal of Economic Perspectives*, Vol. 12, No. 4, 1998, pp. 201–210.

47. Lee, D.B. Methods for Evaluation of Transportation Projects in the USA. *Transport Policy*, Vol. 7, 2000, pp. 41–50.

48. DeCorla-Souza, P, Everett, J., Gardner, B., Culp, M. Total Cost Analysis: An Alternative to Benefit-Cost Analysis in Evaluating Transportation Alternatives. *Transportation*, Vol. 24, 1997, pp. 107–123.

49. Avineri, E., Prashker, J., Ceder, A. Transportation Projects Selection Process Using Fuzzy Sets Theory. *Fuzzy Sets and Systems*, Vol. 116, 2000, pp.35-47.

50. Stewart, T.J. A Critical Survey on the Status of Multiple Criteria Decision Making Theory and Practice. *International Journal of Management Science*, Vol. 20, No. 5/6A, 1992, pp. 569–586.

51. Ross, C.L., and Davis, W.J. Multi-jurisdictional Project Evaluation in Chattanooga Urban Area. *Journal of Urban Planning Development*, Vol. 122, No. 2, 1996, pp. 71–81.

52. Rutherford, G.S. *Multimodal Evaluation of Passenger Transportation*. Washington, DC: National Academic Press, National Cooperative Highway Research Program, 1994.

53. Perl, J. Goal-Programming Approach to Multi-Objective Highway Network Design Model. In *Transportation Research Record: Journal of the Transportation Research Board*, No. 751, TRB, National Research Council, Washington, D.C., 1981, pp. 41–44.

54. Davis, C.F., Campbell, G.M. Selection of Pavement Marking Using Multi-criteria Decision Making. In *Transportation Research Record: Journal of the Transportation Research Board*, No. 1509, TRB, National Research Council, Washington, D.C., 1995, pp. 28–37.

55. Teng J.Y., and Tzeng, G.H. Fuzzy Multi-criteria Ranking of Urban Transportation Investment Alternatives. *Transportation Planning Technologies*, Vol. 20, No. 1, 1996, pp. 15–31.

56. Sayers, T.M., Jessop, A.T., Hills, P.J. Multi-criteria Evaluation of Transport Options—Flexible, Transparent and User-friendly?. *Transport Policy*, Vol. 10, 2003, pp. 95–105.

57. Azis, I.J. Analytic Hierarchy Process in the Benefit Cost Framework: A Post-Evaluation of the Trans-sumatra Highway Project. *European Journal of Operations Research*, Vol. 48, No. 1, 1990, pp. 38–48.

58. Holguin-Veras, J. Comparative Assessment of AHP and MAV in Highway Planning: Case Study. *Journal of Transportation Engineering*, ASCE, Vol. 121, No. 2, 1995, pp. 191–200.

59. Shang J.S., Tjader Y., Ding Y. A Unified Framework for Multi-criteria Evaluation of Transportation Projects. *IEEE Transactions on Engineering Management*, Vol. 51, No. 3, 2004, pp. 300-313.

60. Ozbay K. D. Jawad, D., Parker, Hussain, S, “Guidelines for Life Cycle Cost Analysis”, Final Report, NJDOT, FHWA-NJ-2003-012-TB, 2003, Ozbay K. D. (123pages).

61. Ozbay, K., Jawad, D., N. Parker, Hussain, S. "Life Cycle Cost Analysis: State-of-the Art vs. State-of-Practice". *Journal of Transportation Research Record*, No. 1864, pp. 62-71, 2004.

62. Jawad, D., and **Ozbay, K.** “The Cost Behavior of Intelligent Transportation Systems.” *Proceedings of the ITSC'05, 8th International IEEE Conference on Intelligent Transportation Systems*, Vienna, 13 - 16 September 2005.

63. Jawad, D., **Ozbay, K.** and Nassif, H. “Life-Cycle Cost Optimization of Infrastructure using Genetic Algorithms and Monte Carlo Simulation *Journal of Reliability of Structures and Materials*, Vol. 1, No. 3, 2007, pp.47-65.

64. http://onlinepubs.trb.org/onlinepubs/circulars/ec011/davis.pdf. Accessed Feb 5, 2009.

65. North Jersey Regional Transportation Model- Transportation Modeling Overview, North Jersey Transportation Planning Authority Training Sessions Volume 1, Newark, New Jersey, May 19, 2008.

66. Discover Cube Base Tutorial, Version 4.2, Document Revision 42-001-0, Citilabs, October 18, 2007.

67. K. Gwilliam. *The Value of Time in Economic Evaluation of Transport Projects; Lessons from Recent Research*. World Bank (Washington DC), January 1997.

68. USDOT. *Departmental Guidance on the Evaluation of Travel Time in Economic Analysis*”, Memo, USDOT Available online at http://ostpxweb.dot .gov/policy/safety/VOT_Guidance_ Revision_1.pdf, April 9, 1997.

69. Mayeres, I., Ochelen, S. and Proost., S. (1996) “The Marginal External Cost of Urban Transport”, *Transportation Research Part D*, No.2, pp. 111-130.

70. Booz Allen Hamilton, ACT (2003). “Transport Costing Study”, Canberra Department of Urban Services Available online at http://www.actpla.act.gov.au/plandev/tp-intro/tp-archive/transportstudy.pdf.

71. I.T. Transport. “The Value of Time in Least Developed Countries”, Department for International Development, UK under its Knowledge and Research (KaR) Programme, available online at www.transport-links.org /transport_links, Accessed June 2005.

72. Apogee Research (1994). “The Costs of Transportation”, Conservation Law Foundation (Boston; www.clf.org).

73. U.S. Department of Labor (2007). "State Occupational and Wage Estimates New Jersey". Available online at http://www.bls.gov/oes/2007/may/oes_nj.htm#b00-0000. Accessed December 2008.

74. Miller, T. R., *Societal Costs of Transportation Crashes*, In The Full Costs and Benefits of Transportation edited by Greene, D.L., Jones, D.W., Delucchi, M. A.. Springer Verlag , Sullivan, E. C., 1997.

75. National Safety Council (2007). "Estimating the Costs of Unintentional Injuries." Available online at http://www.nsc.org/resources/issues/estcost.aspx. Accessed on January 15, 2009.

76. National Highway Traffic Safety Administration, US Department of Transportation (2000). "The Economic Impact of Motor Vehicle Crashes". Available online at http://www.nhtsa.dot.gov. Accessed on February 22, 2009.

77. Federal Highway Administration (1994). "Motor Vehicle Accident Costs." Available online at http://www.fhwa.dot.gov/legsregs/directives/techadvs/t75702.htm. Accessed September 2005.

78. American Association of State Highway and Transportation Officials (2007) "Poll Results: Crash Costs used for Prioritizing Safety Projects." Available online at http://www.transportation.org/?siteid=62&pageid=1622. Accessed on February 22, 2009.

79. Small, K. and Kazimi, C. (1995). “On Costs of Air Pollution from Motor Vehicles,” *Journal of Transport Economics and Policy*,” 29 (1), pp. 7-32.

80. Small, K. (1977). “Estimating the Air Pollution Cost of Transportation Modes,” *Journal of Transport Economics and Policy*, Vol. 11, pp. 109-132.

81. Avineri, E., Prashker, J., Ceder, A. (2000). "Transportation Projects Selection Process Using Fuzzy Sets Theory." *Fuzzy Sets and Systems*, Vol. 116, pp.35-47.

82. New Jersey Department of Transportation Website (2009). http://www.state.nj.us/transportation/capital/cpd/. Accessed April, 2009.

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DISCLAIMER STATEMENT

APPENDIX I: DEFINITION OF PROJECT TYPES COVERED IN THE ANALYSIS

1. Bridge Rehabilitation and Repair
This project type includes both small- and large-scale rehabilitation and repair projects aimed at keeping existing bridges in good operating condition, but does not include full-scale bridge replacement or construction of new bridges.

2. Bridge Construction/Replacement
This project type covers the construction of new and/or full replacement of existing bridges.

3. Bridge Painting
This project type covers both one-time bridge painting projects and ongoing contracts for bridge painting.

4. Drainage Improvements
This project type includes addition and repair of inlets and pipe systems and other activities associated with drainage system upgrades.

5. Drainage Restoration
These projects are generally of a smaller scale than drainage improvement projects and mainly involve the clearing and repair of existing drainage systems.

6. Interchange Improvements
This project type covers a broad range of improvements to highway interchanges, usually including realignment and/or addition of lanes, ramp construction and reconfiguration, addition of shoulders, and signalization.

7. Intersection Improvements
These projects typically involve addition, widening and/or reconfiguration of turn lanes and signalization, as well as other minor operational and safety improvements.

8. Resurfacing
This project type refers to one-time, often large-scale resurfacing contracts.

9. Resurfacing Maintenance Contracts
These contracts cover ongoing maintenance resurfacing as needed.

10. Road Construction and Widening
These projects cover a broad range of activities usually incorporating land grading, planting, paving, and installation of drainage systems, signage, street lighting and related structures.

11. Roadway Repair
These are maintenance contracts covering pothole repair, road patching and other minor repair work, and associated lane painting, removal and/or installation of pavement markers and reflectors, etc.

12. Bridge Deck Replacement
This project type includes the replacement of steel grate and/or concrete bridge decks, and is considered separate from the other bridge repair and bridge replacement project types.

13. Pavement Repair
This project type covers both one-time projects and ongoing maintenance contracts for repair and rehabilitation of paved roads and walkways, primarily concrete and/or asphalt, and often incorporating some road painting or marker and/or reflector installation.

14. Pavement Marking
This project type covers the installation of pavement markings and raised pavement markers.

APPENDIX II: PRODUCTION FUNCTIONS AND UNDERLYING PAST PROJECTS BY PROJECT TYPE/SIZE

Table 30 - Bridge Replacements

	Size:	**Large**	**Small**
	Cost Range ($ millions):	**>30**	**0 - 30**
	Number of Projects:	**3**	**24**
	Construction Component	**Share**	**Share**
	Services		
42	Landscape and horticultural services	0.32	0.49
53	General construction contractors	0.16	0.46
54	Highway and street construction	15.35	16.81
55	Other heavy construction contractors	38.20	38.24
57	Painting, papering, decorating	0.00	0.22
58	Electrical construction contractors	2.05	1.74
63	Water well drilling	0.01	0.00
64	Specialty trade constractors	0.15	0.28
66	Maintenance and repair of highways & streets	0.01	0.00
68	Other repair and maintenance construction	0.20	1.03
432	Telephone, telgraph communications, and communications services n.e.c.	0.02	0.09
439	Sanitary services, steam supply	0.71	0.55
441	Wholesale trade, durable	4.62	4.24
442	Wholesale trade, nondurable	0.28	0.35
459	Insurance carriers	0.08	0.31
460	Insurance agents, brokers, and services	0.67	1.07
473	Computer and data processing services	0.00	0.03
474	Detective and protective services	0.01	0.00
475	Miscellaneous equipment rental and leasing	2.34	1.08
479	Research, development, and testing services, except noncommercial	0.45	0.18
482	Engineering, architectural, and surveying services	1.68	2.04
486	Automotive repair shops and services	0.01	0.01
509	Job training and related services	0.01	0.16
	Services Subtotal	**67.33**	**69.38**
	Materials		
18	Hay	0.00	0.01
38	Greenhouse and nursery products	0.38	0.57
48	Dimension, crushed and broken stone	0.35	0.79
49	Sand and gravel	0.19	0.63
125	Broadwoven fabric mills and fabric finishing plants	0.40	0.23
148	Sawmills and planing mills, general	0.15	0.27
149	Hardwood dimension and flooring mills	0.02	0.01
153	Veneer and plywood	0.44	0.58
154	Structural wood members, n.e.c.	0.00	0.00
159	Wood products, n.e.c.	0.02	0.01
178	Paper coating and glazing	0.00	0.02
201	Adhesives and sealants	0.00	0.02
215	Paints and allied products	0.17	0.61
216	Petroleum refining	0.11	0.07
219	Asphalt paving mixtures and blocks	0.79	1.33
223	Fabricated rubber products, n.e.c.	0.00	0.00
224	Miscellaneous plastics products, n.e.c.	0.79	0.80
239	Brick and structural clay tile	0.03	0.03
242	Structural clay products, n.e.c.	0.05	0.04
249	Concrete products, except block and brick	4.16	5.59
250	Ready-mixed concrete	5.82	4.76
253	Cut stone and stone products	0.35	0.04
260	Blast furnaces and steel mills	6.46	1.37
262	Steel wiredrawing and steel nails and spikes	0.01	0.76
263	Iron and steel foundries	0.45	0.93
264	Iron and steel forgings	0.18	0.11
271	Rolling, drawing, and extruding of copper	0.00	0.00
272	Aluminum rolling and drawing	0.70	0.59
273	Nonferrous rolling and drawing, n.e.c.	0.00	0.01
274	Nonferrous wiredrawing and insulating	0.56	0.11
277	Metal shipping barrels, drums, kegs, and pails	0.02	0.07
281	Fabricated structural metal	5.59	4.40
284	Sheet metal	1.47	2.98
285	Architectural and ornamental metal work	0.00	0.20
298	Miscellaneous fabricated wire products	0.03	0.02
300	Pipe, valves, and pipe fittings	0.23	0.32
307	Construction machinery and equipment	0.00	0.01
319	Electric and gas welding and soldering equipment	0.00	0.00
328	Pumps and compressors	0.00	0.01
329	Ball and roller bearings	0.43	0.00
333	General industrial machinery and equipment, n.e.c.	0.00	0.00
347	Service industry machinery, n.e.c.	0.02	0.31
351	Relays and industrial controls	0.03	0.01
361	Lighting fixtures and equipment	0.46	0.29
362	Wiring devices	0.18	0.25
365	Telephone and telegraph apparatus	0.04	0.06
366	Communication equipment	0.62	0.51
369	Other electronic components	0.00	0.00
377	Motor vehicles and passenger car bodies	0.02	0.17
391	Mechanical measuring devices	0.61	0.18
419	Signs and advertising specialties	0.34	0.57
	Materials Subtotal	**32.67**	**30.62**
	Total	**100.00**	**100.00**

Table 31 - Past Projects: Bridge Replacements

DP No.	Award Date
Large	
DP06110	6/16/2006
DP00122	6/30/2000
DP05148	12/7/2005
Small	
DP02124	1/6/2003
DP02122	10/15/2002
DP06154	4/12/2007
DP02114	6/20/2002
DP07105	3/21/2007
DP07131	6/12/2007
DP04103	5/27/2004
DP07101	4/4/2007
DP04140	2/9/2005
DP06104	4/13/2006
DP07109	5/14/2007
DP07138	5/31/2007
DP02108	5/16/2002
DP04137	1/12/2005
DP04130	1/13/2005
DP06135	12/7/2006
DP06123	1/31/2007
DP02128	1/3/2003
DP05105	5/10/2005
DP07142	6/27/2007
DP06136	11/16/2006
DP06132	10/26/2006
DP00111	5/17/2000
DP00110	6/23/2000

Table 32 - Drainage Improvements

	Size:	Large	Small
	Cost Range ($ millions):	**>3**	**0 - 3**
	Number of Projects:	**2**	**5**
	Construction Component	**Share**	**Share**
	Services		
42	Landscape and horticultural services	0.54	1.24
53	General construction contractors	0.44	1.29
54	Highway and street construction	19.17	17.83
55	Other heavy construction contractors	34.14	34.09
58	Electrical construction contractors	1.12	0.28
64	Specialty trade constractors	0.05	0.33
68	Other repair and maintenance construction	0.43	3.08
432	Telephone, telgraph communications, and communications services n.e.c.	0.06	0.36
439	Sanitary services, steam supply	0.58	1.31
441	Wholesale trade, durable	4.56	4.03
442	Wholesale trade, nondurable	0.68	0.60
459	Insurance carriers	0.17	0.00
460	Insurance agents, brokers, and services	0.90	1.71
475	Miscellaneous equipment rental and leasing	0.00	0.61
479	Research, development, and testing services, except noncommercial	0.05	0.03
482	Engineering, architectural, and surveying services	0.72	2.25
486	Automotive repair shops and services	0.48	0.00
509	Job training and related services	0.95	0.10
	Services Subtotal	**65.05**	**69.13**
	Materials		
18	Hay	0.01	0.09
38	Greenhouse and nursery products	0.59	1.30
48	Dimension, crushed and broken stone	0.79	1.29
49	Sand and gravel	0.76	1.19
125	Broadwoven fabric mills and fabric finishing plants	0.48	0.80
154	Structural wood members, n.e.c.	0.00	0.69
159	Wood products, n.e.c.	0.02	0.04
178	Paper coating and glazing	0.39	0.09
201	Adhesives and sealants	0.01	0.00
215	Paints and allied products	0.09	0.06
216	Petroleum refining	0.06	0.02
219	Asphalt paving mixtures and blocks	3.74	1.73
224	Miscellaneous plastics products, n.e.c.	3.90	2.52
242	Structural clay products, n.e.c.	0.04	0.02
249	Concrete products, except block and brick	8.45	8.58
250	Ready-mixed concrete	1.77	3.02
260	Blast furnaces and steel mills	0.72	0.02
262	Steel wiredrawing and steel nails and spikes	0.28	0.40
263	Iron and steel foundries	6.28	0.22
264	Iron and steel forgings	0.26	0.26
272	Aluminum rolling and drawing	0.34	0.08
277	Metal shipping barrels, drums, kegs, and pails	0.18	0.34
281	Fabricated structural metal	0.12	0.50
284	Sheet metal	1.05	1.59
300	Pipe, valves, and pipe fittings	1.71	2.39
347	Service industry machinery, n.e.c.	0.00	0.30
351	Relays and industrial controls	0.33	0.00
361	Lighting fixtures and equipment	0.07	0.11
362	Wiring devices	0.53	0.24
366	Communication equipment	0.44	0.00
377	Motor vehicles and passenger car bodies	0.35	0.59
391	Mechanical measuring devices	0.00	0.41
419	Signs and advertising specialties	1.18	1.99
	Materials Subtotal	**34.95**	**30.87**
	Total	**100.00**	**100.00**

Table 33 - Past Projects: Drainage Improvements

DP No.	Award Date
Large	
DP07133	6/18/2007
DP05115	6/10/2005
Small	
DP04128	3/16/2005
DP05144	11/22/2005
DP00129	6/20/2000
DP04113	6/28/2004
DP04106	6/7/2004

Table 34 - Resurfacing Maintenance Project

	Size:	**Any**
	Cost Range ($ millions):	**1 - 7**
	Number of Projects:	**35**
	Construction Component	**Share**
	Services	
42	Landscape and horticultural services	0.47
53	General construction contractors	0.64
54	Highway and street construction	46.03
55	Other heavy construction contractors	8.12
58	Electrical construction contractors	1.15
64	Specialty trade contractors	0.01
66	Maintenance and repair of highways & streets	0.21
68	Other repair and maintenance construction	0.73
432	Telephone, telgraph communications, and communications services	0.11
439	Sanitary services, steam supply	0.02
441	Wholesale trade, durable	5.30
460	Insurance agents, brokers, and services	0.77
479	Research, development, and testing services, except noncommercia	0.00
482	Engineering, architectural, and surveying services	0.52
486	Automotive repair shops and services	0.12
509	Job training and related services	0.49
	Services Subtotal	**64.68**
	Materials	
18	Hay	0.00
38	Greenhouse and nursery products	0.30
48	Dimension, crushed and broken stone	0.90
49	Sand and gravel	0.02
125	Broadwoven fabric mills and fabric finishing plants	0.02
159	Wood products, n.e.c.	0.01
201	Adhesives and sealants	0.23
205	Chemicals and chemical preparations, n.e.c.	0.00
215	Paints and allied products	0.38
216	Petroleum refining	0.27
219	Asphalt paving mixtures and blocks	19.06
224	Miscellaneous plastics products, n.e.c.	2.15
242	Structural clay products, n.e.c.	0.02
249	Concrete products, except block and brick	0.52
250	Ready-mixed concrete	5.30
253	Cut stone and stone products	0.05
260	Blast furnaces and steel mills	0.28
263	Iron and steel foundries	1.81
264	Iron and steel forgings	0.17
272	Aluminum rolling and drawing	0.21
274	Nonferrous wiredrawing and insulating	0.02
277	Metal shipping barrels, drums, kegs, and pails	0.10
281	Fabricated structural metal	0.69
284	Sheet metal	0.28
298	Miscellaneous fabricated wire products	0.01
300	Pipe, valves, and pipe fittings	0.01
340	Electronic computers	0.04
351	Relays and industrial controls	0.64
361	Lighting fixtures and equipment	0.07
362	Wiring devices	0.17
365	Telephone and telegraph apparatus	0.00
366	Communication equipment	0.20
377	Motor vehicles and passenger car bodies	0.34
391	Mechanical measuring devices	0.23
419	Signs and advertising specialties	0.82
	Materials Subtotal	**35.32**
	Total	**100.00**

Table 35 - Past Projects: Resurfacing Maintenance Contracts

DP No.	Award Date
DP05456	11/29/2005
DP05442	2/22/2006
DP05407	4/11/2005
DP07423	4/25/2007
DP07414	5/29/2007
DP06433	9/27/2006
DP02409	5/7/2002
DP00453	7/24/2000
DP02472	3/26/2003
DP02423	8/28/2002
DP06426	8/2/2006
DP04416	10/18/2004
DP01452	8/13/2001
DP04142	4/1/2005
DP05439	10/19/2005
DP04458	1/19/2005
DP00462	12/19/2000
DP04453	1/26/2005
DP04482	3/11/2005
DP04420	5/14/2004
DP02453	5/23/2003
DP01468	3/20/2002
DP01110	5/23/2001
DP01421	5/11/2001
DP06427	9/8/2006
DP07422	6/18/2007
DP01446	7/23/2001
DP03421	7/21/2003
DP02457	3/27/2003
DP00466	7/23/2001
DP04446	10/18/2004
DP02407	3/20/2002
DP07421	6/4/2007
DP00429	10/27/2000
DP04428	9/2/2004

Table 36 - Resurfacing

	Size:	**Any**
	Cost Range ($ millions):	**>0**
	Number of Projects:	**22**

	Construction Component	Share
	Services	
42	Landscape and horticultural services	0.40
53	General construction contractors	0.28
54	Highway and street construction	47.05
55	Other heavy construction contractors	6.59
58	Electrical construction contractors	1.29
68	Other repair and maintenance construction	1.51
432	Telephone, telgraph communications, and communications services	0.03
439	Sanitary services, steam supply	0.01
441	Wholesale trade, durable	5.43
459	Insurance carriers	0.02
460	Insurance agents, brokers, and services	0.59
482	Engineering, architectural, and surveying services	0.41
509	Job training and related services	0.21
	Services Subtotal	**63.83**
38	Greenhouse and nursery products	0.05
48	Dimension, crushed and broken stone	0.03
49	Sand and gravel	0.08
125	Broadwoven fabric mills and fabric finishing plants	0.00
201	Adhesives and sealants	0.12
205	Chemicals and chemical preparations, n.e.c.	0.25
215	Paints and allied products	1.54
216	Petroleum refining	0.42
219	Asphalt paving mixtures and blocks	24.66
224	Miscellaneous plastics products, n.e.c.	4.35
242	Structural clay products, n.e.c.	0.19
249	Concrete products, except block and brick	0.02
250	Ready-mixed concrete	1.14
260	Blast furnaces and steel mills	0.37
263	Iron and steel foundries	0.04
264	Iron and steel forgings	0.19
274	Nonferrous wiredrawing and insulating	0.46
277	Metal shipping barrels, drums, kegs, and pails	0.02
281	Fabricated structural metal	0.41
284	Sheet metal	0.04
351	Relays and industrial controls	0.25
361	Lighting fixtures and equipment	0.05
362	Wiring devices	0.15
377	Motor vehicles and passenger car bodies	0.29
391	Mechanical measuring devices	0.67
419	Signs and advertising specialties	0.39
	Materials Subtotal	**36.17**
	Total	**100.00**

Table 37 - Past Projects: Resurfacing

DP No.	Award Date
DP06139	11/27/2006
DP06140	12/7/2006
DP05117	6/21/2005
DP06143	12/7/2006
DP05157	1/27/2006
DP07139	6/25/2008
DP05131	9/21/2005
DP02111	5/16/2002
DP06131	9/27/2006
DP05136	9/22/2005
DP06144	12/22/2006
DP05133	9/22/2005
DP01126	6/26/2001
DP07124	5/24/2007
DP06129	8/29/2006
DP06149	1/16/2007
DP06117	7/10/2006
DP00119	6/7/2000
DP06138	12/7/2006
DP00432	5/2/2002
DP07126	5/31/2007
DP07118	5/24/2007

Table 38 - Intersection Improvements

		Large	Small
	Size:	**Large**	**Small**
	Cost Range ($ millions):	**1 - 8**	**<1**
	Number of Projects:	**18**	**8**
	Construction Component	**Share**	**Share**
	Services		
42	Landscape and horticultural services	1.39	0.44
53	General construction contractors	0.59	0.72
54	Highway and street construction	26.34	28.88
55	Other heavy construction contractors	23.86	11.92
57	Painting, papering, decorating	0.10	0.12
58	Electrical construction contractors	5.60	13.64
64	Specialty trade contractors	0.16	0.07
66	Maintenance and repair of highways & streets	0.04	0.00
68	Other repair and maintenance construction	1.16	0.48
432	Telephone, telgraph communications, and communications services n.e.c.	0.14	0.25
438	Water supply and sewerage systems	0.07	0.00
439	Sanitary services, steam supply	0.13	0.05
441	Wholesale trade, durable	4.14	4.60
442	Wholesale trade, nondurable	0.68	0.65
459	Insurance carriers	0.00	0.05
460	Insurance agents, brokers, and services	1.00	1.31
475	Miscellaneous equipment rental and leasing	0.07	0.00
479	Research, development, and testing services, except noncommercial	0.03	0.03
482	Engineering, architectural, and surveying services	2.04	1.67
486	Automotive repair shops and services	0.06	0.00
509	Job training and related services	0.27	0.06
	Services Subtotal	**67.87**	**64.95**
	Materials		
18	Hay	0.02	0.05
38	Greenhouse and nursery products	0.43	0.12
48	Dimension, crushed and broken stone	1.97	0.53
49	Sand and gravel	0.03	0.13
125	Broadwoven fabric mills and fabric finishing plants	0.58	0.43
148	Sawmills and planing mills, general	0.00	0.00
149	Hardwood dimension and flooring mills	0.00	0.00
153	Veneer and plywood	0.00	0.00
157	Wood preserving	0.01	0.00
159	Wood products, n.e.c.	0.06	0.04
178	Paper coating and glazing	0.09	0.22
201	Adhesives and sealants	0.06	0.00
205	Chemicals and chemical preparations, n.e.c.	0.02	0.00
215	Paints and allied products	0.67	0.70
216	Petroleum refining	0.21	0.04
219	Asphalt paving mixtures and blocks	6.68	4.96
224	Miscellaneous plastics products, n.e.c.	2.44	2.79
239	Brick and structural clay tile	0.00	3.70
242	Structural clay products, n.e.c.	0.02	0.00
249	Concrete products, except block and brick	3.43	1.50
250	Ready-mixed concrete	3.39	3.32
253	Cut stone and stone products	0.22	0.06
260	Blast furnaces and steel mills	0.61	1.60
262	Steel wiredrawing and steel nails and spikes	0.26	0.17
263	Iron and steel foundries	0.50	0.18
264	Iron and steel forgings	0.25	0.34
272	Aluminum rolling and drawing	0.31	0.51
274	Nonferrous wiredrawing and insulating	0.60	0.37
277	Metal shipping barrels, drums, kegs, and pails	0.24	0.55
281	Fabricated structural metal	0.82	0.00
284	Sheet metal	0.50	0.00
300	Pipe, valves, and pipe fittings	0.55	0.08
328	Pumps and compressors	0.01	0.00
347	Service industry machinery, n.e.c.	0.25	0.00
351	Relays and industrial controls	0.55	0.59
361	Lighting fixtures and equipment	0.43	0.33
362	Wiring devices	1.41	1.00
365	Telephone and telegraph apparatus	0.00	0.00
366	Communication equipment	2.14	5.70
369	Other electronic components	0.01	0.00
377	Motor vehicles and passenger car bodies	0.80	1.78
391	Mechanical measuring devices	0.04	0.04
419	Signs and advertising specialties	1.51	3.20
	Materials Subtotal	**32.13**	**35.05**
	Total	**100.00**	**100.00**

Table 39 - Past Projects: Intersection Improvements

DP No.	Award Date
Large	
DP06114	7/10/2006
DP02118	6/26/2002
DP06126	8/22/2006
DP06108	3/27/2007
DP03133	2/19/2004
DP04115	6/29/2004
DP03132	2/2/2004
DP01129	6/28/2001
DP05134	9/21/2005
DP04110	7/9/2004
DP00145	11/15/2000
DP03121	7/18/2003
DP03113	6/10/2003
DP03135	2/5/2004
DP00142	11/3/2000
DP00151	1/25/2001
DP05122	6/29/2005
DP00138	10/18/2000
Small	
DP01111	4/25/2001
DP03103	4/9/2003
DP04121	10/27/2004
DP06141	12/5/2006
DP05111	5/25/2005
DP00427	4/14/2000
DP07112	4/25/2007
DP06116	6/8/2006

Table 40 - Road Construction and Widening

		Very Large	Others
	Size:	**Very Large**	**Others**
	Cost Range ($ millions):	**>90**	**0 - 90**
	Number of Projects:	**2**	**60**
	Construction Component	**Share**	**Share**
	Services		
41	Agricultural, forestry, and fishery services	0.00	0.00
42	Landscape and horticultural services	0.39	0.87
53	General construction contractors	0.06	0.25
54	Highway and street construction	16.28	20.98
55	Other heavy construction contractors	37.51	32.33
57	Painting, papering, decorating	0.11	0.06
58	Electrical construction contractors	2.44	4.36
59	Masonry, drywall, plastering	0.00	0.01
62	Concrete work	0.00	0.01
63	Water well drilling	0.00	0.01
64	Specialty trade contractors	0.90	0.12
66	Maintenance and repair of highways & streets	0.00	0.51
68	Other repair and maintenance construction	0.17	0.40
432	Telephone, telgraph communications, and communications services n.e.c.	0.01	0.04
435	Electric services (utilities)	0.02	0.00
438	Water supply and sewerage systems	0.00	0.01
439	Sanitary services, steam supply	0.66	0.47
441	Wholesale trade, durable	4.95	4.76
459	Insurance carriers	0.02	0.06
460	Insurance agents, brokers, and services	0.91	0.77
473	Computer and data processing services	0.00	0.00
475	Miscellaneous equipment rental and leasing	0.57	0.45
479	Research, development, and testing services, except noncommercial	0.09	0.09
482	Engineering, architectural, and surveying services	1.88	1.46
486	Automotive repair shops and services	0.02	0.02
509	Job training and related services	0.00	0.20
	Services Subtotal	**66.99**	**68.24**
18	Hay	0.01	0.01
38	Greenhouse and nursery products	0.43	0.99
48	Dimension, crushed and broken stone	1.61	0.86
49	Sand and gravel	0.72	1.32
114	Animal and marine fats and oils	0.04	0.00
125	Broadwoven fabric mills and fabric finishing plants	0.04	0.28
149	Hardwood dimension and flooring mills	0.00	0.01
153	Veneer and plywood	0.16	0.49
154	Structural wood members, n.e.c.	0.01	0.03
157	Wood preserving	0.19	0.01
159	Wood products, n.e.c.	0.02	0.03
169	Office furniture, except wood	0.01	0.01
178	Paper coating and glazing	0.01	0.03
201	Adhesives and sealants	0.02	0.05
205	Chemicals and chemical preparations, n.e.c.	0.00	0.01
215	Paints and allied products	0.32	0.08
216	Petroleum refining	0.07	0.16
219	Asphalt paving mixtures and blocks	1.44	3.75
223	Fabricated rubber products, n.e.c.	0.00	0.00
224	Miscellaneous plastics products, n.e.c.	1.84	1.08
239	Brick and structural clay tile	0.03	0.21
240	Ceramic wall and floor tile	0.00	0.00
242	Structural clay products, n.e.c.	0.08	0.15
248	Concrete block and brick	0.00	0.01
249	Concrete products, except block and brick	7.88	5.03
250	Ready-mixed concrete	4.17	4.45
253	Cut stone and stone products	0.22	0.85
259	Nonmetallic mineral products, n.e.c.	0.12	0.00
260	Blast furnaces and steel mills	1.31	0.71
262	Steel wiredrawing and steel nails and spikes	0.72	0.20
263	Iron and steel foundries	1.42	0.60
264	Iron and steel forgings	0.06	0.08
271	Rolling, drawing, and extruding of copper	0.00	0.01
272	Aluminum rolling and drawing	2.48	0.87
273	Nonferrous rolling and drawing, n.e.c.	0.02	0.00
274	Nonferrous wiredrawing and insulating	0.51	0.68
277	Metal shipping barrels, drums, kegs, and pails	0.03	0.10
281	Fabricated structural metal	2.86	2.89
283	Fabricated plate work (boiler shops)	0.00	0.01
284	Sheet metal	1.04	0.80
285	Architectural and ornamental metal work	0.06	0.02
288	Screw machine products, bolts, etc.	0.00	0.01
298	Miscellaneous fabricated wire products	0.01	0.02
300	Pipe, valves, and pipe fittings	0.23	0.82
307	Construction machinery and equipment	0.38	0.00
315	Machine tools, metal forming types	0.00	0.00
319	Electric and gas welding and soldering equipment	0.01	0.01
329	Ball and roller bearings	0.00	0.10
347	Service industry machinery, n.e.c.	0.06	0.11
351	Relays and industrial controls	0.04	0.19
361	Lighting fixtures and equipment	1.17	0.82
362	Wiring devices	0.36	0.72
363	Household audio and video equipment	0.00	0.00
364	Prerecorded records and tapes	0.06	0.01
365	Telephone and telegraph apparatus	0.03	0.01
366	Communication equipment	0.37	1.03
369	Other electronic components	0.00	0.01
377	Motor vehicles and passenger car bodies	0.04	0.21
391	Mechanical measuring devices	0.07	0.24
400	Instruments to measure electricity	0.00	0.00
419	Signs and advertising specialties	0.26	0.58
	Materials Subtotal	**33.01**	**31.76**
	Total	**100.00**	**100.00**

Table 41 - Past Projects: Road Construction and Widening

DP No.	Award Date	DP No.	Award Date
Large		**Small (cont.)**	
DP04135	3/16/2005	DP02116	6/14/2002
DP02127	12/27/2002	DP01130	6/26/2001
		DP00150	1/9/2001
Small		DP04145	5/10/2005
DP00144	11/29/2000	DP04116	7/29/2004
DP06118	7/19/2006	DP01112	5/31/2001
DP01140	11/16/2001	DP04120	9/22/2004
DP03128	6/14/2004	DP06111	5/31/2006
DP02131	2/21/2003	DP02102	3/27/2002
DP05114	10/19/2005	DP06121	7/17/2006
DP05118	6/30/2005	DP04125	12/1/2004
DP02103	3/20/2002	DP04101	6/16/2004
DP05140	3/1/2006	DP05152	4/7/2006
DP03110	6/19/2003	DP04102	3/16/2005
DP03112	6/11/2003	DP07130	5/31/2007
DP00124	6/16/2000	DP03107	6/2/2003
DP06120	8/4/2006	DP01115	6/25/2001
DP01113	5/31/2001	DP03124	3/8/2004
DP04136	4/1/2005	DP03115	7/24/2003
DP02107	4/29/2002	DP06109	7/10/2006
DP05108	6/21/2005	DP03106	6/12/2003
DP03114	3/25/2004	DP06119	7/10/2006
DP03111	7/1/2003	DP07116	5/7/2007
DP00137	11/15/2000	DP03118	7/24/2003
DP05149	1/27/2006	DP02104	4/29/2002
DP03116	6/26/2003	DP06151	3/5/2007
DP03127	4/22/2004	DP04141	2/2/2005
DP04117	7/19/2004	DP03119	7/24/2003
DP03131	1/22/2004	DP00135	10/16/2000
DP01103	1/25/2001	DP02406	3/13/2002
DP02110	5/23/2002	DP07113	5/14/2007
DP00118	5/17/2000	DP07117	5/21/2007

Table 42 - Roadway Repair

	Size:	**Any**
	Cost Range ($ millions):	**>0**
	Number of Projects:	**112**
	Construction Component	**Share**
	Services	
42	Landscape and horticultural services	0.11
53	General construction contractors	0.57
54	Highway and street construction	50.03
55	Other heavy construction contractors	2.56
56	Plumbing/heating/air conditioning contractors	0.01
58	Electrical construction contractors	2.56
63	Water well drilling	0.01
64	Specialty trade contractors	0.00
68	Other repair and maintenance construction	0.45
432	Telephone, telgraph communications, and communications services	0.05
439	Sanitary services, steam supply	0.01
441	Wholesale trade, durable	4.95
442	Wholesale trade, nondurable	0.49
460	Insurance agents, brokers, and services	0.68
479	Research, development, and testing services, except noncommercia	0.00
482	Engineering, architectural, and surveying services	0.83
486	Automotive repair shops and services	0.13
509	Job training and related services	0.01
	Services Subtotal	**63.46**
	Materials	
18	Hay	0.0
38	Greenhouse and nursery products	0.0
48	Dimension, crushed and broken stone	0.1
49	Sand and gravel	0.0
201	Adhesives and sealants	0.0
205	Chemicals and chemical preparations, n.e.c.	0.2
215	Paints and allied products	3.0
216	Petroleum refining	0.3
219	Asphalt paving mixtures and blocks	19.0
224	Miscellaneous plastics products, n.e.c.	3.4
242	Structural clay products, n.e.c.	0.1
249	Concrete products, except block and brick	0.3
250	Ready-mixed concrete	5.6
260	Blast furnaces and steel mills	0.2
262	Steel wiredrawing and steel nails and spikes	0.0
263	Iron and steel foundries	0.9
264	Iron and steel forgings	0.2
272	Aluminum rolling and drawing	0.0
274	Nonferrous wiredrawing and insulating	0.0
277	Metal shipping barrels, drums, kegs, and pails	0.1
281	Fabricated structural metal	0.2
284	Sheet metal	0.0
300	Pipe, valves, and pipe fittings	0.0
351	Relays and industrial controls	1.4
361	Lighting fixtures and equipment	0.1
362	Wiring devices	0.1
365	Telephone and telegraph apparatus	0.0
366	Communication equipment	0.3
377	Motor vehicles and passenger car bodies	0.2
391	Mechanical measuring devices	0.2
419	Signs and advertising specialties	0.7
	Materials Subtotal	**36.54**
	Total	**100.00**

Table 43 - Past Projects: Roadway Repair

DP No.	Award Date	DP No.	Award Date	DP No.	Award Date
DP06402	4/7/2006	DP02465	5/16/2003	DP01438	8/7/2001
DP06431	8/23/2006	DP05443	10/11/2005	DP02446	10/17/2002
DP05440	1/6/2006	DP07416	6/5/2007	DP05422	6/29/2005
DP05411	5/13/2005	DP02436	9/24/2002	DP00449	7/24/2000
DP06447	10/20/2006	DP02460	3/12/2003	DP03451	1/14/2004
DP06432	9/8/2006	DP00443	7/24/2000	DP05414	6/21/2005
DP06430	9/19/2006	DP06449	1/22/2007	DP00458	9/13/2000
DP02422	9/16/2002	DP00452	7/31/2000	DP04474	2/14/2005
DP00447	7/24/2000	DP05441	9/29/2005	DP06423	1/22/2007
DP02412	6/3/2002	DP05458	12/20/2005	DP00446	8/1/2000
DP01447	7/18/2001	DP02438	10/1/2002	DP00438	7/24/2000
DP00457	9/13/2000	DP02420	8/19/2002	DP03452	1/14/2004
DP01415	3/12/2001	DP04473	2/1/2005	DP04423	6/29/2004
DP00428	3/14/2000	DP00439	8/1/2000	DP03448	12/13/2003
DP00440	8/1/2000	DP04480	3/28/2005	DP01453	8/21/2001
DP02421	9/16/2002	DP07424	6/8/2007	DP02413	6/27/2002
DP05459	12/27/2005	DP00451	7/24/2000	DP02419	8/19/2002
DP05421	6/28/2005	DP00442	8/1/2000	DP04424	6/29/2004
DP04439	9/23/2004	DP01442	3/25/2002	DP02461	5/20/2003
DP03447	2/4/2004	DP03436	11/18/2003	DP01449	7/18/2001
DP05413	9/22/2005	DP01432	2/26/2002	DP02462	4/14/2003
DP04442	11/4/2004	DP01443	7/8/2002	DP03449	12/15/2003
DP05408	5/13/2005	DP02447	10/17/2002	DP05410	4/11/2005
DP00437	7/25/2000	DP05415	6/28/2005	DP02459	1/24/2003
DP07415	4/19/2007	DP00444	8/1/2000	DP01433	8/6/2001
DP06452	12/11/2006	DP02464	5/23/2003	DP02463	3/28/2003
DP03416	8/12/2003	DP00441	8/1/2000	DP05418	7/11/2005
DP05419	6/28/2005	DP01472	12/17/2001	DP01455	8/30/2001
DP06428	8/23/2006	DP04421	6/30/2004	DP01448	7/26/2001
DP04444	1/26/2005	DP01441	6/28/2002	DP01434	3/25/2002
DP02435	9/24/2002	DP03422	7/22/2003	DP05409	4/11/2005
DP06416	6/8/2006	DP04481	3/31/2005	DP01450	7/26/2001
DP05416	9/13/2005	DP02458	1/29/2003	DP02418	8/8/2002
DP06422	12/4/2006	DP01440	8/21/2001	DP00445	8/11/2000
DP04443	11/4/2004	DP07417	6/18/2007	DP01430	8/7/2001
DP04471	2/18/2005	DP01439	12/26/2001	DP01451	7/18/2001
DP05457	12/6/2005	DP01436	3/27/2002		

Table 44 - Interchange Improvements

	Size:	Large	Medium	Small
	Cost Range ($ millions):	**>45**	**7.5 - 45**	**0 - 7.5**
	Number of Projects:	**1**	**7**	**1**
	Construction Component	**Share**	**Share**	**Share**
	Services			
42	Landscape and horticultural services	0.27	1.26	5.08
54	Highway and street construction	19.98	23.45	26.47
55	Other heavy construction contractors	31.73	29.66	25.16
57	Painting, papering, decorating	0.10	0.00	0.00
58	Electrical construction contractors	7.09	4.75	5.37
64	Specialty trade contractors	0.02	0.18	0.05
66	Maintenance and repair of highways & streets	0.00	0.09	0.00
68	Other repair and maintenance construction	0.15	0.63	0.45
432	Telephone, telgraph communications, and communications services n.e.c.	0.01	0.05	0.07
438	Water supply and sewerage systems	0.02	0.02	0.00
439	Sanitary services, steam supply	0.00	0.07	0.00
441	Wholesale trade, durable	4.18	4.24	3.97
442	Wholesale trade, nondurable	0.34	0.55	0.57
459	Insurance carriers	0.04	0.00	0.00
460	Insurance agents, brokers, and services	0.69	0.82	0.51
475	Miscellaneous equipment rental and leasing	2.37	0.12	0.00
	Services Subtotal	**66.97**	**65.89**	**67.68**
18	Hay	0.00	0.01	0.00
38	Greenhouse and nursery products	0.09	0.43	1.64
48	Dimension, crushed and broken stone	0.46	1.77	1.14
49	Sand and gravel	0.16	0.44	0.64
53	General construction contractors	0.19	0.34	0.15
479	Research, development, and testing services, except noncommercial	0.00	0.05	0.00
482	Engineering, architectural, and surveying services	2.74	1.74	1.90
486	Automotive repair shops and services	0.00	0.01	0.00
125	Broadwoven fabric mills and fabric finishing plants	0.15	0.14	0.09
149	Hardwood dimension and flooring mills	0.01	0.00	0.00
153	Veneer and plywood	4.37	0.86	0.00
154	Structural wood members, n.e.c.	0.00	0.01	0.00
157	Wood preserving	0.00	0.11	0.00
159	Wood products, n.e.c.	0.00	0.02	0.23
178	Paper coating and glazing	0.03	0.00	0.00
201	Adhesives and sealants	0.23	0.04	0.00
215	Paints and allied products	0.12	0.41	0.05
216	Petroleum refining	0.06	0.18	0.02
219	Asphalt paving mixtures and blocks	2.26	4.36	6.13
224	Miscellaneous plastics products, n.e.c.	1.57	2.46	2.01
239	Brick and structural clay tile	0.00	0.37	0.00
242	Structural clay products, n.e.c.	0.01	0.02	0.00
249	Concrete products, except block and brick	3.40	4.02	5.94
250	Ready-mixed concrete	6.33	4.02	4.32
253	Cut stone and stone products	0.00	0.11	0.00
260	Blast furnaces and steel mills	0.73	0.65	0.69
262	Steel wiredrawing and steel nails and spikes	0.11	0.47	0.00
263	Iron and steel foundries	0.17	0.38	0.37
264	Iron and steel forgings	0.27	0.22	0.10
271	Rolling, drawing, and extruding of copper	0.01	0.00	0.00
272	Aluminum rolling and drawing	0.64	1.54	1.17
274	Nonferrous wiredrawing and insulating	0.51	0.79	0.26
277	Metal shipping barrels, drums, kegs, and pails	0.06	0.10	0.52
281	Fabricated structural metal	3.09	2.44	0.24
284	Sheet metal	0.32	0.47	0.27
285	Architectural and ornamental metal work	0.00	0.10	0.00
288	Screw machine products, bolts, etc.	0.03	0.01	0.00
298	Miscellaneous fabricated wire products	0.00	0.00	0.00
300	Pipe, valves, and pipe fittings	0.12	0.46	0.26
319	Electric and gas welding and soldering equipment	0.00	0.00	0.00
328	Pumps and compressors	0.00	0.01	0.00
329	Ball and roller bearings	0.00	0.07	0.00
347	Service industry machinery, n.e.c.	0.00	0.00	0.73
351	Relays and industrial controls	0.02	0.22	0.33
361	Lighting fixtures and equipment	1.12	1.28	0.64
362	Wiring devices	0.27	0.96	0.35
363	Household audio and video equipment	0.00	0.01	0.00
365	Telephone and telegraph apparatus	0.00	0.03	0.00
366	Communication equipment	2.86	0.92	0.79
369	Other electronic components	0.00	0.01	0.00
377	Motor vehicles and passenger car bodies	0.20	0.20	0.50
391	Mechanical measuring devices	0.00	0.03	0.00
419	Signs and advertising specialties	0.33	0.82	0.83
	Materials Subtotal	**33.05**	**34.11**	**32.32**
	Total	**100.00**	**100.00**	**100.00**

Table 45 - Past Projects: Interchange Improvements

DP No.	Award Date
Large	
DP04133	6/21/2005
Medium	
DP01114	6/25/2001
DP05147	12/13/2005
DP06106	6/15/2006
DP04126	4/1/2005
DP01124	7/2/2001
DP05113	6/29/2005
DP00127	6/30/2000
Small	
DP01107	4/3/2001

Table 46 - Bridge Rehab/Repair

	Size:	Large	Medium	Small
	Cost Range ($ millions):	**>25**	**10 - 25**	**0 - 10**
	Number of Projects:	**3**	**2**	**7**
	Construction Component	**Share**	**Share**	**Share**
	Services			
42	Landscape and horticultural services	0.06	0.00	0.36
53	General construction contractors	0.23	0.18	0.37
54	Highway and street construction	18.45	12.37	22.07
55	Other heavy construction contractors	33.72	32.26	31.48
57	Painting, papering, decorating	1.67	2.85	1.15
58	Electrical construction contractors	5.40	14.61	4.02
64	Specialty trade contractors	0.06	0.00	0.08
66	Maintenance and repair of highways & streets	1.20	0.00	0.28
68	Other repair and maintenance construction	0.38	0.78	0.79
425	Water transportation, nec	0.00	0.00	0.02
432	Telephone, telgraph communications, and communications services n.e.c.	0.02	0.03	0.12
435	Electric services (utilities)	0.00	0.00	0.04
439	Sanitary services, steam supply	0.28	0.00	0.25
441	Wholesale trade, durable	4.16	3.38	4.15
442	Wholesale trade, nondurable	0.00	1.09	0.22
459	Insurance carriers	0.01	0.00	0.42
460	Insurance agents, brokers, and services	0.62	0.84	0.85
473	Computer and data processing services	0.08	0.13	0.50
475	Miscellaneous equipment rental and leasing	0.63	0.08	2.32
479	Research, development, and testing services, except noncommercial	0.05	0.10	0.15
482	Engineering, architectural, and surveying services	1.07	0.75	0.48
486	Automotive repair shops and services	0.14	0.31	0.16
509	Job training and related services	0.09	0.46	0.54
	Services Subtotal	**68.34**	**70.22**	**70.83**
	Materials			
18	Hay	0.00	0.00	0.01
38	Greenhouse and nursery products	0.05	0.00	0.28
48	Dimension, crushed and broken stone	0.42	0.00	0.36
49	Sand and gravel	0.02	0.00	0.34
125	Broadwoven fabric mills and fabric finishing plants	0.04	0.02	0.09
132	Cordage and twine	0.00	5.99	0.00
148	Sawmills and planing mills, general	0.00	0.00	0.06
149	Hardwood dimension and flooring mills	0.00	0.00	0.72
153	Veneer and plywood	4.20	0.89	1.65
154	Structural wood members, n.e.c.	0.84	0.16	1.69
159	Wood products, n.e.c.	0.00	0.00	0.00
178	Paper coating and glazing	0.02	0.00	0.01
201	Adhesives and sealants	0.02	0.00	0.03
215	Paints and allied products	1.78	0.94	0.52
216	Petroleum refining	0.03	0.04	0.01
219	Asphalt paving mixtures and blocks	0.34	0.08	1.01
224	Miscellaneous plastics products, n.e.c.	1.88	0.28	0.54
242	Structural clay products, n.e.c.	0.00	0.00	0.03
249	Concrete products, except block and brick	3.51	10.80	2.04
250	Ready-mixed concrete	3.68	0.85	4.97
253	Cut stone and stone products	0.02	0.00	0.05
260	Blast furnaces and steel mills	1.60	0.65	0.44
262	Steel wiredrawing and steel nails and spikes	0.14	1.77	2.20
263	Iron and steel foundries	0.31	0.00	0.36
264	Iron and steel forgings	0.46	0.90	0.15
272	Aluminum rolling and drawing	0.35	0.19	0.53
274	Nonferrous wiredrawing and insulating	1.40	0.27	0.03
277	Metal shipping barrels, drums, kegs, and pails	0.04	0.03	0.01
281	Fabricated structural metal	8.23	0.52	3.44
284	Sheet metal	0.03	0.00	0.36
285	Architectural and ornamental metal work	0.00	0.16	0.00
288	Screw machine products, bolts, etc.	0.00	0.00	0.20
300	Pipe, valves, and pipe fittings	0.11	0.00	0.08
307	Construction machinery and equipment	0.00	0.00	0.92
317	Power-driven handtools	0.00	0.00	0.07
329	Ball and roller bearings	0.62	0.58	0.84
351	Relays and industrial controls	0.00	0.00	0.00
361	Lighting fixtures and equipment	0.30	0.17	0.76
362	Wiring devices	0.43	0.27	2.15
363	Household audio and video equipment	0.00	0.00	0.10
365	Telephone and telegraph apparatus	0.00	0.00	0.06
366	Communication equipment	0.10	2.81	0.20
369	Other electronic components	0.28	0.00	1.38
377	Motor vehicles and passenger car bodies	0.04	0.59	0.17
391	Mechanical measuring devices	0.16	0.00	0.06
419	Signs and advertising specialties	0.18	0.82	0.28
	Materials Subtotal	**31.66**	**29.78**	**29.17**
	Total	**100.00**	**100.00**	**100.00**

Table 47 - Past Projects: Bridge Rehab/Repair

DP No.	Award Date
Large	
DP01123	7/2/2001
DP06124	9/8/2006
DP05129	3/7/2006
Medium	
DP07110	6/27/2007
DP01132	6/26/2001
Small	
DP03417	2/18/2005
DP04112	6/28/2004
DP04144	5/4/2005
DP07122	5/24/2007
DP01102	2/28/2001
DP01138	12/21/2001
DP04114	6/29/2004

Table 48 - Bridge Painting

	Size:	**Any**
	Cost Range ($ millions):	**>0**
	Number of Projects:	**27**
	Construction Component	**Share**
	Services	
53	General construction contractors	0.95
54	Highway and street construction	6.53
55	Other heavy construction contractors	0.08
57	Painting, papering, decorating	62.79
58	Electrical construction contractors	0.20
68	Other repair and maintenance construction	0.10
433	Cable and other pay television services	0.36
443	Building Material and Garden Equipment and Supplies Stores	3.28
460	Insurance agents, brokers, and services	0.11
461	Real estate agents, managers, operators, and lessors	2.83
480	Advertising	0.94
	Services Subtotal	**78.15**
	Materials	
215	Paints and allied products	20.30
219	Asphalt paving mixtures and blocks	0.01
224	Miscellaneous plastics products, n.e.c.	0.09
277	Metal shipping barrels, drums, kegs, and pails	0.10
361	Lighting fixtures and equipment	0.25
377	Motor vehicles and passenger car bodies	0.70
419	Signs and advertising specialties	0.41
	Materials Subtotal	**21.85**
	Total	**100.00**

Table 49 - Past Projects: Bridge Painting

DP No.	Award Date
DP06406	2/8/2007
DP04426	4/25/2005
DP05460	8/22/2006
DP04425	12/27/2004
DP06408	11/8/2006
DP04478	8/22/2006
DP06407	11/17/2006
DP03455	6/29/2004
DP06404	10/27/2006
DP04477	9/21/2005
DP01486	6/27/2002
DP00419	8/24/2000
DP00421	5/25/2000
DP01425	4/9/2002
DP01422	5/17/2001
DP00422	8/13/2001
DP01426	6/3/2002
DP01427	3/3/2003
DP01424	6/17/2002
DP02415	3/3/2003
DP03406	11/13/2003
DP03415	8/26/2003
DP00420	8/24/2000
DP03405	9/16/2003
DP03404	3/19/2004
DP02417	12/16/2002
DP03403	12/22/2003

Table 50 - Pavement Repair

	Size:	**Any**
	Cost Range ($ millions):	**>0**
	Number of Projects:	**25**
	Construction Component	**Share**
	Services	
53	General construction contractors	0.85
54	Highway and street construction	53.83
55	Other heavy construction contractors	1.28
58	Electrical construction contractors	0.19
68	Other repair and maintenance construction	0.76
432	Telephone, telgraph communications, and communications services	0.13
441	Wholesale trade, durable	4.64
442	Wholesale trade, nondurable	0.84
460	Insurance agents, brokers, and services	0.71
482	Engineering, architectural, and surveying services	0.15
	Services Subtotal	**63.41**
	Materials	
215	Paints and allied products	3.61
216	Petroleum refining	0.15
219	Asphalt paving mixtures and blocks	22.92
224	Miscellaneous plastics products, n.e.c.	1.86
249	Concrete products, except block and brick	0.46
250	Ready-mixed concrete	5.47
263	Iron and steel foundries	0.67
264	Iron and steel forgings	0.19
272	Aluminum rolling and drawing	0.01
277	Metal shipping barrels, drums, kegs, and pails	0.01
351	Relays and industrial controls	0.05
361	Lighting fixtures and equipment	0.05
377	Motor vehicles and passenger car bodies	0.17
391	Mechanical measuring devices	0.14
419	Signs and advertising specialties	0.84
	Materials Subtotal	**36.59**
	Total	**100.00**

Table 51 - Past Projects: Pavement Repair

DP No.	Award Date
DP04445	10/4/2004
DP03427	10/2/2003
DP03428	11/18/2003
DP03426	10/2/2003
DP03409	5/30/2003
DP03410	5/30/2003
DP02444	3/3/2003
DP05471	3/16/2006
DP04410	6/8/2004
DP02443	3/3/2003
DP03408	5/30/2003
DP01475	1/22/2002
DP05472	3/16/2006
DP05406	5/11/2005
DP02445	3/3/2003
DP04409	6/8/2004
DP01412	3/7/2001
DP04408	6/8/2004
DP01413	3/12/2001
DP05405	5/26/2005
DP01476	1/28/2002
DP05470	3/16/2006
DP05404	5/11/2005
DP01414	3/9/2001
DP01477	1/28/2002

Table 52 - Bridge Deck Replacements

		Large	Small
	Size:	**Large**	**Small**
	Cost Range ($ millions):	**>20**	**0 - 20**
	Number of Projects:	**1**	**10**
	Construction Component	**Share**	**Share**
	Services		
42	Landscape and horticultural services	0.39	0.11
53	General construction contractors	0.15	0.87
54	Highway and street construction	28.48	19.69
55	Other heavy construction contractors	24.46	36.24
57	Painting, papering, decorating	0.00	0.12
58	Electrical construction contractors	3.68	1.22
64	Specialty trade contractors	0.00	0.01
68	Other repair and maintenance construction	0.50	1.17
432	Telephone, telgraph communications, and communications services n.e.c.	0.01	0.11
439	Sanitary services, steam supply	0.01	0.02
441	Wholesale trade, durable	4.36	3.75
442	Wholesale trade, nondurable	0.87	1.11
460	Insurance agents, brokers, and services	0.68	1.37
473	Computer and data processing services	0.04	0.00
479	Research, development, and testing services, except noncommercial	0.15	0.00
482	Engineering, architectural, and surveying services	1.37	1.78
486	Automotive repair shops and services	0.03	0.00
509	Job training and related services	0.00	0.03
	Services Subtotal	**65.17**	**67.60**
	Materials		
18	Hay	0.01	0.00
38	Greenhouse and nursery products	0.12	0.09
48	Dimension, crushed and broken stone	0.02	0.35
49	Sand and gravel	0.52	0.16
125	Broadwoven fabric mills and fabric finishing plants	0.12	0.21
153	Veneer and plywood	0.70	4.76
178	Paper coating and glazing	0.00	0.16
201	Adhesives and sealants	0.67	0.00
205	Chemicals and chemical preparations, n.e.c.	1.63	0.00
215	Paints and allied products	2.31	2.19
216	Petroleum refining	0.22	0.01
219	Asphalt paving mixtures and blocks	9.01	1.89
224	Miscellaneous plastics products, n.e.c.	1.16	0.74
249	Concrete products, except block and brick	9.06	5.61
250	Ready-mixed concrete	2.96	5.00
260	Blast furnaces and steel mills	0.95	0.98
262	Steel wiredrawing and steel nails and spikes	0.14	0.34
263	Iron and steel foundries	0.19	0.21
264	Iron and steel forgings	0.44	0.45
272	Aluminum rolling and drawing	0.01	0.38
274	Nonferrous wiredrawing and insulating	0.38	0.08
277	Metal shipping barrels, drums, kegs, and pails	0.13	0.20
281	Fabricated structural metal	1.12	4.65
284	Sheet metal	0.15	0.60
288	Screw machine products, bolts, etc.	0.00	0.04
300	Pipe, valves, and pipe fittings	0.00	0.07
361	Lighting fixtures and equipment	0.23	0.32
362	Wiring devices	0.57	0.09
363	Household audio and video equipment	0.44	0.00
365	Telephone and telegraph apparatus	0.00	0.06
366	Communication equipment	0.30	0.00
377	Motor vehicles and passenger car bodies	0.51	1.07
391	Mechanical measuring devices	0.23	0.00
419	Signs and advertising specialties	0.53	1.67
	Materials Subtotal	**34.83**	**32.40**
	Total	**100.00**	**100.00**

Table 53 - Past Projects: Bridge Deck Replacements

DP No.	Award Date
Large	
DP07128	6/25/2007
Small	
DP07119	6/13/2007
DP06153	3/9/2007
DP07123	6/12/2007
DP07102	5/24/2007
DP05120	6/30/2005
DP04109	6/28/2004
DP07103	4/5/2007
DP02466	2/14/2003
DP05156	1/30/2006
DP05151	2/3/2006

Table 54 - Pavement Marking

	Size:	**Any**
	Cost Range ($ millions):	**>0**
	Number of Projects:	**22**
	Construction Component	**Share**
	Services	
53	General construction contractors	0.10
54	Highway and street construction	36.51
55	Other heavy construction contractors	0.42
58	Electrical construction contractors	0.05
64	Specialty trade contractors	1.31
432	Telephone, telgraph communications, and communications services	0.31
441	Wholesale trade, durable	2.98
442	Wholesale trade, nondurable	4.87
460	Insurance agents, brokers, and services	0.99
482	Engineering, architectural, and surveying services	0.16
	Services Subtotal	**47.70**
	Materials	
215	Paints and allied products	7.17
219	Asphalt paving mixtures and blocks	0.25
224	Miscellaneous plastics products, n.e.c.	25.27
277	Metal shipping barrels, drums, kegs, and pails	0.15
340	Electronic computers	2.04
361	Lighting fixtures and equipment	0.07
377	Motor vehicles and passenger car bodies	16.82
419	Signs and advertising specialties	0.54
	Materials Subtotal	**52.30**
	Total	**100.00**

Table 55 - Past Projects: Pavement Marking

DP No.	Award Date
DP04465	3/18/2005
DP04464	3/28/2005
DP04463	3/18/2005
DP05464	2/22/2006
DP05466	2/27/2006
DP05465	2/27/2006
DP03433	4/6/2004
DP01483	3/20/2002
DP02452	3/20/2003
DP03435	4/6/2004
DP00475	1/22/2001
DP00471	1/11/2001
DP03434	4/6/2004
DP02451	3/3/2003
DP02450	3/20/2003
DP01479	3/20/2002
DP01481	3/20/2002
DP00473	1/22/2001
DP06437	1/4/2007
DP00410	1/11/2000
DP06438	1/4/2007
DP06439	1/4/2007

APPENDIX III: CAPITAL PLAN PROJECTS INCLUDED IN THE ANALYSIS (BY TYPE/SIZE/REGION)

DB Number	Name
Bridge Painting/Any/North	
X08 (partial)	Bridge Painting Program
Bridge Painting/Any/South	
X08 (partial)	Bridge Painting Program
Bridge Deck Replacement/Small/North	
03304 (partial)	Bridge Deck Replacement Program
Bridge Deck Replacement/Small/South	
03304 (partial)	Bridge Deck Replacement Program
Bridge Repair/Rehabilitation/Large/North	
03356	Route 1&9, Pulaski Skyway
08370	Route 1&9, Pulaski Skyway Interim Repairs
00357	Route 72, Manahawkin Bay Bridges
053C	Route 139, Contract 3 (Hoboken and Conrail Viaducts)
06369	Route 37, Mathis Bridge Eastbound over Barnegat Bay
06373	Route 495, Route 1&9/Paterson Plank Road Bridge
99417	Route 3, Hackensack River (eastbound and westbound) Rehabilitation
08391	Route 37, Tunney Bridge Westbound over Barnegat Bay
X72A (partial)	Betterments, Bridge Preservation
98315 (partial)	Bridge, Emergency Repair
Bridge Repair/Rehabilitation/Large/South	
01339	Route 54, Route 322 to Cape May Point Branch Bridge
X72A (partial)	Betterments, Bridge Preservation
98315 (partial)	Bridge, Emergency Repair
Bridge Repair/Rehabilitation/Medium/North	
06368	Route 35, Cheesequake Creek Bridge
06371	Route 46, Hackensack River Bridge
94047	Route 1&9, Haynes Ave. Operational Improvements
99316	Oak Tree Road Bridge, CR 604
06391	Barrier Gate Replacement
X72A (partial)	Betterments, Bridge Preservation
98315 (partial)	Bridge, Emergency Repair
Bridge Repair/Rehabilitation/Medium/South	
06370	Route 30, Absecon Boulevard over Beach Thorofare
X72A (partial)	Betterments, Bridge Preservation
98315 (partial)	Bridge, Emergency Repair
Bridge Repair/Rehabilitation/Small/North	
04386	Route 17, Northbound over I-80, Bridge Deck Replacement
NS0109	Eighth Street Bridge
326	Route 206, Stony Brook Bridges
99315	Van Dyke Road and Greenwood Avenue Bridges over Trenton Branch
08357	Route 1, Heathcote Brook Bridge
N9910	Paterson Hamburg Turnpike Over Pequannock River
NS0105	Rockafellows Mill Road Bridge over South Branch of Raritan River (RQ-164)
01339	Route 54, Route 322 to Cape May Point Branch Bridge (DB# 01339)

X72A (partial)	Betterments, Bridge Preservation
98315 (partial)	Bridge, Emergency Repair
08387 (partial)	Local Bridges, Future Needs
06385 (partial)	Bridge Deck Patching Program
X236 (partial)	Historic Bridge Preservation Program
Bridge Repair/Rehabilitation/Small/South	
98348	Route 322, Raccoon Creek Bridge/Mullica Hill Pond Dam
X72A (partial)	Betterments, Bridge Preservation
98315 (partial)	Bridge, Emergency Repair
08387 (partial)	Local Bridges, Future Needs
06385 (partial)	Bridge Deck Patching Program
X236 (partial)	Historic Bridge Preservation Program
Bridge Construction/Replacement/Large/North	
799	Route 3, Passaic River Crossing
051	Route 1&9T, St. Paul's Avenue/Conrail Bridge (25)
075D	Route 7, Hackensack River (Wittpenn) Bridge, Contract 4
185	Route 36, Highlands Bridge over Shrewsbury River
075B	Route 7, Hackensack River (Wittpenn) Bridge, Contract 2
075A	Route 7, Hackensack River (Wittpenn) Bridge, Contract 1
075C	Route 7, Hackensack River (Wittpenn) Bridge, Contract 3
9324A	Tremley Point Access Local Roadway Improvements
NS0311	14th Street Viaduct
065C	Route 4, Bridge over Palisade Avenue, Windsor Road and CSX Railroad
224	Route 46 and Route 15, Contract No. 038960701
9239	Route 1, North of Ryders Lane to south of Milltown Road (6V)
95116	Route 22, Liberty Avenue & Conrail Bridge
9240	Route 1&9, NYS&W RR Bridge (23)
08381 (partial)	Bridge Replacement, Future Projects
Bridge Construction/Replacement/Large/South	
244	Route 52, Causeway Replacement and Somers Point Circle Elimination, Contract B
244A	Route 52, Causeway Replacement and Somers Point Circle Elimination, Contract A
98344	Route 130, Raccoon Creek Bridge Replacement and Pavement Rehabilitation
155C	Route 30/130, Collingswood/Pennsauken (Phase B), PATCO Bridge to North Park Drive
08381 (partial)	Bridge Replacement, Future Projects
Bridge Construction/Replacement/Small/North	
99362	Trenton Amtrak Bridges
9145	Route 21, Southbound Viaduct Chester Avenue (8)
98523	Clifton Avenue/Nesbitt Street Bridges over Morristown Line
NS9306	Monmouth County Bridges W7, W8, W9 over Glimmer Glass and Debbie's Creek
NS9607	West Brook Road Bridge over Wanaque Reservoir
94059	Route 206, CSX Bridge Replacement
95077	Route 183/46, NJ TRANSIT Bridge/Netcong Circle
799B	Route 3, Park Avenue Bridge Replacement
031A	Route 1, Millstone River, Bridge Replacement
9189	Route 22, Park Avenue/Bonnie Burn Road

9102	Route 31, Raritan Valley Line Bridge Replacement (8P)
NS0006	West Front Street Bridge (S-17) over Swimming River, CR 10
NS9606	Fifth Avenue Bridge (AKA Fair Lawn Avenue Bridge) over Passaic River
93259	Morris Avenue Bridge over Morristown Line
658C	Route 22, Bloy Street to Liberty Avenue
95102	Route 27, South Plainfield Branch (Lake Avenue Bridge)
658E	Route 22, Hilldale Place/Broad Street
NS9708	Landing Road Bridge Over Morristown Line, CR 631
94060	Route 206, Crusers Brook Bridge (41)
L064	Route 206, South Broad Street Bridge over Assunpink Creek
98364	Route 46, Broad Street Bridge Replacement and Operational Improvements
NS9801	Two Bridges Road Bridge and West Belt Extension
146	Route 27, Six Mile Run Bridge (3E)
94022	Route 9, Westecunk Creek Bridge (34)
00321	Schalks Station Road Bridge, CR 683
08375	Hillsborough Road and Homestead Road Bridges
NS9806	Church Street Bridge, CR 579
NS9909	Newburgh Road Bridge over Musconetcong River
NS9906	Wertsville Road Bridge (E-174) over Tributary of Back Brook, CR 602
98528	Prospect Street Bridge over Morristown Line, CR 513
NS0503	Middle Valley Road Bridge over South Branch of Raritan River
NS9907	Wertsville Road Bridge (E-166) over Back Brook, CR 602
NS0206	Berkshire Valley Road Bridge over Rockaway River
NS9810	Berkeley Avenue Bridge
NS9314	Cemetery Road Bridge over Pequest River
NS9805	White Bridge Road Bridge
NS0010	Reformatory Road Bridge (C-88) over Beaver Brook
08381 (partial)	Bridge Replacement, Future Projects
99372 (partial)	Orphan Bridge Reconstruction
Bridge Construction/Replacement/Small/South	
98516	Tuckahoe Road NJT Bridge, Cape May Branch Rail Line, CR 557, MP 14.64
242	Route 50, Tuckahoe River Bridge (2E 3B)
01356	Route 130, Craft's Creek Bridge
06367	County Route 561 over Cape May Branch
94024	Route 206, Assiscunk Creek Bridge Replacement (40)
D9902	Hanover Street Bridge over Rancocas Creek, CR 616
D9903	Smithville Road Bridge over Rancocas Creek, CR 684
08381 (partial)	Bridge Replacement, Future Projects
99372 (partial)	Orphan Bridge Reconstruction
Drainage Improvements/Large/North	
93270	Route 9, Pohatcong Lake Dam
93186	Route 7, Kearny, Drainage Improvements
96039	Route 23, Hardyston Twp., Silver Grove Road to Holland Mountain Road
02412	Route 80, North Street, Drainage Improvements
02408	Route 22, Weequahic Park, Drainage Improvements
9029A	Route 46, Van Houten Avenue to Broad Street, Drainage Improvements
02399	Route 287, Glaser's Pond, Long-term Drainage Improvements
Drainage Improvements/Large/South	

02309	Route 130, Crystal Lake Dam
93266	Route 30, Blue Anchor Dam
9377	Route 30, Cooper River Drainage Improvements
Drainage Improvements/Small/North	
98404	Route 22, Rockaway Creek, Drainage Improvements
93174	Route 17, Railroad Avenue, Drainage Improvements
X154D (partial)	Drainage Rehabilitation & Improvements
Drainage Improvements/Small/South	
X154D (partial)	Drainage Rehabilitation & Improvements
Drainage Restoration/Small/North	
X154 (partial)	Drainage Rehabilitation and Maintenance, State
Drainage Restoration/Small/South	
X154 (partial)	Drainage Rehabilitation and Maintenance, State
Interchange Improvements/Large/North	
06318F	North Avenue Corridor Improvement Project (NACI)
98545	Route 78, Garden State Parkway, Interchange 142
04389	Route 287/78, I-287/202/206 Interchange Improvements
9233B6	Route 23/80, Long-term Interchange Improvements
Interchange Improvements/Large/South	
355	Route 295/42/I-76, Direct Connection, Camden County
98543	Garden State Parkway Interchange Improvements in Cape May
Interchange Improvements/Medium/North	
98542	Route 22, Chimney Rock Road Interchange Improvements
NS0414	Garden State Parkway Interchange 91 Improvements and Burnt Tavern Road
00371A	Route 80/287, Safety Improvement
089	Route 10, Route 53 Interchange (2L 3J)
9394	Route 18, Interchange of CRs 516/527
Interchange Improvements/Medium/South	
567	Route 73/70, Marlton Circle Elimination (5)
X227A2	Route 168, I-295 Interchange Improvements
2149H	Route 49/55, Interchange Improvements at Route 55
08340	Atlantic City Expressway Interchange 17 - Route 50 (DB# 08340)
Interchange Improvements/Small/North	
93221B	Route 21 Fwy., Park Avenue Interchange, Safety Improvements
355	Route 295/42/I-76, Direct Connection, Camden County
02378 (partial)	Congestion Relief, Operational Improvements (Fast Move Program)
Interchange Improvements/Small/South	
00349	Route 42, Grenloch-Little Gloucester Road (AKA College Road) (CR 673)
02378 (partial)	Congestion Relief, Operational Improvements (Fast Move Program)
Intersection Improvements/Large/North	
93287	Route 46, Little Ferry Circle, Operational and Safety Improvements
94044	Route 206, Main Street, Chester, intersection improvements (CR 513)
93227C	Route 27, Wood Avenue
94071A	Route 72, East Road
NS9705	Bordentown Avenue/Ernston Road, Intersection Improvements, CR 615, 673
9155	Route 130, Adams Lane (16)
97080A	Route 9, Lacey Road Intersection Improvements
93227B	Route 27, Oak Tree Road/Green Street, Intersection Improvements

97115	Route 46, Main Street, Netcong
98546	Market Street/Essex Street/Rochelle Avenue
403B	Route 31/202, Flemington Circle
03317A	Route 22, Traffic Signal Improvements/Signal Coordination, Somerset County
07358	Route 12, Main Street Roundabout
04314 (partial)	Local Safety/ High Risk Rural Roads Program
06403 (partial)	Pedestrian Safety Improvement Design and Construction
Intersection Improvements/Large/South	
95043	Route 9, Bennett's Crossing, Intersection Improvements
95078B1	Route 130, Campus Drive
252B1	Route 70, Kingston Road, Intersection Improvements
252B2	Route 70, Covered Bridge Road, Intersection Improvements
93263	Route 30, Warwick Road to Jefferson Avenue
93216	Route 130, Hollywood Avenue (CR 618)
97050	Route 45, Swedesboro-Franklinville Road (CR 538)
04314 (partial)	Local Safety/ High Risk Rural Roads Program
06403 (partial)	Pedestrian Safety Improvement Design and Construction
Intersection Improvements/Small/North	
07357	Lincoln Avenue, Intersection Signal Replacements
04314 (partial)	Local Safety/ High Risk Rural Roads Program
06403 (partial)	Pedestrian Safety Improvement Design and Construction
Roadway Repair/Improvements/Any/North	
X72B (partial)	Betterments, Roadway Preservation
Roadway Repair/Improvements/Any/South	
X72B (partial)	Betterments, Roadway Preservation
Pavement Repair/Any/North	
065A	Route 4, Pedestrian Mobility Improvements, Teaneck
9147C	Route 35, Restoration, Toms River Twp. to Mantoloking (MP 4-9)
9147A	Route 35, Restoration, Berkley Twp. to Toms River Twp. (MP 0-4)
00371B	Route 80, Parsippany-Troy Hills Roadway Improvement
X51 (partial)	Pavement Preservation
X69 (partial)	Pavement Management System
Pavement Repair/Any/South	
00372	Route 295, Gloucester/Camden Rehabilitation, Route 45 to Berlin-Haddonfield Road
08324	Route 295, Rancocas-Mount Holly Road to Route 130, Pavement Repair & Resufacing
X51 (partial)	Pavement Preservation
X69 (partial)	Pavement Management System
Pavement Marking/Any/North	
D0412	Mercer County Roadway Safety Improvements
X03A (partial)	Restriping Program & Line Reflectivity Management System
X03E (partial)	Resurfacing Program
X242 (partial)	Accident Reduction Program
Pavement Marking/Any/South	
D0302	Burlington County Roadway Safety Improvements
D0410	Camden County Roadway Safety Improvements
D0401	Gloucester County Roadway Safety Improvements
X03A (partial)	Restriping Program & Line Reflectivity Management System

X03E (partial)	Resurfacing Program
X242 (partial)	Accident Reduction Program
Resurfacing/Any/North	
07307	Route 287, Vicinity of Stelton Road to Vicinity of Main Street, Resurfacing
07312	Route 130, Southbound, North of Deans Road to Vicinity of Lawrence Brook, Resurfacing
99362A	Trenton Amtrak Bridges Detour Route
06410	Route 80, Eastbound, West of Hope-Johnsonburg Road to East of Ledgewood Avenue, Resurfacing
06411	Route 80, Westbound, West of Hope-Johnsonburg Road to East of Ledgewood Avenue, Resurfacing
07308	Route 287, North of Ramapo River to the Vicinity of Franklin Avenue, Resurfacing
05398	Route 78, East of Tunnel Road to East of Beaver Brook, Resurfacing
98438	Route 287, Stelton Avenue to South of I-78, Resurfacing
07309	Route 80, Westbound, West of Route 23 Interchange to East of Squirrelwood Road, Resurfacing
07310	Route 80, Eastbound, West of Madison Avenue to Polify Road, Resurfacing
07311	Route 80, Westbound, East of South Beverwyck Road to West of the Route 23 Interchange, Resurfacing
99327A (partial)	Resurfacing, Federal
Resurfacing/Any/South	
06414	Route 295, Northbound, South of Route 130 to South of Pedricktown-Woodstown Road, Resurfacing
99327A (partial)	Resurfacing, Federal
Road Construction & Widening/Large/North	
93146	Route 1, Widening
8417	Route 1, Bottleneck Relief
103A1	Route 17, North of Moonachie Road to Garden State Parkway
779	Route 206 Bypass, Belle Mead-Griggstown Road to Old Somerville Road (14A 15A)
00373B	Route 78, Union/Essex Rehabilitation, Contract B
Road Construction & Widening/Small/North	
115B	Route 18 Ext., Hoes Lane Extension to I-287 (3A)
04326B	Route 120, Paterson Plank Road from Route 17 to Murray Hill Boulevard
93281	Route 46, Main Street, Lodi
95115	Route 9, Green Street Interchange, Woodbridge
177A	Route 35, Matawan Creek to Laurence Harbor Parkway
NS0002	County Route 515, Vernon Township, Phases II, III, IV
9147D	Route 35, Restoration, Mantoloking to Point Pleasant (MP 9 - 12.5)
03326	Route 295, Route 130 to Route 29/I-195 Interchange, Resurfacing
NS9812	McClellan Street Underpass
97071	Route 9, Craig Road/East Freehold Road, Intersection Improvements
9028	Route 166, Toms River Twp., Highland Parkway to Old Freehold Road, operational improvements
97079	Route 27, Renaissance 2000, Bennetts Lane to Somerset Street
9111B	Route 46, Hollywood Avenue
HP01002	Halls Mill Road
9137A	Route 78, Edna Mahan Frontage Road

L070	Sussex Turnpike, CR 617
95062	Route 35/36, Eatontown
9233B3	Route 46, Passaic Avenue to Willowbrook Mall
HP01009	School Road East
Road Construction & Widening/Small/South	
94068	Route 73, Fox Meadow Road/Fellowship Road
D9912	South Pemberton Road, CR 530
D0503	Egg Harbor Road, Hurffville-Cross Keys Road to Hurffville-Grenloch Road, CR 630
S0009	Sea Isle Boulevard, Section II, Garden State Parkway to Ludlams Thorofare, CR 625
9351	Route 9, Breakwater Road Extension (CR 613)

APPENDIX V

This appendix is divided into three parts. The first part describes the installation procedure and the necessary files for the program. The second and third parts help the user become familiar with all the modules in the full cost estimation tool and the impacts of the policy implications sections of the program and how to use them.

APPENDIX V, PART I – INSTALLATION, INITIALIZATION AND PRELIMINARIES

Required Software

ArcGIS Desktop 9.2 or higher,
TP+/Viper
Or alternately, CUBE

Installation

The installation process can be accomplished automatically or manually. In order to install the software automatically, the user needs to run the setup program located in the installation CD.

If the installation CD is unavailable or inaccessible the software can be installed manually via following the steps below.

Copy the folder "NJCost" under C Drive located in the installation CD.
Open the file "NJCost.exe" to start the NJCost program.

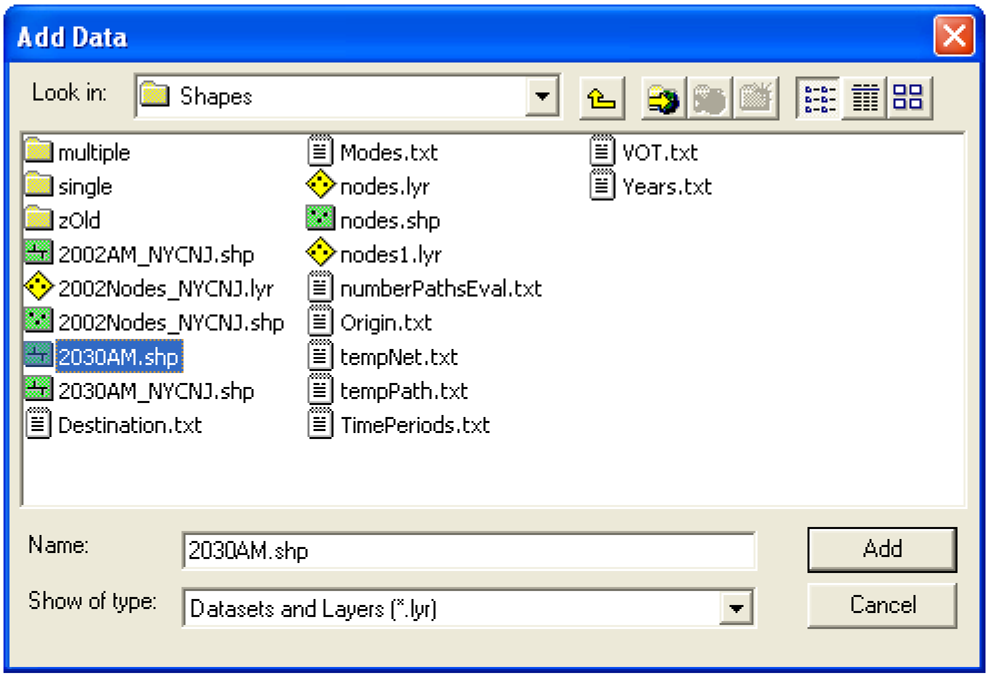
Network file Requirements

All the network files that are used for analysis using this tool are based on the output of the NJTRME. This output, which consists of forecasted traffic flows, travel times, etc., is called a *loaded network*. Once the user runs the NJTRME network for any new scenario and obtains the loaded network, the NJCost tool can use the output of the NJTRME runs, i.e. the loaded network, and provide the user with various network related information as listed above.

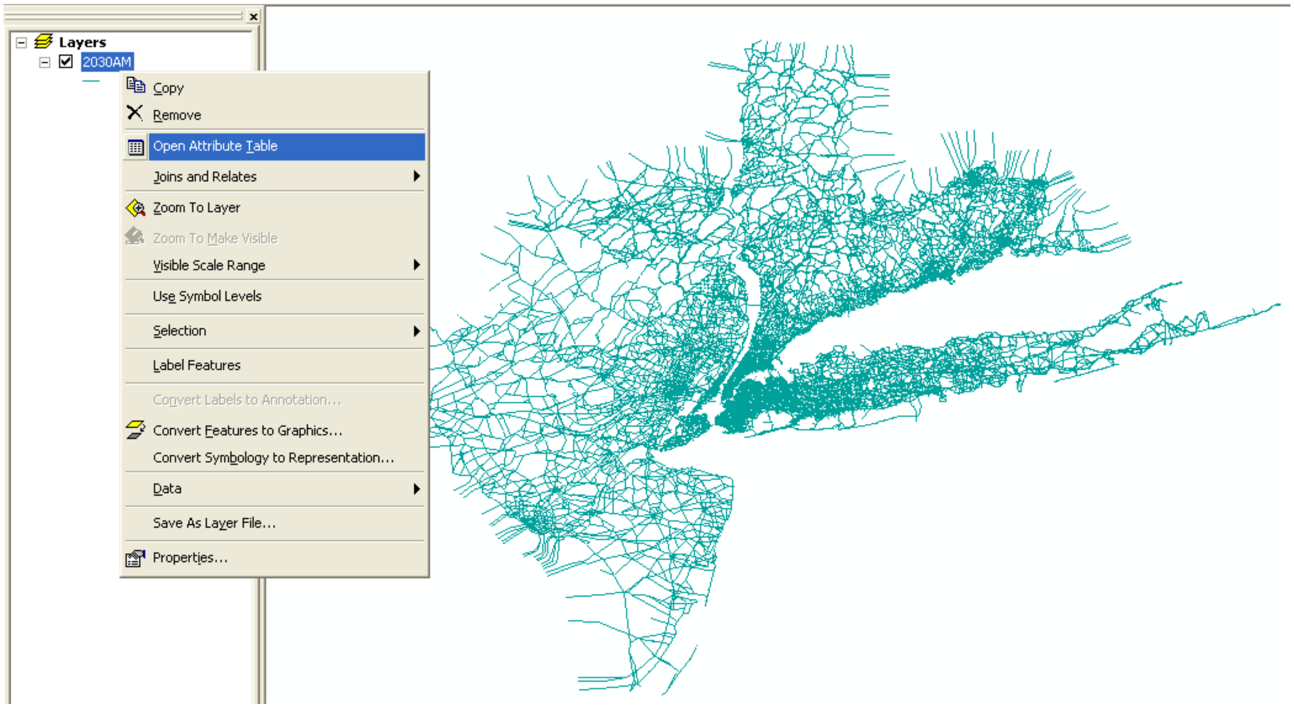
The following are some minor adjustments that are necessary for the input shape files to work with the NJCOST program:

1. Open ArcMap (ArcGIS Desktop)
2. Right-click on the “Layers” option located on the left side of the ArcMap window and select “Add Data”

3. Select the shape file of the loaded network



4. Right-click on the shape file and click on “Open Attribute Table”



5. The list of all the fields is shown in

6. Table 56. The sequence in which the fields occur should the same as shown. The width of the fields should also be the same as shown. The width can be adjusted by opening the dbf file in the exported shape file in Microsoft Excel. Right-click on each of the column and select “Column Width”. Enter the appropriate width from Table 56.

Table 56. Field Names and Column Widths in the Network Shape File

Field Name	Column Width
FID	Default
Shape	Default
A	19
B	19
DISTANCE	19
CAPACITY	19
FT	19
AT	19
LANESAM	19
LANESPM	19
LANESOP	19
LINKTYPE	19
TERTYPE	19
NLTLANE	19
NRTLANE	19
LWIDTH	19
LSHOULD	19
TCD	19
NSIG	19
SIGCYC	19
SIGCOR	19
GC	19
ALCOEFF	19
BTCOEFF	19
JFACT	19
ACCPT	19
FIXCAP	19
FIXTOLL	19
FIXTIME	19
TOLL	19
MCTOLL	19
TOLLAPC	19
TOLLCLASS	19
PARK	19
QUEFLG	19
ZDELAY	19

ADDDELAY	19
SPEED	19
Field Name	Column Width
T0	19
TCODEAM	19
TCODEOP	19
TADDAM	19
TADDOP	19
TSCALEAM	19
TSCALEOP	19
NAME	26
SRI	10
BEGIN_MP	19
END_MP	19
RT_LTR	33
COUNTY	5
COUNT2	19
YEARCT2	19
COUNT3	19
YEARCT3	19
REFZONE	19
COUNT1	19
YEARCT1	19
JAFACT	19
TOLLFACAM	19
TOLLFACPM	19
TOLLFACMD	19
TOLLFACNT	19
PROJN	1
CODESTATUS	7
SCRLINE	19
TR	19
SOVTOLL	19
HOVTOLL	19
TRKTOLL	19
V_1	19
TIME_1	19
VC_1	19
CSPD_1	19
VDT_1	19
VHT_1	19

V1_1	19
V2_1	19
Field Name	Column Width
V3_1	19
V4_1	19
V5_1	19
V6_1	19
V7_1	19
V8_1	19
V9_1	19
VT_1	19
V1T_1	19
V2T_1	19
V3T_1	19
V4T_1	19
V5T_1	19
V6T_1	19
V7T_1	19
V8T_1	19
V9T_1	19
V_2	19
TIME_2	19
VC_2	19
CSPD_2	19
VDT_2	19
VHT_2	19
V1_2	19
V2_2	19
V3_2	19
V4_2	19
V5_2	19
V6_2	19
V7_2	19
V8_2	19
V9_2	19
VT_2	19
V1T_2	19
V2T_2	19
V3T_2	19
V4T_2	19
V5T_2	19

V6T_2	19
Field Name	Column Width
V7T_2	19
V8T_2	19
V9T_2	19

Preliminaries

The program can be started by opening the executable, "NJCost.exe" located in "C:\NJCost\Exe" directory. The start screen is shown in

Figure 10.

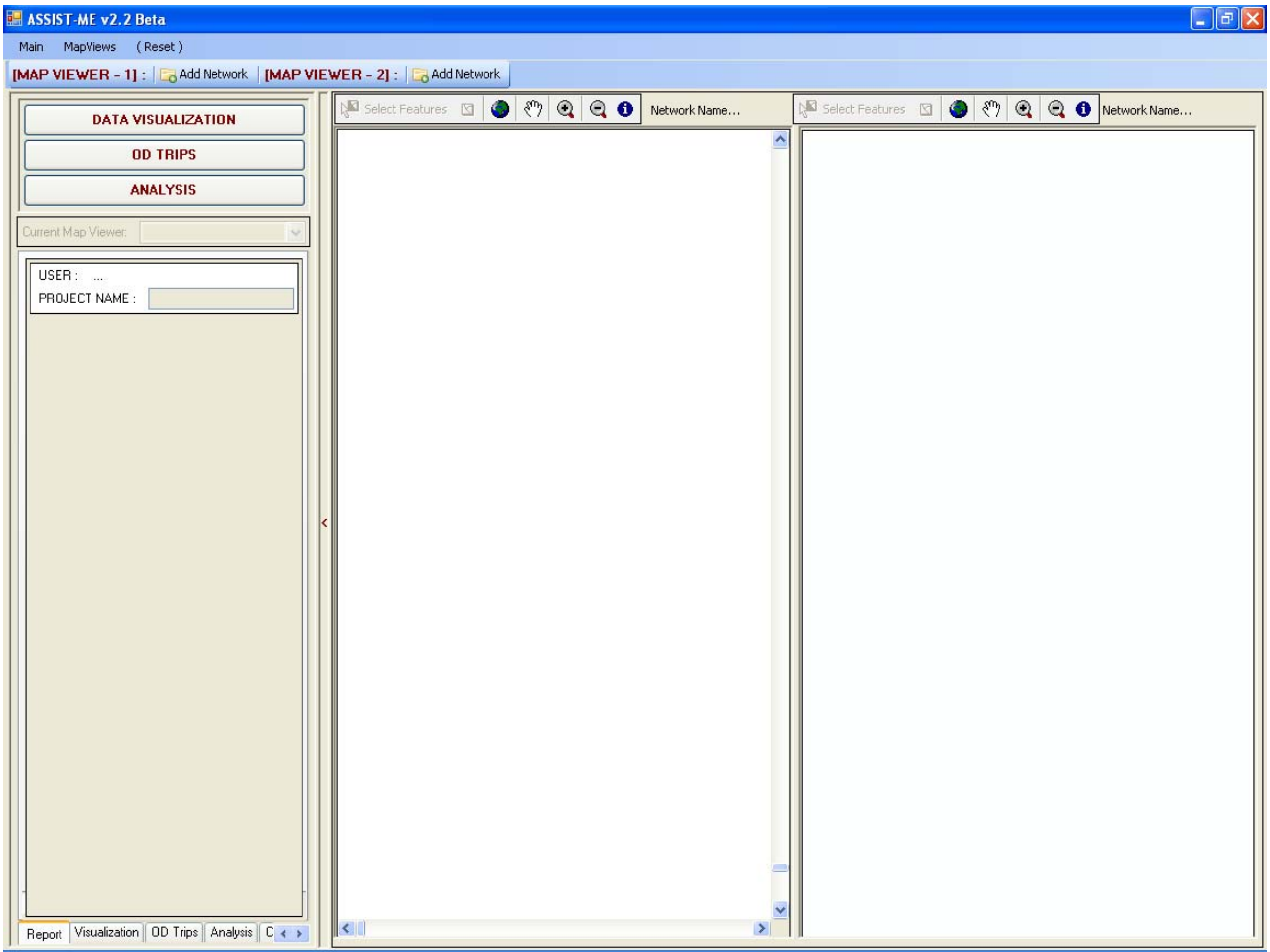
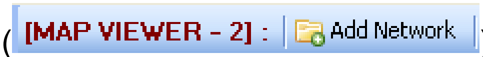


Figure 10. Start Window

In order to analyze a particular loaded network, for instance a loaded network from the BPM, the corresponding set of shape files are necessary. These files, which include a minimum of three files namely, .shp, .dbf and .shx files, are to be included in the directory, "C:\NJCost\Shapes". The format and data in the shape files required for the analysis is described in the **Network / Input file Requirements** section. As it can be noticed from

Figure 10, the program window has two map viewing windows. The controls for Map-Viewer 1 are available on the toolbar located on the *top*, named Map Viewer-1

(
). Similarly, the controls for Map Viewer-2 are located on a toolbar named Map Viewer-2 located beside Map Viewer-1

(
). In order to add a network to Map Viewer-1, click on the "Add Network" button. Then select the appropriate .dbf file from the "Select Network" window as shown in Figure 11.

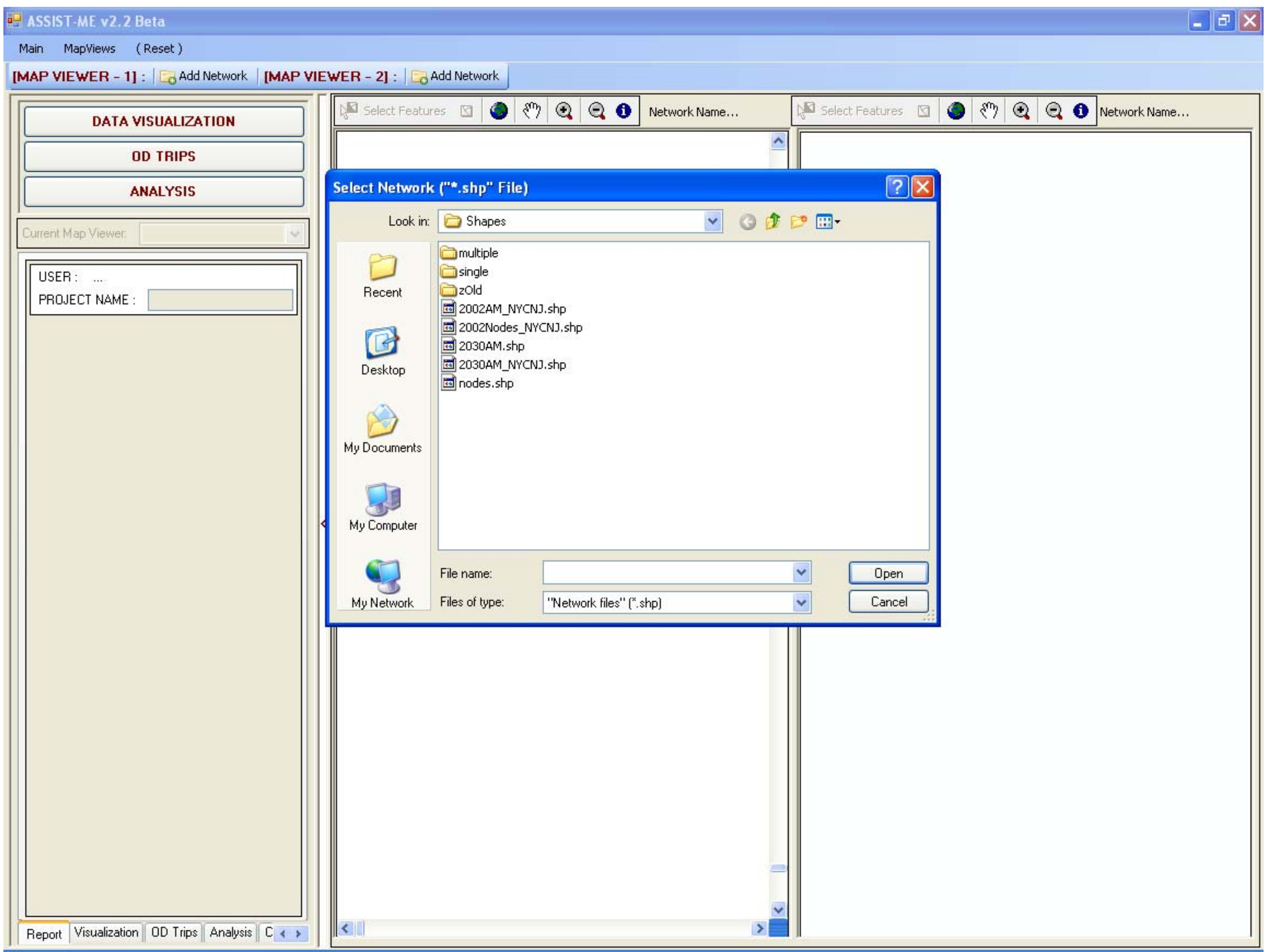


Figure 11. Select Network

After the network is loaded, both the network layer and the nodes layer are visible (as shown in

Figure 12). In the nodes layer, it is to be noted that only the nodes which are origins and destinations (i.e. with value of the ID field less than 5000) are prominently visible.

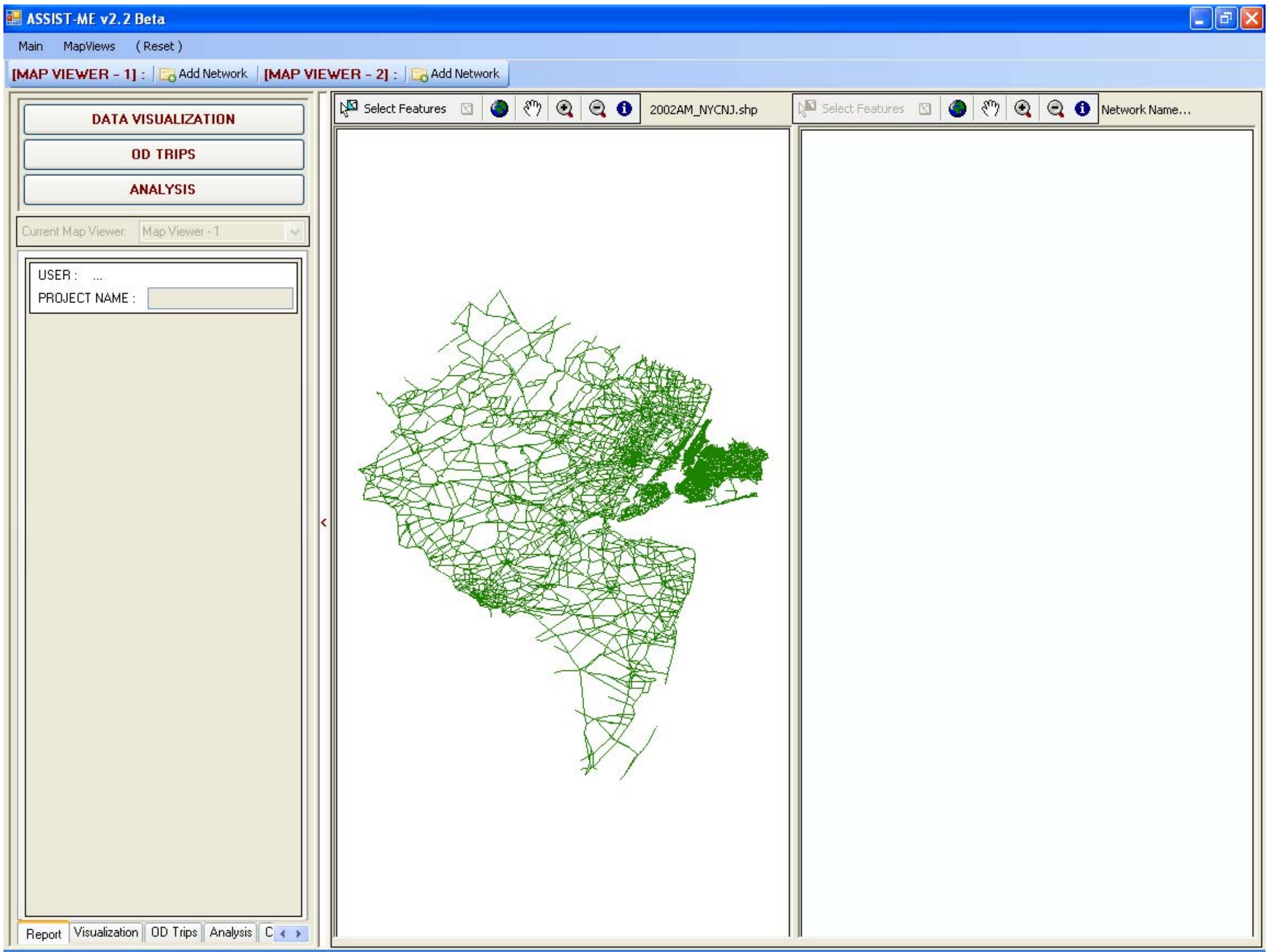
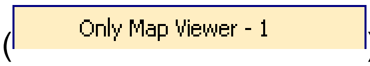


Figure 12. Program Window after Network Addition

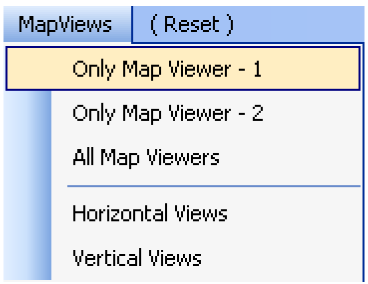
Controls

After the network has been added to either of the map viewers, there are a set of controls using which the views can be changed.

View Controls

The view controls are used to adjust the viewing area of the program window. In order to see only Map Viewer-1 (for instance in the case where the analysis is being performed only on a single network, or for the want of more clear view of a single map), click on the “Map Views” label on the top-most toolbar and select “Only Map Viewer-1” button (

).



The view changes as shown in Figure

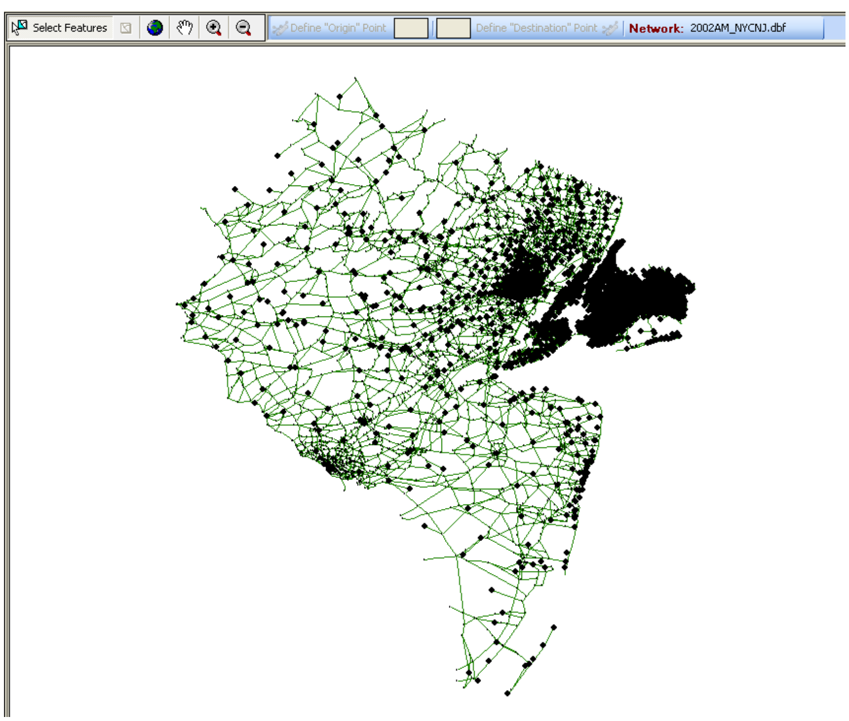


Figure 13. Map Views Menu

By selecting the “Horizontal Views” button (

), the default vertical views of the two Map Viewers are switched to horizontal views, with Map Viewer-1 on the top and Map Viewer-2 at the bottom, as shown in
Figure 14. This view can be switched back to the vertical view by selecting the “Vertical Views” button.

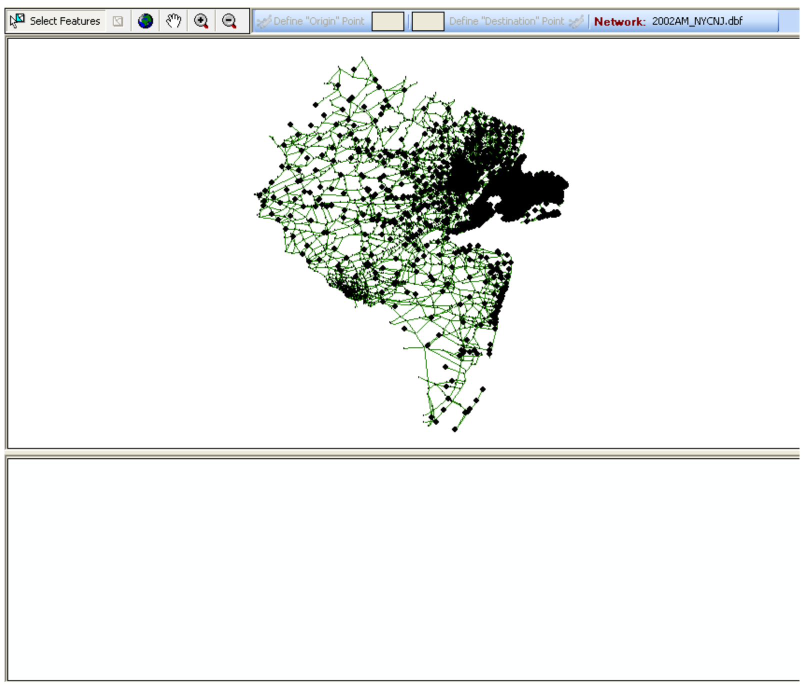
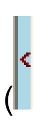


Figure 14. Map View - Horizontal Views

The panel on the left side of the program window consisting of all the analysis features can also be hidden to give a bigger view of the map viewers (as shown in

Figure 15). This can be performed by clicking on the arrow “<” button () located on the space separating the analysis panel from the Map Viewers. The analysis panel can be shown back by clicking on the arrow “>” button on the left side.

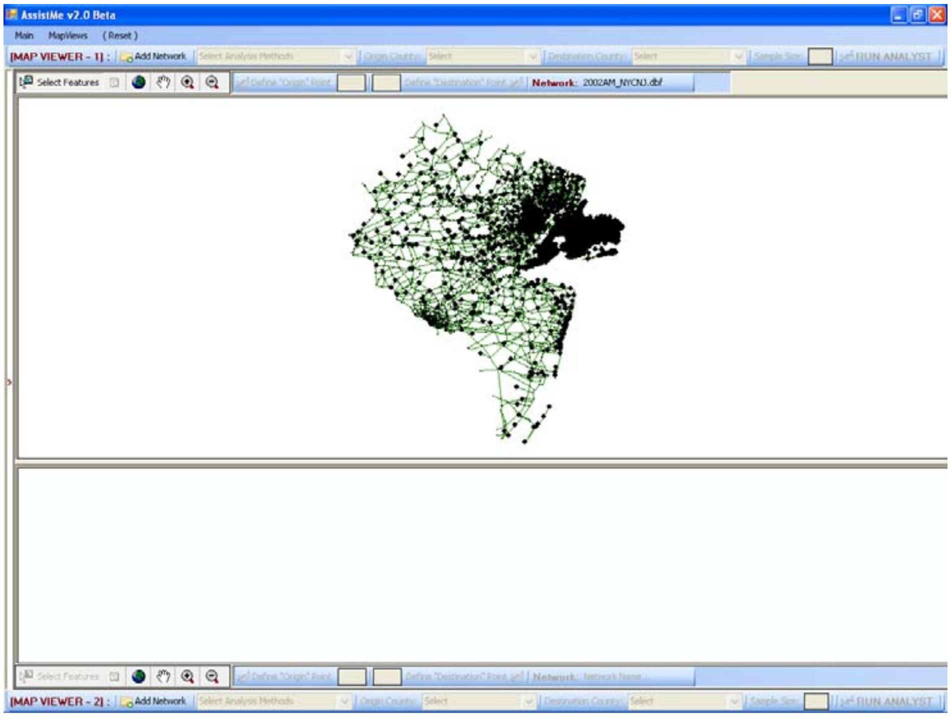


Figure 15. Full Map View - Hidden Panel

<u>Map Controls</u>

In order to navigate and operate on the map in the Map Viewer, there are various controls:

1. Select features (

) – This control is use to select any node(s) or link(s) from the map
2. Clear Selected features() – This feature is use to clear any selected features from the map
3. Pan () – This tool is use to pan or move the map around under the same magnification (zoom)
4. Zoom In () – This control is used to increase the magnification of the map i.e. zoom *into* the map
5. Zoom Out ( ) – This control is used to decrease the magnification of the map i.e. zoom *out of* the map

6. Full Extent ( ) – This tool is used to change the magnification of the map such that all the features in the map are visible in the same viewing window
7. Identify ( ) – This tool is used to get the information about all the attributes for the features in the map.

The map controls for each Map Viewer are located above the corresponding Map Viewer.

APPENDIX V, PART II: FULL COST ESTIMATION

This section intends to make the user familiar with full cost estimation at different level of details as categorized below:

a. Manual Selection: Single O-D pair or Multiple O-D pair located in a Travel Analysis Zone (TAZ)
b. County-to-County: Full cost estimation between different Counties
c. Intra-County: Full cost estimation within a particular County
d. Network-wide: Network-wide Full cost estimation considering the entire network at hand

The travel times on a loaded network can be found between various origins and destinations (OD). These origins and destinations can be chosen manually or randomly from a given set of origins and/or destinations with a county. This module can be accessed by clicking on the "Analysis" button (

) on the panel on the left side of the program window.

After the analysis option is chosen, the other sub-options in the Analysis Panel (as shown in
Figure 16) are activated.

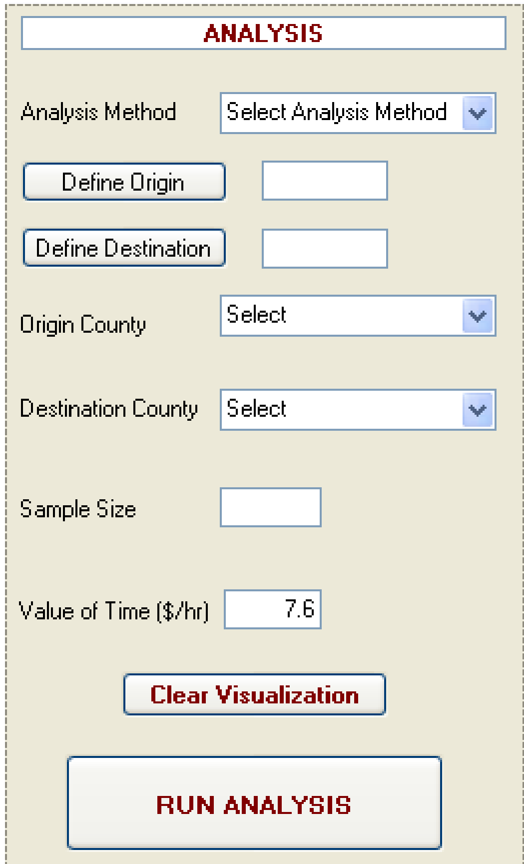
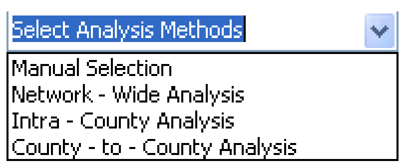


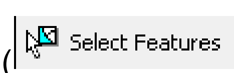
Figure 16. Analysis Panel

From the panel, the OD selection has to be chosen from the drop-down list "Select Analysis Method" 

.

Each of the selection methods is described below.

Manual Selection

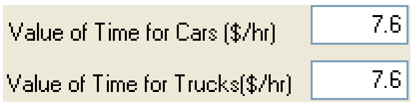
In this method, the OD's are selected using the "Select Features" button. (

) from the map. After selecting the origin or origins, click on the "Define Origin" button (

) on the Analysis panel. Similarly after selecting the destination(s) click on the "Define Destination" button (

) on the Analysis panel. In case there are multiple origins and/or destinations selected, the sample size of the set of shortest paths to be calculated is to be entered in the “Sample Size” box (

).Enter the Value-of-Time for cars and trucks in the corresponding boxes



. This value is used in the calculations for estimating the cost of congestion in the network. The default value is $7.6/hour.

Click the “Analysis” (

) button on the “Analysis” tab to start the calculation of shortest paths. After the calculation is completed, the progress of which is shown by the progress bar on the map, the output is similar to that shown in

Figure 17. By clicking on the “REPORT” button, the results of the shortest path(s) can be visualized. Each path can be selected and visualized in the map by clicking on the row of the report generated *or* by choosing the path from the drop-down list as shown in

Figure 17.

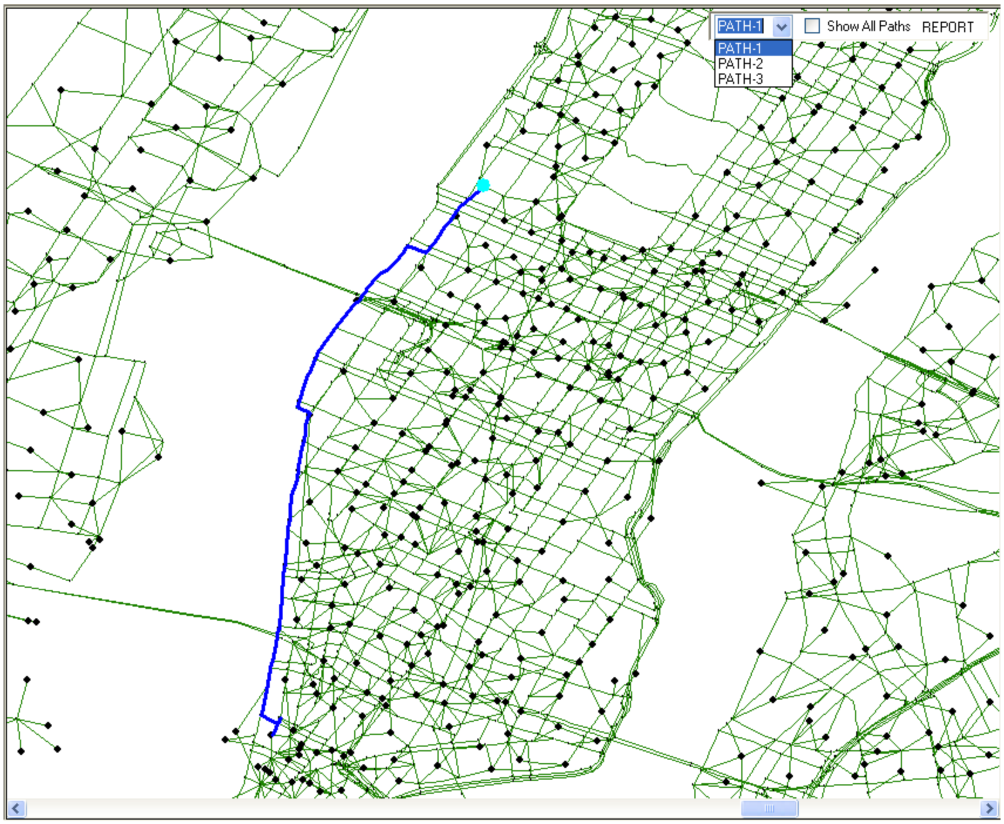


Figure 17. Single Path Visualization

In order to visualize all the paths at the same time, the “Show All Paths” check box is to be checked (as shown in Figure 18).

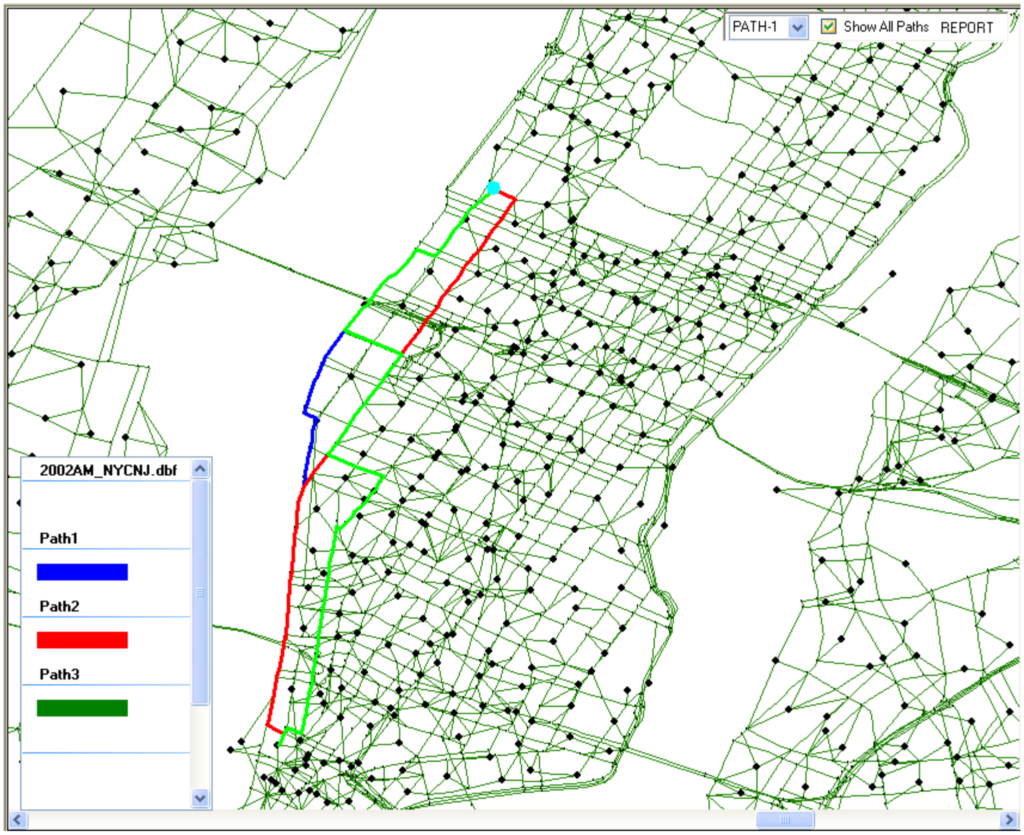


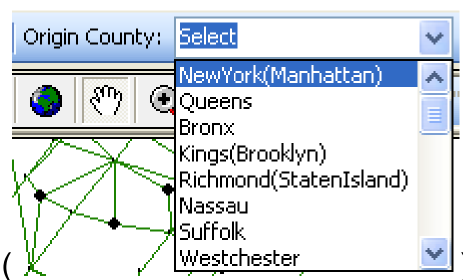
Figure 18. Multiple Path Visualization

The output in the report generated consists of the travel time of the paths, the VMT on the path and various costs involved in traveling along the path. This output can be saved or printed.

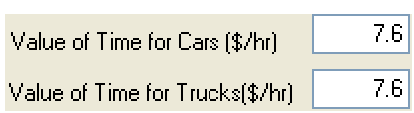
The software automatically saves total, marginal and average costs, path information of each path (each k-shortest path for single O-D selection, and shortest path for multiple O-D selection case), and a final summary file of the estimation process. The final summary file includes the time that the cost estimation is completed, name of the network, O-D selection type, and total, marginal and average cost tables of the corresponding network and O-D pairs. The corresponding text files can be found under (1) **single O-D pair**: NJCost → single → NetworkName → OriginNo_DestinationNo (2) **multiple O-D pair**: NJCost → multiple → NetworkName→ OriginZoneNo_DestinationZoneNo. The cost information is saved under names TotalCosts, MarginalCosts and AverageCosts for total, marginal and average cost results, respectively. The path information is saved under the same location and named as 1, 2 …These text files include the shortest path information of each origin destination pair for the multiple O-D selection case, and each k-shortest path information for the selected O-D pair (maximum of 7 different paths). The final summary file is saved under name final_NetworkName. For each run the output is also saved in folders under the 'finalOutput' folder. These folders are named in increasing order of the run number. Any missing folder in the sequence of run numbers is recreated as the latest folders. So, the final output of the latest run is in the last modified folder.

Intra-County Selection

If full cost analysis needs to be performed for OD's within a single county, then the "Intra-county Analysis" option should be chosen. After the "Intra-county Analysis" option is selected from the "Select Analysis Method" drop-down list, the origin county drop-down list is activated. The origin county

(

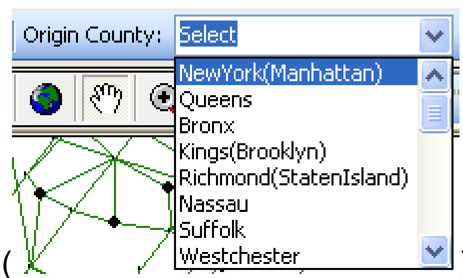
) should be selected from the list and the sample size (as described in the previous section) is to be entered in the "Sample Size" text box (

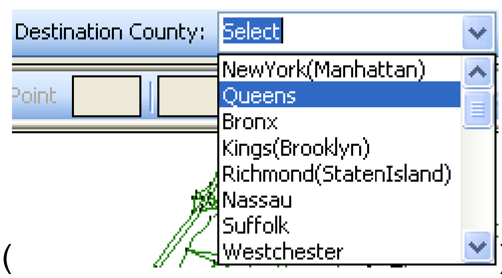
).Enter the Value-of-Time for cars and trucks in the corresponding boxes 

. This value is used in the calculations for estimating the cost of congestion in the network. The default value is $7.6/hour. The “Analysis” button (

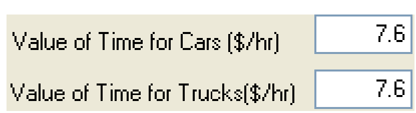
) is clicked to start the calculation of shortest paths between the OD’s in the county chosen.

County-to-County Selection

If full cost analysis needs to be performed for origins located within a county and destinations located within another county, then the “County-to-County Analysis” option should be chosen. After the “County-to-County Analysis” option is selected from the “Select Analysis Method” drop-down list, the origin county and the destination county drop-down lists are activated. The origin county (

) should be selected from the list, the destination county (

) should be selected from the list and the sample size (as described in the previous section) is to be entered in the “Sample Size” text box (

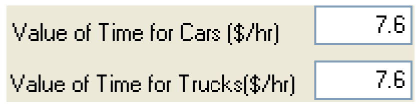
).Enter the Value-of-Time for cars and trucks in the corresponding boxes 

. This value is used in the calculations for estimating the cost of congestion in the network. The default value is $7.6/hour. The “Analysis” button (

) is clicked to start the calculation of shortest paths between the OD’s in the county chosen.

Network-wide Selection

To determine the general / overall behavior of the network, the "Network-wide Selection" option should be selected. If the "Network-wide Selection" option is selected the sample size textbox is activated. The sample size is entered in the "Sample Size" textbox (

). Enter the Value-of-Time for cars and trucks in the corresponding boxes 

. This value is used in the calculations for estimating the cost of congestion in the network. The default value is $7.6/hour. The "Analysis" button should be clicked (

) to start the calculation of shortest paths between the OD's in the network.

In order to visualize the path(s) using the Intra-county, County-to-County or Network-wide selection, the "Report" button located in the right-top portion of the Map Viewer should be clicked. A table showing various parameters of each path is displayed. To visualize "Path 1", the *row* corresponding to Path 1 should be selected as shown in
Figure 29 by clicking on the column to the left of Path 1. In the report displayed, the following is the list of output shown for each path:

1. Operating Cost (OP. COST)
2. Congestion Cost (CG. COST)
3. Accident Cost (AC. COST)
4. Air Pollution Cost (AP. COST)
5. Noise Cost (NS. COST)
6. Maintenance Cost (MN. COST)
7. Construction Cost (CO. COST)
8. Land Acquisition Cost (LA. COST)

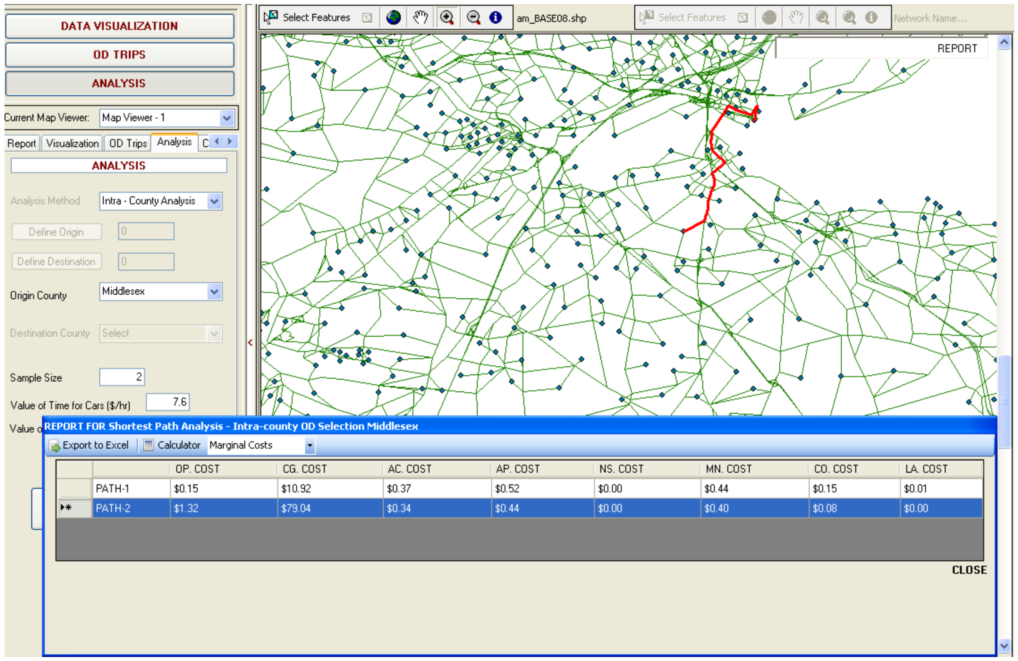
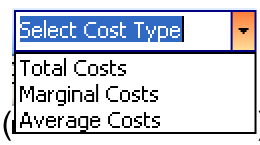


Figure 29. Visualization of Path from Report

There are three types of costs calculated, namely, Total Costs, Marginal and Average Costs for each set of paths. The cost type can be chosen from the "Select Cost Type" drop down list (

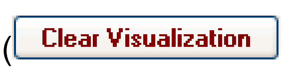
). The Total Cost, Marginal Cost and Average Cost for all the cost categories specified above are shown respectively in the table. This report can be saved to an Excel worksheet by clicking on "Export to Excel" button (

) located on the toolbar on the top of the report.

Clear Visualization

The data visualization performed on each Map Viewer can be cleared by:

Select the Map Viewer in which the visualization has to be cleared

Click the clear visualization button (

).

APPENDIX V, PART III: IMPACTS ANALYSIS OF POLICY IMPLICATIONS

This section intends to make the user familiar with estimation of the impacts of policy implications on the cost of different trips at different level of details as categorized below:

a. Manual Selection - Single O-D pair or Multiple O-D pair located in a Travel Analysis Zone (TAZ)
b. County-to-County: Full cost estimation between different Counties
c. Intra-County: Full cost estimation within a particular County
d. Network-wide: Network-wide impact analysis considering the entire network at hand

In order to perform and compare the shortest-path analysis for two different networks, the two networks in question should be added to Map Viewer-1 and Map Viewer-2.

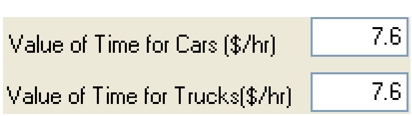
<u>Impact Analysis Manual Selection</u>

In this method the OD's are selected using the "Select Features" button (

) from the map. After selecting the origin or origins, click on the "Define Origin" button (

) on the Analysis panel. Similarly after selecting the destination(s) click on the "Define Destination" button (

) on the Analysis panel. In case there are multiple origins and/or destinations selected, the sample size of the set of shortest paths to be calculated is to be entered in the "Sample Size" box (

).Enter the Value-of-Time for cars and trucks in the corresponding boxes 

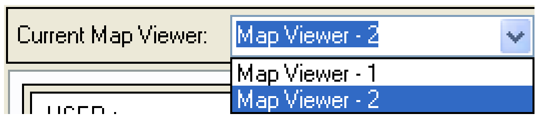
. This value is used in the calculations for estimating the cost of congestion in the network. The default value is $7.6/hour.

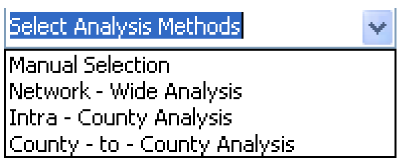
Click the “Analysis” (

) button on the “Analysis” tab to start the calculation of shortest paths.

To perform the same analysis in Map Viewer-2,

1. Choose the “Current Map Viewer” to be Map Viewer-2

2. Choose Analysis Method from the drop-down list “Select Analysis Method” 

on the Map Viewer-2 toolbar at the bottom of the program window.
3. OD’s selected using *manual selection* can be *transferred* from Map Viewer-1 by *double-clicking in the origin textbox*.
4. Click the “Analysis” (

) button on the “Analysis” tab to start the calculation of shortest paths for the network in Map Viewer-2

After the calculation is completed, the progress of which is shown by the progress bar on the map, the output is similar to that shown in Figure20. By clicking on the “REPORT” button, the results of the shortest path(s) can be visualized. Each path can be selected and visualized in the map by clicking on the row of the report generated *or* by choosing the path from the drop-down list as shown in Figure20.

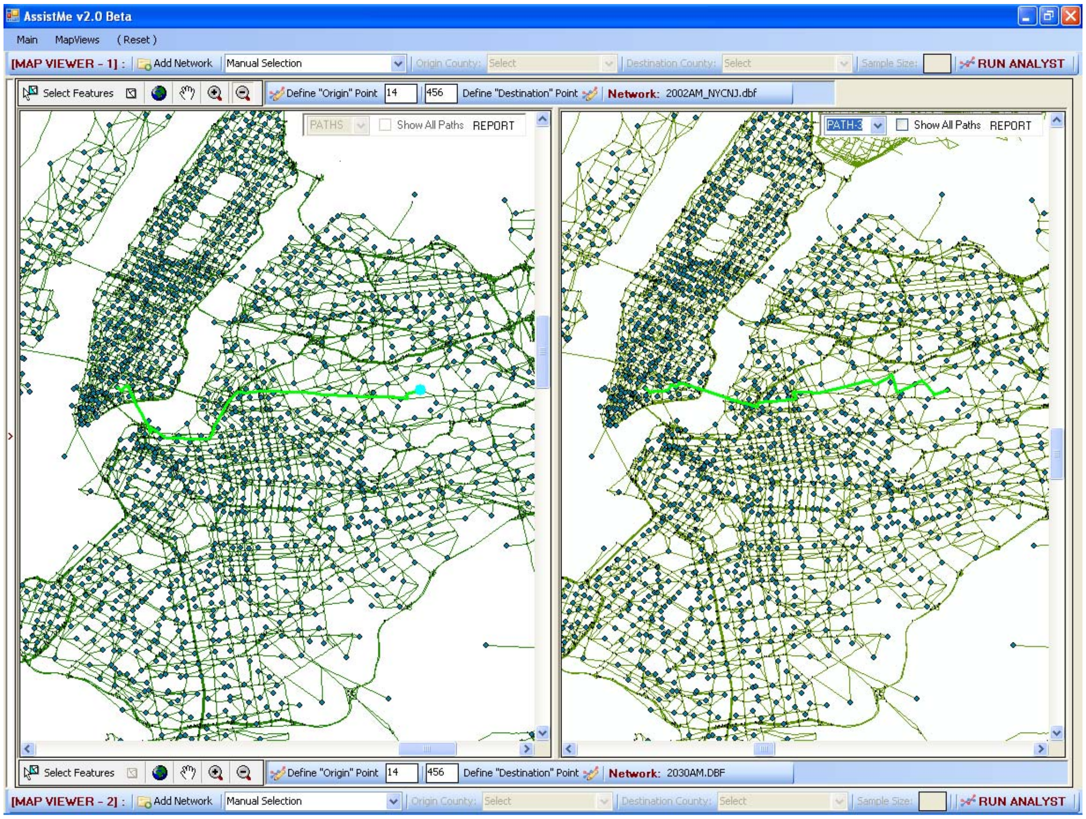
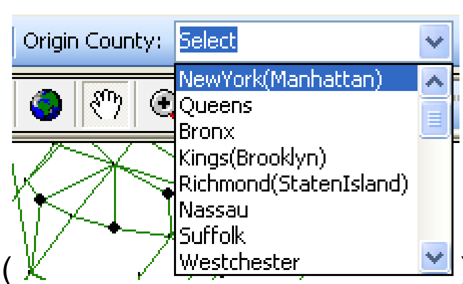


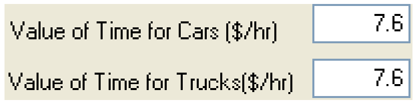
Figure 20. Comparison of Shortest-paths from Two Different Networks

Impact Analysis Intra-County Selection

If the travel time analysis needs to be performed for OD's within a single county, then the "Intra-county Analysis" option should be chosen. After the "Intra-county Analysis" option is selected from the "Select Analysis Method" drop-down list, the origin county drop-down list is activated. The origin county

(

) should be selected from the list and the sample size (as described in the previous section) is to be entered in the "Sample Size" text box (

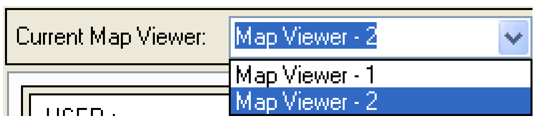
).Enter the Value-of-Time for cars and trucks in the corresponding boxes 

. This value is used in the calculations for estimating the cost of congestion in the network. The default value is $7.6/hour. The "Analysis" button (

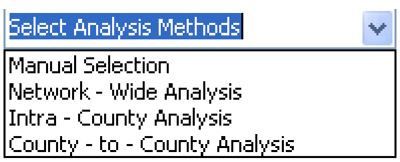
) is clicked to start the calculation of shortest paths between the OD's in the county chosen

To perform the same analysis in Map Viewer-2, the following procedure should be followed:

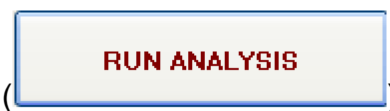
1. Choose the "Current Map Viewer" to be Map Viewer-2



2. Choose Analysis Method from the drop-down list "Select Analysis Method"



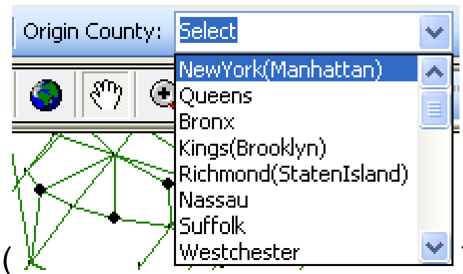
on the Map Viewer-2 toolbar at the bottom of the program window.

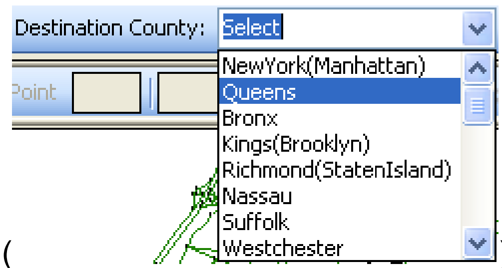
3. Follow the same procedure mentioned above for the selection of counties, sample size and value of time.
4. Click the "Analysis" (

) button on the "Analysis" tab to start the calculation of shortest paths for the network in Map Viewer-2

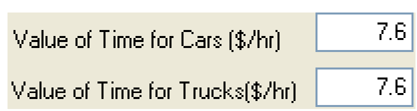
After the calculation is completed, the progress of which is shown by the progress bar on the map, the output is similar to that shown in Figure20. By clicking on the "REPORT" button, the results of the shortest path(s) can be visualized. Each path can be selected and visualized in the map by clicking on the row of the report generated *or* by choosing the path from the drop-down list as shown in Figure20.

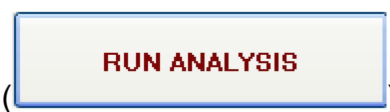
Impact Analysis County-to-County Selection

If the travel time analysis needs to be performed for origins located within a county and destinations located within another county, then the "County-to-County Analysis" option should be chosen. After the "County-to-County Analysis" option is selected from the "Select Analysis Method" drop-down list, the origin county and the destination county drop-down lists are activated. The origin county (

) should be selected from the list, the destination county (

) should be selected from the list and the sample size (as described in the previous section) is to be entered in the "Sample Size" text box (

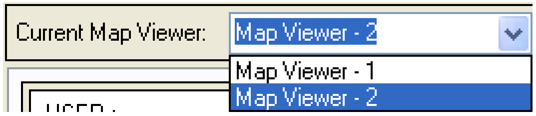
).Enter the Value-of-Time for cars and trucks in the corresponding boxes 

. This value is used in the calculations for estimating the cost of congestion in the network. The default value is $7.6/hour. The "Analysis" button (

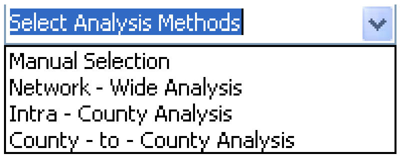
) is clicked to start the calculation of shortest paths between the OD's in the county chosen

To perform the same analysis in Map Viewer-2, the following procedure should be followed:

1. Choose the “Current Map Viewer” to be Map Viewer-2



2. Choose Analysis Method from the drop-down list “Select Analysis Method”



on the Map Viewer-2 toolbar at the bottom of the program window.

3. Follow the same procedure mentioned above for the selection of counties, sample size and value of time.

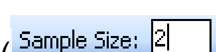
4. Click the “Analysis” (

) button on the “Analysis” tab to start the calculation of shortest paths for the network in Map Viewer-2

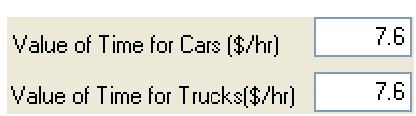
After the calculation is completed, the progress of which is shown by the progress bar on the map, the output is similar to that shown in Figure20. By clicking on the “REPORT” button, the results of the shortest path(s) can be visualized. Each path can be selected and visualized in the map by clicking on the row of the report generated *or* by choosing the path from the drop-down list as shown in Figure20.

<u>Impact Analysis Network-wide Selection</u>

To determine the general / overall behavior of the network, the “Network-wide Selection” option should be selected. If the “Network-wide Selection” option is selected the sample size textbox is activated. The sample size is entered in the “Sample Size” textbox (



).Enter the Value-of-Time for cars and trucks in the corresponding boxes



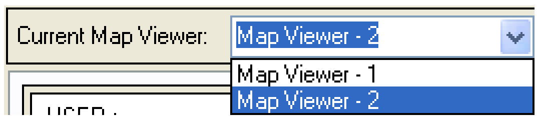
. This value is

used in the calculations for estimating the cost of congestion in the network. The default value is $7.6/hour. The “Analysis” button should be clicked (

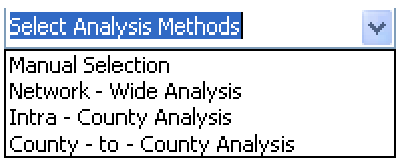
) to start the calculation of shortest paths between the OD’s in the network.

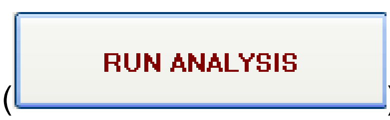
To perform the same analysis in Map Viewer-2, the following procedure should be followed:

1. Choose the “Current Map Viewer” to be Map Viewer-2

2. Choose Analysis Method from the drop-down list “Select Analysis Method”

   on the Map Viewer-2 toolbar at the bottom of the program window.
3. Follow the same procedure mentioned above for the selection of sample size and value of time.
4. Click the “Analysis” (

) button on the “Analysis” tab to start the calculation of shortest paths for the network in Map Viewer-2

After the calculation is completed, the progress of which is shown by the progress bar on the map, the output is similar to that shown in Figure 20. By clicking on the “REPORT” button, the results of the shortest path(s) can be visualized. Each path can be selected and visualized in the map by clicking on the row of the report generated *or* by choosing the path from the drop-down list as shown in Figure 20.