Research at NCTIP
National Center for Transportation and Industrial Productivity

New Jersey Department of Transportation
Sponsored Research Projects

November 2000
About NJIT

The New Jersey Institute of Technology’s (NJIT) history spans from the Industrial Revolution to the Information Age. Newark was a factory town when the tuition-free evening school was founded in 1881 to support local industries. The first 90 students — including machinists, draftsmen, carpenters, printers, electricians and clerks — studied algebra, geometry, trigonometry, chemistry, physics and drawing. The range of courses offered is testimony to the fact that, from the beginning, NJIT’s programs have provided a broad-based foundation to prepare students for success in the workplace. From those early days, science and technology have been the engines fueling the university’s development.

Today, continuing a fourfold mission of instruction, research, economic development and public service, NJIT is among the leading comprehensive technological universities in the nation. With more than 8,800 students, NJIT is the largest technological university in the New York metropolitan region. The university has state-of-the-art facilities with more than 2,000,000 sq. ft. of space located on a 45-acre campus in Newark, a Technology and Engineering Center at our 125-acre campus in Mount Laurel shared with Burlington County College, and a solar observatory in Big Bear, California. With robust Extension and Distance Education programs, NJIT’s degree and non-degree programs are available throughout the state and world.

About NCTIP

The National Center for Transportation and Industrial Productivity (NCTIP) at NJIT is one of four national centers designated by the U.S. Congress under the Intermodal Surface Transportation Efficiency Act (ISTEA) legislation of 1991. The Center was reauthorized in 1998 under the Transportation Equity Act for the 21st Century (TEA-21).

Chartered under the U.S. Department of Transportation's (USDOT) University Transportation Centers Program, NCTIP supports USDOT’s strategic goals of mobility and economic growth, as well as National Transportation Science and Technology Strategy’s objectives of enhancing goods and freight movement at domestic and international gateways; increasing global competitiveness; optimizing intermodal passenger and freight transportation systems; and modeling tools for transportation planning, design and operations. NCTIP is a resource for and works closely with the New Jersey Department of Transportation, which provides funding for mutually acceptable projects.

NCTIP’s mission is to increase efficiency and productivity in private and public sector entities and industries through transportation improvements. This is accomplished by undertaking high quality, multidisciplinary, innovative education; peer-reviewed research activities; and technology transfer.

Aerial Photography by Mike Peters 973-785-7885

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USDOT

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NJDOT

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NOTICE

NJIT, the New Jersey Department of Transportation, and the Federal Highway Administration do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.
Introductions
Dr. Saul Fenster, President
New Jersey Institute of Technology

Honorable James Weinstein, Commissioner
New Jersey Department of Transportation

William Hoffman, Director of Research and Technology
New Jersey Department of Transportation

Dr. Lazar N. Spasovic, Director
National Center for Transportation and Industrial Productivity
New Jersey Institute of Technology

Research Articles
The Uses of State DOT Research: Customer Use of Completed Projects from NJDOT’s Bureau of Research

Project Management and Progress Tracking System (ProMPTS)

Multi-Modal Freight Transportation: Regional Data Development and Analysis

Development of a Model and Decision Support System for use in Forecasting Truck Freight Flow in the Continental United States

Freeway Capacity Analysis with Microscopic Simulation (FRESIM)

Impact of Mid-Block Access Points on Traffic Accidents on State Highways in New Jersey

External Validity Test for Discrete Choice Transportation Forecasting Models Based on the Stated Choice Approach

Moving Telecommunication Forward: An Examination of Organizational Variables

Analysis of Truck Accidents in Work Zones

Digital Map Requirements for Automatic Vehicle Location

Nonlinear Response of Multi-Span Simply Supported Bridges Under Earthquake Ground Motions
Current Project Abstracts

Causes and Control of Transverse Cracking in Concrete Bridges

Data Research - Materials Laboratory Information System

Establishing Safe Driveway Grades for New Jersey Highways

E-Stations for Newark: Infrastructure Planning and the Urban Lab

Evaluation of the Potential for Using Ramp Metering in the ATMS of the I-80 Showcase Corridor

Evaluation of Design Ideas for Prevention of Vehicle Entrapment on Railroad Tracks

Highway Advisory Radio (HAR) Systems

Identifying Factors and Mitigation Technologies in Truck Accidents in New Jersey

Integrated Signals - A Costs Benefits Analysis for the New Jersey Department of Transportation

Riverside Transit Village Project

South Jersey Real-Time Motorist Information System

The Mature Driver - Safety and Mobility Issues

The Research Project Maintenance and Monitoring System (ProMPTS) - Continuation

Water Level Prediction for Transportation Projects

Representative Publications and Presentations

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Port Newark/Elizabeth with downtown Newark in the background

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NJIT campus showing myriad transportation facilities between Newark and New York City

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New Jersey Turnpike Hudson County Extension and Central Railroad of New Jersey Bridges across Newark Bay

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The Pulaski Skyway spanning the Passic and Hackensack rivers between Newark and Jersey City

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New E-Z Pass Lanes on the Garden State Parkway

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Elizabeth Channel of Port Newark/Elizabeth with Newark International Airport in the background

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Croxton Yard by Harmon Cove in Secaucus

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Route 4-17 Interchange in Paramus

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Newark bridges facing east
As a Public Research University, NJIT serves as a conduit through which technology flows into society. NJIT researchers seek new knowledge to improve processes and products for industry. NJIT and NCTIP, through their proven, professional academic expertise and state-of-the-art research labs and equipment, are able to foster applications of new technologies and innovative changes in the field of transportation research. NJIT-NCTIP also offers unparalleled technology transfer opportunities through its working relationships with federal, state, county and municipal governments and agencies, as well as transportation policy, planning, engineering associations and organizations.

NJIT is proud of the relationship that has emerged between NCTIP and the New Jersey Department of Transportation. As an academic and research entity of NJIT, NCTIP has established itself as an important research resource for NJDOT that provides funding for mutually acceptable scientific and academically advanced transportation research. NJIT and NCTIP are committed to support NJDOT in its goal of providing a safe and efficient transportation infrastructure, and to remain committed as we enter the 21st century.

NJDOT has responded by offering its collaboration with NCTIP in several areas of research, some of which are summarized in this report. NJDOT support has been invaluable to NCTIP as it pursues its mission of high quality, multi-disciplinary, innovative education and research activities that can withstand rigorous peer review in the areas of freight and passenger movement efficiency, and facility, institutional, and regulatory transportation efficiency.
As we move forward in the 21st century, the New Jersey Department of Transportation is committed to delivering a safe, reliable, affordable and environmentally responsible transportation system for everyone who lives or works in our great State.

On a typical day in New Jersey, motorists make 18 million vehicle trips on roads and bridges which support the greatest volume of traffic in the country. More than 255,000 people ride buses to work, 100,000 commute by rail, and 23,000 commute via ferry and/or county and para-transit bus services. Each day we expedite the arrival and departure of 20 cargo ships from all over the world, with the transference of 218,400 tons of freight. Daily, there are 324,000 tons of goods manufactured in New Jersey, transported on 136,500 trucks. We are home to 49 public general aviation airports, one of which is the most heavily trafficked airport in the region - Newark International Airport - used by 94,000 travelers a day.

Research and Technology is essential to enhancing our transportation system. Our partnerships with universities such as NJIT have helped us, through their innovations and technological achievements, meet the challenges of renewing and maintaining our infrastructure, expanding mobility options and enhancing the economy of our communities. NJIT-NCTIP has served as a valuable research and technology transfer resource as evidenced by this report. Its research encompasses a variety of subjects, prepared by a multi-disciplinary pool of research investigators. As would be expected from NJIT, there is an emphasis on emerging technology issues and their applications which will assist NJDOT in managing our transportation system.

Together we are working to improve New Jersey’s quality of life and to make it a better place to live, work and raise a family.
The vision of the Division of Research and Technology is to facilitate the implementation of value-added, quality solutions in a timely manner, utilizing education, experience, and professional practices to aid in developing a world-class transportation system in New Jersey. The Division is focused on providing its customers with a robust research and technology transfer program to enhance the performance, safety, and reliability of our transportation system for industry, commerce, and the traveling public.

The Division works as a 'hub' for research activities that connect the NJDOT, DMV, and NJ Transit with our research partners - research university centers, national research organizations, and industry-based institutions. We are the facilitators of information transfer to and from these organizations. We utilize subject matter experts in the transportation categories of infrastructure, safety, environment, economic development, advanced technology and technology transfer. We are charged with finding or developing the information needed to address pressing problems and to enhance the quality of New Jersey's total transportation system - highways, passenger transit, freight, air and sea.

The Division of Research and Technology is fortunate to have strong partnerships with an abundance of university research organizations, such as the New Jersey Institute of Technology. Together, with their outstanding academic and research programs, the Division is able to provide world-class research and technology solutions in improving the quality of the transportation systems in New Jersey.
This volume's eleven papers summarize findings from a variety of research projects funded by the New Jersey Department of Transportation (NJDOT) and the U.S. Department of Transportation (USDOT) through the National Center for Transportation and Industrial Productivity (NCTIP).

NCTIP is a center of excellence of the University Transportation Centers Program of USDOT's Research and Special Programs Administration. Final technical reports with comprehensive reference lists may be found on the NCTIP web site: http://transportation.njit.edu/nctip. As evident from the papers, the Center's research program is multi-disciplinary and comprehensive and varies from using advanced technology for vehicle tracking to bridge design to social impacts of transportation decisions.

Two of the papers deal with assisting NJDOT in managing research projects and improving the service quality that its Division of Research and Technology provides to its internal customers. Schachter explores how internal NJDOT customers use the work completed for them by the Division of Research and Technology. Wen and Tang develop a software application named the Project Management and Progress Tracking System (ProMPTS), a user-friendly data management environment for fast access, search, and summary of relevant financial, business and technical information for research projects. ProMPTS manages research projects from beginning to end - from problem statement to final products and closeout.

Two papers deal with freight transportation. Spasovic, Bladikas and Bieber develop a management information system, a powerful and effective tool for analyzing commodity flows in New Jersey. The system is designed to assist regional and county planners in understanding the
intensity of freight transportation in an area, and supports them in various aspects, including the commodity flow summary report, corridor analysis, multimodal planning, and other strategic freight issues in New Jersey. Lawrence and Kleinman present a model for forecasting truck flows between New Jersey and the continental United States. The regression-based gravity model is capable of predicting freight commodity flows via trucks (in tons) between an origin and a destination state as the function of population, total personal income, total salaries and wages, and total employment in the origin and destination states.

Two papers deal with traffic capacity and design. Chien and Chowdhury identify factors affecting freeway capacity and recommend potential improvements in FRESIM, one of the best freeway simulation programs available, so that these factors are incorporated. Mouskos and Sun conduct a statistical analysis of the impact of mid-block access points on accident rates on New Jersey's multilane highways. A comparison study was conducted to investigate the differences between accidents that occurred between and at signalized intersections under given conditions on Routes 27, 28, 33, and 35.

Two papers deal with behavioral and social issues in transportation. Beaton proposes and tests a model for estimating probabilities of commuters' mode choices. The model is shown to be able to accurately estimate mode shifts when a commuter is faced with a new mode alternative. Rotter, recognizing the socioeconomic and environmental impacts of highway expansion and traffic congestion that have spurred renewed interest in the potentials of telecommuting, investigates the issues involved in a way the telecommuting workforce is managed.

The final three papers focus on safety, Intelligent Transportation Systems, and bridge design issues. Pignataro performs an analysis of truck related accidents which appeared to be over-represented in work zones, especially on interstate and state highways, compared with other types of motor vehicle accidents. The study recommends improving the accident data collection effort to more precisely pinpoint the causes of
truck accidents. Greenfield investigates Automated Vehicle Location systems for monitoring the location of transit buses using the Global Positioning Systems (GPS) and the Continuous Positioning System (CPS). The research develops a methodology to test and evaluate the accuracy of these systems and supporting digital maps. Saadeghvaziri and Yazdani provide a comprehensive analytical study of the seismic response of highway bridges in New Jersey. The overall objective is to evaluate the nonlinear seismic response of actual bridges with emphasis on soil-structure interaction and three-dimensional effect of ground motion.

We hope that the results of the research presented in this volume will also benefit other state departments of transportation as they continue to provide safe and efficient transportation systems across our nation.
This research project explored how internal customers use the work completed for them by the New Jersey Department of Transportation’s (NJDOT) Research Bureau. By use is meant evidence that customers base some further activity or decision on research findings. Organizations are increasingly competing to see internal and external customers as the focal point of quality services (Lengnick-Hall 1996). For transportation research this customer orienta-

The Uses of State DOT Research: Customer Use of Completed Projects from NJDOT’s Bureau of Research

Principal Investigator: Hindy Lauer Schachter, Ph.D
Customer: NJDOT Research Bureau
Project Monitor: Arthur W. Roberts III, NJDOT
tion means enhanced concern with use, and with what happens to findings after reports are filed.

NJDOT’s Research Bureau has managed over 100 projects in the last ten years. The Bureau’s primary goal is to use the scientific method to assist operations professionals to improve the effectiveness and reduce the costs associated with designing, constructing and operating transportation facilities, systems and vehicles. Research Bureau projects differ by type, customer and locus of research. Research can be authorized to prepare a technical concept review, evaluate new technologies, synthesize research literature, or for other purposes. The Bureau’s internal customers can come from anywhere in NJDOT. Prior to 1995 most research was conducted in-house; more recent projects have been contracted out to universities or consulting firms.

This report is based on case-study synthesis of ten projects completed between 1991-1998. The sample contains a diverse mix of projects by purpose, customer and in-house/outside investigator dimensions. (A list of projects is available from the author.) For each case the official report and (where available) ancillary material were read. Open-ended interviews were then conducted with project managers, customers and (where appropriate) outside principal investigators. The aim was to learn about the interactive processes occurring during the research, whether the customer used the findings and what were the reasons for use or its lack.

In organizations research use depends both on the credibility of the research itself and the social context in which the findings are produced. Previous studies have shown that three factors often influence research use: Researcher-Customer Relations (Afuah 1998, Allen 1984, Katz and Allen 1997, Kimberly and Evanisko 1981, Shrivastava and Mitroff 1984); Top Management-Research Relations (Hall 1999, Schneiderman 1991); and Research Credibility and Timing (Hall, 1999). The interviews explore the status of these three factors at NJDOT. Factors the participants perceive as important were explored by noting which descriptive themes emerged in at least several conversations. The strengths of NJDOT’s process are examined along with those areas that can be further strengthened.

The remainder of this report contains five sections. The first gives an overview of research use in the ten case-study projects. The second to fourth summarize themes from the interviews dealing with researcher-customer relations, top management action, and research credibility and timing, respectively. The fifth section analyzes the interview information and relates it to issues drawn from the management literature.
Case-Study Project Use

For this report use means that customers base future activities or decisions on research findings. This definition means that customers can use any project, even a literature synthesis, by taking the recommendations into account in further operations. Second, the definition precludes easy reliance on putting projects into two categories of "used" and "not used." More reasonable is a threefold categorization of 1) significant use, where all or most recommendations are followed; 2) partial use, where some recommendations are followed and others are not; and 3) no use. Third, the definition means that customer perception is the key variable in determining use.

Use can be short or long term. Short-term use occurs when the agency follows the research recommendations for approximately one year or less but then adopts other alternatives, possibly contradicting paths recommended by the research. Such shifts occur for political or technical reasons and some shifts are inevitable in any technological organization. Long-term use occurs when research findings influence a decision for a period over a year.

Partial or short-term use is the typical project outcome at NJDOT. This is true across boundaries of customer function, project purpose (e.g., evaluation, synthesis or development) or whether the project is done in-house or by an outside consultant. Thus, for example, knowing whether a project was done in-house or by an outside consultant, or knowing whether it was done for a customer in bridges or environmental services does not help much in predicting use.

Almost all Research Bureau projects have some impact on subsequent work or decision making; almost all are used by customers in some way. At the same time few sets of recommendations are followed in their entirety. In most cases the customer follows some recommendations and not others or the report has a short-term use and then the agency acts in a way that is clearly not consonant with the findings of the research.

The tendency for partial or short-term use across so many boundaries suggests two questions: What strengths of the NJDOT research process minimize producing reports that are not used at all? What areas of the process need additional strength to increase complete, long-term usefulness? The interview data on researcher-customer relations, top management, and other variables can help answer these questions.

Research Team - Customer Relations
Communication Patterns

Good communication characterizes NJDOT's researcher-customer relations. During the interviews for seven of ten projects the customer explicitly praised communication patterns. Only in three projects were any negative comments made on this subject at all. Typical were two types of positive comments — praise for the project managers' technical skills and praise for their ability to work with customers. In general, project managers want to communicate and involve customers from the project's start until the report is filed. At an early stage, customers get to review and sign off on work plans that are revised, if appropriate, based on customer comments.

During the conduct of the research, project managers use many communication
methods to keep customers informed, including memoranda and meetings. For larger projects managers convene technical panels or advisory committees with customer members. When an outside investigator completes the research, project managers send chapters of the report to customers for their comments.

Project managers learn about customer needs through face-to-face communication. In a project evaluating de-icing materials, the project manager and customer agree that it was through intensive face-to-face communication that the research representative learned how important a "bare pavements" policy was to operating personnel in New Jersey.

Because NJDOT project managers and customers generally work in the same building they can take advantage of their proximity for long conversations when needed. The project manager of one successful project said "We met in hallways." Another said simply, "You try to get heads together."

**Stable, Long-Term Relationships**

Project managers and customers often do not have the long-term, stable relationships they would like. Where long-term, stable relations exist both project managers and customers applaud them. The project manager learns the customers' long term needs and can suggest additional research ideas to them. But organizational dynamics do not always facilitate long-term relationships. In several interviews both project managers and customers noted that many people were transferred or left NJDOT between start-up and end. Lack of long-term relationships may be a reason participants do not always continue to inform each other about projects after reports are filed.

**Top Management**

Interviews show the importance of NJDOT executive action. Nearly all project managers and customers mention top management actions as affecting project use while less than half the people interviewed mentioned the role of the federal government, industry or other state agencies in affecting use of their work.

One positive theme that emerged in several interviews is the role of executive support as an asset, propelling a project to completion and use. On one successful project both the manager and the customer noted that an assistant commissioner was a proponent and this made a big difference! At other times project managers mentioned that a change in personnel at top manager levels led to variable amounts of support and hence different probabilities of use.

**Research: Credibility and Time Lags**

Aspects of the research itself may affect use. Such aspects include research type and time lags in delivery and implementation.

**What Kind of Research?**

Several project managers and one customer argued that research use depends, at least in part, on enthusiasm for a given project. One project manager said that the organization has to make a realistic appraisal of success before it accepts a project. In his view, the Research Bureau should not get involved unless it is clear that the customer has a strong desire to use findings from the work. Another project manager noted, however, that it is easiest to get enthusiastic customers for projects that make small-scale changes; the more difficult task is getting enthusiasm for major changes. This insight
accords with the organizational behavior literature finding that people are most likely to adopt innovations that are compatible with existing systems.

**Time Lags**

For political and technical reasons NJDOT exists in a landscape of constant change. The political environment shifts because ultimately NJDOT, as a state agency, is accountable to a governor and legislature who are held accountable to the public through voting. The technical landscape shifts through engineering advances and new product developments. For research to have maximum impact, projects have to be completed as quickly as the nature of the problem allows.

One theme that emerged in interviews for over one-half the projects was the slow pace of research work. Many customers mentioned the time issue. Time lags can emerge for valid scientific reasons. Unsuitable weather conditions or unforeseen equipment problems can force researchers to wait before collecting data. When information must be analyzed, haste can mean skimping on accuracy. It is possible that some respondents who criticized the slow Bureau work pace were not aware of the time frame needed to get scientifically valid results.

But some lags have organizational origins. In the interviews, the most frequently cited reason for delay was administrative action. Downsizing and shifts in research personnel slowed operations. Executive-level personnel changes led to long holds on implementing research. In the fast paced world of state transportation agencies, these delays made projects less likely to be implemented.

**Analysis**

The interviews suggest many issues that could be explored further. Discussions with project managers, customers and outside principal investigators show that many contextual factors — some within and others outside the control of researchers and customers — influence use. This section considers three areas that emerge from the interviews where the Research Bureau can at least partially influence outcomes. The questions asked are:

1. How can the Bureau build on its considerable strengths in communicating with customers to improve use?
2. How can the Bureau position itself to maximize the support of top NJDOT management?
3. To what extent can the Bureau develop a faster, more flexible delivery system without compromising its adherence to scientific methodologies?

**Researcher-Customer Communication**

Researcher-customer communication is a significant strength of NJDOT’s research process. Project managers are generally regarded as good translators and communicators during the life of a project. The only problematic stage may occur after report completion. Very little follow-up occurs in most situations.

The role of the Research Bureau at the project implementation stage can become a prickly issue. The Bureau cannot dictate how operating personnel use reports and some follow-up might be interpreted as an attempt to dictate. Yet successful change
agents argue that innovation is not fostered when researchers do a study, offer advice and move on. The need is for follow-up of a kind that customers want and view as helpful — research experts on tap to assist, not on top to dictate. This means follow-up that is mutually agreed on by the project manager and customer at an early stage of proposal development. Follow-up should be built into projects through mutual consent at the start of the project’s life cycle; it should be thought through from the project’s inception.

**Top Management Support**

The literature argues that the values of top management influence research use since agency executives set the organization’s vision and priorities. The interview data show that many NJDOT projects do prosper or languish depending, in part, on support at the assistant commissioner level or higher. It is important for the Research Bureau to have top management positively disposed to the research function, aware of its benefits, and concerned with its needs. Since most agency executives do not come from a research background, they need to be educated as to the importance of the bureau’s work.

One way to increase top management support is to explain the benefits of research findings to the operation of the department as a whole over the short and long run. Another way is to show NJDOT executives the importance of research to their own particular policy agenda by adding policy analysis to its project mix. NJDOT executives would become direct customers of Research Bureau studies if the work program addressed policy.

**Faster Delivery Systems**

To increase use, the Research Bureau has to be able to move projects from proposal to completion at a faster rate to the extent this can be done without compromising the Bureau's adherence to scientific methodologies. A balance is needed between speed and effectiveness. Such a balance can be struck by shifts in administrative processes that do not decrease the scientific care devoted to projects.

The Bureau is already aware of the importance of resources for accelerating the time dimension and has mechanisms in place for shifting resources or requesting additional resources from operating units if a particular project is falling behind schedule. In an ideal world, the surest long-range organizational strategy for increasing the speed of Bureau work would be for top management to authorize additional resources and people for the Bureau.

Given the resources the Bureau actually has, however, some time gains may come from adopting a schedule with more flexibility than an annual research program allows. With an annual program some customers wait a considerable time between submitting problems and the start of research. A more flexible cycle might result in smaller waiting times and hence, faster delivery.

One fast and efficient way for potential customers to communicate with the Bureau might be through a Research Bureau Web page. Many national professional organizations already seek solicitations for conference presentations through the Web, and the Bureau could seek research suggestions in the same way.
Dr. Hindy Lauer Schachter is a professor in the School of Management at NJIT. She received her Ph.D. from Columbia University in 1978. Dr. Schachter has written three books: "Reinventing Government or Reinventing Ourselves" (SUNY Press, 1997), "Frederick Taylor and the Public Administration Community" (SUNY Press, 1989), and "Public Agency Communication" (Nelson Hall, 1983), and has authored articles which have appeared in Public Administration Review, Administration and Society, International Journal of Public Administration, Review of Public Personnel Administration, Public Works Management and Policy, etc. Her areas of research interest include public administration, communication, and management of transportation agencies.

References


Maintenance and monitoring systems are a key component of planning and control, affecting fiscal and operational performance within an agency. By facilitating monitoring, project maintenance and monitoring systems permit more optimal use of organizational resources, thereby increasing efficiency. They permit administrators of research units to monitor the status of projects from initiation through disposition, providing greater assurance that projects will be completed within budget and time constraints.

Research Project

As an organization's strategies and policies change, its monitoring systems must conform to the new environment. The New Jersey Department of Transportation (NJDOT) required a computer-based operating system that would monitor the disposition of problem-statement submissions and projects of the

Project Management and Progress Tracking System (ProMPTS)

Principal Investigators: H. Joseph Wen, Ph.D., Chi Tang, Ph.D.
Customer: NJDOT Research Bureau
Project Monitor: Robert Sasor, NJDOT
The result of this research project was the development of a software application called the Project Management and Progress Tracking System, or ProMPTS. The goal of ProMPTS is to create a user-friendly data management environment to let users quickly and easily access, search, and summarize relevant financial and business information for research projects. Detailed and summarized up-to-date reports can be generated efficiently.

**Overview of ProMPTS Software**

ProMPTS is a computer software program designed to help staff manage and track research projects from beginning to end — from problem statement to final products and closeout. With graphical interfaces and database developed in Microsoft Access97, ProMPTS has features to track both project and program information. ProMPTS has six main functional areas:

- Project Information
- Problem Statements
- Project Data Input
- Program Information
- Reports
- Administration.

After logging on, the Main Menu for ProMPTS appears (Figure 1). The Main Menu provides access to the main program functions, provides information on how up-to-date system data are, and allows a user to customize his password. Clicking on any of the button bars will take the user to the corresponding function.

**Project Information**

The first main program function is the Project Information screen (Figure 2). This screen provides summary information about
projects, including project number, title, manager, customer, principal investigator, start date, estimated completion date, percent completed, status, etc., and budget and expenditure amounts for all years or any single year. With this interface, the user can query the ProMPTS database by either project number, active projects, bureau, completed projects, customer, estimated completion date, funding, job number, manager, my projects, principal investigator, program year, related projects, resource, standard title, start date, and total budget. This querying is done using the Query Criterion and Query Value combo boxes. Summary financial information, for all projects that are listed in the query, is shown at the bottom of the screen.

The Project Information screen also allows retrieval of detailed data at the project-specific level. By selecting a project with the selector bar on the left and then clicking on the Info Type combo box, the user can view any of the following areas:

- Financial
- Staffing
- Project Update
- Problem Statements (also accessible via Main Menu, Problem Statements screen)
- Description (also accessible via Main Menu, Project Data Input screen)
- Schedule (also accessible via Main Menu, Project Data Input screen)
- State Planning & Research (SPR)

![Figure 2. Project Information Screen](image-url)
Budgets (also accessible via Main Menu, Project Data Input screen)

Contract Documents (also accessible via Main Menu, Project Data Input screen)

Reports (also accessible via Main Menu, Reports screen)

Unauthorized personnel can only view the project-specific data retrieved via the Project Information screen. Only the manager assigned to a project can enter data on these screens. On leaving these areas, the user will be returned to the Project Information Screen.

Financial Information. This section provides budget and expenditure information for the selected project. The Budget and Cost Tracking screen is shown in Figure 3. In-house and contract budgets and expenses are shown with a federal and state dollar breakdown. The contract section also lists any matching funds. Totals are provided to the right of the screen. Information can be displayed for all years or any single year. Expenditure amounts are downloaded from the Financial Management Information System (FMIS) on a weekly basis. Funding and resources by job number are shown at the bottom. The Project Number combo box allows the user to switch between projects.

Clicking on the "Detail" buttons below the graphs provides the user with greater In-House and Contract budget and cost detail. The In-House Detail screen shows a line item level of In-House detail for both salary and non-salary accounts, with links to salary details for specific individuals. The Contract Detail screen shows a line item level of Contract detail, with links to a list of contract invoices, payments against a particular line item, and details of Modifications (MOD's) for a contract at the line item level.

Staffing. The Staffing Screen provides
budgeted and expended work hour information for NJDOT staff on a yearly or an all years basis for the selected project. Work hour data are downloaded weekly from the FMIS. Budgeted and expended time for each individual working on a project can be viewed, with links to timesheet information. The "All Projects" function, which is still under development, will provide a work hour listing for all the projects that the selected individual worked on for a particular time period, either grouped by year or by project.

**Project Update.** Every month, project managers are required to confirm that the information on their Description and Schedule screens is still accurate, which can be done via the Project Update screen. Managers can confirm information for a selected project, or they can select the option to confirm "All My Projects." In the latter case, ProMPTS will automatically cycle them through the confirmation process for all of their projects.

The other project-specific information available via the Project Information screen (Problem Statements, Description, Schedule, SPR Budget, Contract Documents and Reports) is discussed in the following sections.

**Problem Statement**

Clicking on the "Problem Statements" button bar of the ProMPTS Main Menu opens up a pop-up window from where the user can select either Problem Statement, Attachment A or Final Disposition, Attach-
ment B. Problem statements and Final Dispositions can be retrieved for a particular year by either problem statement number or title. As previously noted, this information can also be accessed from the Project Information Screen.

**Problem Statement Attachment A.** Typical information from the hardcopy Problem Statement, Attachment A form can be entered on this screen (Figure 4), along with some additional optional information. Problem statements can then be viewed and printed.

**Final Disposition Attachment B.** Typical information from the hardcopy Final Disposition, Attachment B form can be entered on the this screen (Figure 5), which has Page 1 and Page 2 tabs to complete each page of the form. Final Dispositions can then be viewed and printed.

**Project Data Input**

The Project Data Input menu provides links to several project-specific screens: Description, Schedule, SPR Planning Budget, and Contract Documents, where the user can go to input data. For first three functions, the project number must be entered before clicking the button. For "Contract Documents," selecting the job number is not required. As previously noted, all of these functions can also be accessed from the Project Information Screen.

**Description.** Descriptive information related to many aspects of a project can be entered in this screen (Figure 6). In addition, a list of technical reports for the project can be entered, and space for a project graphic is...
Figure 6: Project Description Screen

provided. Double clicking in the abstract field will retrieve the report abstract. Only the manager assigned to a project can enter on this screen. Descriptive information on another project can be viewed by selecting a different project number in the Project Number combo box. A history of changes to the project descriptive information is kept, and it can be viewed by clicking the "History" button.

Schedule. A project manager enters his schedule information on a task-by-task basis in this input screen. This information includes milestones, products, estimated completion dates, percent completed, date completed, and comments. The schedule for a different project can be viewed by selecting its number in the Project No. combo box. A schedule history is automatically kept and can be viewed by clicking the "History" button. The schedule can then be viewed and printed.

SPR Planning Budgets. Only the project manager is permitted to input data on the SPR Planning Budgets screen, where the salary and non-salary budget items for an SPR project for a given year is entered. The "Project Number." and "Standard Title" combo boxes can be used to select a project, and the "Program Year" combo box
selects the year. Under the heading "Staffing Current Project," a staffing plan can be developed. This is done by clicking on the "Add" button and selecting a name from the "Employee Name" combo box, then entering the number of regular salary, paid overtime, and XP overtime months. The small window to the right, "Staffing All Projects," lists all of the projects to which the selected employee has been assigned for that year, and it shows the number of months designated for each project, as well as the total for all projects for the year.

From the number of months entered by the manager, salary, fringe, and indirect dollar amounts are automatically calculated and shown in the "Budget Detail" section. Also in the Budget Detail section, amounts for non-salary accounts such as Travel, Office Supplies, etc., as well as SPR funding can be entered. The total budget for all items is shown at the bottom of the screen.

**Contract Documents.** The Contract Documents data input screen is used to track information about the processing of contract documents such as RFP's, proposals, task orders, and notices to proceed for the original contract and any subsequent contract MOD's. The starting point for document tracking for the original contract is the RUC approved problem statement. The "Program Year"
combo box is used to select the year, and the "Problem Number" combo box lists the numbers of all of the problem statements for that year excluding those that were combined.

Proposals received in the Response for Proposals (RFP's) phase can be individually tracked by resource (such as NCTIP or CAIT - Rutgers' Center for Advanced Infrastructure and Transportation), principal investigator (PI), and title, and a proposal rating can be entered in the "Proposal Rating" text box. Task Order Number and Study Number can also be entered for a contract, and the Notice-to-Proceed date can be entered separately for the original contract and any MOD's. When a project number is available, it can be assigned here to a proposal to establish a link between a project and the tracking of its contract documents.

Program Information

The Program Information area provides financial, contract, and personnel information at the Research program level rather than at the project level.

Financial. Program financial information is provided on a yearly basis broken down by funding categories such as SPR (State Planning & Research), TTF (Transportation Trust Fund), National Pooled Fund, FHWA Funds, NCHRP Agreements, etc. SPR funding has In-

Figure 8: Report Screen
STATE PLANNING AND RESEARCH PROGRAM 1999 - 2001

ACTIVITY: Technology Transfer and Implementation
MANAGER: William Hoffman
UNIT: Office of Research & Technology

PURPOSE:
Maintain literature searches, review technical literature, attend national and committee meetings, and prepare correspondence to funders and other interested parties. Assist Operations unit with the application of new techniques and materials.

OBJECTIVES:
This project is for the interaction with other research organizations, and the review of work results from other organizations and the determination of potential use by NJDOT. It is also for the implementation of both outside results and the concluding assistance to implement improved methodologies.

TASKS/ACTIONS:
Work proposed is divided into three categories:
Category I comprises the review of completed research from all sources, a determination of feasibility of and approaches toward implementation of the research findings or developments, and administrative guidance and coordination necessary to carry out proposed implementation efforts. This includes all reports received under the FHWA Technology Transfer program and participating in R&D Work Program (1999-99) projects. Also includes PRT administrative duties to set up PDW project arrangements.

Category II work includes a substantial literature search which is conducted in response to a current solicitation of proposal statements. For those statements which are potential new projects, the literature search is used to develop a workplan.

Figure 9: Sample Work Program Report

House and Contract categories including university centers, and TTF funding also includes the university center contracts as well as others. The amounts shown are the summation of the budgets and expenditures for research projects programmed in the selected year. NJDOT funding is divided into state and federal, and matching funds are shown in the "Other" column. Percent expended in each category is provided, and amounts are totaled to the right for each funding source. A grand total for the year is shown at the bottom of the screen.

Contract Spreadsheets. This screen links to the program contract spreadsheets provided by Lorraine Stallings of the Bureau of Financial Administration. A copy of these spreadsheets will be stored on DOTNET and will be available through ProMPTS in this section. The spreadsheets are in a Lotus 1-2-3 workbook divided into worksheets for more than 15 contract resource categories such as Rutgers, NJIT, LTAP (Rutgers’ Local Technical Assistance Program), UTRC (University Transportation Research Centers), CAIT, Task Order 54 TF98, NCTIP FY98, Consultants, etc. They are a valuable source of contract information for resource categories.

Personnel. The Personnel screen retrieves Research Program personnel information for In-House staff, principal investigators, and customers, and is a good source of contact information (i.e. telephone, fax, e-mail, or regular mail).

Reports
The Reports menu allows the user to prepare, view, or print a variety of reports at the project-specific or program level.
Program reports can only be previewed and printed by designated staff, so for most users this area will be grayed out.

The "All Projects" and "My Projects" check boxes define the project number and standard title lists that appear on the combo boxes. Many of the single reports require that a year be specified; this is accomplished with the "Program Year" combo box. Projects can be selected by either project number or standard title, using the corresponding combo box. The financial and close out project reports are under development, and monthly reports probably will not be included in the final version of ProMPTS.

The Reports menu links to a project report prepare form, where information not contained in the ProMPTS database (such as "Purpose" and "Objective," which were entered in the "Project Description" section), can be entered. A sample "Work Program" report is shown in Figure 9.

**Administration**

The Administration menu is only available to those designated as ProMPTS administrators; all others will see the "Administration" button grayed out after they log on.

In this area, the basic framework for ProMPTS is set up, and In-House and contract financial data are imported from FMIS downloaded files. The basic framework consists of job numbers and project numbers (subjobs) with their associated funding sources, resources, federal participation percentages, contract identifiers, and approved budgets. Also entered in this section are additive percentages, project personnel information for In-House staff, principal investigators, customers, permissions, and contract line item descriptions.

**Summary**

The ProMPTS computer system has been installed at the NJDOT Research and Technology division. There are several potential benefits of the ProMPTS software package. First, it should significantly reduce the time spent searching to find relevant research project data from existing NJDOT databases. Responses to inquiries regarding description and current status of problem-statement submissions and current research projects can be quickly accessed, searched, and summarized.

Next, it is not only a data management system, but also an operational process monitoring system. It provides both detailed and summarized up-to-date reports on project status and financial information including salary costs, program year budgets of individual funding sources, and budget/cost comparison for individual research projects.

Finally, ProMPTS is very user-friendly. The graphical user interfaces create a system that is simple and intuitive to use. Many data manipulation tasks have
**Dr. H. Joseph Wen** is an associate professor of Management Information Systems at NJIT. He holds a Ph.D. in Information Systems from Virginia Commonwealth University, and has over 15 years of information systems design experience on decision support systems (DSS), executive information systems (EIS) and client/server databases. Dr. Wen has been principal/co-principal investigator in the development of numerous transportation information systems, such as ProMPTS, TELUS (the Transportation, Economic, and Land Use System), Air Quality Monitoring Computer Systems, and the Capital Program Management Tracking System (CAPAS). He has published 63 papers in academic journals, book chapters, encyclopedias and national conference proceedings. His areas of expertise are transportation systems analysis and design, relational database design, geographical information systems, electronic commerce, and decision support modeling.

**Dr. Chi Tang** is a senior research associate with NCTIP who also has numerous transportation information systems projects to his credit, including ProMPTS and CAPAS. He is currently co-PI for an NJDOT project: Data Research - Materials Laboratory Information System, a computerized Laboratory Information System (LIMS), which will significantly reduce paper workloads and provide the capability of rapid data organization. Dr. Tang has successfully developed and implemented a web-based project tracking system for NCTIP, and is working with NJIT to develop a research productivity system based on ProMPTS. Dr. Tang received his Ph.D. from Rutgers University in 1995 in Operations Research.
In New Jersey, as well as in all other states and regions of the country, information on freight movements has lagged significantly in terms of both availability and quality of data compared with information available about personal trips. Freight movement information is critical for comprehensive transportation planning. Commodity flow data and related analytical and modeling tools are needed for intelligent decision-making, which determines the state’s expenditure of capital improvement funds. They are necessary inputs in the state's evaluation of its position in the regional, national and global economy, and in designing the actions that will improve the its economic competitiveness.

In cooperation with NJDOT’s recognition of the need for regional freight information, NCTIP undertook the following goals:

- Integrate two databases of commodity flows by standard transportation commodity code (STCC) and mode of transport between New Jersey counties and selected U.S. and foreign destinations.
Develop a model for assigning commodity origin-destination (O-D) trip tables over the regional multi-modal transportation network.

Use the model for various transportation analyses (e.g., estimating through truck traffic, exclusive freight facilities, toll changes, mode shifts).

This article focuses on the first goal of the project, development of descriptions of commodity flows in and out of New Jersey. This research generated a product using the NJDOT freight database that was made available to planners throughout the northern portion of the state and the New York/New Jersey Metropolitan region.

Research Project

The goal of NJDOT Freight Information Management System (NJFIMS) is to provide a powerful and effective tool to manage the commodity flow data in New Jersey. With the accumulation of the commodity flow data year by year, it becomes imperative to create an integrated freight movement database management system that supports the user in various aspects, including the commodity flow summary report, corridor analysis, multimodal planning, and other strategic issues in New Jersey.

The main objective for this portion of the research project was to develop descriptions of commodity flows in and out of New Jersey and to organize the data in user-friendly reports and databases. In addition, it was important to interface the existing databases and analytical tools within an executive management information system (MIS) capable of providing analytical answers to a myriad of critical planning questions. Finally, a hypertext capability for the executive MIS was developed. The MIS is available for use on the Internet at http://freight.njit.edu.

It was envisioned that via the data review interfaces, the MIS would enable users to drill down the database to obtain specified information about the commodity flows for a single pair or multiple pairs of origin and destination counties. Following are examples of the search queries that the system could handle:

- What is the amount of commodity flows from Bergen, NJ to Bronx, NY in 1993, summarized by Standard Transportation Commodity Code (STCC) and Transportation Mode?
- What is the aggregate amount of commodity flows from Atlantic, Bergen, and Camden to Atlantic, Essex, Hudson and Hunterdon in 1982, summarized by STCC and Transportation Mode?
- What is the change in commodity flows between 1993 and 1982 databases from the Delaware Valley counties to Cape May, NJ?

Comparative Analysis of the Data

The research project was to use the most recent data available to generate reports for each of the 21 counties New Jersey showing commodity flows broken down by STCC and mode of transport. At the outset of this project it was established that two separate databases containing information on com-
Commodity flows were in use at NJDOT: the Reebie Associates' TRANSEARCH for 1982 and DRI/McGraw-Hill's (DRI) database containing 1993 flows. In the source databases, flows were given on a county-to-county scale, and between each county and points outside the state. The NJFIMS was developed using both sources of data so that the DRI database could be compared to the TRANSEARCH database.

The DRI database contains commodity flows among 21 NJ counties as well as those between NJ counties, 19 external adjacent areas and eight distant domestic areas. The data selected allow users to examine commodity flows based on various data sources and transportation modes.

Another comprehensive source of data is the Commodity Flow Survey (CFS), undertaken through a partnership between the Bureau of the Census, U.S. Department of Commerce, and the Bureau of Transportation Statistics, U.S. Department of Transportation. This survey, conducted as part of the Economic Census, produces data on the movement of goods in the United States. It provides information on commodities shipped, their value, weight, and mode of transportation, as well as the origin and destination of shipments of manufacturing, mining, wholesale, and selected retail establishments.

This section presents a comparison analysis of the 1993 CFS results (issued October 1996) and the DRI database, concentrating on New Jersey State commodity flow data validation. It identifies the discrepancies in the two data sources, in terms of magnitude of tonnage moved, five most shipped commodities, transportation modal shares and most likely destinations.

More recent CFS data was issued in December 1999, well after the research was underway. However, the commodities shown in the 1997 CFS report were not classified using the STCC coding system, but rather used the Standard Classification of Transported Goods (SCTG) coding system. Because of the different approaches used by these two systems in classifying commodities (the STCC links them to an industry structure while the SCTG does not), a direct comparison by commodity of the DRI database with the 1997 CFS is difficult, if not impossible, to do. Because of the different approaches, this research focused on verifying that DRI 1993 data were comparable in tonnage and ranking to the 1993 CFS data, which used the STCC system.

It is important to keep in mind that the two databases are only preliminary estimates. In addition, the 1993 CFS does not include most crude oil shipments and DRI does not include overnight mail services.

1. Overall Tonnage Estimate

The total tonnage from all origins to all destinations in the U.S., as shown in Table 1, was estimated as 7679.9 million tons by the DRI database, while the CFS database estimated 9688.5 million tons of total USA shipments. There is a difference of 2008.6 million tons between those two estimates.

However, at the state levels, also shown in Table 1, the overall total commodity flow estimate of 179.66 million tons made by DRI is close to the 1993 CFS result of 179.5 million tons of shipments originating in New Jersey.
Table 1. Overall Total Tonnage Estimates (in million tons)

<table>
<thead>
<tr>
<th>Database</th>
<th>Total Tonnage of USA</th>
<th>Outboard Tonnage in NJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993 CFS</td>
<td>9688.5*</td>
<td>179.5</td>
</tr>
<tr>
<td>DRI/ McGraw-Hill</td>
<td>7679.9</td>
<td>179.66</td>
</tr>
<tr>
<td>Difference</td>
<td>2008.6</td>
<td>-0.16</td>
</tr>
</tbody>
</table>

*9688.5 = (12157.1 - 1609.3 - 859.3), where the total excludes the Oak Ridge National Laboratory (ORNL) for pipeline and water shipments estimates.

2. NJ Total Tonnage by Transportation Modes

The total of New Jersey shipments moved by truck, as shown in Table 2, was estimated at 155.88 million tons, in the 1993 CFS, which is close to the DRI estimate of 147.5 million tons. However, there is a significant difference in the total New Jersey shipments moved by rail as shown in Table 3 — 2.87 million tons in the 1993 CFS versus 21.3 million tons in the DRI database.

Table 2. NJ Shipments by Truck Mode (in million tons)

<table>
<thead>
<tr>
<th>Database</th>
<th>Total Tonnage (NJ)</th>
<th>Moved by Truck (NJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993 CFS</td>
<td>179.5</td>
<td>135.88</td>
</tr>
<tr>
<td>DRI/ McGraw-Hill</td>
<td>179.66</td>
<td>147.5</td>
</tr>
<tr>
<td>Difference</td>
<td>-0.16</td>
<td>-11.62</td>
</tr>
</tbody>
</table>

3. NJ Total Tonnage by Commodity

The top commodities of outbound shipments in New Jersey are similar, but the order is different. Food or kindred products rank 4th and chemical and allied products rank 5th in the 1993 CFS data. According to the DRI database, chemical products rank 4th and food or kindred products rank 5th. A summary comparison is shown in Table 4.

Table 3. NJ Shipments by Rail Mode (in million tons)

<table>
<thead>
<tr>
<th>Database</th>
<th>Total Tonnage (NJ)</th>
<th>Moved by Rail (NJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993 CFS</td>
<td>179.5</td>
<td>2.87</td>
</tr>
<tr>
<td>DRI/ McGraw-Hill</td>
<td>179.66</td>
<td>21.3</td>
</tr>
<tr>
<td>Difference</td>
<td>16</td>
<td>-18.43</td>
</tr>
</tbody>
</table>

4. Most Likely Destinations of NJ Shipments

The region definitions differ for the top destinations of New Jersey outboard shipments of the 1993 CFS data and the DRI data, which makes it difficult to compare them directly. A summary comparison is shown in Table 5.

Overview of Freight Information Management System

The research focused on developing an integrated graphical interface to help users access and search commodity flow information quickly and easily. The developed NJFIMS is a relational database management system based on MS Access platform. It is easy-to-use, intuitive in navigation, and flexible with enhanced multiple-Origin/Destination selection functionality. NJFIMS integrates the two NJDOT original databases, the 1993 database bought by the NJDOT from DRI/McGraw-Hill and the 1982 database prepared by Reebie Associates into the...
NJFIMS. The customized reorganization and unified formats of the data in NJFIMS make the maintenance and the analysis of the NJ freight movement information more effective and informative for seeking summarized information at different detail levels.

The system consists of diverse objects such as Access Data tables, SQL queries, Date Review forms, Visual Basic modules, and a group of linked Word documents. The integrated design of the system ties these objects together to perform certain predefined functionality as a whole.

The Access forms serve as the user interfaces for the system. Each form is designed to accomplish certain tasks, such as collecting, presenting or filtering information. The Main Menu, shown in Figure 1, serves as a control center of the system.

The basic components on the Main Menu form are a group of checkboxes. By clicking the option checkbox or its link, a corresponding form is opened. The "About the MIS" link introduces the basic information of the system, such as the name and the copyright of the system, and briefly describes the other sections of the MIS.

The other links open data review forms for retrieving commodity flow information based on user interests. Selection combination boxes on these forms provide a convenient and intuitive guidance for users to search relevant data. Particularly, the system has multiple-selection functionality in selecting Origin/Destination lists. Users obtain high flexibility in grouping regions of

<table>
<thead>
<tr>
<th></th>
<th>1993 CFS</th>
<th>CFS Tonnage</th>
<th>%</th>
<th>DRI</th>
<th>DRI Tonnage</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Petroleum or Coal Products</td>
<td>64.08</td>
<td>35.7</td>
<td>Petroleum or Coal Products</td>
<td>50.95</td>
<td>28.4</td>
</tr>
<tr>
<td>2</td>
<td>Nonmetallic Minerals</td>
<td>29.44</td>
<td>16.4</td>
<td>Nonmetallic Minerals</td>
<td>32.36</td>
<td>18.0</td>
</tr>
<tr>
<td>3</td>
<td>N/A</td>
<td></td>
<td>3</td>
<td>Crude Petroleum, Natural Gas</td>
<td>25.85</td>
<td>14.4</td>
</tr>
<tr>
<td>4</td>
<td>Food or Kindred Products</td>
<td>23.51</td>
<td>13.1</td>
<td>Food or Kindred Products</td>
<td>13.56</td>
<td>7.5</td>
</tr>
<tr>
<td>5</td>
<td>Chemical or Allied Products</td>
<td>13.64</td>
<td>7.6</td>
<td>Chemical</td>
<td>19.61</td>
<td>10.9</td>
</tr>
<tr>
<td>6</td>
<td>Clay, Concrete, Glass or Stone Products</td>
<td>9.51</td>
<td>5.3</td>
<td>Clay, Concrete, Glass or Stone Products</td>
<td>7.06</td>
<td>3.9</td>
</tr>
<tr>
<td>7</td>
<td>Others</td>
<td>39.31</td>
<td>21.9</td>
<td>Others</td>
<td>58.03</td>
<td>32.3</td>
</tr>
<tr>
<td>Totals</td>
<td>179.5</td>
<td>100.0</td>
<td>0</td>
<td>Totals</td>
<td>179.66</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Table 4. Top Commodities of NJ Outboard Shipments (in million tons)
commodity flows according to their interests, thus getting insight of commodity flow patterns in New Jersey areas at different aggregated levels.

**Executive Summary Reports**

This form contains geographic and economic data descriptions, and describes commodity flow information for each of the 21 counties of New Jersey. Each Executive Summary Report contains the following:

- Introduction
- Transportation Overview
- Population and Industry Overview
- Section 1: Commodity Flows between County and 21 New Jersey Counties
- Section 2: Commodity Flows between County and Selected Counties Bordering New Jersey
- Section 3: Commodity Flows between County and Selected Surrounding Zones
- Section 4: Largest Commodity Flows between County and Selected Surrounding Zones
- Section 5: Commodity Flows between County and US and Canadian Regions
- Section 6: Largest Commodity Flows between County and US and Canadian Regions
- Section 7: County Foreign Trading Partners
- Section 8: Miscellaneous Comparative Statistics
- Section 9: Commodity Flows between The State of New Jersey and the Foreign Trading Partners
- Section 10: Changes of County Commodity Flows between 1982-1993

**Table 5. Most Likely Destinations of NJ Outboard Shipments (in million tons)**

<table>
<thead>
<tr>
<th></th>
<th>1993 CFS (Top Six)</th>
<th>CFS Tonnage</th>
<th>%</th>
<th>DRI (Top Six)</th>
<th>DRI Tonnage</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. New Jersey</td>
<td>106.62</td>
<td>59.4</td>
<td></td>
<td>1. New Jersey</td>
<td>73.47</td>
<td>40.9</td>
</tr>
<tr>
<td>4. Massachusetts</td>
<td>5.56</td>
<td>3.1</td>
<td></td>
<td>4. South Coast</td>
<td>14.56</td>
<td>8.1</td>
</tr>
<tr>
<td>5. Connecticut</td>
<td>4.49</td>
<td>2.5</td>
<td></td>
<td>5. Pennsylvania</td>
<td>10.17</td>
<td>5.7</td>
</tr>
<tr>
<td>6. Maryland</td>
<td>2.33</td>
<td>1.3</td>
<td></td>
<td>6. Midwest</td>
<td>7.22</td>
<td>4.0</td>
</tr>
<tr>
<td>7. Others</td>
<td>20.64</td>
<td>11.5</td>
<td></td>
<td>7. Others</td>
<td>34.46</td>
<td>19.2</td>
</tr>
<tr>
<td>Totals</td>
<td>179.5</td>
<td>100.0</td>
<td></td>
<td>Totals</td>
<td>179.5</td>
<td>100.0</td>
</tr>
</tbody>
</table>
The Introduction provides a brief description of the geographic location of the selected county, while the Transportation Overview describes the major roadway, rail, and pipeline networks. Figures showing the location of the facilities on a New Jersey map are included.

The Population and Industry Overview describes the selected county’s population trends and corresponding economic data. Also highlighted are the major industries and top employers in the county.

The Commodity Flows (Sections 1-10) describe intrastate commodity flows, which include inter-county flows as well as intra-county flows. Net Commodity flows are given, as well as total inflows and outflows by STCC and mode. Summary tables are presented indicating the total commodity flows among all New Jersey counties for each mode of transport. In addition, summary tables presenting commodity flows originating in the county and destined for the county are shown.

All statistics are presented in inbound and outbound flows (in thousand tons) sorted by the two-digit STCC and by mode of transport: Truck (common carrier, package carrier, and company fleet), Rail (boxcar and trailer on flat car/container on flat car, known as TOFC/COFC), Air, and Water/Other. Some examples of STCC are Farm Products (01), Food and Kindred Products (20), Apparel (23), Petroleum and Coal Products (29), and Hazardous Waste (48).

**Commodity Flows Summation Reports (DRI 1993)**

This form contains the commodity flow summations for each of the 21 counties of New Jersey contained in the DRI 1993 database. Each Summation Report contains the following:

- Flows Between County and County
- Flows Between County and Zone

![Figure 1: MIS Interface for Main Menu](image-url)
Figure 2: MIS Interface for DRI 1993 Database Query

Flows Between County and Region

This form includes combination boxes to provide a convenient and intuitive guidance for users to search relevant data. Figure 2 shows the MIS interface used to search the DRI 1993 database for County-to-County flows. The MIS is very flexible with respect to the database queries: users are permitted to select multiple counties for the origin and destination counties.

The MIS interface for the other commodity flows summation reports mimic Figure 2. Users can obtain high flexibility in grouping regions of commodity at the origin and destination levels, so that results can be examined for different aggregated levels.

Commodity Flows Summation Reports (Rebee 1982)

This form contains the commodity flow summations for each of the 21 counties of New Jersey contained in the Rebee 1982 database. Each Summation Report contains the following:

- Flows Between County and County
- Flows Between County and Zone

Like the Commodity Flows Summation Reports (DRI 1993) interface, the MIS interface for the Rebee 1982 database is very flexible with respect to the database queries. The user can have multiple selections of origins and destinations.

Commodity Flows Summation Reports (DRI 1993 versus Rebee 1982)

This form contains the commodity flow comparisons of the DRI 1993 and Rebee 1982 databases. Each Summation Report contains the following:

- Flows Between County and County
- Flows Between County and Zone

Due to the different Origin/Destination specifications in the two original databases, only the inter-county and intra-county commodity flows of New Jersey counties and
the commodity flows between counties and selected zones (Delaware Valley, New Jersey, New Jersey South, NJTPA, and the USA) are compared.

**Miscellaneous Statistics**

This section presents additional comparative netflow statistics for each county using either the DRI 1993 or Rebee 1982 databases. Available summation reports include the following:

- Netflows (DRI 1993 or Rebee 1982 databases)
- Trading Partners for Each Mode (Outflow or Inflow)
- Total Commodity Flow by Transportation Mode (DRI 1993 or Rebee 1982 databases)

Also accessible from the Miscellaneous Statistics form is Trading Partners for each County (or group of counties) by mode (Air, Rail, Truck, Water, Total). The MIS interface is presented in Figure 4. In the resulting queries, Trading Partners are divided into ten categories: Canada, North Europe, South Europe, East Europe, Mexico, LA/Other Caribbean, Mideast IS, Japan, Asia/Other, and Other. Thirty four different categories of two-digit STCC are presented.

**Summary**

The goal of NJFIMS is to provide a powerful and effective tool for managing the commodity flow data in New Jersey. To this end, an integrated graphical interface to help users access and search commodity flow information quickly and easily was developed. This user-friendly program is available on the Internet for engineers and planners to provide input into the transportation planning process.

The research product examined the most recent information available to develop the NJFIMS. The 1993 DRI database was compared against other available sources to ensure validity, including the 1993 CFS.

Compared with 1993 CFS results, the DRI database provides fairly close estimates for New Jersey information. Most categories of compared elements fall in 90-percent confidence intervals listed by 1993 CFS. However, some discrepancies exist, most notably in the different estimates of USA total tonnage, a significant difference in NJ originated shipments moved by rail mode, and different orders of the top five NJ outboard shipments.

The DRI data, along with the Rebee 1982 database, provided a basis by which commodity flows in and out of New Jersey were generated.

The Executive Summaries provide a general assessment of the role of New Jersey in the regional, national and world transportation market. Trends in population and economic data are provided, along with an overview of the transportation network. Commodity flows in and out of each county in New Jersey to selected areas are presented, along with information on foreign trading partners. Changes in commodity flows between 1982 and 1993 are highlighted.

In addition to the information available in the Executive Summaries, the databases are available online to query. Users can obtain high flexibility in grouping regions of commodity flows at the origin and destination levels, so that results can be
examined for different aggregated levels. Consequently, the MIS is capable of providing analytical answers to a myriad of critical planning issues.

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**Dr. Athanassios K. Bladikas** is chair of the Industrial and Manufacturing Engineering Department at NJIT, and director of the Interdisciplinary Program in Transportation. He is an expert in the areas of public transit, finance and pricing and logistics. Dr. Bladikas received an MBA in operations research from Columbia University and an M.S. and Ph.D. in transportation planning and engineering from Polytechnic University in New York.
Development of a Model and Decision Support System for use in Forecasting Truck Freight Flow in the Continental United States

Principal Investigators:
Gary Kleinman, Ph.D.
Kenneth D. Lawrence, Ph.D.
Customer: John C. Powers, NJDOT
Project Monitor: Arthur W. Roberts III, NJDOT
This research developed a regression-based model for forecasting truck borne freight in the continental United States. This model is capable of predicting freight commodity flow information via trucks to assist transportation planners who wish to understand when and where new road facilities are needed. Such an understanding is important because shipments by truck account for 53 percent of total tonnage shipped within the United States and 72 percent of total shipments for value (Chin, Hopson and Hwang, 1998). The methods used here can be generalized to other transportation modalities. When, as was done here, this model is allied with databases of forecast economic and population data, it can be used to forecast future truck freight flows.

This research begins with the use of a traditional gravity model to predict freight flow within the states of the continental United States. Such a model posits that freight volume between any two areas is a direct function of the attraction of each area and is inversely proportional to the distance between the two areas. Obviously, the populations of the destination and origin states serve as one possible measure of their demand for, and ability to supply, goods and services. The greater the distance between the destination and origin states, however, the less likely that freight will move between them since shipment costs will be higher.

Population alone, however, has certain limitations as an indicator of the power of a region to draw freight flows from any other area since the purchasing power of the population may be low. In order to increase the model’s predictive ability, we included several socio-economic variables. These include each region’s total employment, earned income, and total personal income. Each of these is described more fully below.

**Methodology**

**General Description of Data Sources**

To accomplish our objectives, we created a database of economic and trucking shipment information. The economic information was obtained from the Bureau of Economic Affairs’ (BEA) web site (URL http://www.stat-usa.gov/BEA/ebb1). The latter contained information on state population, total employment, total wages paid, and total personal income. Of the data available, the database used to develop the prediction model only included data for 1993 since the commodity flow data exists only for 1993.

The Excel forecasting system, however, was developed using BEA forecast data on state total personal and earned income, and forecasts of the employment for the years 2000 to 2015. Population projections by county were obtained from the neighboring states’ data centers. Creation of county
income and employment will be described below. Neither the U.S. Bureau of Economic Affairs nor the U.S. Bureau of the Census provides economic or population projections by county.

The U.S. Department of Transportation’s Commodity Flow Survey provides 1993 data on inter-state and intra-state commodity flows by truck. This data consists of weight of shipment, value of shipment, and ton-miles. We used the portion of data that was broken down by state of origin and destination. During the model’s development, this was the latest data available.

Next, we describe the data used. These descriptions are pertinent to both the 1993 economic and population data and also the BEA’s projects of economic data for New Jersey and its neighboring states for the years 2000 to 2015.

Specific Variable Descriptions

Bureau of Economic Analysis (BEA) Data

1. Total Employment. Employment includes each job that an employed person holds, in any employment setting.

2. Population. Population is defined by the BEA as the resident population as of July 1 for calendar year 1993.

3. Earnings. Earnings are defined as the sum of private and government wage and salary disbursements, other labor income, farm proprietors’ and non-farm proprietors’ income. This is presented in constant 1987 dollars.

4. Total Personal Income. Personal income is defined as the sum of all income received by all persons, less personal contributions for social insurance. Personal income is presented in constant 1987 dollars.

Commodity Flow Survey Data

The 1993 Commodity Flow Survey (CFS) provides data on the movement of goods by mode of transportation. This section summarizes pertinent information on the CFS data.

The CFS provides data for each of the 49 contiguous, continental states. This data was collected from establishments in mining, manufacturing, wholesale trade, and selected retail and service industries. Certain other auxiliary establishments (e.g., warehouses) of multi-unit and retail companies were also covered.

The Bureau of the Census, which actually conducted the survey, generated its sampling frame from the Standard Statistical Establishment List (SSEL) of separate business locations with paid employees. The selected firms were required, for inclusion, to have had a non-zero payroll in at least one quarter of 1991. The total number of firms sampled came to some 250,000. Each contacted company was asked to record information on shipments that they made within a specified two-week period.

We used the information on tons and ton-miles of freight shipped solely by truck between any state of origin and destination.

The dependent or criterion variable is:
Tonnage of freight between the origin state and the destination state.

The independent or predictor variables are:
Populations of the origin and destination states; personal incomes of the origin and destination states; wages of the origin and destination states; total employment of the origin and destination states.
1. Weight of Shipment (or tons) is defined as the total weight of the entire shipment.
2. Ton-miles equal the weight for a shipment multiplied by the mileage that shipment traveled. Mileage was calculated as “the distance between the shipment origin and destination ZIP codes (p. VIII, 1993 Commodity Flow Survey).” The actual distance calculation followed an algorithm developed by the Center for Transportation Analysis.
3. Distance Between Origin and Destination. The average distance between origin and destination was calculated by dividing the ton-miles variable by the weight of the total shipments that took this route.

Altogether, the database constructed for this study consisted of 2,304 observations (48 states of origin by 48 states of destination).

**Statistical Testing**

Eight potential models were tested using the standard regression techniques in SAS (Statistical Analysis System). Regression analysis provides a systematic method for building equations that summarize the relationships between the variables.

Seven models were subsets of the overall model structure given below. The overall, eighth, model was also run. We normalized the data by taking its natural log in order to ameliorate the effects of skewed data on the regression analysis outcomes.

**Variable Definitions**

Specifically, we analyzed eight different combinations of the variables in order to find the most descriptive model. Each model contained the basic gravity model. The latter consisted of the population of the origin and destination states and the average number of miles that each shipment traveled from state A to state B. First, we tested the predictive power of the gravity model itself. Then we added pairs or sets of the economic variables to the basic gravity model. In one extended model, both origin total personal income and destination total personal income were added. In another, total earned wages for the origin and destination states were added. In a third, total employment for the origin and destination states were added. In subsequent model analyses, we added the sets of economic variables two at a time into the same regression model. Finally, we ran a regression consisting of the basic gravity model and all three sets of economic variables.

**Results**

Based on results, we concluded that the extended gravity model, which included total personal income, and total salaries and wages, but not total employment, produced the best model. The best model’s characteristics are shown in Table 1.

**Practical Application of Forecasting Model**

The research underlying this paper has established a regression-based forecasting
Table 2: Using the Regression Model to Predict Freight Flow in 1993 and the year 2000

<table>
<thead>
<tr>
<th>Origin State</th>
<th>Predicted freight flow between other state and New Jersey as destination state</th>
<th>Year 2000 freight flows, assuming that independent variables each increase about 5% from 1993 to 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connecticut</td>
<td>819.00</td>
<td>859.95</td>
</tr>
<tr>
<td>Maine</td>
<td>294.00</td>
<td>308.70</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>1,016.00</td>
<td>1066.80</td>
</tr>
<tr>
<td>New Hampshire</td>
<td>208.00</td>
<td>218.40</td>
</tr>
<tr>
<td>New Jersey</td>
<td>81,294.00</td>
<td>85,358.70</td>
</tr>
<tr>
<td>New York</td>
<td>6,959.00</td>
<td>7,306.95</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>18,729.00</td>
<td>19,665.45</td>
</tr>
<tr>
<td>Rhode Island</td>
<td>198.00</td>
<td>207.90</td>
</tr>
<tr>
<td>Vermont</td>
<td>126.00</td>
<td>132.30</td>
</tr>
</tbody>
</table>

model. Having developed what we believe to be the best extant model for predicting freight flows between states, we then sought to develop a useful application of this technique. Specifically, we used the forecasting model developed above to forecast truck freight flow between New Jersey and the other 47 contiguous states, between counties within New Jersey and between New Jersey counties and non-New Jersey counties within 100 miles of the borders of New Jersey. These forecasts were embedded in an Excel spreadsheet and were manipulated using pivot tables.

In order to do this, we developed a database of forecasts of population, personal income, wages, and total employment of the 48 states of interest. To do this, we used BEA forecasts of state economic data, and Bureau of the Census forecasts for the years 2000, 2005, 2010, and 2015. Historical data existed for the earlier years. Using accepted statistical techniques, we interpolated the variable values for the intervening years. Having completed the state database of projected data, we then used the best regression model found above to forecast freight flow for each interstate linkage. Each forecast was then turned into a percentage of the total inter-state forecast. These percentages were then multiplied by the total inter-state freight flow forecasts shown in the American Trucking Association (1999) study in order to get specific interstate freight flow projections. We used the same average distances between each pair of states that were used in developing the original model described above.

Similar procedures were used in construction the inter-county databases and freight flow forecasts. In this case, the county-level economic data was estimated using the BEA’s forecast of state level economic information multiplied by each county’s share of the projected population. Forecasts of county population were supplied by the data centers of the neighboring states. Forecasts of future state population were taken from the Bureau of the Census. Inter-county distance formation was derived as the distance between the zip code of the county seat of the origin county and the des-
The creation of the databases within Excel allowed us to use pivot tables to provide unique views of the data. These views allow the decision-maker to have a good idea as to how inter-county or inter-state freight flow will look in later years. This information, in effect a decision support system for transportation planners, allows for the efficient production of freight flow forecasts between states in a given period with a given forecast scenario.

The Forecasting Process

This study has demonstrated that it is possible to develop a highly reliable model for predicting the flow of freight between any two of the forty-eight contiguous, continental U.S. states. Being able to predict the flow of freight between states and regions is important for businesses, industries, and consumers in the U.S. Such predictions are useful as indicators of where to construct transportation facilities by indicating where truck freight flow is likely to be. To have an effective basis upon which to decide how to expend the required massive amounts of public funds, it is necessary to have an accurate method of forecasting the volume of traffic freight that moves between the states. The consequences of these expenditures are vital for the economic and social life of many communities. Highway facilities are a means of promoting economic growth.

References


Dr. Gary Kleinman is an assistant professor of accounting at Fairleigh Dickinson University. He earned his doctorate and MBA from Rutgers University. His extensive published work includes one book, 19 refereed journal articles in the group decision-making and forecasting areas; sixteen national or international, and ten regional conference presentations. Dr. Kleinman has published articles dealing with pension fund performance measurement, financial accounting standard setting and relevance, auditor independence, work value acquisition by accounting students, mentoring in accounting firms, forecasting tax revenues, etc. His work with Dr. Kenneth Lawrence has included forecasting freight flow between states within the continental United States.

Dr. Kenneth D. Lawrence is a Professor of Management Science and Decision Support Systems in the School of Management at NJIT, and a full member of the Graduate Faculty of Management at Rutgers University. His professional employment includes over 20 years of technical management experience in private industry and with the U.S. Army in forecasting, marketing planning and research, statistical analysis and operations research. His graduate education includes study in statistics, operations research, industrial engineering, finance, management, and operations research. Dr. Lawrence is the 1989 recipient of the Institute of Industrial Engineers Award for significant accomplishments in the theory and applications of operations research. He is a member of the honorary societies Alpha Iota Delta (Decision Sciences Institute) and Beta Gamma Sigma (Schools of Management), and has conducted significant funded research projects in health care and transportation.
Traffic engineers are being challenged with the problem of determining freeway capacity. Applying a microscopic simulation model such as FRESIM (FREeway SIMulator) to the problem, freeway capacity can be observed through a series of runs. The key issues that arise when applying FRESIM are:

1. **What are the factors affecting freeway capacity?**
2. **How sensitive are the identified factors affecting freeway capacity?**
3. **What are the FRESIM deficiencies that should be modified and/or enhanced in order to determine freeway capacity more accurately?**
4. **How does FRESIM analyze parameters suggested by the Highway Capacity Manual (1994-HCM)?**

**Freeway Capacity Microscopic Model**

Principal
Steven I-Jy
Shoaib M.
Customer: Federal Project Monitor:

**Research Project**

Understanding the capacity of a freeway system is critical to the evaluation its level of service and the development of congestion control measures. FRESIM, one of the best freeway simulation programs avail-
able, does have some limitations and deficiencies for analyzing freeway capacity.

The major thrust of the efforts in this first phase of comprehensive analytical study will concentrate on identifying the factors affecting freeway capacity, indicating deficiencies and recommending potential improvements in FRESIM. Subsequent phases of this study will concentrate on the remaining key issues identified in the Introduction.

**Background**

The microscopic freeway simulation model, FRESIM, is an enhanced and reprogrammed version of the INTRAS (Integrated Transportation Simulation) model. INTRAS was developed for the FHWA in the late 1970s to access the effectiveness of freeway control and management strategies (e.g., ramp metering and incident detection) (Skabardonis, Cassidy, May and Cohen, 1989), and was operational on a mainframe computer.

The FRESIM model was developed in 1990. Unlike INTRAS, FRESIM runs on a microcomputer, and it is a microscopic and stochastic freeway traffic simulation program. In simulating freeway traffic, it considers traffic and geometric conditions, driver characteristics, and vehicle performance. Modeling vehicle movement, such as car following, lane changing, and crash
avoidance, maneuvers are programmed within FRESIM. Over the years, FRESIM has been extensively enhanced, tested, and validated (Chien and Lieu 1997).

FRESIM treats each vehicle as a separate entity and models traffic based on complex maneuvers (CORSIM User Manual 1996), such as car-following, lane-changing and crash. Individual vehicle attributes are selected from an embedded vehicle operational characteristics table. It can simulate entire freeway networks including frontage roads, urban arterial streets, meters, and detectors. It can evaluate incident detection algorithms, real time ramp metering strategies, traffic operations, geometric design strategies, and weaving sections.

FRESIM can handle various geometric configurations of freeways, including (1) variation in grades, radius of curvature, and super-elevations on the freeway, (2) lane additions and drops anywhere on the freeway, (3) freeway blockages, (4) work zones, (5) up to three-lane ramps and interfreeway connectors, and (6) up-to five through lane freeway mainlines, with up to three auxiliary lanes. FRESIM can simulate various operational features such as pre-timed and traffic responsive ramp metering controls, freeway surveillance systems, heavy vehicle movements, and different vehicle types, driver types, and driver reaction times.

**Recommended Improvements**

The objective of this task is to provide recommendations to improve FRESIM to obtain more accurate traffic information, such as the maximum flow passing a freeway section, defined as the freeway capacity. An enhanced FRESIM model should reduce the discrepancy between the simulation results and data collected from the real world freeway network. Recommendations are classified according to the following general areas:

- Driver population related factors
- Vehicle population related factors
- Freeway geometry related factors
- Other pertinent factors

Highlights of the identified areas are presented below.

**Driver Population Related Factors**

**Car-Following Sensitivity Factor**

The car following sensitivity factor is defined by a time gap representing the minimum gap between a vehicle and its leader. Generally, a vehicle will accelerate until its desired free flow speed or the minimum time gap to its leader is achieved. Users can calibrate the values, which vary by driver code.

To better model real traffic behavior, the car following sensitivity factor should vary with both driver and vehicle types. In addition, the car following sensitivity factor varies with roadway surface, geometry, weather, and traffic conditions. Recommendations include:

- The factor should be dependent on both driver and vehicle types.
- The factor should be adjusted internally with respect to the user specified lane width and lateral clearance, roadway, and weather.
- Link specific and time-varied factors should be introduced for reflecting local driving behavior.
The phenomenon that the factor varies with the level of traffic congestion should be validated in order to adjust the sensitivity factor rationally.

**Driver Reaction Time**

The driver response lag time for acceleration and deceleration is the time delay that motorists experience when making required maneuvers. The response lag time affects the safe distance being kept between a pair of vehicles (i.e., a vehicle and its leader). If the response lag time is long, the safe distance kept for avoiding collision between vehicles will be long, and the density on the freeway segment will reduce. Therefore, the freeway capacity decreases. On the other hand, if the response lag time is short, the freeway capacity increases.

In the current FRESIM, response lag times for both acceleration and deceleration are constant for all drivers, and implemented identically. In real traffic situations, the reaction lag time varies from one driver to another. Even one individual’s driver reaction time may vary from one situation to another. For example, driver reaction time can vary with congested versus non-congested conditions, weather conditions, or driver fatigue/alertness; in response to complexity of tasks; or to anticipated or unexpected situations.

Recommendations include:

- Driver type, varied anticipatory and expected lag time should be introduced into the model.
- Lag time should not be a constant for all driver types. Possible factors include driver distribution, congestion, geometry, and vehicle acceleration/deceleration rate.

Lag time should not be implemented by the relative acceleration or deceleration rates for the current and the previous time steps. If acceleration or deceleration of a vehicle is continuous from the previous time step, the driver response lag time should not be taken into account in either the car following model or the anti-collision model.

**Hiatus Time Period**

The current hiatus period is fixed (e.g., 3 seconds) and cannot be modified by users. The determination for the value of the hiatus period is based on an assumption that a lane-changing maneuver will always take the average hiatus time period. During the hiatus time period, the vehicle will not consider another lane changing action. Moreover, the follower of a vehicle will not consider a lane change maneuver if the vehicle is within the hiatus period.

The duration of the hiatus period is a very significant factor that greatly affects the number of lane changes on freeway links. A major limitation in FRESIM is that a pair of vehicles (i.e., a vehicle and its follower) cannot simultaneously execute lane-changing maneuvers, although this type of lane changing operation does exist in most freeway networks.

Recommendations include:

- The duration should differ according to location and should be calibrated by users.
- Factors affecting the duration include vehicle types and driver types of the lane changer and its leader, and the level of congestion.

**Warning Signs**

The purpose of warning signs is to
inform drivers that they should move to their designated lanes. The FRESIM model allows only one warning sign and serves one object, which differs from most real freeway segments (see Figures 1a and 1b).

In reality, as regular commuters are familiar with the location of their designated off-ramps, they may change to their proper lanes prior to the warning sign. Drivers, who are not familiar with the location of warning signs, will change lanes after passing the sign. Consequently, it is difficult to model warning sign behavior.

Recommendations include:

n The probabilistic mandatory lane-changing model should vary in relation to the distance between the warning sign and the associated object (i.e., off-ramp, lane drop, or blockages) based on traffic conditions and driver types.

n Multiple warning signs associated with an object should be allowed. This modification can represent more complex distribution other than uniform, normal, or gamma distribution.
Vehicle Population Related Factors

Percentages of Fleet Components

The percentage for every vehicle type in each fleet component is fixed and cannot be modified by users. The code of a vehicle affects several operational vehicular characteristics; such as the vehicle length, maximum acceleration and deceleration rates, and jerking.

Recommendations include:

- Comparative analysis for the traffic impact, which was observed from simulation results and data collected from the field sites, for various combinations of vehicle types to the freeway capacity, average speed, and delays should be conducted in the future.

- Including calibrated distribution of vehicle types in each fleet. The percentages of the vehicle types should also vary by time period and entry link.

- Including calibrated bus length and bus acceleration/deceleration rates, so that users can simulate realistic bus operations on bus routes.

- Introducing additional bus types: mini-buses (20 feet long); standard buses (40 feet long); and high-capacity buses (60 feet long).

Truck Turn Movements (Specific Truck O-D Matrix)

FRESIM has limitations in handling vehicle percentage information by vehicle types (such as an unreasonable number of trucks in weaving streams within a freeway weaving section). Because of significant traffic impacts (i.e., reduced capacity, increased average delay, and decreased average travel speed) incurred by the number of trucks traveling on freeway networks, it is suggested that the turn movement and origin-destination (O/D) demand information for truck fleets be enhanced for freeway capacity analysis.

The current vehicle turn movement logic should remain in the FRESIM logic, and should be utilized in the analysis of design and planning work when users can not collect the actual truck O/D demand information. However, for improving the accuracy of the simulation output in freeway operational analysis using FRESIM, the following modifications are suggested:

- The specification of vehicle turn movement percentage should be divided into three parts, such as the percentages of passenger cars, carpool, and trucks (card type 25).

- The input regarding vehicle O/D information may follow the previously specified structure and be replaced by various O/Ds categorized by vehicular types (card type 74).

Truck Movements Before Work Zones or Incident Areas

Although all vehicles passing an incident warning sign will perform mandatory lane changes if the vehicles are in front of the blocked lane, simulation results have demonstrated that a truck cannot shift to its designated lane if the truck is the first vehicle before the blocked lane, irregardless of the percentage of cooperative drivers. The truck would stand still until the blocked lane was reopened or a safer gap emerged.

In the real world, vehicles on lanes usually take turns using the open lane in front of a work or an incident zone. It is very unusual for trucks to remain for long before a blocked lane without being able to shift to
the opened lane. Consequently, enhancement of the current mandatory lane changing logic for work zones or incident areas to eliminate unusual truck delays is recommended.

**Freeway Geometry Related Factors**

**Lane Width and Lateral Clearance**

When the lane width is less than 12 feet, drivers are forced to travel laterally closer than they would normally desire (Highway Capacity Manual, 1985). Drivers tend to compensate for this by maintaining longer spacing with their leaders. The effect of restricted lateral clearance is similar to that of narrow lanes. When roadside or median objects are too close to the pavement edge (less than 6 feet), drivers will shy away from them, positioning themselves further from the pavement edge. When drivers keep longer spacing between vehicles at a given speed, the volume decreases. Thus lane width and lateral clearance do affect freeway capacity; however, this factor could not be modeled by FRESIM.

The car following sensitivity factors increase with the reduction of lane width and lateral clearance. There is no established relationship between car following sensitivity factors and lane width and lateral clearance in FRESIM. It has been found that with the reduction of lateral clearance and lane width, the service flow rate will be reduced (Highway Capacity Manual, 1985), and accordingly, the capacity will be reduced.

Recommendations include:

- Adjustment factors should vary by car following sensitivity factors.

**Warning Signs for Grade Geometry**

For vehicles moving on a freeway section on upgrades, the low-speed vehicles (i.e., trucks, buses, and some low-performance cars) tend to shift to the outer lanes. Currently, FRESIM cannot simulate this situation because there are no warning signs designed for alerting those vehicles. As FRESIM emits vehicles in any lane irrespective of their desired speed, slow vehicles, such as trucks, may still operate in the left lane. Therefore, unnecessary lane changing phenomena were observed from TRAFFVU. This situation becomes worse when slow vehicles operate on upgrades as their speeds are further reduced. Due to the operational characteristics of slow vehicles, they cannot maintain their desired speed on upgrades. Hence, it is recommended that FRESIM include the introduction of a new warning sign category to serve vertical grades.

**Other Pertinent Factors**

**Anticipatory Lane Change Model**

In freeways, especially in proximity to on-ramp and off-ramp areas, vehicles changing lanes cannot be fully modeled by mandatory or discretionary lane changing models. FRESIM simulates such lane changing phenomena by the module called anticipatory lane changing module.

Recommendations include:

- The distance of warning signs associated with the downstream on-ramp congestion should be calibrated by the user instead of using a fixed number of 1500 feet. Additional analysis is necessary for
evaluating the anticipatory lane-changing model.

The designated zone length should be a variable for calculating the reference average speed. This should either vary with local geometric conditions or allow users to calibrate it.

The variable LSPCMN representing the space mean speed in subroutine ANTCP has never been used, and it is suggested it be removed.

**Discretionary Lane Change Model**

FRESIM currently cannot efficiently handle discretionary lane changes, especially for slow vehicles that are operating in the left lane. A slow vehicle will not move toward the right lanes if it is able to maintain its desired speed or where no mandatory lane change is required. Thus, the slow vehicle may force its follower to change lanes if the desired speed of its follower is higher than the current speed of the slow vehicle.

In real freeway situations, slow vehicles will shift towards the right lane. To overcome this problem, it is recommended that the discretionary lane changing logic be revised so that slow vehicles that are emitted onto a left lane through entry link should move to the right lane.

**Summary of Findings and Conclusions**

This project reviewed the background literature regarding capacity analysis models to identify limitations and deficiencies in the microscopic freeway simulation model FRESIM. Specific problems were classified into four parts: driver, vehicle, geometry, and other factors. The recommendations and suggestions for each identified deficiency were summarized.

Deficiencies of various factors in the current FRESIM model were identified by comparing the logic of each factor in FRESIM and its validity on the basis of the findings from various related literature. For most areas, specific recommendations were made to improve the performance of the FRESIM model. Due to lack of extensive research in some areas however, specific recommendations were not provided. This research helped to identify those areas that are in need of further study.

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**References**


Dr. Steven I-Jy Chien is an assistant professor of Civil and Environmental Engineering and has a joint appointment with the Interdisciplinary Program in Transportation at NJIT. Dr. Chien earned his master's and Ph.D. degrees from the University of Maryland at College Park. His teaching interests are in transportation systems planning and operations, traffic simulation, and urban system engineering. His research interests are focused on intermodal transit systems, microscopic traffic simulation, transportation system analysis, intelligent transportation systems and application of artificial intelligence in transportation problems. Dr. Chien has published more than 30 refereed journal papers and technical conference papers on transit systems planning, traffic simulation, dynamic prediction and control systems, and transportation systems management.

Dr. M. Shoaib Chowdhury received his Ph.D. in Transportation in May 2000. During his studies at NJIT he was involved in several significant research projects in addition to FRESIM including Scheduling of Coordinated Transfers for Public Transit Services, and Lane Occupancy Charge Estimation Models. He was also a recipient of the George Krambles Transit foundation Scholarship in 1998 and ITS America Scholarship in 1997. Dr. Chowdhury is currently a transportation engineer with Parsons Brinckerhoff. His thesis is titled: “Intermodal Transit System Coordination with Dynamic Vehicle Dispatching.” His research interests include travel demand forecasting and traffic flow modeling, intermodal operation and planning and intelligent transportation system planning and design.
The primary objective of this research was to conduct a statistical analysis of the impact of mid-block access points on accident rates on multilane highways in the state of New Jersey. The study locations for this analysis included New Jersey State highways, Routes 27, 28, 33, and 35.

For this purpose, a comparison study was conducted to investigate the differences between accidents that occurred between and at signalized intersections under given conditions. The impact of single factors such as (access density, median, shoulder, number of lanes and speed limits) on accident rates was also investigated through the Kruskal-Wallis test, a distribution-free mean equality test. A set of regression models was developed for each road category.

**Methodology**

**Identification of Access-Related Accidents**

Vehicle action information from accident reports was used to identify access-related accidents among section accidents. Vehicle actions in accident reports include right turning, left turning, going straight, changing lanes, merging and backing. An accident involving two vehicles, where one of them was reported in a left-turning action, was classified as a left-turning section accident. The same rule was applied to right turning section accidents.

**Comparative Analysis of Section Accidents versus Intersection Accidents**

A comparative analysis was conducted to identify the potential impact of various factors on both section and intersection accidents. These factors included light conditions, road surface conditions, weather conditions, accident occurrence time and vehicle contributing factors. Patterns of section and intersection accidents were also
Access Points on Traffic Highways in New Jersey

Investigators:
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compared by collision type which includes same direction rear collision, same direction side collision, turn collision, object obstacles, overturn, head-on, struck parked vehicle or pedestrian.

**Relationship Between Accident Rate and Access Density, Geometric Characteristics and Traffic Volume**

**Descriptive Statistical Analysis**

Accident rate and access density were calculated for each of the study sections of NJ state highways 27, 28, 33, and 35. For each route, graphs of kilometer-post based accident rates and graphs of access density were plotted on the same figure to demonstrate the relationship between the two. To investigate the overall impact of access density on accident rates, the study sections were grouped by access density from 0 to 50 with increments of 10. Figure 1 shows an access density study.

**Distribution Patterns of Accident Rates**

Log-normal distribution tests were conducted because the shape of the accident rate data on scatter plots indicated log-normal distribution patterns. To test log-normality, the logarithm values of the accident rates were calculated, and normality plots were drawn based on these values. Finally, the parameters of the probability density functions of the accident
rates were estimated using the collected data samples.

**Test of Impacts of Factors on Accident Rates (Mean Equality Tests)**

Instead of the most commonly used ANOVA model, a distribution free analysis of variance method, the Kruskal-Wallis test, was chosen to test mean equalities, because the normality distribution assumptions of ANOVA were not satisfied for the accident rate data.

**Accident Rate Prediction Models**

Regression models were developed based on geometric, volume and access data to identify the quantitative impacts of independent variables on accident rates. There were two types of independent variables: quantitative factors and descriptive factors. Quantitative factors included the AADT, access density, speed limit and segment length and their corresponding logarithmic form. Descriptive factors included number of lanes, median/no median, and shoulder/no shoulder. Accident rates were categorized into 7 groups of highways/arterials as follows:

- 4-lane with shoulder
- 4-lane without shoulder
- 2-lane with shoulder
- 2-lane without shoulder
- 4-lane with median
- 4-lane without median
- 2-lane without median

Regression models were developed separately for each of the seven highway groups. Eight independent variables (AADT, access density, speed limit, segment length, and their corresponding logarithmic form) were considered for the regression analysis with the accident rate the dependent variable.

**Study Locations and Data Collection**

The analysis was carried out by classify-

---

**Table 1. Percentage of Section and Intersection Accidents**

<table>
<thead>
<tr>
<th>Route</th>
<th>Percentage of Section Accidents (%)</th>
<th>Percentage of Intersection Accidents (%)</th>
<th>Percentage of Intersection Accidents (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left-Turning</td>
<td>Right-Turning</td>
<td>Turn (Total)</td>
</tr>
<tr>
<td>27</td>
<td>34.6</td>
<td>65.4</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>32.5</td>
<td>67.5</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>32.7</td>
<td>67.3</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>28.7</td>
<td>71.3</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>29.7</td>
<td>70.3</td>
<td></td>
</tr>
</tbody>
</table>
ing roadway sections based on geometric characteristics, such as shoulder/no
shoulder, median/no median, access classification, and traffic control factors, such as
the speed limit. Each study section had uniform characteristics in terms of the
number of lanes, median, shoulder, speed limit and Annual Average Daily Traffic
(AADT). The four study routes were divided into 200 study sections ranging from
0.5 to 3.2 kilometers of length. The access density and the accident rate were calculated
for each study section.

**Results**

**Identification of Access Related Accidents**

Table 1 shows the percentage of section accidents and intersection accidents estimated for each highway. Nearly 30% of all accidents were section accidents. Note that turning vehicles caused 20.8% to 31.3% of all section accidents. On average, turning vehicles caused 25.3% of all section accidents. This indicates that approximately 7.5% of all accidents were access related accidents.

<table>
<thead>
<tr>
<th>Collision Type</th>
<th>Section Accidents</th>
<th>Intersection Accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same direction – rear</td>
<td>37.1%</td>
<td>33.2%</td>
</tr>
<tr>
<td>Same direction – side</td>
<td>15.5%</td>
<td>15.3%</td>
</tr>
<tr>
<td>Left turn</td>
<td>6.3%</td>
<td>13.9%</td>
</tr>
<tr>
<td>Fixed object</td>
<td>8.9%</td>
<td>5.6%</td>
</tr>
<tr>
<td>Overtur</td>
<td>0.3%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Struck parked vehicle</td>
<td>7.9%</td>
<td>2.2%</td>
</tr>
<tr>
<td>Pedestrian</td>
<td>2.7%</td>
<td>1.8%</td>
</tr>
<tr>
<td>Angle</td>
<td>13.4%</td>
<td>22.3%</td>
</tr>
<tr>
<td>Head-on</td>
<td>3.2%</td>
<td>2.4%</td>
</tr>
<tr>
<td>Other</td>
<td>4.7%</td>
<td>3.2%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vehicle Contribution Circumstance</th>
<th>Section Accidents</th>
<th>Intersection Accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improper turning</td>
<td>3.2%</td>
<td>5.6%</td>
</tr>
<tr>
<td>Driving inattention</td>
<td>37.4%</td>
<td>33.1%</td>
</tr>
<tr>
<td>Following too close</td>
<td>2.3%</td>
<td>2.0%</td>
</tr>
<tr>
<td>Unsafe speed</td>
<td>2.8%</td>
<td>2.6%</td>
</tr>
<tr>
<td>Improper parking</td>
<td>0.5%</td>
<td>0.2%</td>
</tr>
<tr>
<td>Improper lane changing</td>
<td>2.6%</td>
<td>2.3%</td>
</tr>
<tr>
<td>Improper passing</td>
<td>1.9%</td>
<td>1.4%</td>
</tr>
<tr>
<td>Other</td>
<td>49.3%</td>
<td>52.8%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Weather Condition</th>
<th>Section Accidents</th>
<th>Intersection Accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear</td>
<td>77.4%</td>
<td>79.3%</td>
</tr>
<tr>
<td>Rain</td>
<td>18.9%</td>
<td>18.3%</td>
</tr>
<tr>
<td>Snow</td>
<td>3.7%</td>
<td>2.4%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Surface Condition</th>
<th>Section Accidents</th>
<th>Intersection Accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry</td>
<td>73.4%</td>
<td>74.3%</td>
</tr>
<tr>
<td>Wet</td>
<td>22.7%</td>
<td>23.4%</td>
</tr>
<tr>
<td>Snow and ice</td>
<td>3.9%</td>
<td>2.3%</td>
</tr>
</tbody>
</table>
Accident Analysis of Section Accidents and Intersection Accidents

Collision Type

For both section and intersection accidents, the percentages of the types of collisions were calculated and are summarized in Table 2. The percentages of left turn collisions and angle collisions for intersection accidents were higher than those among section-accidents. The higher percentage of intersection accidents involving left turning vehicles can be justified by the fact that there are more left turning movements at signalized intersections in comparison to those which occurred between signalized intersections.

The higher percentage of intersection accidents involving angle collisions may be attributed to the presence of a higher number of conflicting movements at signalized intersections than between signalized intersections.

The percentages of same direction rear collision, collisions with objects, pedestrians, overturns and struck parking vehicles for intersection accidents are lower than those for the section accidents.

Vehicle Contribution Circumstances

In the accident records, vehicle contribution circumstances were divided into improper turning, driving inattention, following too close, unsafe speed, improper parking, improper lane changing, improper passing, and other. The percentages for each of these circumstances for both section and intersection accidents are presented in Table 2.

Weather and Road Surface Conditions

Weather conditions in accident statistics are grouped into clear, rain, and snow, while surface conditions are grouped into dry, wet, snow and ice. Table 2 shows the percentages of accidents that occurred under each of these conditions for both section and inter-
section accidents.

Note that the percentages of section accidents that occurred under snow weather or on road surfaces covered with snow or ice were significantly higher than the corresponding ones for intersection accidents. This indicated that snow weather and snow covered road conditions had a larger impact on the occurrence of accidents between inter-sections than at signalized intersections. However, this observation did not hold for clear, rainy weather or dry, wet surface conditions. Rainy weather and wet surface conditions did not show any significant difference in the occurrence of section and intersection accidents.

Time of Accident Occurrence

Figure 2 shows the percentages of hourly accidents in one day for both section and intersection accidents. The hourly distributions of section-accidents and signalized-intersection-accidents are very similar. The lowest accident rate occurs between 4:00 a.m. and 5:00 a.m., and then it starts to climb continuously. The accident rate reaches its peak between 3:00 p.m. and 6:00 p.m., and then starts to decline until the period of 4:00 a.m. to 5:00 a.m., where the next cycle starts.

Relationship Among Accident Rate and Access Density, Geometric Characteristics and Traffic Volume

Descriptive Statistical Analysis Results

Figure 3 presents the corresponding graphs of the access density and accident rate per section of NJ State Route 27 southbound. Other routes exhibited similar results.

Accident Rate Distribution Analysis

The analysis was conducted based on the six access density levels, which were identified earlier (Table 3). The logarithm values of accident rates were calculated, and
normality plots were drawn based on these logarithm values. The plotted points showed a reasonably linear pattern, which indicates that a log-normal distribution assumption of accident rates is more reasonable than the conventional normality assumption. The parameters of the probability density functions of accident rates were then estimated and are summarized in Table 3.

Mean Equality Tests (Kruskal-Wallis) Results

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0-6.2</td>
<td>32</td>
<td>0.90</td>
<td>-0.59</td>
</tr>
<tr>
<td>6.2-12.4</td>
<td>38</td>
<td>1.09</td>
<td>-0.39</td>
</tr>
<tr>
<td>12.4-18.6</td>
<td>40</td>
<td>1.90</td>
<td>0.17</td>
</tr>
<tr>
<td>18.6-24.8</td>
<td>37</td>
<td>2.05</td>
<td>0.24</td>
</tr>
<tr>
<td>24.8-31.0</td>
<td>30</td>
<td>2.06</td>
<td>0.24</td>
</tr>
<tr>
<td>&gt;31.0</td>
<td>6</td>
<td>1.56</td>
<td>-0.03</td>
</tr>
</tbody>
</table>

The purpose of the mean equality tests is to identify the impact of single factors on accident rates. These factors include the AADT, access density, median, number of lanes, shoulder, and speed limit.

The probability of equal means for the 4-lane and 2-lane subgroups is 28.17%, which is much larger than that of subgroups defined by other factors. The main conclusion is that AADT, access density, median, shoulder, and speed limit have a

Table 4. Regression Models for the 7 Highway Section Types

<table>
<thead>
<tr>
<th>Highway Type</th>
<th>Model Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-lane with shoulder</td>
<td>ln(Accident Rate) = -0.22 – 3.3E–05<em>AADT + 0.025</em>Access Density</td>
</tr>
<tr>
<td>4-lane without shoulder</td>
<td>Accident Rate = -0.88 + 0.46<em>ln(Speed Limit) – 0.16</em>ln(AADT) + 0.63*Access Density</td>
</tr>
<tr>
<td>2-lane with shoulder</td>
<td>Accident Rate = 12.13 - 0.42<em>ln(Speed Limit) – 1.04</em>ln(AADT) + 0.27*ln(Access Density)</td>
</tr>
<tr>
<td>2-lane without shoulder</td>
<td>ln(Accident Rate) = 31.29 - 0.22<em>ln(Speed Limit) – 2.81</em>ln(AADT) - 0.50*ln(Access Density)</td>
</tr>
<tr>
<td>2-lane without median</td>
<td>Accident Rate = 21.76 - 0.61<em>ln(Speed Limit) – 1.92</em>ln(AADT) + 0.17*ln(Access Density)</td>
</tr>
<tr>
<td>4-lane with median</td>
<td>Accident Rate = 0.21 – 1.2E–05<em>AADT + 0.044</em>Access Density</td>
</tr>
<tr>
<td>4-lane with median</td>
<td>ln(Accident Rate) = -0.96 – 3.04E–05<em>AADT + 0.043</em>Access Density</td>
</tr>
<tr>
<td>4-lane with median</td>
<td>Accident Rate = 4.93 – 0.56<em>ln(AADT) + 0.57</em>ln(Access Density)</td>
</tr>
<tr>
<td>4-lane with median</td>
<td>ln(Accident Rate) = 6.86 – 0.91<em>ln(AADT) + 0.54</em>ln(Access Density)</td>
</tr>
<tr>
<td>4-lane without median</td>
<td>ln(Accident Rate) = 5.90 - 0.0028<em>Speed Limit – 0.61</em>AADT + 0.078*Access Density</td>
</tr>
</tbody>
</table>
significant impact on accident rates, whereas the impact of the number of lanes on accident rates is not as significant.

**Accident Prediction Models**

The main candidate independent variables considered were the following: AADT, access density, speed limit, and segment length. The square forms of these variables, as well as their corresponding logarithmic forms, were also considered as candidate independent variables.

Some of the results of the regression analysis conducted for all seven groups of highways are summarized in Table 4. For the following types of highway sections, the regression results can be used with caution to predict accident rates for accidents between intersections: 2-lane highway without shoulder, and 4-lane highway with median.

**Summary and Conclusions**

The primary results of this study are the following:

- Approximately 30% of the total accidents on the study state highways/arterials in NJ are expected to occur between signalized intersections.
- Approximately 7% of the total accidents can be directly attributed to access points, involving turning vehicles to/from access points.
- Snow and ice surface conditions contribute more to the overall accidents occurring between signalized intersections than at signalized intersections, on a comparative basis.
- The highest percentage of accidents was observed to occur during the evening peak from 3:00 p.m. to 6:00 p.m.
- Driver inattention is the primary factor in accident occurrence for both the section (37%) and signalized intersection accidents (33%).
- Accident rates are better represented by a log-normal versus a normal distribution.
- Two regression models for 4-lane with shoulder, 2-lane without shoulder and 4-lane with median were found to have sufficiently good R-square values and their use is recommended with caution.
- Access density is a contributing factor to the occurrence of accidents between signalized intersections, although not necessarily the only one. There are sections with high access density and low accident rates, which indicates that other factors should be considered in the accident analysis for sections between intersections.
Kyriacos C. Mouskos received his B.S., M.S. and Ph.D. degrees in civil engineering from the University of Texas at Austin. He was an assistant professor of civil and environmental engineering at NJIT, and is currently research professor at the Institute for Transportation Systems at the City College of New York. Dr. Mouskos is a member of various transportation and operations research organizations and is an active member of the Traffic Flow Theory and Characteristics Committee of the Transportation Research Board of the National Academy of Science. He currently collaborates with the Institute for Transportation Systems at CCNY and the Transportation Information Decision Engineering (TIDE) Center at NJIT, in addition to NCTIP. Dr. Mouskos’ primary areas of interest include transportation system analysis and design, intelligent transportation systems, traffic engineering, transportation planning and operations research.

Dr. Wu Sun assumed a position as a research associate with NJIT’s Transportation Information and Decision Engineering (TIDE) Center after receiving his Ph.D. in Transportation from NJIT in 1999. Since that time, he has also completed an additional Master's Degree in Computer Science. Dr. Sun's thesis is titled Optimization of Urban Traffic Control Strategies by a Network Design Model. His current areas of research are internet-based traveler information systems and transportation network design problems.
External Validity Test for Discrete Choice Transportation Forecasting Models Based on the Stated Choice Approach

Principal Investigator: W. Patrick Beaton, Ph.D.
Customer: James Redeker, NJ Transit
Project Monitor: Arthur W. Roberts III, NDOT
The Conditional Logit Model (CLM) is the theoretical and analytical model of choice for transportation policy studies. However, current use of the discrete choice theory underlying the CLM may be flawed. The low accuracy of prediction may indicate that current models have significant biases or errors.

Resource constraints explicitly exist in an individual's travel mode switching behavior and therefore significantly affect this behavior. As such, ignoring these constraints in the systematic utility term will cause biases in the model calibration. Explicit inclusion of constraints is incorporated into an extended theoretical model, the Constrained Conditional Logit Model (CCLM). The constraints that govern travel mode switching behavior are no longer limited to monetary and time budgets, but are extended generally to all resources which are consumed in travel.

The study shows that the CCLM is capable of recovering the effects of constraints when these constraints do exist. Also, ignoring these effects would cause significant biases in estimation of the effects of a travel service change. An empirical study is made to test the hypothesis about the existence of constraints. A mode split analysis is made based upon the comparison of the forecast and real mode shift due to imposition of a parking charge. The CCLM can effectively correct the biases and errors caused by exclusion of constraints in the indirect utility function.

**Literature Review**

Discrete mode choice theory is considered as an extension of the fields of microeconomics, psychology and sociology. Travel mode choice models are the application of probability decision theory (Ben-Akiva and Lerman, 1985). This theory recognizes the imperfect information attainment for decision makers. A random or probabilistic element is included in the decision process (Palma, Myers, and Papageorgiou, 1994). The randomness can be incorporated in a number of ways and many models have been developed in travel demand analysis (Bovy and Bradley, 1985, Golob and Meurs, 1987). Techniques that extend the decision theory of microeconomics to the choices among discrete sets of alternatives are called discrete choice models (Ben-Akiva and Lerman, 1985, Domencich and McFadden, 1975). These models, like other standard models in microeconomics, assume that an individual's preferences among the possible alternatives can be described by a utility function.

**Problem Statement and Hypothesis**

Travel mode switching is defined as an individual changing his mode due to a
change in travel services, such as an increase in parking charges. One characteristic of mode switching is that the decision maker has a current travel mode. The commuter needs to consider the benefit, or utility, derived from the current alternative, as well as the feasibility of switching to another mode.

Consumer theory underlying the discrete choice models is based upon utility maximization. It is noteworthy that the arguments in the systematic utility term contain the resources consumed in travel, i.e., travel cost and travel time. Generally, the resources are defined as the prices for the corresponding travel mode. As distinguished from the utility function with arguments of quantities of commodities used in classical economics, the utility function with arguments of prices is called the indirect utility function (Ben-Akiva & Lerman, 1985).

The total amount of resources available should be included into the indirect utility function as a constraint. Bates (1988) indicates the necessity of the inclusion of constraints into the indirect utility function, although he does not identify a theoretical model or an empirical model to test this supposition. Kitamura (1990) suggests that the constraints that govern travel behavior are not limited to monetary and time budgets as in classical utility maximization. The constraints may also include spatial and temporal fixity constraints associated with the respective activities, interpersonal linkages and other types of constraints.

Methodology

The CCLM is derived as an extension of the CLM. The form of the CCLM is as follows, where:

\[
P(c, i) = \frac{\exp\left(\sum_{k=1}^{K} x_{ik} + \frac{\sum_{n=1}^{N} (x_{nk} - x_{nk}^*)}{\sigma^2}\right)}{\int_{j=1}^{J} \exp\left(\sum_{k=1}^{K} x_{jk} + \frac{\sum_{n=1}^{N} (x_{nk} - x_{nk}^*)}{\sigma^2}\right) \, dJ}
\]

\(P(c, i)\) -- the probability for switching travel mode from current mode \(c\) to proposed alternative \(i\)

\(x_{ik}\) -- attribute \(k\) for proposed alternative \(i\)

\(x_{ck}\) -- attribute \(k\) for current mode \(c\)

\(k\) and \(K\) -- parameters

\(n\) -- Scaling factor for individual \(n\)

Internal Validity of the Model Structure

An internal validity is conducted to answer whether the CCLM makes a difference from the CLM on the replication of actual travel mode switching; and to determine the impact of assuming a CLM where the actual model should be the CCLM.

For this example, data was taken from a 1968 survey in the Washington, D. C. metropolitan area (Ben-Akiva & Lerman 1985) and is summarized in Table 1. There are three travel modes in the survey: drive alone, bus and carpool. Three attributes are included in the systematic utility function: travel time, travel cost and out-of-vehicle time.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Share</th>
<th>Travel Time (Min)</th>
<th>Travel Cost (Cents)</th>
<th>Out-of-Vehicle Time (Min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto</td>
<td>57%</td>
<td>26.7</td>
<td>88.5</td>
<td>5.4</td>
</tr>
<tr>
<td>Bus</td>
<td>16%</td>
<td>56.5</td>
<td>47.1</td>
<td>18.6</td>
</tr>
<tr>
<td>Carpool</td>
<td>27%</td>
<td>36.7</td>
<td>35.4</td>
<td>10.4</td>
</tr>
</tbody>
</table>

Table 1: Washington, DC Survey Data

In order to generate records for individ-
Table 2: Summary of True Values and Estimated Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>True Value</td>
<td>-0.0389</td>
<td>-0.00725</td>
<td>-0.00121</td>
<td>-0.0054</td>
<td>-0.00012</td>
<td>-0.0112</td>
</tr>
<tr>
<td>CCLM Estimate</td>
<td>-0.04483</td>
<td>-0.01123</td>
<td>-0.00691</td>
<td>-0.00689</td>
<td>-0.00014</td>
<td>-0.01245</td>
</tr>
<tr>
<td>CLM Estimate</td>
<td>-0.05815</td>
<td>-0.01183</td>
<td>-0.00244</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The survey and data collection, the parameters for the corresponding attributes have to be pre-determined, and are shown in the Table 2. The parameters, 1, 2 and 3 are for travel alternative specific attributes, travel time, travel cost and out-vehicle time and, 1, 2 and 3 are the parameters for the constraint variables imposed on the three travel alternative specific attributes.

The parameters are estimated for both the CLM and CCLM and are also shown in Table 2. Using the t-test, each of the parameter estimates obtained for the CLM are identified as significantly different from both the pre-determined parameter values as well as from the parameter estimates for the CCLM. In other words, if the CCLM can capture the effects of constraints while these constraints do exist in individuals mode switching, the CLM will lose accurate estimates for these parameters.

Survey and Data Collection

Although the validity of the CCLM has been identified theoretically, an empirical study is still necessary for supporting the conclusion that the model can effectively replicate the effects of constraints on individuals’ travel mode switching.

Surveys of commuters were conducted at two employment sites in downtown Newark, New Jersey in 1994. Both sites are similar in many regards. Parking is provided at both sites; at Site 1, a $3 per day fee is charged; at Site 2, the parking is free. Both sites are also well served by both bus and commuter rail. The employee job distribution is also similar. Table 3 summarizes the two sites.

The CCLM is calibrated to a particular set of alternatives by the data obtained from the survey instrument. First, the respondents are requested to report their current travel choices and income information.

Second, the mode choice scenarios are presented to the respondents. A total of 18 scenarios, consisting of a mode, in-vehicle time, out-of-vehicle time and travel cost, were designed. Respondents are asked to choose just one travel mode according to their tastes or preferences. The final data set contains 646 and 898 observations for the two sites, respectively.

Estimation and Test of Hypothesis

The empirical evidence is used to test the hypothesis proposed earlier that constraints should be explicitly included in the indirect utility functions. The hypothesis tests are conducted through the following steps:
1. The coefficients in the systematic utility function are estimated for the CLM and the CCLM. This process is conducted for the two data sets separately.

2. A $\chi^2$ test is performed for the null structural difference hypothesis and a $t$ test is performed to test the null coefficient hypothesis for each constraint variable.

3. The two data sets are pooled and tested for a common underlying structural model.

The following significant conclusions were drawn from the analysis of the two data sets.

1. The null structural difference hypothesis was rejected for both data sets. The parameters underlying the CCLM were found to be significantly different from the CLM.

2. The results of the $t$ test found that the constraints on both travel time and cost do exist for both data sets and do affect mode switching.

3. The coefficients for the constraint terms are all negative. This result shows that the constraints for travel time and cost tend to encourage individuals to remain in their current modes, instead of switching to an alternative.

4. Empirical evidence has identified the existence of the constrained resources, such as time and cost, on individual mode switching behavior. Ignoring the effects of these constraints will cause biased coefficient estimates. The CCLM can correct these biases and errors.

5. In addition, correcting the biases in the estimation of the coefficients makes the transferability of the empirical models possible. The joint estimation improves the estimation efficiency as well as the accuracy.

**External Validity Test**

An external validity test of the CCLM

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Site 1</th>
<th>Site 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employees</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Professional</td>
<td>36%</td>
<td>39%</td>
</tr>
<tr>
<td>% Administrative/Managers</td>
<td>25%</td>
<td>20%</td>
</tr>
<tr>
<td>% Other Classifications</td>
<td>39%</td>
<td>41%</td>
</tr>
<tr>
<td>Number of Parking Spaces</td>
<td>756</td>
<td>902</td>
</tr>
<tr>
<td>Average Commute (miles)</td>
<td>18 mi</td>
<td>19 mi</td>
</tr>
<tr>
<td>Mode Share</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drive Alone (DA)</td>
<td>60.5%</td>
<td>63.2%</td>
</tr>
<tr>
<td>Carpool / Vanpool (CP)</td>
<td>14.5%</td>
<td>13.1%</td>
</tr>
<tr>
<td>Public Transit (PT)</td>
<td>20.5%</td>
<td>23.2%</td>
</tr>
<tr>
<td>Other</td>
<td>4.5%</td>
<td>0.5%</td>
</tr>
</tbody>
</table>
examines the model's ability to predict travel mode switching behavior associated with a change in travel conditions, such as imposition of a parking charge. The test includes the following steps:

1. Randomly select a set of individuals and record their current mode and attributes.
2. Randomly assign these individuals to either the control condition or to the test condition. The control condition maintains the current conditions while the test condition imposes a parking charge.
3. Observe and record the real mode choice for the two sub-samples before and after the parking charge is imposed.
4. Predict travel mode switching behavior using the CCLM.
5. Compare the CCLM prediction with the actual switching behavior. If the prediction is similar to the actual behavior, then the CCLM is externally valid.

An ideal external validity test is seldom supported by real world conditions. A longitudinal design effectively guarantees the control and test samples identical by observing the sample's behavior before and after the test condition is executed. For this study, two samples were selected based on their similar characteristics to replace the panel data. This data is called cross-sectional data.

Cross-sectional experimental designs should also meet the equal distribution requirement, i.e. both samples should have identical covariate distributions. Data taken from the two sites however revealed differences across many variables: travel time, income, etc. The difference between direct observations of the two samples' mode split will therefore include a confounding effect as well as the parking charge impact. To remove the confounding effect, an adjustment of the covariate values is required.

The Site 1 and Site 2 data were combined to create a truth set. Using the Site 2 mean and variance as the parameters, a set of normally distributed elements are generated and are used to adjust the covariates for the Site 1 data. These adjusted covariates are then used to produce an adjusted mode choice using the CCLM. Table 4 presents the results of the truth set, the forecast values and the external validity test result.

The null difference hypothesis cannot be rejected for the Drive Alone and Transit modes, but can be rejected for Carpool. The reason for the rejection is that very few individuals in the two sites use Carpool as their commute mode. The small number of observations causes a loss of accuracy when computing the mode split values for Carpool. However, the mode split forecast generated by the CCLM model is statistically identical with the adjusted observation for the Drive Alone and Transit modes.

The results of an external validity test using a cross-section experimental design

<table>
<thead>
<tr>
<th>Mode</th>
<th>Mode Split Value (Truth Set)</th>
<th>Mode Split Value (Forecast)</th>
<th>Forecast Error</th>
<th>T-Test Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drive Alone</td>
<td>65.5%</td>
<td>66.7%</td>
<td>1.2%</td>
<td>1.51</td>
</tr>
<tr>
<td>Carpool</td>
<td>12.1%</td>
<td>12.8%</td>
<td>0.7%</td>
<td>2.28</td>
</tr>
<tr>
<td>Transit</td>
<td>22.4%</td>
<td>20.6%</td>
<td>1.8%</td>
<td>1.90</td>
</tr>
<tr>
<td>Total</td>
<td>100.0%</td>
<td>100.0%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
for the CCLM model certify that:
1. Cross-sectional experimental design can be used in external validity test where panel data is not available. The two samples used in the cross-section experimental design must be identified as drawn from the same target population.
2. To remove the confounding factor, the covariates of two samples must be adjusted to have identical distributions.

The CCLM model has been identified valid through both internal and external validity test. This study shows that the CCLM model can successfully forecast the mode split change associated with a parking charge imposition for the Drive Alone and Public Transit modes.

Conclusions
The CCLM was developed based on the hypothesis that existing resource constraints have significant effect on an individual's mode switching. The theoretical and empirical studies presented herein support the validity of this hypothesis.

The first contribution is the development of the CCLM model which explicitly includes the resource constraint into the decision making process and the switching probability function. This advance gets the discrete choice theory underlying travel mode choice consistent with classical economic theory. The explanatory model estimation and the internal and external validity study herein show that the CCLM can successfully address this issue without increasing the complexity of the model estimation.

The CCLM therefore provides a tool for evaluating the effect of various constraints beyond time and cost and including exogenously-imposed schedules, physical needs, authority and morality.

The second contribution is the advance to model estimation. A factor grid searching approach that was developed originally in stated preference (SP) and revealed preference (RP) data combination is applied on the joint estimation by the combination of two samples. This process not only improves the efficiency of the estimation but also provides a tool on the study of transferability of empirical models.

As the CCLM corrects the errors caused by failing to incorporate constraints in the indirect utility function, more precise estimates for the attributes in systematic utility become passable. These improvements can help to promote the accuracy on predicting the individuals' mode switching at different sites and under different situations.

The third contribution is the improvement of the experimental design for the external validity test. A cross-sectional design was used in this study to replace the longitude design that is generally used. The cross-sectional design makes the external validity test available when researchers have no opportunity to manipulate both test and control conditions in the actual experiment.

The cross-sectional design can also avoid the time effect in the longitude design, such as individual's taste change with time. However, the cross-section experimental design can only be used under the following conditions:
1. The two samples must be identified as drawn from the same target population.
2. The two samples' covariates distribution must be identical. Otherwise, the mode split values must be adjusted.

If the above two conditions are not true in the real situation, confounding factor will affect the observation of the actual mode switching behavior. The confounding effect caused by using two samples to form a truth set has been studied in this report. The adjustment of the covariate values of the two samples is another important contribution. Without removal of the confounding effect by the covariate values adjustment, cross-sectional design has little opportunity to be applied since it is impractical to expect two samples with identical distributions of attributes in the real world.

Further work is still needed to improve the approach for establishing empirical models. One issue is how to design the proposed travel alternatives and the associated attributes so as to avoid the errors related to RP and SP combination. Further study about the survey method and data collection is also necessary.

The analysis of the effects of other constraints, such as physical and morality, on the individual travel mode switching also requires more empirical studies.

References


Dr. W. Patrick Beaton is a professor of social science and policy studies with the Department of Humanities and Social Sciences at NJIT. His research interests are public policy evaluation and policy analysis. Dr. Beaton received his MCRP degree in Community and Regional Planning and Ph.D. degree in Urban Planning from Rutgers University.
Socioeconomic and environmental impacts of highway expansion and traffic congestion have spurred renewed interest in the potentials of telecommuting. This can be seen in New Jersey company surveys such as those at AT&T, where 61 percent of employees sampled preferred telecommuting to other alternatives; and at Educational Testing Service, where 18 percent of the professional staff are already telecommuting (Cunnie, 1995). Transportation 2020: the New Jersey Statewide Long Range Transportation Plan speaks to the need to work with businesses on incentives for telecommuting.

The Clean Air Act Amendments of 1990 required large employers to develop ways of reducing the use of automobiles for travel to and from work. Despite a revision to the amendments that removed penalties for not meeting employee trip reduction targets, interest in telecommuting continues to grow. This continued interest stems from a number of forces — technical, social, and economic.
The *technical* push comes from advances in telecommunications, including increased availability of PCs and modems at home, personal use of the Internet, and growth of intranets in the workplace. The *social* push stems from changing demographics of the workforce with the increasing entrance of women and demands for more flexibility in work-time, as well as the inclusion of more workers with disabilities in the workforce. The *economic* push comes from the change of manufacturing to a service economy. Unlike manufacturing, the service sector does not demand work be done in a fixed location. Moreover, corporate America is eyeing other productivity gains to be realized from telecommuting.

A 1995 national telephone survey resulted in an estimate of 8.1 million telecommuters, or about 6.6 percent of the working population (including home businesses) working one or more days per month from home (Business Week, 1995). A more recent telephone survey showed a dramatic increase to 11.1 million telecommuters. Given the increase in the total workforce to about 136.5 million in 1997, this represents 8.1 percent of the civilian workforce (FIND/SVP, 1997).

**Research Project**

Given the paucity of research relating to managing telecommuters, this project sought to fill some of the void by probing the knowledge gained through experience by those in management positions. Through semi-structured interviews, specific changes in practices and behaviors in regard to telecommuters was elicited. The majority of the interview time was devoted to management issues, as outlined in Figure 1.

It was found that, by far, most workers telecommuted part time, one or two days per week, and telecommuting from a telecenter was also feasible. For the purposes of this research project, those who own businesses and conduct their business entirely from the home were excluded.

**Structural Issues Regarding Telecommuting**

Specific questions revealed basic information about the extent of telecommuting at the twelve companies interviewed. Five of the twelve interviewees reported no formal telecommuting program within their business unit or company, but all indicated that informal telecommuting was occurring. According to the interviewees, the approximate number of participants in formal telecommuting programs ranged from 0 to 4,600, while the number of participants in informal telecommuting programs was approximated as two to 15,000.

Very few organizations had full time telecommuters except those with large sales contingents. The sales units tended to be virtual offices. Most had employees who telecommuted anywhere from one to three days per week.
Figure 1: Code and subcode categories for communication and teamwork
Managerial Control and Performance Appraisal

A review of the various modes of communication used by managers showed that they most frequently used e-mail, followed by phone calls, with e-mail functioning both for messages and for the transmission of files. Phones were significant where managers required immediate feedback.

Telecommuters were usually supplied with computers, printers, and at least one phone line, although frequently they were given two lines - one for voice, the other for data. Since most managers were supervising part-time telecommuters, there was ample opportunity for face-to-face communication. Five of the managers reported use of phone conferences. They also indicated that phone conferences were one of the ways that employees at remote locations could still function as a team.

Those who managed both telecommuters and non-telecommuters reported that productivity measurement was similar for both. Goal achievement was mentioned most frequently, followed by work timeliness, contract and sales, work accuracy, cost efficiency, and in one instance, publications. Notable about all of these measures is that they focused on work outcomes and not on work process.

In response to the question concerning potential problems performance appraisal might hold in judging the work of telecommuters, all interviewed reported that current appraisal formats were equally appropriate for both telecommuters and non-telecommuters, and that they had experienced no difficulties.

Research Issues Regarding Managerial Planning

Managers did not perceive any changes in the way goals were set for telecommuting employees; goals are driven by business objectives regardless of where an individual works, and goal specification is still results-oriented.

Similar to goal setting, no major change was seen in giving feedback to employees who telecommuted. Where immediate feedback was needed, e-mail or telephone was used if the employee was not on site that day. In that sense, this was seen as a less personal touch.

While no major changes were seen in the techniques of managing or management style as a result of managing telecommuters, some themes did recur in response to the item about problems managing telecommuters. Two managers mentioned the sense of not knowing what their people were doing, while one was concerned that higher levels of management might overlook telecommuters. Several mentioned frustrations of both managers and employees due to technical problems that would occur. Four mentioned the demands on both manager and telecommuter for being more organized. For example, this took the form of making sure conference call lines were set up and working, getting out agendas, and setting up time frames for tasks.

In response to the question about management style, the majority responded that theirs was one of flexibility. Moreover, they believed that a "command and control" style of management was not conducive to managing telecommuters. They believed that managers who required a great deal of
control would feel uneasy about the fact that they could not have instant access to the employee.

**Research Issues Concerning Communication and Coordination**

The most frequently mentioned form of communication was that of e-mail to communicate general organizational information such as memos and reports. Managers were likely to be using both phones and e-mail as communication modes. Questions concerning satisfaction with the quality of communication show that 12 out of 12 managers were satisfied, and, moreover, found that the varieties of media served them well.

Another area of concern was that of informal communication (i.e., small talk). Managers expressed little or no concern about deterioration of informal communication, but it needs to be kept in mind that most were managing part-time telecommuters.

Of major concern regarding informal communication and telecommuting was that certain individuals might feel excluded. Eight of twelve interviewees indicated concern about telecommuters feeling included in the organization or group. Six of twelve mentioned exclusion as well. While there were more concerns expressed about feelings of inclusion than exclusion, some sense of exclusion does reside, and it needs monitoring.

**Research Issues Concerning Equity**

The managers interviewed generally did not have a problem with equity in terms of work assignments and distribution. Half of the managers did see promotional opportunities being affected by telecommuting, with visibility and networking being cited as problems. Managers were more positive when it came to assessing the affect of telecommuting on compensation. Their response typically was that pay was tied to performance, not location.

In most organizations, choice of telecommuters was mostly a matter of self-selection. There were, however, a few organizations that insisted employees spend some time within the organization before telecommuting. Those that requested telecommuting were high performers and management wanted to accommodate their needs. The trait mentioned frequently was that of trust.

**Research Issues Regarding Socialization and Teamwork**

Managers reported that work was assigned on both an individual and a team basis. Since most telecommuters weren’t telecommuting full-time, there was little impact on teamwork. Also, teams often consisted of workers from various locations. Even where the employee was a full time telecommuter, use of telecommunications enabled the team to function effectively.

Four of the twelve interviewees indicated they saw no evidence of conflicts due to telecommuting. The remaining eight reported conflicts due to miscommunication of e-mails or scheduling problems. However, conflicts were largely manageable.

Managers were very positive regarding the support that team members give each other. Either they believed that telecommuting did not affect team member cooperation
in any negative way, or they saw positives.

**Summary of Findings and Conclusions**

The study indicated that few changes have been observed since most managers were supervising telecommuters who used the work arrangement part-time. A major finding was that many companies do not track the number of telecommuters, and even where they do, there is a great deal of informal or casual telecommuting.

While the interviewed managers saw little differences in their way of managing telecommuters and non-telecommuters, they did rely on performance indicators as a way of appraising productivity. Some talked about the premium put on organizational skills — their own and their telecommuting employees’. Moreover, these managers were comfortable using e-mail as a means of communicating with all employees in addition to phones and face-to-face interactions. The one area of concern to them regarding their telecommuting employees was the impact of long-term, full time telecommuting on career advancement.

Teamwork continued even with some employees telecommuting. This was possible because of the part-time nature of telecommuting and the flexibility enabled by phone conferences. Since team members were often geographically dispersed anyway, telecommuting was not seen as a disruption. The managers sampled also often had their own managers working in different geographical locations so they were accustomed to not being in close proximity to their colleagues.

These managers, who were supportive of telecommuting work arrangements, characterized their own management style as flexible, trusting of their employees, and wanting to provide work environments that were conducive to accomplishing the work. In the cases of some of their employees, this meant telecommuting.

A number of recommendations were made.

1. **To assess the readiness of an organization for telecommuting, an audit to find out how much casual telecommuting already exists should be conducted.** An organization may be further ahead than expected.

2. **Communication:** the extent to which an organization is using e-mail, phone conferences and other asynchronous forms of communication should be determined. The greater variety in telecommunication modalities used, the more an organization can adapt to telecommuting.

3. **Part-time telecommuting does not appear to present much need for change in management style or process.** Managers should be reassured regarding the limited requirements for change. The fact that these managers perceived virtually no change in their behaviors toward part-time telecommuters in comparison to non-telecommuters suggests that future studies should focus on full time telecommuting arrangements. This project will continue to add managers to the database already developed.

4. **Management assessment of employee performance needs to be based on outcomes.** Most organizations are already using formal appraisal systems which should be reviewed. Chances are that, in fact, the current performance appraisal
form will work. In this study, even where managers were supervising full-time telecommuters, their current performance appraisal form worked.

5. **Where full time telecommuting is contemplated, managers and employees need to go through a "learning curve" as they adjust to a new working arrangement.** Both should be prepared to undertake added effort in communication while "the manager" adapts to not having the employee readily available. Both need to go through some orientation to telecommuting issues. There are several sources and WEB sites that are helpful in giving guidelines for successful telecommuting programs.

6. **Equity.** The problem here deals with opportunities for promotion while telecommuting full time for an extended duration. While there may be some positions available, in most large organizations this currently does not seem to be a viable alternative. Career counseling should alert employees to maintain visibility. If long-term, full-time telecommuting is a job requirement for an employee, the employee needs to be counseled about ramifications for career progress. One alternative is to seek an organization that is comfortable with telecommuting as a full-time work arrangement.

7. **Selection.** Currently, telecommuting is available at a professional level in the organizations sampled, but not to hourly workers. Those wishing to telecommute can select it as an option but most organizations are not promoting it. This lack of promotion may give the impression that it is a second-class work arrangement. If an organization gives the option, then it should publicize the option as an alternative work arrangement through its Human Resource Department or other logical functional area.

8. **Teamwork.** This way of assigning tasks is disrupted less by telecommuting than one might think. Teamwork with telecommuting places a priority on organizational skills and attention to the details so that participants in teleconferences have available all materials that one would normally have available at a meeting. Coordination for a teleconference requires efforts similar to coordinating times for a face-to-face meeting. Communication in between can be handled by e-mail. With distribution lists, e-mail is often a better manager of communication than the team leader, who may forget to relay messages to everyone, may delay in relaying messages, or may distort or relay incomplete messages.

9. **Moving towards remote management.** An interesting and unexpected trend discerned in this project has been the move toward remote management regardless of telecommuting or non-telecommuting. That is, work is becoming distributed over geographical areas and managers are more and more likely to be based at locations that are apart from their subordinates. This portends a change so that managers, in general, will need the same skill set and style found among managers of telecommuters. Those skills place a priority on organization, communication over a variety of modalities,
an ability to set specific and unambiguous goals with employees, and the capacity to build trust of subordinates based on their performance.

References


Dr. Naomi Rotter, professor of management at NJIT's School of Management, received her Ph.D. in Industrial/Organizational Psychology from New York University in 1974. Since joining the faculty of NJIT in 1977, she has focused her research on organizational behavior and human research management. Dr. Rotter’s recent work in the behavioral side of transportation includes research on organizational variables in the implementation of telecommuting programs and, currently, a study of driving safety among mature drivers in the state of New Jersey. Another area of research involves faculty adaptation to distance and tele-learning.
Work zone operations are as common in New Jersey, as they are in other states in the country. However, New Jersey is a major thoroughfare for truck movements in the Northeast Corridor, and truck accidents in work zones in New Jersey have been found to be disproportionate to those in the general population. As illustrated in Table 1, accidents involving trucks are overly represented in work zone areas. Around twenty-five percent of such accidents involve trucks, compared to ten percent of all truck-related accidents.

Table 1: Accident Experience in New Jersey for 1993 and 1994

<table>
<thead>
<tr>
<th></th>
<th>General Population of Motor Vehicle Accidents</th>
<th>Accidents Involving Trucks</th>
<th>Truck Accidents/General Population of Accidents (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>219,972</td>
<td>23,434</td>
<td>10.7%</td>
</tr>
<tr>
<td>Statewide</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1993 in Work Zones</td>
<td>4,861</td>
<td>1,189</td>
<td>24.5%</td>
</tr>
<tr>
<td>1994</td>
<td>228,691</td>
<td>23,452</td>
<td>10.3%</td>
</tr>
<tr>
<td>Statewide</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1994 in Work Zones</td>
<td>4,485</td>
<td>1,227</td>
<td>27.4%</td>
</tr>
</tbody>
</table>
Research Project

The Problem Identification Committee of the Safety Management System of the New Jersey Department of Transportation (NJDOT), in reviewing a full year of accident summaries to determine unusual occurrences, found the incident of truck accidents in work zones to be disproportionately high. NJDOT approached NCTIP to undertake an analysis of the police accident reports with the expectation that a list of prominent causes for these occurrences would be ascertained. Initially, a pilot study was conducted using 28 truck/work zone accident reports. The lessons of this study were used to design a research approach and to estimate both the time and miscellaneous cost requirements for successful completion.

The objective of the research study was to identify distinguishing characteristics of and prominent causes for the overly represented truck accidents in work zones, which might lead to safety improvements in work zone operations. This was to be accomplished by analyzing the differences between truck accidents in work zones and truck accidents in non-work zones and by determining the correlation between collision types and physical environment for truck accidents in work zones in New Jersey for the years of 1993 and 1994.

The database used in this study contains three parts:
1. Database developed and maintained by the Bureau of Transportation Data Development (BTDD) of NJDOT, which includes all the coded information, except for information related to drivers and occupants of the vehicles who were involved in the accidents, from original police accident reports for all truck accidents in New Jersey for the years of 1993 and 1994.
2. Database developed and maintained by the New Jersey Turnpike Authority (NJTP) which includes two components - general data and vehicle data - for each accidents record, for truck accidents on the NJTP for the years of 1993 and 1994.
3. Database developed for the purpose of this study by NJIT.

The part of the database that was developed by NJIT is for truck accidents in work zones on interstate and state highway in New Jersey (excluding NJTP) for the years of 1993 and 1994. This portion of the database includes all coded information as well as information that can be retrieved from the descriptive part and diagrams by examining the hard copies of the accident reports. The information retrieved from the descriptive part and diagrams of the accident reports was summarized into two categories: physical environment and direct contribution. The physical environment refers to what kind of traffic control was used in the work zone, where and what kind of the activities were taking place, if and how any construction crew or vehicle was involved in the accident, and if any change in roadway geometry resulted from the work zone traffic control plan. The direct contribution refers to the major or most direct contributing factor to the accident.

Summary of Findings

The study relied on the database extracted from the Geographic Information System (GIS) database developed and maintained by the BTDD of NJDOT. This
database contained all the coded information from police reports of accidents involving trucks for the years of 1993 and 1994. All the hard copies of the statewide police truck accident reports in work zones, interstate and state highways for 1993 and 1994 were retrieved from the files. The hard copies were carefully analyzed to gather the narrative information that is contained in the descriptive portion and diagram part of the reports. A database was established based on information contained in the hard copies.

There were 23,434 truck accidents in 1993 statewide. Of these, 1,189 were coded as work zone accidents; 808 were coded as work zone accidents that occurred on interstate or state highways (excluding accidents occurring on toll facilities); and 145 were filed by NJTP as work zone truck accidents. For 1994, there were 23,452 truck accidents, 1,227 of which were coded as work zone accidents; 780 were coded as work zone accidents that occurred on interstate or state highways (excluding accidents occurring on toll facilities); and 235 were filed by NJTP as work zone truck accidents.

It was possible to retrieve 803 hard copies of truck accident reports on interstate or state highway work zones for 1993, and 764 for 1994. Narrative information was examined for mention of work zone activities. In addition, the date and location of the remaining truck accidents were compared against known work zone activities. A total of 417 truck accidents for 1993 and 453 truck accidents for 1994 were taken into consideration.

In order to understand the nature of truck accidents in work zones, truck accidents in non-work zones provide a basis for comparison. The comparison analysis was done to examine the distinguishing characteristics of truck accidents in work zones by comparing truck accidents in work zone with those in non-work zone areas based on the roadway system, day of the week, light condition, severity and time of the day. For collision type, not only truck accidents in non-work zones but also the general population of accidents in work zones was used for the comparison with truck accidents in work zones. The analysis used the coded information in the accident reports.

Roadway Systems. In non-work zones, a low percentage of truck accidents occur on interstate and toll authority roadways versus county and municipal roads, even though the former carry much of the interstate truck traffic. However, a review of truck accidents in work zones showed a much higher percentage on interstate and toll authority roadways.

Roadway Character. In both non-work zones and work zones, the majority of truck accidents occurred on roadway sections that were level and straight. This may be attributed to the fact that most roadways do not have curves or grades. The percentage of truck accidents in work zones is slightly higher than in non-work zones when a horizontal curve is present.

Days of the Week. The percentage of truck accidents in work zones is lower than in non-work zones during weekends. The fact that most work zone activities take place during weekdays certainly contributes to this.

Time of the Day. The highest percentage of truck accidents in both work and non-work zones occur between the hours of 8 a.m. and
3 p.m. These hours are also the time of the greatest amount of truck, as well as auto, traffic on the roadway system.

**Light Condition.** Approximately 80 percent of all truck accidents occur during daylight for work and non-work zones and for both highways and local roadways. There are minimal differences comparing daylight versus dark conditions.

**Weather Condition.** Approximately 85 percent of all work zone accidents occur during clear conditions versus 80 percent of all non-work zone accidents. There are minimal differences comparing clear versus inclement weather conditions.

**Location of the First Collision Event.** Approximately 90 percent of all truck accidents occur on-roadway for work and non-work zones and for all roadway types. There are minimal differences comparing on-roadway versus off-roadway accidents.

**Vehicle Type.** The vehicles involved in accidents are usually car versus truck. Approximately 80 percent of all truck accidents in both work and non-work zones involve a car and a truck. Again, there are minimal differences comparing the types of vehicles involved.

**Severity of Accidents.** Less than one percent of all truck accidents are fatal and approximately 25 percent involve personal injury. The percentages are slightly lower for work zone versus non-work zone accidents, as shown in Table 2.

**Collision Type.** Sideswipe and rear-end collisions are the predominant collision type in truck accidents in both work and non-work zones. A higher percentage of work zone traffic accidents are sideswipe (44 percent) versus non-work zones (25 percent).

**Contributing Factors.** Major contributing factors for truck accidents that were coded as work zone accidents are tabulated in Table 3. Over 70 percent of the accidents were attributed to driver’s fault. The most common contributing factor for truck accidents in work zones is "driver inattention," followed by "improper lane change," which may explain the large number of collisions. The third most common contributing factor for truck accidents in work zones is "failed to yield to ROW vehicle," which should focus attention on the treatment of ramps adjacent to work zones.

Nearly half of the reports show nothing relative to the location or activity at work zones. The information that can be

### Table 2: Severity of Truck Accidents

<table>
<thead>
<tr>
<th>Accident Severity</th>
<th>All Truck Accidents</th>
<th>Work Zone Truck Accidents</th>
<th>Work Zone Truck Accidents State and Interstate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1993</td>
<td>1994</td>
</tr>
<tr>
<td>Fatal</td>
<td>94</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>0.4%</td>
<td>0.6%</td>
<td></td>
</tr>
<tr>
<td>Injury</td>
<td>6,170</td>
<td>275</td>
<td>193</td>
</tr>
<tr>
<td></td>
<td>26.3%</td>
<td>23.1%</td>
<td></td>
</tr>
<tr>
<td>Property Damage</td>
<td>17,170</td>
<td>907</td>
<td>611</td>
</tr>
<tr>
<td></td>
<td>73.3%</td>
<td>76.3%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1994</td>
<td>1994</td>
</tr>
<tr>
<td>Fatal</td>
<td>82</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>0.3%</td>
<td>0.4%</td>
<td></td>
</tr>
<tr>
<td>Injury</td>
<td>5,773</td>
<td>249</td>
<td>164</td>
</tr>
<tr>
<td></td>
<td>24.6%</td>
<td>20.3%</td>
<td></td>
</tr>
<tr>
<td>Property Damage</td>
<td>17,597</td>
<td>973</td>
<td>614</td>
</tr>
<tr>
<td></td>
<td>75.0%</td>
<td>79.3%</td>
<td></td>
</tr>
</tbody>
</table>
Conclusions and Recommendations

There are about 25,000 truck related motor vehicle accidents occurring in the State of New Jersey each year. Of these, around 1,300 accidents happened in work zones statewide and more than 1,100 of these were either on interstate or state highways. Truck related accidents appear to be over-represented in work zones, especially on interstate and state highways, compared with other types of motor vehicle accidents. This study describes the characteristics of truck related motor vehicle accidents in work zones occurring on interstate and state highways.

To provide comprehensive data, a careful study was done of the hard copies of the original police accident reports obtained from the Bureau of Accident Reports of NJDOT, along with their database and data from the New Jersey Turnpike Authority. A database was developed and analyzed based on all the information provided by the two agencies. Statistical analyses were carried out to identify the relationship among the types of accidents, severity of the accidents, geometric layout of work zones and characteristics of the roadway. Countermeasures to reduce the severity of accidents are recommended. Rear-end and sideswipe are the two major types of truck related accidents in work zones.

Coding of the accident report by police officers was found not to be as accurate as desired. Recommendations are also made on the format of accident reports and proper training of police officers since accident reports are the basic source of information for conducting all kinds of traffic safety studies.

Major findings of this study include the following:

Table 3: Accident Experience in New Jersey for 1993 and 1994

<table>
<thead>
<tr>
<th>Direct Contribution to the Accident</th>
<th>Year 1993</th>
<th>Year 1994</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Driver at fault</td>
<td>371</td>
<td>312</td>
</tr>
<tr>
<td>Driver inattention</td>
<td>85</td>
<td>122</td>
</tr>
<tr>
<td>Improper lane change</td>
<td>59</td>
<td>49</td>
</tr>
<tr>
<td>Failed to yield to ROW vehicle</td>
<td>7</td>
<td>21</td>
</tr>
<tr>
<td>Improper passing</td>
<td>14</td>
<td>19</td>
</tr>
<tr>
<td>Following too close</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>Unsafe backing</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Disregarding traffic control</td>
<td>14</td>
<td>10</td>
</tr>
<tr>
<td>Speeding</td>
<td>8</td>
<td>42</td>
</tr>
<tr>
<td>2. Ice and snow on road</td>
<td>45</td>
<td>36</td>
</tr>
<tr>
<td>3. Due to unknown vehicle/hit-run</td>
<td>24</td>
<td>22</td>
</tr>
<tr>
<td>4. Vehicle defect/disabled vehicle</td>
<td>26</td>
<td>17</td>
</tr>
<tr>
<td>5. View obstruction/limited</td>
<td>85</td>
<td>114</td>
</tr>
</tbody>
</table>
1. The frequency of truck accidents in work zones is not significantly different from that in non-work zones by roadway system, roadway character, day of week, time of the day, weather condition, types of vehicles involved, light conditions, and the location of the first crash.

2. The severity of truck accidents in work zones was similar to that for truck accidents in non-work zones.

3. The predominate collision type is side-sweep, followed by rear-end for truck accidents in work zones.

4. Reporting of accidents in work zones was found not to be as accurate as desired; more information on the contribution of work zone activities relative to accidents is needed for the purpose of identifying the problem created by work zone traffic control plans, work zone layout and work zone signing. In-depth study of work zone safety requires more information on the location of accidents relative to the work zone.

It is recommended that two check boxes be added to the current accident report form used in New Jersey to provide additional information about the nature of accidents in work zones, which could result in improving traffic safety in work zones. The current accident report form has two check boxes regarding work zone activities: the first check box is whether the road is under construction (yes or no); and the second check box is whether workers are present at the accident scene (yes or no). In addition to these, two more check boxes would be helpful in providing information for work zone safety analysis as well as accident investigation where construction activities are conducted, and a description of the location of the accidents relative to the work zone layout.

For the first recommended check box, where construction activities are conducted, three choices should be made available to the accident investigator:

1. Construction on roadway/lane closure
2. Construction at median
3. Construction at roadside.

For the second recommended check box, description of the location of the accident relative to the layout of work zones, four choices should be made available to the accident investigator:

1. Advance warning area
2. Transition area
3. Activity area
4. Termination area.

The definitions of the work zone are provided in the Manual on Uniform Control Devices (FHWA, 1988). The advanced warning area starts from the first work zone warning sign to the beginning of the transition area. The transition area defines the starting point of physical closure and the starting point of the activity area. The activity area is the portion in which any closure is in effect and work is taking place. The terminal area is the section that allows the traffic to clear the activity area and revert to normal travel conditions. With this additional information, it would be possible to identify work zone activities that are most hazardous for traffic flow through the work area, and develop countermeasures to improve safety in work zones.
References

Louis J. Pignataro is a distinguished research professor of transportation at NJIT. He currently directs the Transportation Information and Decision Engineering (TIDE) Center, a New Jersey Commission for Science and Technology grant, and the Transportation Economic and Land Use System (TELUS) project. Dr. Pignataro received his Dr. of Tech. Sci. degree from the Technical University of Graz, Austria. His research interests are in the areas of traffic engineering, economic development, and the impact of transportation investments.
Automated vehicle locator (AVL) is a technology that enables a fleet operator to track and monitor the location of its vehicles at any given time. It is used mainly in transit and in commercial vehicle operation (management) systems. In transit applications, the information on the exact location of the vehicle can be uniquely identified. In order for the matching process to be successful, the map and the AVL system must be consistent, compatible and sufficiently accurate.

Research Project

In a research project funded by NCTIP and NJDOT, NJ Transit (NJT) cooperated in the investigation of AVL systems to monitor the location of buses. NJ Transit was particularly interested in comparing the accuracy of Global Positioning Systems (GPS) with Continuous Positioning System (CPS).

In an urban area, the AVL system may have location tracking problems, especially if the system is based on GPS technology. Building canyons and overpasses can block satellite signals. Interference from wireless and radio communications as well as reflections of the GPS signal from structures is problematic. Many AVL systems use addi-
tional positioning systems such as dead reckoning and map matching techniques to maintain the location of a vehicle where GPS fails. The actual accuracy of AVL systems under these conditions, such as downtown Newark, has yet to be evaluated.

To monitor bus locations, their positional information as determined by the AVL is displayed on a digital map such as a Geographic Information System (GIS). To ensure accurate information, the location of the bus reported by the AVL must be consistent with the location in the digital map. The digital map also contains information about bus routes, bus stops, intersections, landmarks, etc. The position of these features must be sufficiently accurate so that if the AVL system indicates that the bus arrived at a bus stop, that bus stop could be clearly identified on the GIS. Incompatibility of as little as a fraction of a street block could result in matching problems. A stop for a red light at an intersection could be mistakenly interpreted as a bus stop or one bus stop could be misidentified as being another nearby bus stop. This problem may become especially critical in an urban area where the system would be most valuable.

The research project consisted of developing a methodology to test and evaluate the accuracy of an AVL system and supporting digital maps.

The AVL system analyzed in this project was the Continuous Positioning System (CPS) by Andrew Sensor Products Corporation. The CPS is a land navigation system for fleet vehicle position location, equipped with both a GPS sensor and a CPS sensor. An advantage to using this device in the research project is that both GPS and CPS datasets were generated for analysis during each test run. Consequently, a comparison of a solely GPS based AVL system versus a CPS-based AVL system was evaluated under test conditions.

Another objective of the research project was to evaluate current mapping accuracy at NJT and their appropriateness for AVL. Digital mapping products evaluated were TIGER/LINE, Navtech Navigable Map Database and Digital Orthophotos. Navtech, developed by Navigation Technologies, is currently being used by NJT as a land base for geocoding NJT bus routes. The above data sets were evaluated with an accurate network of control points measured by a GPS System.

**Selection of Test Areas**

The most important aspect of designing
the evaluation study was to establish a test bed that simulated real-world conditions. The AVL had to be tested while mounted on a bus operating under typical daily service. In addition, the test bus routes had to be representative of the varying operating conditions.

A densely built urban area with high-rise buildings, tunnels, and overpasses, such as downtown Newark, may present serious operational problems for any AVL system. Since many of the bus routes operated by NJT converge in downtown Newark, the system must be tested under these conditions. At the other extreme of operating conditions are routes in rural areas with no obstructions or surroundings that could pose difficulties to the AVL positioning sensors. To select test areas, NJT routes were divided into three categories. Category 'A' included underground and completely enclosed areas; category 'B' included urban areas; and category 'C' included suburban and rural areas.

Routes that encompass all three categories were developed. One bus route was a test route in the city of Newark. This route was made up of mainly category 'B'. A second route was based on NJT routes #113 and #40 that travel between Dunellen, New Jersey through the Lincoln Tunnel to the Port Authority Bus Terminal (PABT) in New York City. This route included sections from categories 'A', 'B' and 'C'.

**Development of Field Data under Real-World Circumstances**

The tested AVL system was a CPS land navigation system for fleet vehicle position location. It includes a GPS sensor, but was designed to operate under diverse conditions including urban area applications where GPS positioning may fail. The CPS is built around a gyroscope to measure vehicle azimuth change and an odometer to measure distance traveled, which constitute the required dead reckoning sensors. If the sensors were perfectly calibrated, and the initial geographic position and azimuth of the vehicle were known, then the position...
speed. During a long drive, the dead-reckoned position would increasingly diverge from the actual position. Therefore, the system was complemented by a GPS component to increase the accuracy of location determination.

The simplest approach to AVL is to use the GPS data when it is present, and switch to dead reckoning when the GPS signal is lost. However, GPS is subject to many errors from noise-like small errors to multipath that can sporadically lead to irregular, large and unexpected position errors. To avoid relying on erroneous GPS locations when large errors are present, it was necessary to aid the GPS positioning with a dead reckoned position to act as a data pre-filter. The CPS tested in this research project used a Kalman filtering method to filter out jumps and inconsistent GPS positioning observations. The algorithm estimated the present values of system descriptors (the "state variables") based on the last measurement, the previous values of the state variables, and the estimated accuracy of the state variables and sensor data.

The AVL system was mounted on a fully equipped bus that included radio communication and other electronic devices emitting electromagnetic energy. The objective of this setup was to test whether the electromagnetic field generated by these devices had an adverse impact on the accuracy of the AVL system, particularly with GPS. The bus that participated in this study simulated a routine passenger pick-up and drop-off service during the testing in order to show how the system will perform on a regular basis. Some of the routes were measured only once while others were repeated to allow consistency and repeatability analysis of the system.

**Development of the Base Reference Data**
Control points were selected at actual bus stops along the tested routes: twenty from category 'C', and eight from categories 'A' and 'B'. The selected control points were measured with the Leica MX-8600-RT GPS receiver, a GPS/GIS data collection device with a wide variety of applications. The control point measurement with GPS campaign was carried out in the winter of 1998 to avert GPS signal weakening or blockage due to dense foliage. All measurements
were made with real-time differential correction. The minimum PDOP (an indicator of the satellite constellation geometry) was set to a maximum of six. If this minimum standard was not met, additional visits were made to these points.

GPS control points provided means for evaluating the AVL systems (CPS and GPS), as well as the mapping datasets (Navtech and TIGER/Line) at specific points. A weakness of this evaluation model was that a limited number of measured control points were being tested. In addition, two points had to be excluded from the mapping evaluation because they were not included in the Navtech or TIGER/Line datasets. Consequently, it was necessary to find an additional accurate data source that could provide a continuous reference check for these tested data sets. It was found that digital orthophoto quarter quadrangles (DOQQs) compiled by the USGS were suitable for this purpose. The field-measured location of all GPS control points matched exactly the corresponding points on the orthophotos. Therefore, it was decided to use DOQQs as a basis for evaluating the tested data sets. The New Jersey Department of Environmental Protection (NJDEP) geocoded them and made them available to the study.

Determination of the required error tolerance for AVL applications at NJT was beyond the scope of this study. A 30-foot tolerance was selected to reflect stringent accuracy requirements. This conservative tolerance was used because it represents a typical street width in the tested area. It therefore allows a distinction between a stop at a traffic signal or stop sign versus a bus stop that is located on the opposite side of the street.

**Analysis of AVL Systems**

A comparison between the AVL's GPS data and the DOQQ base reference data revealed that two of the tested areas showed higher error rates than others. The first route was the Newark test route in which the GPS seemed to fail about 45 percent of the time. The second route that produced relatively inaccurate results was between Dunellen and the PABT, where the percent of erroneous GPS positioning was 8.51 percent. A possible reason for this failure was poor GPS signal and lack of differential correction. The accuracy of GPS positioning without differential correction is relatively poor due to an intentional degradation of the GPS signal by the US Department of Defense. Excluding the Newark route, the AVL's GPS data was within the DOQQ's reference location more than 95 percent of the time.

The next comparison was between the AVL's CPS data and the DOQQ base reference data. Positions computed by the CPS were based on data from both sensors, dead reckoning and GPS. While in most cases GPS assists the CPS in refining its position, it may also have a negative effect. In locations where the GPS is erroneous, CPS positions may exhibit bias towards the erroneous GPS as a result of trying to adjust its positioning with the GPS input. Overall, the AVL's CPS data was within the DOQQ's reference location more than 95 percent of the time. Most of the CPS errors were experienced at the origin of the routes. Only on one route, Iron Bound to Dunellen, were the
results less than 90 percent accurate. No particular reason for this poor performance could be inferred from the data.

One of the most interesting results from the analysis of the AVL’s CPS data was the performance of the system in Newark. In Newark, the CPS system performed within the 30-foot error tolerance of the DOQQ base reference data more than 96 percent of the time. It is likely that the short length of the Newark route helped the system’s performance since the CPS system, as other dead reckoning devices, performs relatively well for a short distance immediately after its initialization. It is only after longer distances that it becomes more dependent on GPS data to correct accumulated odometer and gyro errors.

It is interesting to note that if we are to exclude the Newark route, the average performance of the AVL’s GPS sensor and CPS sensor are both approximately 95 percent correct. However, while the average was the same, there appeared to be no correlation between the magnitudes of the error of each positioning system in specific routes. In other words, routes that had larger GPS errors did not necessarily have more CPS errors and visa versa.

The accuracy analysis of the AVL data with respect to the GPS control points was consistent with the comparison to DOQQs. The results were slightly better than those observed during the comparison with the DOQQs. Analysis indicated that if Newark data were excluded the AVL’s GPS positioning was comparable to the CPS when compared to the GPS control points.

**Analysis of Digital Map Data**

The first analysis consisted of overlaying the Navtech and TIGER/Line data sets on the DOQQs and measuring the discrepancies between them. Navtech data was within the 30-foot error tolerance about 96 percent of the time. The predominant characteristics of the errors were a parallel shift of streets or street segments with respect to the orthophoto. These errors looked like coordinate shift errors with no scale change, since the relative position of the streets seemed to be correct. In comparison, TIGER/Line data was erroneous in 66 percent of the tested area. The characteristics of TIGER/Line errors were more arbitrary than those of Navtech. TIGER/Line errors displayed coordinate shifts as well as variations in scale and orientation.

Comparison of the GPS control points versus TIGER/Line and Navtech data sets yielded similar results. The conclusion from these analyses was that the TIGER/Line data was inadequate for applications where 30-foot distance error tolerance was required. Aside from some isolated locations, Navtech data was observed to be accurate for AVL applications. However, visual checks of the Navtech dataset against DOQQs were advised to locate the few possible errors.

**Summary of Findings and Conclusions**

The objective of this study was to develop a methodology for evaluating AVL systems and digital map data. The main findings of this study were:

- The accuracy of about 87 percent of the tested routes was within the established error tolerance of 30 feet (≈10m).
- In most cases, AVL with a CPS sensor
did not offer a measurable advantage over an AVL system with differential GPS sensor only. GPS-based AVL was found to be as accurate and as reliable as the CPS-based AVL except for downtown areas with taller buildings and numerous over/under passes. Two of the advantages of a GPS-based AVL system were that they are less expensive and require a less complicated setup. A simpler setup usually means fewer problems and less malfunctioning.

The average repeatability of the system was 89 percent. In other words, if the same route is run with the same bus, one can expect that 11 percent of the route will differ by more than 30 feet. This could potentially cause problems in sophisticated AVL applications.

Buses operating in predominantly downtown routes of large cities such as Newark should be equipped with CPS sensors. In this environment, GPS sensors were found to be practically ineffective.

Navtech data was accurate within 30 feet of the street network 96 percent of the time. Thus, using Navtech as a GIS digital base map was found to be appropriate. It was recommended to identify and correct the predicted 4 percent errors in this data set.

As expected, and as previously determined by NJT staff, TIGER/Line data was found to be inappropriate for AVL application at NJT.

The errors observed in this study (except for Newark) appeared to be independent of the operating environment. In other words, one cannot predict the performance accuracy of the AVL system as a function of the characteristic of the operating environment. The accuracy per-

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Most bridges in New Jersey are multi-span simply supported (MSSS) where, due to impact at the joints, the seismic response is highly nonlinear. Therefore, although the response of each bent, or frame, in an MSSS bridge in any direction (longitudinal or transverse) is dominated by a single mode, the use of single mode spectral analysis is not expected to give an accurate estimate of the seismic forces. Detailed seismic analysis of essential bridges should employ nonlinear computer models that consider the important characteristics of MSSS bridges. Among these characteristics for MSSS bridges in New Jersey are: behavior of steel bearings, impact between adjacent spans and between the end-span and the abutment, soil-structure interaction, frictional characteristics following bearing failure, plastic hinges and/or shear failure at the columns, and combined effect of horizontal and transverse ground motion excitations.

This paper presents the results
of the second phase of a comprehensive analytical study on the seismic response of highway bridges in New Jersey. The overall objective of this phase of the study is to evaluate the nonlinear seismic response of actual bridges with emphasis on soil-structure interaction and three-dimensional effect of ground motion. Capacity/demand ratios for various components are determined based on the Federal Highway Administration’s (FHWA) Seismic Retrofitting Manual for Highway Bridges.

Research Project

The overall objective of this phase of the study was to evaluate the nonlinear seismic response of actual bridges with emphasis on soil-structure interaction and three-dimensional effect of ground excitation. The research tasks were:

- Identify three typical bridges of various spans for detailed analyses as case studies.
- Identify/develop suitable methodologies to determine the properties (strength and stiffness) of boundary springs to model soil-structure interaction at the abutments and at the base of column piers.
- Perform a parametric study to investigate the nonlinear response of actual MSSS bridges in the longitudinal direction reported to be the most vulnerable direction for MSSS bridges under earthquake ground motion. Consider the significant parameters of soil-structure interaction and frictional coefficient at failed bearings.
- Evaluate the combined effect of longitudinal and transverse earthquake excitations on the response of actual MSSS bridges using 3-D models.
- Determine the capacity/demand (C/D) ratios for various bridge components using FHWA guidelines.
- Recommend possible modifications to the design of new bridges and propose possible retrofit procedures for existing bridges.

Case Studies

Three simple span and simply supported bridges, representative of typical bridges in New Jersey, were evaluated under this study. For these bridges the number of spans are
equal to two, three and four. They have concrete slab on steel girder decks and reinforced concrete pier bents and abutments. The pier columns are all circular with spiral or circular lateral reinforcements and footings are rested on soil without any pile. The spread footings for each abutment, beneath two wing walls and one back wall, are continuous U-shaped foundations. A brief description of each of the three bridges follows.

**Clements Bridge**, shown in Figure 1, is a three-span bridge located in Gloucester County, Deptford Township, on County Route 544 (Clements Bridge Road) over Route 55, Sec. 13a. This bridge has three spans in lengths of 140 feet, 95 feet and 140 feet. The width of the bridge is made of two separated symmetric half-decks. Each half-deck has 6 girders 89 inches apart supporting a 9.5 inch-thick 3000 pounds per square inch (psi) concrete slab. Separate pier bents beneath each half-deck consist of two 4 feet-diameter circular columns and a cap beam. Reinforcing bars are ASTM A615 Grade 60 and structural steel is ASTM A36 - 75.

**Alexander Bridge**, shown in Figure 2, is a two span bridge located in West Windsor Township, Mercer County on U.S. Route 1. This bridge has two equal spans in length of 97 feet-4 inches. Each deck has 15 girders 95.5 inches apart, supporting an 8.75 inch-thick 4000 psi concrete slab. The deck cross section has two separate parts. Correspondingly, the pier bent consists of two parts with a total of ten 3’-diameter circular columns. Concrete used in foundations is 3000 psi. Reinforcing bars are ASTM A615 Grade 60 and structural steel is ASTM 709 Grade 36.

**Bridge 5**, shown in Figure 3, is a four-span bridge located in Morris County, Parsippany-Troy Hills Township, at Eastbound Littleton Road Relocation over Interstate Route 80, Sec. 3g-2. This bridge has four spans in lengths of 42 feet, 130 feet, 120 feet and 88 feet. Each deck has 7 girders 86 inches apart, supporting an 8 inch-thick 3000 psi concrete slab. Each column bent consists of five 3.5’-diameter circular columns and a cap beam. Reinforcing bars are Grade 40 and structural steel is ASTM A36.

**Modeling of Soil-Structure Interaction (SSI)**

The importance of including the flexibil-
Figure 3: Cross Section of Bridge Five

ity and strength of supports at the abutments and piers in dynamic analysis of highway bridges is well recognized by various agencies including AASHTO (1992) and CALTRANS (California Department of Transportation 1989) in their respective design specifications. In designing new bridges using these specifications, either an iterative process is used to estimate the stiffness and displacement at the abutments or simplified rules are employed to determine the stiffness and strength of the boundary springs. Such procedures are overly simplified and do not take into account the properties of soil and all physical dimension of the substructure.

A recent study (Goel, Rakesh and Chopra 1997) concluded that the CALTRANS procedure results in a good estimate of the stiffness and capacity of the abutment in the transverse direction. However, in the longitudinal direction the CALTRANS procedure overestimates the capacity and stiffness by a factor of two. The study also concluded that the AASHTO-83/ATC-6 procedure results in large estimate of the abutment stiffness in both directions.

Other researchers (Siddharthan, El-Gamal and Maragakis 1997; Wilson and Tan 1990) have also conducted extensive investigations to determine the stiffness and strength of boundary springs to represent the abutments in an analytical model used in time history analysis. Such studies are based on scientific knowledge of the properties of soil and more detailed consideration of the geometrical properties of the abutment.

In this study, the procedures given by FHWA’s Seismic Design of Highway Bridge Foundations (1986) and Wilson and Tan (1990) are used to determine the parameters of the boundary springs at the abutments and at the base of the column piers. An important aspect of soil-structure interaction is foundation damping which is a complex problem. Radiation damping associated with wave propagation between the masses of the superstructure and foundation-soil is one form of energy dissipation due to soil-structure interaction. Material nonlinearity in the foundation-soil is another form of damping. In this study the latter form of energy dissipation is explicitly modeled, while the radiation damping is implicitly accounted for through equivalent viscous damping.
Stiffness and Capacity of the Reinforced Concrete Pier Columns

All three bridges analyzed under this study have round columns. The confinement effect is considered in the evaluation of column curvature ductility and plastic rotation capacity using FHWA guidelines (1995). The effects of column curvature ductility and lateral reinforcement on shear capacity are also considered. The exact moment-curvature relationship and moment-axial load interaction for column cross-sections are determined. This is achieved by dividing the cross-section into a number of fibers and satisfying compatibility and equilibrium by commonly used stress-strain relationships for concrete and steel materials. The column is then modeled using elasto-plastic beam elements with initial stiffness equal to effective moment of inertia determined using FHWA guidelines (1995). The plastic moment capacity is determined by fitting the bilinear model to the actual moment-curvature relationship. The actual moment-curvature relationship, along with the equations given by FHWA for plastic hinge rotation and plastic hinge length, is used to determine the plastic hinge capacity.

Stiffness and Capacity of the Bearings

Steel bearings are used to transfer the vertical and horizontal forces from the superstructure to the substructure. Typically four 22-mm (7/8 inch) diameter A325 steel bolts are used to connect the bearing to the girder, and two 38-mm (2 1/2 inch) diameter A615 anchor bolts are used to connect the bearings to the abutments and cap beams. These elements are the weak links in the load transfer through the bearing from the superstructure to the substructure, and impact forces can easily exceed their shear capacity. Therefore, the post-failure behavior of the bearings (Coulomb Friction) is also investigated and is modeled by using a bilinear force-deformation relationship with yield strength equal to coefficient of friction times the normal force per bearing due to gravity. The coefficient of friction is taken to be in the range of 0.2 to 0.6 as a parameter. Parametric studies have shown that the bridge response is not sensitive to the bearing stiffness. In this study for the modeling of frictional behavior at failed bearings, relatively large values are assigned to bearing stiffness in computer simulations.

Computer Models

The bridges are analyzed using DRAIN-2DX (Prakash, Powell, Campbell and Filippa 1992) and DRAIN-3DX (Powell and Campbell 1994) computer programs, where beam-column elements are used to model the columns and simple connection elements are employed in modeling bearings and soil-structure springs. The link elements are used to model the gap and impact between adjacent spans and between an end-span and the abutment.

In this study, a 5 percent damping is considered in the bridge models. This is consistent with AASHTO response spectra and it is a commonly used value in time history analyses. This level of damping can be looked upon as radiation damping at the foundations since there is no other source of viscous damping due to high rigidity of the deck cross-section. Note that, as mentioned before, energy dissipation due to nonlinear phenomena such as plasticity in the columns...
and friction at the bearings are modeled explicitly. It is assumed that the abutment back wall is always in contact with the backfill soil and contributes to the abutment stiffness. Abutment geometry, cap beam and deck widths are modeled with relatively rigid elements.

Several parameters are investigated for each bridge: types of soils (shear modules of 400 psi, 4000 psi and 40,000 psi), backwall condition (intact and broken), bearing performance (intact and failed with two different coefficient of frictions equal to 0.2 and 0.6).

Three different earthquake records are considered for the analyses. Each record was scaled to two different peak ground accelerations (PGA): 0.18g and 0.4g. The former is the maximum acceleration coefficient in New Jersey per AASHTO. The latter is for higher seismic regions such as California or can be considered as an event with a longer return period in New Jersey.

Two horizontal earthquake components were considered simultaneously to excite the 3-D models of the bridges in longitudinal and transverse directions. For each set of components two possible alternatives are considered. Alternative 1 refers to the earthquake record when component-1 is in the longitudinal direction and component-2 is in the transverse direction of the bridge. Alternative 2 is the reverse of this. For 2-D models only the first component of the earthquake records, which is the stronger one, is considered. In the time history analyses only the first 10 seconds of the following records are used.

2-D Models
The Drain-2DX program is employed for modeling bridges in the longitudinal direction. For MSSS bridges it is reported that longitudinal seismic response is more important. Two-dimensional models are not able to represent the bridge skewness, for which one of the consequences is having a negligible axial force variation at pier columns from earthquake analyses. Cap beams and deck elements are assumed to remain elastic. A rigid-end-zone equal to the height of a bridge cap beam was placed at the top of pier columns.

3-D Models
The DRAIN-3DX program is used for 3-D nonlinear time history analysis. For major mode shapes in the three translational directions (i.e., longitudinal, transverse and vertical), corresponding mass proportional damping was assigned to the bridge models. For cap beams half of the gross moment of inertia (Ig) and torsional constant (J) are used to account for concrete cracking. However, for the composite decks due to the presence of steel girders, 75 percent of Ig for transverse bending and 75 percent of the torsional constant J are used. In the vertical direction due to low amplitude, response the gross moment of inertia is assumed for the composite deck sections.

Summary of Findings and Conclusions
Based on the results of both phases of this comprehensive analytical study, which included both 2-D and 3-D computer simulations, the following conclusions can be made:

Steel bearings will most likely fail even under low level of earthquake ground accelerations because of development of high level of impact forces during the
dynamic response of MSSS bridges.

Assuming stable post-failure behavior at the bearings, the failure at the bearing will act like a fuse and will limit further response of the bridge. This will lower the shear demand in the columns and the abutments. Therefore, due to dissipation of seismic energy through friction, the collapse of the bridge under 0.18g PGA will most likely be prevented.

Friction coefficient at the failed bearing affects the response. Efforts should be made to quantify its actual value and/or sensitivity analysis must be performed on a case-by-case basis to determine the most critical value.

Seismic response of MSSS bridges is sensitive to soil-structure interaction and it should be considered in dynamic analysis of this class of bridges.

Three-dimensional models must be used in nonlinear time history analyses, especially for skewed bridges.

Under earthquakes with 0.4g PGA most bridges will sustain damage in the form of shear failure in the columns. This will most likely cause the collapse of the bridge. However, this level of ground acceleration is higher (in many locations much higher) than the AASHTO seismic coefficient for New Jersey. It is more typical for high seismic regions or it maybe considered as an event with significantly higher return period for New Jersey.

In light of the observations made during this research investigation and the above conclusions, the following recommendations are made with regard to retrofit and design of bridges in New Jersey:

Although current seat length for the bridges considered is marginally adequate, consideration should be given to increasing the seat lengths of existing bridges. The current AASHTO requirements for seat length will be adequate for the design of new bridges.

Bearing seats must be regularly inspected to ensure their integrity so that in the event of an earthquake, bearing failure will occur rather than pullout of the concrete seat.

Retrofit of columns, if considered, should include considerations to increasing both confinement and cross-sectional size. Both of these factors should be considered in order to obtain an optimal balance between higher flexural ductility and higher shear capacity.

Analysis of new and existing bridges should employ nonlinear time history analysis using 3-D models.

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should employ nonlinear time history analysis using 3-D models.

**Dr. M. Ala Saadeghvaziri, P.E.** is an associate professor of civil and environmental engineering at NJIT. He received his Ph.D., M.S., and B.S. (high honors) degrees from University of Illinois at Urbana-Champaign in 1988, 1983, and 1982, respectively. He joined NJIT in the August of 1988 as an assistant professor. Dr. Saadeghvaziri’s research interests are non-linear response of RC structures, finite element and computational methods, earthquake engineering, and structural applications of composite and recycled materials. Among his current research activities are design of continuity connections, finite element analysis of transverse deck cracking, and seismic rehab of transformers using base-isolation technology, which are supported by NJDOT and NSF.

**Alireza Yazdani-Motlagh** is a research assistant and Ph.D. student of civil and environmental engineering at New Jersey Institute of Technology. He earned his master's degree from Sharif University of Tehran, Iran. His current research areas are earthquake response of typical multi-span-simply-supported (MSSS) bridges in New Jersey, nonlinear response of stiffening systems, and developing pseudo-static analysis methods applicable for stiffening systems resembling MSSS bridges. Mr. Yazdani-Motlagh has more than three years experience in structural analysis and design at consulting engineering companies and has published three journal papers.
Current Project Abstracts

Causes and Control of Transverse Cracking in Concrete Bridges
M. Ala Saadeghvaziri, Ph.D.

Causes of transverse cracking in concrete bridge decks, which can accelerate structural deterioration, increase maintenance costs and potentially shorten system service life, are not yet fully understood despite several significant studies. Disagreements and contradictory results have indicated the need for further research on this significant phenomenon. This research addresses the correlation between the results of NJDOT's survey of cracking in bridge decks and the findings of previous research work. As NJDOT indicates that quality control procedures employed in the preparation of the concrete used for bridge decks in New Jersey are excellent, material factors will be included in the study but not emphasized. Once the possible causes of bridge deck cracking are identified through a focused analytical study using 3-D FEA, possible design recommendations to reduce cracking will be formulated. In support of the analytical work several bridges are being instrumented for measurements.

Data Research - Materials Laboratory Information System
Jay Meegoda, Ph.D., Chi Tang, Ph.D.

To integrate the operational functionality of material data filing, processing and transfer, a computerized remote network management system is being developed by NCTIP. This system will standardize data entry procedures, define performance evaluation measures, analyze relationships between testing data and field performances, streamline the project closeout processes, generate summary reports, and communicate with existing NJDOT information systems (such as PMIS). The NCTIP team is using an SQL database, installed on an NT server, to develop a Laboratory Information Management System (LIMS). The LIMS will make a sampling plan, notify the sampler, take the sample, pack and send the sample to the laboratory for tests, record and calculate test results; issue an approval/noncompliance certificate and/or sign responsibility review forms, and generate summary reports; file relevant documents for plant inspection, product quality control, project monitoring and closeout. During these processes it is required that all related information be automatically indexed with each other to maintain the integrity of the data. LIMS will develop unified layout formats to minimize duplicate documents. Each sample will be uniquely coded using a user defined sample number seed. (Bar code labels may use this number for immediate identification of samples). All relevant information, such as project specification, vendor and customer ID and testing statistics will be automatically indexed together with primal and foreign key relationships.
Establishing Safe Driveway Grades for New Jersey State Highways
Louis J. Pignataro, Ph.D.

Safety driveway design encompasses many elements, namely, spacing, volume, highway classification, use of property, angle of exit and entry, and grade of the driveway. The significance of these elements is reflected in the safety and capacity of the roadway and the driveway. Over time, there have been several studies, and some judgments, giving guidelines for various design factors. The use of the term "guidelines" concedes the potential for situations that are beyond those ordinarily encountered. There are occasions when an increase, beyond the accepted guidelines, in the positive or negative grade of a driveway, would considerably reduce the cost of providing driveway access to the land parcel. It was this situation that was addressed in this research project. Prior to this study, existing NJDOT standards for state highway driveway grades were based on AASHTO guidelines established in 1959. Although these were not supported by research, they were probably based on the best engineering judgment of the time. Reevaluation in light of modern traffic and vehicle conditions and sight distance was imperative. NJDOT wished to determine if steeper driveway profiles could be safe and provide adequate sight distance, and if developing more liberal grade design standards for county and local roads would be possible. The basic approach to the study was the development and application of a computer simulation model to assist an engineer in selecting a driveway profile from the main road.

E-Stations for Newark: Infrastructure Planning and the Urban Lab
Darius Sollohub, M.A.

Today a tremendous amount of information and a wide range of services are offered on the Internet. However, without knowledge, financial resources or access to computers many Newark residents cannot utilize the many opportunities offered electronically, depriving them of the ability to use all kinds of resources, from e-mail to job information to purchasing goods through e-commerce. The concurrent absence of easy and comfortable physical access to public transportation to jobs, amenities and services can be addressed simultaneously with a new building type, i.e., building and maintaining a series of e-stations complete with a connection to the electronic world that would link them.

E-stations are an innovative concept, combining and connecting elements that are currently available but that have not been previously brought together in this manner. An e-station is one of a series of enclosed bus stations, each of which has six key components: an intelligent transportation system, e-commerce services, a portal to the internet, a telecommunications center, a full-time concierge or facilitator, and the
opportunity to provide supplemental social services and stimulate mixed use
development. Approximately 2,000 square feet in size, each station would have a
storefront facade, adequate seating, storage areas, banks of computers, a concierge desk
and an ATM machine. The e-stations would be sponsored and maintained by local
community organizations.

Co-sponsored by NCTIP and the New Jersey School of Architecture at NJIT, in part-
nership with NJ Transit and NJIT’s TIDE Center, this project will research, design and
ultimately build a prototype of an e-station in Newark, working closely with a host
community organization and following a two step process. In the first step, a graduate
design studio in the Masters of Infrastructure Program will develop a detailed proposal
for the Intelligent Transportation System and the e-commerce components. At the same
time, a design studio in the graduate architecture program will develop architectural
design proposals for e-stations, working in concert under the guidance of faculty and
planners at NJ Transit. The second step will focus on financing, constructing and operat-
ing the first e-station.

Evaluation of the Potential for Using Ramp Metering in the
ATMS of the I-80 Showcase Corridor

Steven Chien, Ph.D.

Releasing single vehicles on either a pre-timed or a demand-responsive basis metering
generally reduces accidents, as the turbulence at the ramp/freeway merge point is reduced.
To achieve the full benefits of ramp metering, traffic-responsive systems are necessary.
Ramp metering can increase the capacity of the freeway, maximize throughput and speed,
reduce accidents, and reduce emissions resulting from stop-and-go conditions. Vehicles on
the ramps will have longer delays than on unmetered ramps, but the increased freeway
speeds may compensate. The primary objectives of this project include: evaluating the
effects of "short ramps" to local traffic congestion (e.g., delays and accidents); developing
real-time multiple-ramp metering control systems (e.g., pre-timed system control and
demand-responsive system control); developing a methodology for evaluating freeways
with unmetered ramps and alternative ramp metering control systems; and developing pro-
cedures for quantifying benefits. To achieve the ultimate benefits for the selected freeway
corridor, various metering control strategies (including an integrated real-time ramp meter-
ing model) will be developed and tested by a selected simulation program. The core con-
cept of the metering model is to capture the dynamic traffic characteristics. To be imple-
mented in real-time, an effective optimization algorithm will be developed for determining
the time-varying metering rates. The entire algorithm will be integrated with the simulation
program The primary objectives of the research have been to evaluate the effects of "short ramps" to traffic congestion; develop real-time multiple-ramp metering control systems;
evaluate freeways with un-metered ramps and alternative ramp metering control systems; and developing procedures for quantifying benefits.

**Evaluation of Design Ideas for Prevention of Vehicle Entrapment on Railroad Tracks**

**One-Jang Jeng, Ph.D.**

According to past research, both active and passive devices exist for reducing the probability of vehicle accidents occurring at grade crossings. Active devices position temporary barriers to prevent vehicles from passing the railroad, with the duration determined by the speed and the length of the train. Typical active devices are two- and four-quadrant gate systems; full crossing closures; and devices using sensors or video monitoring to detect a vehicle being trapped at a grade crossing, and which apply a tolerable deceleration to the train. Passive devices require the vehicle drivers' direct attention and ability to understand the meaning of signs and signals. In terms of the cost of the devices alone, active devices are significantly more expensive than passive devices.

The new $615 million South Jersey Light Rail line, scheduled to open in 2002-2003, will have 53 grade crossings. With a 15 minute headway between light rail cars, research to investigate the problem of train-vehicle collisions occurring at grade crossings where streets run parallel to railroad tracks and motorists make left turns across the tracks is deemed critical. Errors produced by either incorrect information processing or aggressive driving behaviors require different solutions. This research is undertaken to determine which types of errors contribute to such accidents. Possible design ideas for solving vehicle entrapment problems will be examined using human subjects both in the lab and in the field. Implementation of design ideas derived from the results of this project will benefit other similar configurations of railroad crossings.

**Highway Advisory Radio (HAR) Systems**

**Edip Niver, Ph.D.**

Highway Advisory Radio (HAR) Systems are primarily used to provide information to motorists. These systems are regulated by the Federal Communications Commission (FCC) which authorizes establishment of such services for local governments and permits usage of AM transmitters to provide motorist information via conventional automobile AM radio receivers. In the past, permitted bands were at either 530 or 1610 KHz - the lower and upper limits of the commercial AM radio broadcast band. More recently FCC extended bands from 1605 to 1705 KHz and now allows the usage of any open bands not being utilized from 530 to 1705 KHz for HAR. The currently available options in HAR systems are: regular; low powered; portable; and radio stations to provide statewide coverage.
With emerging technologies in the electronics industry, HAR systems have undergone significant changes in the recent years. Today, they include features such as but not limited to: wired and wireless access to change messages; digital recorders to store received messages; novel circuitry to eliminate noise and improve message quality; computer controlled centralized operation; remote diagnostic capabilities to expedite trouble shooting; solar powered operation to reduce installation and maintenance costs; mobile units to respond to emergency incidents; phase synchronization between adjacent HAR stations to eliminate co-channel interference; antenna options for site-specific needs; better ground availability for more efficient operation at the antenna sites; and signs and messages for alerting motorists.

This project will identify various technical alternatives in the state-of-the-art of HAR systems applicable for state-wide coverage in New Jersey. Issues to be addressed include coverage zones for existing HAR systems within the state; frequency interference and co-ordination issues for HAR systems so that similar systems operated by different agencies may coexist within the state; institutional issues in management and operation of HAR systems on the state level; and FCC regulatory issues pertinent to HAR systems and related licensing requirements. Costs will be explored for potential HAR systems and alternatives, and the feasibility of replacing HAR systems through the purchase of perhaps two radio stations that will cover the entire state will be explored.

**Identifying Factors and Mitigation Technologies in Truck Accidents in New Jersey**

**Janice Daniel, Ph.D.**

It is well known that the roadways in New Jersey that have the highest design standards: the New Jersey Turnpike, the Garden State Parkway, the Atlantic City Expressway and the Interstate system also have the lowest accident rates. Recognizing this fact, legislation was recently passed restricting through truck traffic to these higher type facilities. This legislation however does not address the large number of trucks that are making deliveries to locations within the state or that originate at industries and businesses throughout New Jersey. These trucks must use all roadways in the state to reach their destinations.

Truck accidents are generally grouped with auto accidents; consequently accident analysis does not address specific roadway geometry or other conditions that may affect truck accidents to a much greater degree than autos. If the specific causes of truck accidents could be identified, then innovative measures, including advanced technologies, could be identified and implemented to help reduce the number of truck accidents. Research has shown that one prevalent factor associated with motor vehicle crashes is speeding, exceeding the posted speed limit or driving too fast for conditions. Speeding increases the
potential for loss of vehicle control; reduces the effectiveness of passenger safety equipment; increases the amount of stopping distance required; increases the amount of distance traveled during driver reaction time; and increases the degree of crash severity resulting in more disabling injuries. The effects of speeding by truck traffic has even greater impacts than passenger vehicles on roadway safety and warrants the implementation of strategies and technologies aimed at reducing truck speeds. This research will address several of the goals outlined in the Governor’s *New Jersey First: A Transportation Vision for the 21st Century*. Its goals are to identify statistically significant factors that contribute to truck accidents in New Jersey and to recommend technologies and strategies holding potential for use as countermeasures for the most prevalent of these factors.

**Integrated Signals - A Cost Benefits Analysis for the New Jersey Department of Transportation**

*Kyriacos C. Mouskos, Ph.D.*

The primary objective of this research is to study the costs and benefits of integrated traffic signals for the state of New Jersey. The specific objectives of the study are to identify the costs of both integrated and non-integrated signals; identify the benefits of both integrated and non-integrated signals; and conduct a cost-benefit analysis to compare integrated and non-integrated signals. The majority of signalized intersections in the State of New Jersey are controlled locally by a single controller. Any change to the signal timing of a single signalized intersection requires the dispatch of a person to this intersection who manually changes the traffic signal. The majority of the arterials are interconnected through a single field controller. However, they are not controlled through a central computer, necessitating the dispatch of a person to make any changes to the signal timing or respond to any malfunction of the system. An advantage of integrated signals is that any change to the signal timing of any signalized intersection can be achieved through an instruction from a PC to which all the traffic signals are connected. The central monitoring of the signals of several intersections provides also for efficient changes to signal progression in arterials where continuous monitoring of the system is necessary. The basic trade-off between these two approaches - integrated signalized systems and isolated signal control - is the cost of operation and maintenance as well as the capital and installation cost, and the benefits that each system provides.

**Riverside Transit Village Project**

*Darius Sollohub, M.A.*

Using Riverside, New Jersey as its specific focus, a modeling study has been completed by the New Jersey School of Architecture’s Masters in Infrastructure Planning program as the first stage in a new approach to help towns maximize the benefits of transit access by planning the areas around stations. The study has modeled possible
development scenarios for the area surrounding a planned station site along the Southern New Jersey Light Rail System. When complete, the $450 million system will serve a corridor that includes 17 towns and over 400,000 residents along the existing right-of-way of the former Camden and Amboy line. Riverside, a town of 9,000 is located at a midway point between the light rail’s terminus cities, Trenton and Camden. The findings of the study will be used to develop some general rules of thumb about the use of light rail in providing transportation support to communities.

The modeling project is a new approach to help towns maximize the benefits of transit access by planning the areas around stations. The state advocates the concept and launched a “Transit Village Program” in 1999 to restore stations to their historical role, enhance investment in urban areas and promote community leadership. Communities that create Transit Villages are given priority consideration for funding from NJDOT’s Local Aid for Centers program, the Transportation Enhancements program, and the Bicycle and Pedestrian Projects program. The initial segment of the project involved two phases. In the first phase, local conditions were inventoried and the area around the rail line was modeled to demonstrate three different scenarios for creating a transit village. One scenario has a waterfront residential area, another builds around a craft industry with a fishing pier for recreation and essential services like a supermarket and day care center, and a third focuses on commercial development along the rail line. In the second phase, models were presented to representatives from the town at a meeting hosted by Burlington County, and reviewed by local government agencies. Taking their responses into account, concepts and features from each model were used to develop a comprehensive urban design proposal.

Key recommendations from the study will be incorporated into the town’s redevelopment plan. It is also planned to leverage NJIT’s work in conducting further development studies, applying for funding and attracting private sector investment.

**South Jersey Real-Time Motorist Information System**

**Steven I-Jy Chien, Ph.D.**

For many commuters and visitors traveling from New Jersey into Philadelphia via the Walt Whitman and Ben Franklin Bridges, the road is paved with too much traffic and congestion, causing the motoring public significant delays in reaching their destination. In order to alleviate the traffic congestion problem on these crossings and in the adjacent regional highway network, NJIT is proposing to develop a delay prediction system within the south Jersey real-time motorist information system for the New Jersey Department of Transportation (NJDOT).

This project will involve a major commuter corridor that encompasses both freeways
and arterials and includes State Routes 42, 55, 76, 90, Interstate 295 and 676, and Routes 30, 38, 70, 73, and 130, as well as the bridges connecting the Camden and Philadelphia areas. The commuting pattern in the corridor is spread out in a radial pattern with demand concentrated toward the Philadelphia urban core from the north, south and east. The real-time information, such as the expected delay and recommended alternate routes, will be disseminated through variable message signs (VMS) located at critical junctions (e.g., the interchanges of Routes 295, 42, and 76 and Routes 30 and 73) or other communication media such as highway advisory radio (HAR) or a website.

The Mature Driver: Safety and Mobility Issues
Naomi Rotter, Ph.D.

The safety and mobility of mature drivers is rapidly becoming an important issue in New Jersey given demographics that indicate an aging population. Census statistics and estimates reveal that New Jersey is gaining an aging population in a consistently higher percentage than the nationwide average. Not only is the 65-and-older population witnessing increase, but within it the oldest old (people 85 and older) are also increasing. When these data are coupled with the higher accident rate (per million miles driven) of the older driver, a problem clearly emerges for concern regarding public policy and quality of life. License restriction can bring a high cost to society and to the rapidly increasing older population, severely reducing the older person's independence and ability to contribute to society or their own support, and providing alternative means of mobility is expensive and can seldom equate with a high level of independence and quality of life. Setting criteria for license restriction can also involve the state in a delicate position of balancing the welfare of one group against that of the general public. This project aims to provide the New Jersey Division of Motor Vehicles with information that can be used to develop a policy for promoting traffic safety with minimum restriction to the mobility of mature drivers. It is building a knowledge base. It will build a knowledge base regarding the extent to which aging drivers create a safety threat in New Jersey; collating, organizing, and assessing existing information about mature drivers' driving behavior, including functional abilities; which disabilities significantly diminish driving ability; ability to self-evaluate those abilities; voluntary restriction and cessation of driving among this group. The project will document and analyze the practices and experiences of DMVs across the United States; and explore in-depth the feelings and experiences of mature drivers regarding driving as an entitlement.

The Research Project Maintenance and Monitoring System
ProMPTS - Continuation
Chi Tang, Ph.D.

The Research Project Management and Progress Tracking System (ProMPTS) is a
computer software program designed to help the New Jersey Department of Transportation’s Division of Research & Technology staff manage and track research projects from beginning to end -- from problem statement to final products and closeout. It was developed by NCTIP in partnership with NJDOT. With its graphical interfaces and database developed in Microsoft Access97, ProMPTS has both project and program features. Maintenance and monitoring systems are key components of planning and control within an agency. They are one way to increase efficiency in state departments of transportation. By facilitating monitoring, these computer-based systems permit more optimal use of organizational resources, thereby increasing efficiency. They permit administrators of research units to follow the status of suggestions and projects from initiation through disposition, providing greater assurance that tasks will be completed within budget and on time. As an organization’s strategies and policies change, its monitoring systems must conform to new environments. The activities of NJDOT required a computer-based project system that could monitor online the disposition of problem statement submissions and the projects in the current research program. This research is related to both the CAPAS and TELUS projects, all of which are designed to increase the productivity of transportation project management.

**Water Level Prediction for Transportation Projects**

*Joshua Greenfeld, Ph.D.*

The determination of bridge clearance and the proper design of cofferdams, caissons and bridge fenders over navigable waterways are important safety and management issues. Tidal level is a dynamic phenomenon, changing constantly. Recent observations suggest tidal levels are slowly increasing due to global warming and other changes in global weather patterns. Ship sizes are increasing as well. These changes may require an update of current clearance values computed many years ago. Employing inappropriate procedures and potentially outdated data, which has not been documented and field verified, could result in construction difficulties. Implementation mistakes may lead to waterway operation problems, and, in some cases, to a more restrictive usage of the waterway, creating problems with regulatory agencies and impacting the public and adjacent owners. Not using the waterway may, in turn, have a negative impact on the local economy.

NJDOT is seeking to provide guidance to its consultants and in-house staff on water level determination of bridge clearance over navigable rivers and other waterways, establish a policy on the minimum efforts required to determine current, historic and regulatory water levels, and predict the various water levels needed on various projects.

The objective of this project is to study the many issues of determining water level needs
as related to transportation projects. It will include a thorough survey of current practices of water level determination and prediction. Current practices at agencies such as FHWA, FEMA, U.S. Coast Guard, The National Ocean Service (of NOAA), Army Corps of Engineers, N.J. Tidelands Resource Council, NJDEP, and state DOTs will be studied and evaluated. Methods for height determination at the construction site will also be studied. Results will be documented and made available to NJDOT consultants and in-house staff to serve as a general reference. The final stage of the project will be developing a uniform NJDOT procedure for determining bridge clearances and adequate water level determination.
### Selected Publications and Presentations

### 1999 - 2000

#### Referenced Journal Articles and Conference Papers

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