

**Mid-Atlantic Universities Transportation Center  
Region III**

**2000-2001 Annual Report**

**September 28, 2001**

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## I.A. CENTER DIRECTOR'S SUMMARY

The Mid-Atlantic Universities Transportation Center (MAUTC) has just completed its thirteenth year as the competitively selected University Transportation Center for Region III, the five-state Mid-Atlantic Region. This document reports on our activities in the most recent year. MAUTC is a five-university consortium, led by The Pennsylvania State University, that also includes the University of Pennsylvania, The University of Virginia, Virginia Polytechnic Institute and State University, and West Virginia University.

Throughout its history, MAUTC has designed its activities guided by the vision that it should be a university-based center of transportation excellence that is recognized as a vital resource to transportation organizations within the region, especially state departments of transportation and transit agencies. Further, MAUTC has sought to be a leader in recruiting and educating transportation professionals who will lead the industry in the 21<sup>st</sup> century. We believe that our program of activities has allowed MAUTC to accomplish both of these objectives. Furthermore, in the past few years we have increased our emphasis adding to our nation's intellectual and human capital by recruiting and educating future transportation professionals. This vision, which is consistent and supportive of the UTC Program's mission, is shared by all MAUTC's faculty and staff, and it has led to the creation of a program that is capable of extending its outreach to meet the objectives of the UTC Program.

MAUTC has worked closely with the other UTCs within the Mid-Atlantic region. This close collaboration is possible because MAUTC universities are part of two of the other UTCs in the region, and because of MAUTC's past participation with the third UTC, Morgan State. The University of Virginia and Virginia Tech are member schools of the Virginia Center for ITS Implementation; West Virginia University has signed a memorandum of agreement with the Appalachian Transportation Institute that will allow it to work on joint activities with this new UTC. Finally, MAUTC has established and will maintain close working relationships with Morgan State University faculty -- relationships that were developed when Morgan State was a part of the MAUTC consortium.

MAUTC faculty have also fostered closer working relationships between all UTCs and the academic transportation community by assuming leadership positions in the Council of University Transportation Centers. I had the privilege of serving as CUTC President during the past year and had as a major objective bringing all UTCs and other university transportation education and research programs closer together to share experiences and design programs to enhance the scope and quality of university-based activities. Dr. Michael Demetsky, the lead faculty member for MAUTC's efforts at the University of Virginia, served as CUTC Treasurer and is in line to serve as Vice President and then President of the organization in the coming years.

MAUTC has also reached out to non-UTC universities in the Mid-Atlantic region and serve as a catalyst and coordinator of research and educational activities. The primary tool for this outreach effort has been Penn State's "Cooperative Agreement" with PennDOT. As a result of this long-term, open-ended contract, Penn State set up relationships with thirteen other

universities throughout the nation so that these universities can conduct research or educational programs for PennDOT. We have forged relationships with Historically Black Colleges and Universities including Lincoln University, Cheyney State University, and Howard University. Each of these universities is working through Penn State to conduct educational or research projects for PennDOT. Because of Penn State's and MAUTC's research experience and administrative resources, we are able to assist these universities in obtaining and carrying out sponsored projects.

MAUTC universities are working together to expand the scope of our educational offerings and to concentrate MAUTC's financial resources on funding for students so that we can attract and educate as many undergraduate and graduate students as possible. Because of the funding cutbacks to the UTC program, our ability to offer financial aid is limited; however, we have overcome this financial set back by making student financial support the highest priority use of MAUTC funds.

To implement the educational priority for MAUTC, we have invested in state-of-the-art laboratories for students to use for research and course projects, we have developed new course materials, and have funded undergraduate and graduate students through internships and graduate assistantships.

MAUTC research projects are selected on the basis of their ability to provide financial support for students. Furthermore, we have continued a model developed as part of the PennDOT/MAUTC Partnership activity whereby we provide financial support to promising graduate students to extend the research of an agency-sponsored applied project by conducting more basic research leading to a thesis or dissertation. Linking student research to agency-sponsored activities will ensure that the research topics are relevant to real-world problems, but at the same time, by not tying the student support to completion of project deliverables, we will be able to develop new knowledge and techniques that can be applied in the future.

MAUTC continues to conduct research in support of state DOT and local transportation agency needs. Further, we consider USDOT research priorities when seeking matching funds for projects. We look forward to continuing our partnerships with the Pennsylvania, Virginia, and West Virginia Departments of Transportation. All three agencies are committed to continuing to fund research activities that support MAUTC's objectives as well as delivering products that meet the agencies' current needs. As part of our regional leadership mission, we have continued to seek collaborative research and technology transfer activities with the other two states in the region – Maryland and Delaware.

Because our research activities are focused on the needs of operating agencies, technology transfer is an integral part of our research effort. An explicit part of each project is a plan for implementation of the research results. Such implementation includes conduct of training programs, installation of software, and/or presentation of findings at agency or professional meetings and seminars. Further, MAUTC has taken advantage of current information technology to make the MAUTC web page a principal source of information on our

projects and other activities. Potential users of our work have been able to get updates on ongoing projects and full-text versions of current reports.

MAUTC faculty, staff, and students look forward to continuing our regional leadership in the coming years by recruiting students and providing them multidisciplinary, multimodal educational opportunities, and applying our expertise and resources to addressing key technical and policy issues facing transportation operating agencies in our region.

## **I.B. MAUTC THEME**

The theme of the Mid-Atlantic Universities Transportation Center (MAUTC) is Advanced Technologies in Transportation Operations and Management. This theme recognizes the critical link between technology and management of our transportation infrastructure, and it provides for a multidisciplinary approach to many critical transportation issues facing the Mid-Atlantic region. As illustrated in Figure 1, MAUTC's research, education, and technology transfer programs focus on the integration of knowledge and expertise in transportation operations, organizational management, and infrastructure management. The theme clearly reflects the strengths of the five universities of MAUTC and the interests of the faculty and state agencies that support much of the research conducted by MAUTC.

The distinctive elements of MAUTC's theme include the following:

- Design and implementation of research and educational programs that apply advanced technologies for information acquisition, analysis, and application to the management of the transportation system;
- Multidisciplinary approach to research, education, and technology transfer activities;
- Emphasis on the operations and management of the transportation system; and
- Multimodal mission that addresses passenger and freight transportation, highway and transit and intermodal facilities.

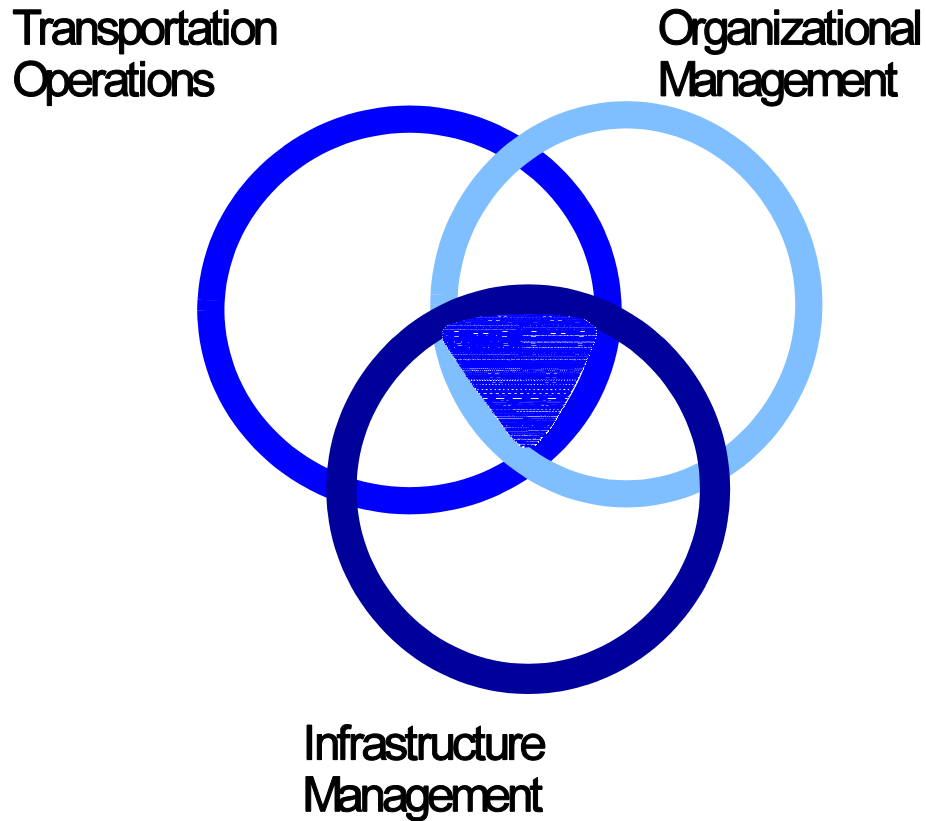


Figure 1. MAUTC's Theme: the intersection of transportation operations, organizational management and infrastructure management

### **I.C. MANAGEMENT STRUCTURE**

The Mid-Atlantic Universities Transportation Center was formed in 1986 by six universities in the five-state Mid-Atlantic region. The current five universities include The Pennsylvania State University (University Park, Pennsylvania), the University of Pennsylvania (Philadelphia, Pennsylvania), The University of Virginia (Charlottesville, Virginia), Virginia

Polytechnic Institute and State University (Blacksburg, Virginia), and West Virginia University (Morgantown, West Virginia). The original six university consortium also included Morgan State University (Baltimore, Maryland). The consortium was formed in anticipation of the University Transportation Centers Program, but its purposes were not limited to this single program; other opportunities for collaboration were anticipated.

Technically, Penn State is the lead university and grantee for the UTC Program funds. It then enters into subgrant agreements with each of the other MAUTC members for their share of the MAUTC activities and federal funds. Each subgrant agreement includes a description of the tasks that the member has agreed to perform and a budget for the federal and matching share of the MAUTC-supported activities. The MAUTC Director delegates day-to-day responsibility for MAUTC activities at the member universities to the member of the MAUTC Steering Committee from that university. The MAUTC Steering Committee interacts formally and informally to direct and coordinate the overall activities of the consortium. At least 3-4 times a year, the Steering Committee meets to formulate its future plan of activities and long-term strategy. In this way, all MAUTC members collaborate in shaping the direction of the MAUTC program.

MAUTC is be administered through the Pennsylvania Transportation Institute (PTI) at Penn State. With the help of the PTI staff, the Center Director monitors the expenditures and activities of the consortium members. Dr. James H. Miller, director of the Mid-Atlantic Universities Transportation Center, is responsible for all aspects of the center's operation. He is a full-time faculty member and holds a joint appointment with the College of Business Administration's Department of Business Logistics and the Pennsylvania Transportation Institute. A faculty member and researcher for the past 24 years, he has been the MAUTC director since its inception in 1988. Furthermore, he served as coordinator of the UTC directors for seven years.

While devoting approximately 25 percent of his time to teaching in the College of Business Administration, he devotes approximately 65 percent of his time to his duties as director of MAUTC and as director of the State Program. The remaining 10 percent of his time is devoted to other research projects at PTI. Approximately 30 percent of his time is devoted directly to MAUTC; however, because many of the state-funded projects are part of the PennDOT/MAUTC Partnership activities, an additional 10-15 percent of his time can be attributed to MAUTC-related activities.

As MAUTC Director, Dr. Miller is considered by Penn State to be the principal investigator for the federal UTC grant. As such, he is held responsible by the university for project fiscal and administrative management.

Dr. Miller serves as the chairman of the MAUTC Steering Committee and is the primary contact for U.S. DOT officials. He acts as the spokesperson for MAUTC at regional and national meetings and seeks opportunities to publicize MAUTC's program and activities.

Dr. Miller also leads the MAUTC steering committee whose members are the lead faculty responsible for MAUTC activities at the consortium member universities. Figure 2 illustrates MAUTC's organizational structure. The organizational structure features MAUTC's Steering Committee and the MAUTC Partners Roundtable. The MAUTC Steering Committee is responsible for general direction of MAUTC activities. Members include the MAUTC Director (Dr. James H. Miller) and a senior faculty member from each MAUTC member university (Dr. Michael Demetsky, Dr. Edward Morlok, Dr. Konstadinos Goulias, Dr. Hesham Rakha, and Dr. David Martinelli). The mentioned members are responsible for MAUTC-related activities at their respective universities. The MAUTC Partners Roundtable are the actual or potential sponsors of research funding agencies and/or future employers of our undergraduate and graduate students.

All faculty members involved in MAUTC activities are full-time members of academic departments at their respective universities. They devote sufficient time to MAUTC activities in supervising graduate students and staff and administering their portion of the MAUTC program. However, with the exception of the MAUTC Director, these faculty devote less than 50 percent of their time to MAUTC-sponsored projects.

To the maximum extent possible, MAUTC uses existing staff resources at the consortium member universities. West Virginia University administers its MAUTC activities through the Harley O. Staggers National Transportation Center of the university and uses the staff resources of this organization to manage project budgets and prepare reports. Likewise, Virginia Tech's activities are managed through the University Center for Transportation Research, which provides support for its programs. Departmental staff provide Penn and the University of Virginia faculty with needed support as well.



# MAUTC

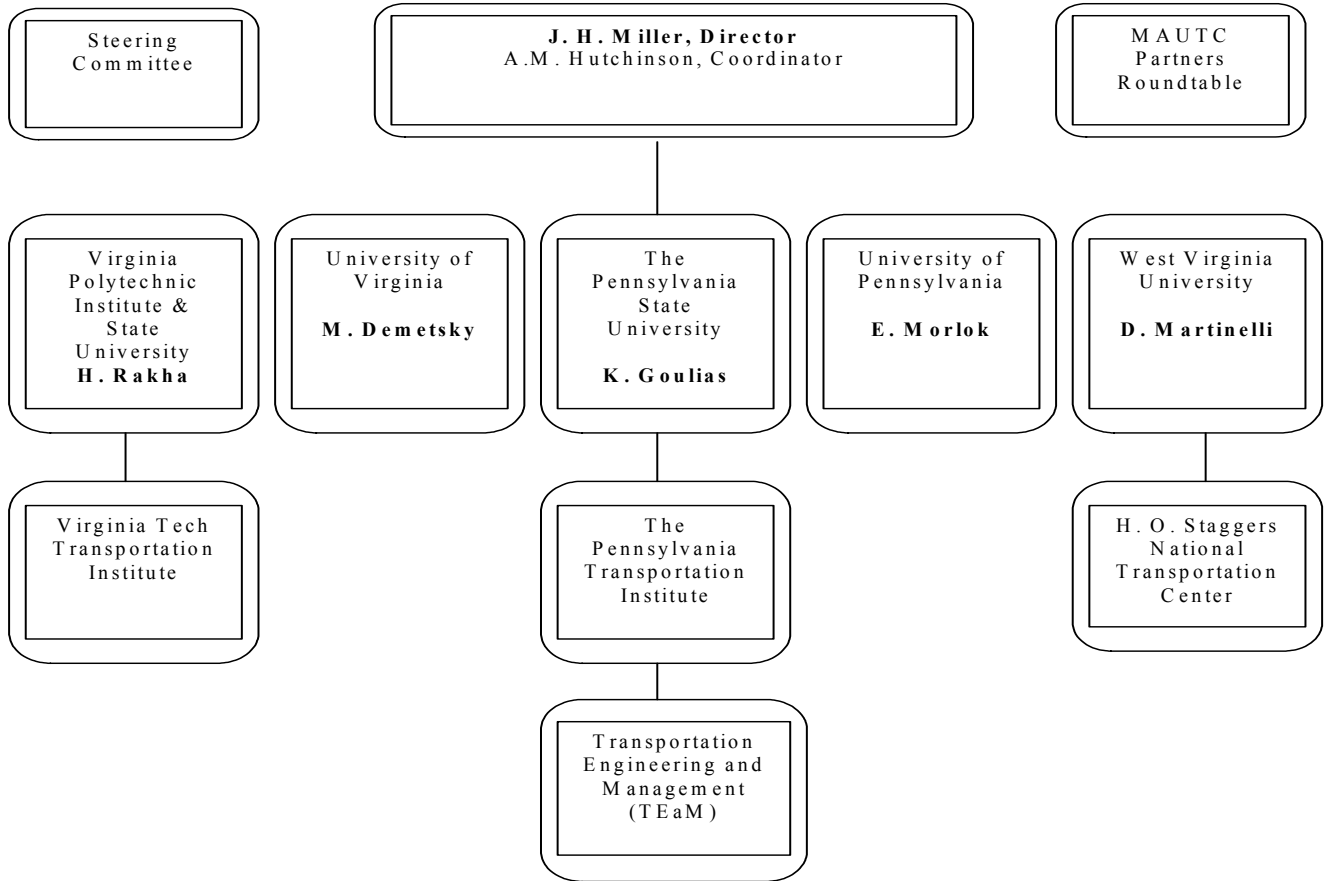


Figure 2. MAUTC's organizational structure.

At Penn State, PTI's State Program and general administrative, clerical, editorial, and financial staff are used to the maximum extent possible; however, due to the extent of PTI's MAUTC-related responsibilities, MAUTC provides partial support for four full-time staff members. Ms. Ann Marie Hutchinson, MAUTC Coordinator, is responsible for MAUTC's technology transfer activities (including the Annual Student Fair at TRB), publicity, report preparation, and coordination of the Pennsylvania TRAC Center, a joint MAUTC/PennDOT outreach initiative. She devotes approximately 90 percent of her time to MAUTC activities. Ms. Hutchinson has served in this capacity for the past six years, and has ensured that all program reporting requirements are met. She has played a lead role in preparing annual strategic plans. Furthermore, she managed the UTC Clearinghouse throughout the time that the U.S. DOT contracted with Penn State to perform this function.

Other staff members who devote significant time to MAUTC activities and are key to its success are Ms. Susan Fuoss, the Staff Assistant for MAUTC who provides clerical support for the overall MAUTC administrative activities as well as for Penn State's MAUTC projects and programs. Likewise, Ms. Deb Clemmer, a finance clerk, maintains budgets and expenditure information for MAUTC, particularly for the PennDOT/MAUTC Partnership. Finally, Mr. Jacob George develops and manages the MAUTC web site and other PTI-related sites. He is responsible for setting up the web capabilities that are required by the new UTC reporting requirements.

## **II.A. MAUTC EDUCATION**

<b>Project Title:</b>	Transportation and Logistics Doctoral Program Support
<b>Principal Investigator:</b>	Chun-Hung Chen (2000), Edward K. Morlok (2001)
<b>University:</b>	University of Pennsylvania
<b>Sponsor:</b>	MAUTC

Penn has traditionally been a major supplier of Ph.D. graduates to both academia and to industry. This program formalizes this and makes a major goal the production of well-trained Ph.D.s, in a program of study that encompasses not only the traditional transportation subjects but also includes other fields that are increasingly important. These include operations research and systems analysis methodology, economics and other social science fields, and subjects dealing with information sciences and new technology.

Five Ph.D. students were partly supported by MAUTC during the past year: three continuing students and two new ones. These are:

Stephanie Riddle: Partly supported by the Navy, she expects to complete her dissertation in late 2001. She already has two publications, and is working on a third.

Henry (Hang) Xu: MAUTC funds were used to purchase optimization software and data management tools that enabled him to tackle realistic problems in his dissertation work. He is just completing his dissertation research (expected graduation in fall 2001), and shortly will join Manugistics in their Transportation Planning Software group. He has submitted two papers for publication: Hang Xu, Zhi-Long Chen, Srinivas Rajagopal, and Sundar Arunapuram, "Solving a Practical Pickup and Delivery Problem," and Zhi-Long Chen, Hang Xu, and Srinivas Rajagopal, "Vehicle Routing with Cross-Docking."

Jianwu Lin: Partly supported by MAUTC, he has applied his simulation optimization techniques to large scale transportation network design problems. Two publications have resulted from this effort: Chun-Hung Chen, Peter M. Hahn, Jianwu Lin, and Edward K. Morlok, "Web-Based Simulation and Decision Support System for Bulk Mail (Parcel) Network Planning," *Proceedings of the Transportation Research Forum, 2000*, Vol. 42, No. 1, pages 283-292, and Chun-Hung Chen, Jianwu Lin, Enver Yucesan, and Stephen E. Chick, "Simulation Budget Allocation for Further Enhancing the Efficiency of Ordinal Optimization," *Discrete Event Dynamic Systems: Theory and Applications*, Vol. 10, page 251ff., Kluwer Academic Publishers, Boston, 2000.

Denny Cho: Partly supported by the Boeing Company, from which he is on leave, he just matriculated as a full time student in 2001. He already has one paper in preparation, along with a presentation accepted for the November 2001 INFORMS National Meeting: "Capacity and Flexibility Assessment of Transportation Systems."

David Chang: He returns to Penn on educational leave from the U.S. Army. He will begin dissertation work shortly. Initial research has led to one paper to be submitted for publication: David J. Chang and Edward K. Morlok, "Rules for Optimal Train Speed to Minimize Fuel Consumption," June 2001.

<b>Project Title:</b>	Transportation and Logistics Systems Laboratory and Course Development, Phase 3
<b>Principal Investigator:</b>	Edward K. Morlok
<b>University:</b>	University of Pennsylvania
<b>Sponsor:</b>	Manugistics, Inc.

The laboratory was recently expanded with a grant from the Beatty Trust, and a major grant of software from Manugistics enables the inclusion of realistic distribution and truck scheduling problems in laboratory exercises. A computer specialist will be attending a Manugistics course, and will be working with faculty to develop new courseware problems. The use of problems and data from various firms is anticipated. Additional software in the form of network models and industrial databases is also contemplated.

The person in charge of the laboratory, Bradley Nitzberg, attended two courses offered in Transportation and Supply Chain software, and these enabled him to develop, with faculty assistance, realistic problem sets for the courses SYS 550, Transportation and Logistics Systems, and SYS 650, Advanced Logistics. The latter were used with enthusiastic student response in the spring 2001 semester. Peter Hahn attended two workshops on simulation, which will substantially enhance simulation capability in future projects and in course work. Additional software to support student independent study and research, including data management packages and computer sided drawing/design packages, was obtained.

**Project Title:** Development of Design Vehicles and Characteristics for the HANGUP Software  
**Principal Investigator:** J. French and R. Eck  
**University:** West Virginia University  
**Sponsor:** West Virginia Department of Transportation

The project involves identifying design vehicles to be used in evaluating high profile vertical geometry and to determine overhang, ground clearance, and wheelbase dimensions for each class of design vehicle. The results will be used in the HANGUP software to enable engineers to model specific types of low clearance vehicles at a specific railroad crossing or other high profile vertical curve. Field data collection was performed, the database was analyzed, and a preliminary proposal was submitted for design vehicle dimensions.

**Project Title:** Graduate Student Assistantships in Transportation  
**Principal Investigator:** David R. Martinelli  
**University:** West Virginia University  
**Sponsor:** West Virginia Department of Transportation

The success of the highway system in West Virginia and the nation relies heavily on the abundance of engineering talent attracted to the transportation and civil engineering profession. The challenges for the future almost certainly will require a substantial number of transportation professionals to have an education beyond the bachelor's degree. Attracting students will ensure that a competent workforce in transportation analysis, design, and research is maintained.

The package of competitive financial support, coupled with strong graduate programs at WVU, is a very powerful recruiting tool for attracting quality students.

**Project Title:** Ozone Formation Attributable to Emissions from Rural Interstate Traffic  
**Principal Investigator:** Michael J. Demetsky  
**University:** University of Virginia  
**Sponsors:** Virginia Transportation Research Council and MAUTC

The contribution of emissions from rural interstate traffic to local, ground-level ozone formation was examined using microscopic traffic simulation and a photochemical simulation model. Atmospheric and micrometeorological data from a remote Canadian forest were simulated as a baseline case. Several traffic and traffic emissions scenarios were then compared to the baseline case. The results indicated that traffic emissions along a rural interstate contribute to substantial ozone formation in the rural environment when such ozone formation is compared to ozone formation in the absence of vehicle emissions. Ozone levels immediately above the roadway were estimated to be around 120 ppbv, roughly three times those produced in the baseline case. It was shown that the relatively large amounts of anthropogenic NO<sub>x</sub> emitted from traffic, particularly heavy duty vehicles, dominated the ozone formation in the immediate vicinity of the rural interstate. The results of the research support the most recent emission standards imposed on the trucking industry that require NO<sub>x</sub> emissions for vehicles manufactured after 2004 to be reduced to half of their 1998 values. The results also support technologies and alternative fuels that further reduce NO<sub>x</sub> emissions from heavy duty vehicles. The research suggests that rural interstates may be a significant local source of photochemical pollutants that requires explicit treatment in regional scale analyses.

**Project Title:** The Study on Effective Value Pricing Strategy in Washington, D.C.,-Richmond Area  
**Principal Investigator:** Lester A. Hoel and Jianxin Ma  
**University:** University of Virginia  
**Sponsors:** U.S. Department of Transportation and Virginia Department of Transportation

The project was divided into three phases. The first phase will develop a graphical model that displays the interaction among road capacity, user demand, travel speed, toll charges, and peak-period traffic congestion with elastic demand to identify the high-priority corridors and toll facilities in the Washington, D.C.,-Richmond region for application of value pricing.

The second phase will consider a broad range of value pricing strategies at the corridor level (implementing value pricing on individual corridors) and at the system level (implementing value pricing on several interrelated corridors). These strategies will be screened using sketch planning techniques (qualitative assessment and evaluation of information from other value pricing studies) in order to refine the strategies into a smaller number of options.

The remaining strategies will then undergo a more detailed analysis in the third phase, and the strategy choice will be determined.

**Project Title:** Advanced Traffic Simulation Laboratory (ATLAS)  
**Principal Investigator:** Lily Elefteriadou  
**University:** The Pennsylvania State University  
**Sponsor:** Pennsylvania Department of Transportation

Researchers at Penn State designed and implemented a laboratory for real-time traffic data collection in the State College, Pennsylvania, area using video imaging technology. The laboratory provides researchers and students with the opportunity to observe real transportation facilities in real time, record and analyze a multitude of traffic and travel data, and create models with much finer detail than previously possible.

Dr. Lily Elefteriadou, associate professor of civil engineering and research associate at Penn State's Pennsylvania Transportation Institute (PTI), is directing this initiative, in cooperation with MAUTC and the Pennsylvania Department of Transportation. The laboratory is instrumented using the AUTOSCOPE™ video detection system, developed by Econolite/ISS. The system includes cameras in the field to transmit images to the laboratory for further processing. The laboratory component also includes a data collection/reduction system based on image processing, allowing researchers to observe and record traffic data on a continuous basis. In addition, the capability for microscopic observation of traffic and driver behavior provided researchers with unique opportunities to develop more efficient traffic operations models, greater safety measures, and more efficient management of transportation facilities.

The research includes development of traffic optimization models based on drivers' actions, which constitutes the continuation of previous research conducted by Dr. Elefteriadou. Testing of these models is conducted on existing and new simulation models. In addition, research will be conducted on requirements for quality and quantity data, as these are used in transportation applications. A unique feature of the State College area is that the roadway network is often used by recreational drivers and drivers not familiar with the area. Thus, research will focus on investigating operational effects of various driver populations, including "unfamiliar" drivers. The laboratory provides the necessary setting to expand existing research capabilities in the area of new and advanced technologies (e.g., automatic traffic recording, geographic information systems, etc.). Local and state, public and private agencies will likewise benefit from the technology transfer capabilities and data availability. Aside from the vast opportunities in conducting research, the laboratory serves as a unique educational tool for graduate and undergraduate students.

**Project Title:** OPTIPATH Lab  
**Principal Investigator:** Elise Miller-Hooks  
**University:** The Pennsylvania State University  
**Sponsor:** MAUTC

Dr. Elise Miller-Hooks, assistant professor of civil engineering, created a specialized laboratory called OPTIPATH with specific objective the use of high-speed processing computers (DEC - Alpha) to solve networks' problems in the area of transportation logistics. The new laboratory will be housed at The Pennsylvania Transportation Institute at Penn State and will be used in education and research. The primary sponsors during the past two years have been the Center for Intelligent Transportation Systems (CITranS) and the Department of Civil and Environmental Engineering at Penn State, MAUTC, and the National Science Foundation.

Dr. Miller-Hooks, who received a CAREER award from the National Science Foundation for her project, Robust On-Line Location and Routing for Urban Service Systems, is focusing on the development of the conceptual framework and algorithmic steps for real-time location and routing decisions in dynamically changing environments for urban service operations, including emergency response services, vehicles carrying hazardous materials, and teams responding to incidents involving hazardous materials. Response time and the associated level-of-service of many of these urban service operations, such as ambulance, police, fire, and emergency repair, depend on travel times experienced on the roadways and the relative location of the call for service to that of the response vehicle. Thus, optimal location and routing decisions are vital to the performance of many emergency service operations. Real-time information can be used to make improved tactical and operational location and routing decisions for emergency services and other urban operations, including the transport of hazardous materials. However, it is critical that procedures that dynamically respond to current conditions on the state of the network consider the time-varying and uncertain nature of future travel conditions in order to generate robust solutions, i.e., solutions that will remain optimal, or nearly optimal, despite variations in travel conditions and that can be applied to a variety of situations. The inherent stochastic and dynamic characteristics of future travel conditions, including the probability of arc or node failures, as well as the spatial and temporal correlation in travel conditions and the possibility of multiple conflicting objectives, will be considered in this work.

**Project Title:** PennPlan and Statewide Simulation  
**Principal Investigator:** Konstadinos Goulias  
**University:** The Pennsylvania State University  
**Sponsor:** Pennsylvania Department of Transportation

The Commonwealth of Pennsylvania is becoming a national champion in innovation for statewide, long range planning. Its processes promote performance-based planning, a comprehensive public involvement process, and corridor-based needs assessment. This spirit of innovation has motivated work toward a statewide needs assessment tool that is currently under development in the department. In parallel, however, the state must assess a variety of other

needs that may or may not be highway oriented. A general simulation framework must first be designed that addresses the actors in each stage of plan development and needs assessment.

The goal of this project is to develop a long-range-planning, multilevel simulation model that incorporates interacting agents with diverse objectives operating at different levels of the attitude-behavior space. The model will consider economic development, demographic evolution, technology adoption and use, changes in activity and travel behavior, and processes such as relocation and car ownership. This formulation will allow for a natural hierarchy in social organizations such as households, neighborhoods, and communities. In addition, a variety of new simulation technologies will be considered and used in collaboration with researchers in Europe and Australia. The first major objective of the project is to identify advantages and disadvantages of different simulation techniques. The second objective is to make operational a demographic simulator (based on past work by Dr. Konstadinos Goulias in The Netherlands; Centre County, Pennsylvania; and the Puget Sound region) called DEMOS. The third objective is to demonstrate a statewide simulation model system. The fourth objective is linked to Dr. Goulias's Fulbright assignment and efforts to collaborate with European and Australian universities in state of the art multilevel simulation for nationwide (statewide in the U.S.) models. For this a variety of presentations will be made in international conferences, and proposals to international funding organizations will be written in support of these activities.

**Project:** Continuing Education Courses  
**Principal Investigators:** Alejandra Medina, Francois Dion, John Collura, Antoine Hobeika, and Hesham Rakha  
**University:** Virginia Polytechnic Institute & State University  
**Sponsors:** Virginia Department of Transportation, Federal Highway Administration, and MAUTC

This educational effort involves offering a combination of one-day, two-day, and three-day short courses to the Virginia Department of Transportation, the Federal Highway Administration, and transportation consulting firms for continuing education purposes based on any requests received. Courses that cover a wide range of areas, including transportation planning, traffic operations in traffic-signalized networks, traffic operations on freeways, communication networks, and transit operations, will be offered on demand.



**Project Title:** Graduate Studies in Transportation Engineering and Planning at the University of Virginia  
**Principal Investigator:** Michael J. Demetsky  
**University:** University of Virginia  
**Sponsors:** Virginia Department of Transportation and MAUTC

The graduate program of advanced study in transportation at the University of Virginia (UVA) is managed through the Center for Transportation Studies (CTS) and is interdisciplinary in its academic focus and research activity. It stresses the introduction of new technology in planning, design, construction, operation, and management of multimodal transportation systems in its core courses, and it supplements these courses with advanced courses that teach the fundamentals of emerging technologies such as artificial intelligence, simulation, image processing, and geographic information systems.

Students with varying academic backgrounds such as planning, environmental science, economics, mathematics, and electrical engineering are admitted to the program. Depending upon the students' academic and research objectives, faculty from various university divisions collaborate on curriculum, research supervision, and graduate student committees.

A special feature of UVA's transportation studies program is the partnership that UVA has with the Virginia Department of Transportation (VDOT). Through this partnership, two employees were given academic leave from VDOT to pursue graduate degrees. Both VDOT and MAUTC provided financial assistance for these students.

Most graduates of the program are required to write a thesis or dissertation on a problem or issue in Region III or a topic of interest to the Virginia Transportation Research Council (VTRC). Resources to carry out the thesis research are provided through UVA (using university and MAUTC funds) and through the VTRC and other projects. In addition to serving as a student's thesis, the results of a student's research are published as MAUTC reports and as technical papers in journals.

**Project Title:** Maintain and Enhance Transportation Laboratories  
**Principal Investigators:** Konstadinos Goulias, Hesham Rakha, Michael Demetsky, Edward Morlok, and David Martinelli  
**Universities:** The Pennsylvania State University, Virginia Polytechnic Institute & State University, University of Virginia, University of Pennsylvania, and West Virginia University  
**Sponsor:** MAUTC

Transportation laboratories have been established at all MAUTC universities to enhance education and research programs. During the past year, hardware and software were purchased and replaced to maintain state-of-the-art facilities. The functions of the labs are to maintain computational equipment and software at transportation computer laboratories at the universities; maintain current hardware and software support for the GIS course being developed at the

University of Virginia; and provide software and hardware support for the Transportation and Logistics Systems Program and associated undergraduate and graduate courses.

**Project Title:** Transportation and Logistics Systems Laboratory and Course Development  
**Principal Investigator:** Edward K. Morlok  
**University:** University of Pennsylvania  
**Sponsors:** Beatty Trust, Manugistics, Inc., 21<sup>st</sup> Century Project for the Undergraduate Experience, UPS Foundation Fund, and MAUTC

The purpose of this effort is to enhance undergraduate and graduate education, and to support research by faculty, students, and staff. Two new courses have been introduced that have been very popular with students from a variety of fields, and this led to the expansion of the laboratory in November 1999 to accommodate larger classes (from a maximum of 24 students to 32, depending on the course). Another major milestone was the signing of an agreement with Manugistics, Inc., which provides for the installation in the laboratory of their MTM software. This is probably the most widely used transportation and logistics software in the world, and it is valued at about \$2 million. Exercises based on actual company data have been prepared for the graduate Logistics Systems course, taught by Z. L. Chen, and exercises for use by undergraduates in the Transportation Systems course are being prepared by Bradley Nitzberg, on the lab's staff, and E. K. Morlok. The lab is also used for a joint Engineering-Wharton logistics course for undergraduates, and is widely used by undergraduates in their senior design or other capstone project.

**Project Title:** Development of a Laboratory for Analysis of Commercial Aviation Issues  
**Principal Investigators:** Marcello Napolitano, David Martinelli  
**University:** West Virginia University  
**Sponsor:** MAUTC

An important effort is underway at West Virginia University in a collaboration between the Mechanical and Aerospace Engineering Department and the Civil and Environmental Engineering Department. Capabilities have been acquired for a study of several commercial aviation issues using flight simulators. In particular, the research efforts will focus on developing compensating control laws to assist a commercial pilot in the event of a catastrophic failure within the flight control system. The objective is to introduce prototype control algorithms to allow pilots to recover from failures in actuators of primary aircraft control surfaces. Additional investigations are being conducted on traffic patterns within congested air spaces for the development of collision avoidance schemes. Several graduate and undergraduate students are involved in this effort.

**Project Title:** Transit Internship Program  
**Principal Investigators:** James H. Miller, Edward K. Morlok, and Lester Hoel

**Universities:** The Pennsylvania State University, University of Pennsylvania, University of Virginia, and Virginia Polytechnic Institute & State University

**Sponsor:** MAUTC

MAUTC at The Pennsylvania State University sponsored an Undergraduate Internship Program in which students who have completed the sophomore or junior year in a transportation-related curriculum are selected to fill paid internships in the Centre Area Transportation Authority, Beaver County Transportation Authority, and York County Community Transportation Authority in Pennsylvania.

The University of Pennsylvania's MAUTC Program has established a national program to encourage young men and women to choose careers in transportation, particularly railroad management and engineering. The University of Pennsylvania's internship program is administered through the Kent T. Healy Memorial Fund. The program also provides a clearinghouse for summer internship opportunities. Future activities will include a symposium dealing with the future of the railroad industry and associated research.

MAUTC at The University of Virginia (UVA) arranges for student interns to work with the Charlottesville Transit System on a yearly basis. Their work at the transit system is used for their senior theses. UVA researchers have also established graduate student projects requested by other transit agencies.

MAUTC at Virginia Polytechnic Institute & State University has been successful in attracting students to the ITIS Internship Program. These internships have not only provided funding opportunities to students but have also enabled participation in advancing the state of the art in transportation research.

**Project Title:** Virginia Department of Transportation Fellowship Program at University of Virginia and Virginia Polytechnic Institute & State University  
**Principal Investigators:** Hesham Rakha, Michael J. Demetsky  
**University:** University of Virginia and Virginia Polytechnic Institute & State University  
**Sponsors:** Virginia Department of Transportation and MAUTC

As part of its partnership with the University of Virginia and Virginia Tech, the Virginia Department of Transportation has committed to supporting its employees while they return to these schools for a master's degrees. Through this highly effective program to upgrade the capabilities of its staff, the department continues the employees' salaries while they attend the university full time. MAUTC provides an additional stipend and pays tuition, and the department employee works on a MAUTC-supported research project that is selected by the department.

**Project Title:** Transportation Engineering and Management (TEaM) Advanced Institute Program at Penn State  
**Principal Investigator:** Konstadinos G. Goulias  
**University:** The Pennsylvania State University  
**Sponsors:** U.S. Department of Transportation and MAUTC

TEaM is the name given to Penn State's transportation education activities. TEaM's goal is to provide students from several transportation disciplines with educational opportunities that focus on both the engineering and technical aspects of transportation systems and the management of these systems. MAUTC at Penn State markets its transportation education activities under the TEaM logo, and the logo is used internally to identify students and activities related to MAUTC. During the past year approximately 15 graduate students were recruited through the TEaM effort and were supported on PENNDOT/MAUTC Partnership projects; undergraduate interns were supported with MAUTC funds.

**Project Title:** Intelligent Transportation Systems Research and Development Fellowship Program at The Pennsylvania State University  
**Principal Investigator:** Konstadinos Goulias  
**University:** The Pennsylvania State University  
**Sponsors:** U.S. Department of Transportation and MAUTC

In this educational activity, Penn State faculty and graduate students aimed at developing new ideas in the area of intelligent transportation systems (ITS) and creating the foundation for new methods, software, and hardware to be moved into practice. The project will be renewed yearly, and changes in the emphases of the MAUTC Program at Penn State will be reflected. In addition, a review of new needs for ITS research and development will be performed at regular intervals, and new directions will be incorporated. Two research topics are:

## **1. Traveler Information and Transportation System Utilization**

Traveler information systems within the ITS arena provide major benefits to the transportation system users and managers. Recent evidence may suggest the potential emergence of “induced demand” (i.e., trip making may increase because of information availability, thus nullifying any gains from managing traffic). In addition, longer term changes in the ways people travel (e.g., peak spreading, increase in weekend travel) may require development of information systems different from most of the current systems, which are targeting peak hour commuters. In this topic Penn State researchers will identify the determinants of change in the nature of travel demand, study the relationship between travel demand and information systems, and provide specific guidelines for the design of information systems. Emphasis in this topic will be given to the type of information needed by prospective travelers, the use of multimedia in providing information to them, and their effect on trip-making propensity. Statistical models that can be used to analyze data of this type must be developed.

## **2. Network Modeling and Stochastic Demand**

Many ITS aim at improving network performance. However, network modeling and traffic assignment become extremely complex when one considers fluctuations in the demand for travel. These fluctuations may be due to predictable temporal variation of demand and predictable user variation of demand, but also unpredictable factors. In addition, network modeling under ITS is needed in real time. This implies that a traffic control center or an emergency management center requires traffic predictions in a very short time as new information about the demand for travel becomes available. Within this topic, researchers at Penn State will design new algorithms, methods, and software that advance the state of the art in network modeling.

**Project Title:** TRAC Outreach Program for Junior and Senior High Schools  
**Principal Investigator:** James H. Miller  
**Universities:** The Pennsylvania State University and West Virginia University  
**Sponsors:** U.S. Department of Transportation, Pennsylvania Department of Transportation, West Virginia Department of Transportation, and MAUTC

A major endeavor of MAUTC is the development of the Transportation and Civil Engineering Careers Center (TRAC) program in Pennsylvania and West Virginia. The primary goal of TRAC, a federally funded outreach program associated with the American Association of State Highway and Transportation Officials, is to increase the number and diversity of students who pursue careers in engineering and transportation-related fields. As part of their activities, Pennsylvania and West Virginia TRAC faculty and staff provide high school science and mathematics teachers with the training and materials they need to establish sound engineering and transportation-related curricula in their classrooms. In addition, Pennsylvania and West Virginia have implemented a state-based Regional TRAC Center to encourage partnerships

among the transportation department, education department, and university in each state to develop an effective administrative structure.

During the past year, training for prospective TRAC teachers and volunteer engineers was held at each university. The training was designed to showcase TRAC's purpose and train the attendees on the equipment, software, and curriculum.

West Virginia's TRAC program was expanded during the year with the development of a transportation careers web resource. The name of this program is TCAP (Transportation Careers Awareness Program). A web page was designed and developed to house this new program and went live in April 2001. The program will enable TRAC to reach all secondary schools in West Virginia, not just those involved with the current TRAC program. The program was presented at the TRAC National Conference held in July and was well received.

The TRAC program has been active in 39 schools in Pennsylvania and 51 schools in West Virginia. Plans were in place to expand to more high schools in the 2001-2002 academic year. To further strengthen the Mid-Atlantic Region's involvement in TRAC, MAUTC has asked researchers at Virginia Polytechnic Institute & State University to consider hosting TRAC.

**Project Title:** Design MAUTC Regional Transportation Courses  
**Principal Investigator:** James H. Miller  
**University:** The Pennsylvania State University  
**Sponsors:** U.S. Department of Transportation and MAUTC

MAUTC researchers are in the process of designing regional transportation courses that will be offered at each MAUTC university. Researchers from participating universities will hold a series of meetings to develop course outlines and assign modules to each university; develop assigned modules; pilot-test modules at each university; develop and package course materials; distribute courses at each university; and advertise courses at each university.

The first course will focus on Urban Goods Movement, with an emphasis on Intelligent Transportation Systems topics. It will be directed toward upper level undergraduates or first year graduate students. The course will be comprised of modules, each covering a specific topic. The modules will be capable of combination in various ways to form a course, which can be tailored to specific groups (metropolitan planning organizations, departments of transportation, logistics companies, consulting firms, etc.). The use of the web for offering the course will be explored. A book is a possibility, but not part of current plans.

**Project Title:** Develop Transportation Courses in Information Technology for Graduates and Undergraduates  
**Principal Investigator:** Brian L. Smith  
**University:** University of Virginia  
**Sponsor:** Virginia Transportation Research Council

Researchers at the University of Virginia are developing transportation courses in information technology for graduate and undergraduate students. During the past year, a work station and three terminals were purchased for the transportation laboratory. A GIS course was developed and taught by Virginia Transportation Research Council previously. A second course for graduate students will be developed that uses the work station for advanced training and research.

**Project Title:** Education Program at the Virginia Tech Transportation Institute  
**Principal Investigator:** Hesham Rakha  
**University:** Virginia Polytechnic Institute & State University  
**Sponsors:** Virginia Department of Transportation and MAUTC

Virginia Tech's Transportation Institute offers an interdisciplinary program of educational experiences and research opportunities in the areas of information technology and transportation. Students in the program come from diverse backgrounds, with interest in advanced transportation studies. Furthermore, there is opportunity for two to three Virginia Department of Transportation (VDOT) employees to regularly enroll and pursue M.S. degrees at Virginia Tech. These students can work on research projects of interest to VDOT and within the theme of education in advanced transportation studies.

The key feature of Virginia Tech's education in advanced transportation technologies is the interdisciplinary nature of the focus and the range of disciplines drawn to the activities. Students not only from engineering branches but also from other disciplines, who have interest in transportation, will be attracted. In addition to the graduate financial support provided through the center, Virginia Tech provided \$2,500 in undergraduate summer internships to students, based upon outstanding performance. These students were also recruited aggressively for the Transportation Institute.

## **II.B. MAUTC RESEARCH**

**Project:** The MAUTC Freight Transportation Partnership  
**Principal Investigators:** James H. Miller, Michael J. Demetsky, David Martinelli, Edward K. Morlok, Hesham Rakha  
**Universities:** The Pennsylvania State University, University of Virginia, West Virginia University, University of Pennsylvania, Virginia Polytechnic Institute & State University  
**Sponsor:** MAUTC

MAUTC researchers are developing a Region III Freight Transportation Partnership by surveying departments at prospective university partners for expertise in freight transportation. Each participating university will select two to three research topics that will benefit the Mid-Atlantic Region. The research partnership will run for the duration of the 1999-2004 MAUTC contract.

**Project Title:** Undergraduate Research Experience  
**Principal Investigator:** Edward K. Morlok  
**University:** University of Pennsylvania  
**Sponsor:** MAUTC

A major goal of the University of Pennsylvania is to increase the involvement of undergraduates in research, and this initiative is directed toward transportation and logistics research. This is accomplished in three ways. One is to have students work part time on projects with faculty and graduate students. A second is to have them work on topics of interest to them that are related to research projects but not necessarily part of such projects. The third is to have students work on design, analysis, or strategy projects in the field with clients, advised by a faculty member and the client organization.

Eight undergraduates were involved in research during the past year. The specific efforts included:

1. Development of a Simulation Model of the Philadelphia Bulk Mail facility for Operations Planning. This effort, supervised by Peter Hahn, involved four students in their Senior Design Project. They worked closely with staff of the U.S. Postal Service.
2. One senior worked closely with Edward Morlok in gathering data and analyzing trends in the intermodal freight system, as part of the project, Freight Transportation Trends and Services.
3. Three students worked on various aspects of the project on estimating the Capacity of Transportation Infrastructure Systems. Included were two system engineering students and one economics major. Each of these student projects will be the subject of a paper to be published in a transportation journal.



**Project Title:** Real-World Vehicle Routing and Scheduling Problems  
**Principal Investigator:** Zhi-Long Chen  
**University:** University of Pennsylvania  
**Sponsor:** Manugistics, Inc.

Real-world vehicle routing and scheduling (VRS) problems can rarely be solved optimally because of many complicating constraints, such as prohibitions on mixing cargoes. The complexity of these problems will increase when the new U.S. Department of Transportation driver-hours-of-service rules take effect. The purpose of this research was to develop practical ways to incorporate these constraints into vehicle routing problems, and then to develop efficient ways to find good if not optimal solutions. Real problems from firms such as Hershey Foods were used for data and as test beds for the resulting methods.

Close collaboration between faculty, graduate students, and the sponsoring firm (Manugistics) resulted in development of two new approaches to significant VRS problems, involving innovative algorithms and theoretical development. Two papers jointly authored by the academic and industry researchers were prepared for distribution and publication in operations research and transportation science journals. The papers are:

1. Hang Xu, Zhi-Long Chen, Srinivas Rajagopal, and Sundar Arunapuram, "Solving a Practical Pickup and Delivery Problem," January 2001.
2. Zhi-Long Chen, Hang Xu, and Srinivas Rajagopal, "Vehicle Routing with Cross-Docking," June 2001.

These papers were presented at meetings of INFORMS, the major society in this field of work.

In addition, these procedures are being implemented for large-scale testing by the sponsor, and if they prove effective, will become part of the suite of transportation operations planning packages offered to trucking companies and shippers by that firm. Of course, the methods are in the published literature and can be used directly or built upon by others as well.

**Project Title:** Trends and Status of Freight Transportation in the U.S.  
**Principal Investigator:** Edward K. Morlok  
**University:** University of Pennsylvania  
**Sponsor:** United Parcel Service, Inc.

This project originated as a study of the size and impact of the intermodal parcel service industry in the United States. Completion of this effort revealed the extent to which data were available on freight transportation and the extent to which the data have never been mined to describe important characteristics of the industry.

A major report was prepared and distributed by UPS on the first phase of this effort, which deals with the parcel industry:

Edward K. Morlok, Bradley F. Nitzberg, Karthik Balasubramaniam, and Mark L. Sands, "The Parcel Service Industry in the U.S.: Its Size and Role in Commerce," 108 pages, August 2000.

It is also available on the web at: <http://www.seas.upenn.edu/sys/logistics/parcelstudy.html>.

One journal article and an article in a managerial and policy magazine are being prepared on the parcel service portion of this work.

The second phase of this work was to examine the remainder of the domestic freight industry, starting with rail and intermodal rail-based services. This work was largely postponed to 2001-2002, due to the medical leave of the principal investigator for most of the 2000-2001 academic year. However, during this period, staff and students assembled a data base consisting of all the known public sources of rail and related freight data.

**Project Title:** Exploratory Study of the Impact of Urban Congestion on Freight Transport and the Costs of Goods and Services  
**Principal Investigator:** Edward K. Morlok  
**University:** University of Pennsylvania  
**Sponsor:** Manugistics, Inc.

This project is an outgrowth of recent projects we have completed for United Parcel Service, the European Commission, and other studies of the growth of goods movement activity. The purpose is to identify the impacts of increasing congestion on goods movement via road, and to trace the indirect costs on producing goods and providing services. These then will provide the basis for one or more major research programs in such areas as assessing the magnitude of costs and whom they impact, identifying ways to avoid the problem, or identifying ways to deal with it directly.

Due to medical leave of the principal investigator during most of the 2000-2001 academic year, work on this project was postponed until 2001-2002.

**Project Title:** Operational Effects of Highway Geometrics in Mountainous Terrain  
**Principal Investigator:** J. French, D. Martinelli, and R. Eck  
**University:** West Virginia University  
**Sponsor:** West Virginia Department of Transportation

This project involves the collection of certain speed and headway data on highway geometry unique to mountainous terrain, including steep grades, sharp curves, and switchback curves. These data can support headway distributions, capacity studies, and traffic flow modeling and simulation. During the year, a theory was developed that demonstrated that part of downgrade force acts to the outside of horizontal curves, thus counteracting superelevation. Also, factors were identified that lead to crashes in this terrain. A peer review committee was established to provide a validation of these findings.

**Project Title:** Effect of Dowel Bonding Force on Stresses in Concrete Slabs  
**Principal Investigator:** Samir N. Shoukry  
**University:** West Virginia University  
**Sponsor:** West Virginia Department of Transportation

Experiments will be conducted on simulated doweled joints to determine the effectiveness of different types of bond breakers in eliminating the dowel-concrete bonding. The measured pulling forces will be used in finite element programs to compute the thermal stresses induced in concrete slabs.

**Project Title:** Finite Element Evaluation of the Structural Integrity of Composite Concrete-Steel Bridge Decks  
**Principal Investigator:** Carlos E. Orozco  
**University:** University of Virginia  
**Sponsor:** Virginia Department of Transportation

The Virginia Department of Transportation (VDOT) is interested in the development of efficient and economical procedures to evaluate the structural integrity of bridge structures. The project will develop a finite-element-based methodology for the evaluation of the structural integrity of composite bridge decks. Given that VDOT is interested in assessing the structural integrity of the New River Bridge along I-81, this bridge will be used to test the evaluation methodology. The New River Bridge on Interstate 81 has an unusual composite steel-concrete deck. This bridge presents severe deterioration problems in the deck. The methodology that will be developed will include a finite element model, the instrumentation of one of the spans of the bridge, and a load test. Actual strains in the girders of the bridge will be measured, and the results will be compared with those corresponding to the finite-element model. A direct comparison of these two sets of results will help VDOT assess the structural integrity of the bridge superstructure.

**Project Title:** Oversized Vehicle Routing and Scheduling

**Principal Investigator:** Lester Hoel, Cheng Xu  
**University:** University of Virginia  
**Sponsor:** Virginia Department of Transportation

Current specifications allow for a wide range of starting times for oversized vehicles' travel. This study will integrate routing and scheduling to accommodate time-varying network attributes, and in so doing, develop algorithms for the safest departure time for a selected route. The methodology will identify the hourly distribution of risk for oversized vehicles traveling on a specific roadway type. Risk will be estimated using oversized vehicle accident probabilities and accident consequences.

**Project Title:** Feasibility Study of Alternative Travel Modes and Vehicle Fuels for UVA "Groundswalk"  
**Principal Investigator:** Michael J. Demetsky  
**University:** University of Virginia  
**Sponsor:** Virginia Department of Transportation

In June 1999, the Board of Visitors adopted a new Master Plan for the University of Virginia. The centerpiece of this plan is a 3-mile circulation spine linking North, Central, and West Grounds through a pathway system that favors pedestrian, bicycle, and mass transit modes of travel over private vehicles. The traditional 30-passenger bus that forms the backbone of the current UTS fleet, however, is unsuitable for use on the proposed route, which passes through some very narrow corridors next to neighborhoods where residents object to the noise and fumes from these diesel-powered vehicles. Therefore, the Office of the Architect for the university requested assistance from the Center for Transportation Studies in evaluating alternatives for a transit shuttle along the "Groundswalk" route.

**Project Title:** Spatial Analysis Tools for Integrated Transportation Data:  
Northern Virginia Intelligent Transportation Systems Prototype  
**Principal Investigator:** Brian L. Smith  
**University:** University of Virginia  
**Sponsor:** Virginia Department of Transportation

The purpose of this project is to investigate the use of intelligent transportation systems (ITS) data in conjunction with other, more traditional, transportation data (such as data from planning, traffic engineering, construction, maintenance, etc.) to develop decision support tools to improve the Virginia Department of Transportation (UVA) business processes. This effort will include the development of prototype tools built upon a web-enabled, geographic information system (GIS) platform. The project will conclude with the development of an implementation plan to assist VDOT in applying the lessons learned in the research project. This project will provide a tangible example of ways to integrate and use the many types of data that VDOT currently collects. The prototype, and the experience gained while developing the prototype, will improve VDOT's use of GIS enterprise-wide, particularly in terms of web-based GIS applications; serve as the proving ground for the development of new models to support the analysis of integrated

transportation data; and provide information that has the potential to help the Data Management Division's data warehousing efforts, especially regarding ITS data. Project has developed "Build 1" of a mobility datamart for use in the prototype system and basic, web-based database-query-tools to support prototype program.

**Project Title:** Safety Impacts of Differential Speed Limits (DSL)  
**Principal Investigator:** Nicholas J. Garber  
**University:** University of Virginia  
**Sponsors:** Federal Highway Administration and Virginia Department of Transportation

After the enactment of the Surface Transportation and Uniform Relocation Assistance (STURA) Act in 1987, several states changed the speed limit on rural interstate highways from 55 mph to 65 mph. Some of these states restricted truck speeds by imposing Differential Speed Limits (DSL), in which the maximum speed limit for trucks was 55 mph and that for passenger cars was 65 mph, with the objective being to reduce the impact of the increased speed limit on truck-involved crashes. Some of these states have subsequently increased the speed limit of trucks to 65 mph on rural interstate highways. Several studies have been conducted to investigate the extent to which DSL have been successful in achieving the desired objective. However, the data used for most of these studies were obtained for short periods after the change of the speed limit, and the results of these studies have not been consistent. It is now appropriate for the topic to be revisited, as additional data are available. This study will assess the nature and extent of the effects of DSL on vehicle speeds and crash characteristics. Data will be obtained on speed and crashes at test and comparison sites operating under DSL and non-DSL conditions in as many states as possible, including California, Maryland, Virginia, West Virginia, and North Carolina. The speed and crash data will be obtained for before-and-after periods of the speed limit change. The data will then be statistically analyzed to determine whether speed and crash characteristics changed significantly as a result of the higher speed limit. The analyses will be conducted for trucks and passenger cars separately. The t-test will be used to conduct the analysis on speeds, while both the t-test and the empirical Baye's method will be used to conduct the tests on crashes.

**Project Title:** Investigation of Freight Commodity Flow O-D  
**Principal Investigator:** Michael J. Demetsky  
**University:** University of Virginia  
**Sponsor:** Virginia Department of Transportation

In a previous study by the principal investigator and others at the Virginia Transportation Research Council, freight generation and attraction relationships were defined, and predictive equations were developed for each of Virginia's key commodities. This study used a database that was established from various sources, including commodity flow information and freight transportation modal networks.

The distribution of freight-commodity-generation-measures to show O-D flows was the next step in the development of a process that follows the logic of the person-travel forecasting process. Initially, a growth-factor model was investigated to initiate the distribution phase, because of its simplicity and application without calibration. However, this effort produced mixed results, and further investigation was needed. Alternative methods used for passenger traffic forecasting will be investigated to complete this phase of the forecasting process, along with other strategies, including input-output models. Subsequently, modal choice and route assignment models or variations will be studied. The resulting methodology will aid transportation planners in identifying infrastructure improvements and policies for enhancing the safety and efficiency of freight transportation in the state.

**Project Title:** Pennsylvania Statewide Long Range Transportation Plan (PennPlan)  
**Principal Investigator:** Konstadinos Goulias  
**University:** The Pennsylvania State University  
**Sponsor:** Pennsylvania Department of Transportation

In the Pennsylvania Statewide Long Range Transportation Plan (PennPlan), the Pennsylvania Department of Transportation, with the help of The Pennsylvania Transportation Institute (PTI) at Penn State, created a new approach to long range planning in the Commonwealth. The approach contained an aggressive, two-stage, public involvement program and an extensive consensus building effort that are unprecedented. The approach provided for an update to the previously defined Statewide Transportation Long Range Policy Plan of 1995, while at the same time it designed an ongoing system for public involvement and statewide decision making to assist in project selection in Pennsylvania.

PennPlan used a unique approach to integrate the needs of people and firms within a complex system of corridors and facilities. From a transportation supply viewpoint, the building blocks of a transportation system are its facilities and the connections (or links) among these facilities, which may be unimodal or multimodal. Examples of these links are airline routes, rail routes, or highway routes. Examples of facilities are marine ports, airports, and major distribution centers. Unlike in other systems (e.g., telecommunications), in which the links perform simple functions, the links of a transportation system play significant roles in enhancing the residents' and visitors'

quality of life and fostering economic development. For example, the existence and level of service offered by a transportation link determine the land use patterns and environment of settlements at the two ends of a link and also along each link. For this reason PennPlan considered corridors, instead of modal-specific links among facilities. Corridors were identified by their predominant theme (e.g., US 219, The Allegheny Mountains Corridor). They were described in terms of the area affected, existing conditions, connectively with other routes, objectives, and specific projects.

In the way that living organisms are made of many cells with specialized functions, PennPlan was envisioned as a living organism constituted by its specialized cells, which were the groups of people identified in the public involvement process. Each group was identified, data collection surveys were defined for it, and associated data were collected from each group to take advantage of the specialization in expertise and experience of the Commonwealth's residents and visitors. The information was in turn used within PennPlan to identify goals, objectives, and priorities for the state as a whole and for each corridor and facility in the Commonwealth. PennPlan was published in January 2000, while its emphasis on public involvement continued into 2001 with publication of a report on first-year progress toward its statewide and corridor objectives. Research on theoretical issues about attitudes and long range planning as a knowledge-management activity for public agencies will continue to August 2002.

**Project Title:** ITS Fellowship Program  
**Principal Investigator:** Konstadinos Goulias  
**University:** The Pennsylvania State University  
**Sponsor:** MAUTC

Penn State faculty and graduate students aim at developing new ideas in the area of intelligent transportation systems (ITS) and creating the foundation for new methods, software, and hardware to be moved into practice. This project will be renewed yearly, and changes in the emphasis of the MAUTC program at Penn State will be reflected. In addition, a review of new needs for ITS research and development will be performed at regular intervals and new directions will be incorporated. A sample of research topics is:

1. Traveler Information and Transportation System Utilization: Traveler information systems within the ITS arena claim major benefits to transportation system users and managers. Recent evidence may suggest the potential emergence of "induced demand" (i.e., trip making may increase because of information availability, thus, nullifying any gains from managing traffic). In addition, longer term changes in the ways people travel (e.g., peak spreading, increase in weekend travel) may require development of information systems different from most of the current systems, which target peak hour commuters. In this topic, Penn State researchers will identify the determinants of change in the nature of travel demand, study the relationship between travel demand and information systems, and provide specific guidelines for the design of information systems. Emphasis in this topic will be given to the type of information needed by prospective travelers, the use of multimedia in providing information to them, and their effect

on trip-making propensity. In addition, statistical models that can analyze data of this type must be developed and tested.

2. Network Modeling and Stochastic Demand: Many ITS aim at improving network performance. However, network modeling and traffic assignment become extremely complex when one considers fluctuation in the demand for travel. These fluctuations may be due to predictable temporal variation of demand and predictable user variation of demand, but also unpredictable factors. In addition, network modeling under ITS is needed in real time. This implies that a traffic control center or an emergency management center requires traffic predictions in a very short time as new information about the demand for travel becomes available. Within this topic, researchers at Penn State will design new algorithms, methods, and software that advance the state of the art in network modeling.

**Project:** E-Commerce and Transportation  
**Principal Investigator:** Konstadinos Goulias  
**University:** The Pennsylvania State University  
**Sponsor:** MAUTC

Household replenishment and consumer direct, two closely related and developing forms of teleshopping, are emerging as strategies within the broader field of supply chain management, and they have the potential to radically change the grocery business. These changes may have a strong effect upon traffic, changing grocery-shopping-trip-making behavior and potentially altering human activity patterns, the mix of vehicles in traffic, and the spatial and temporal distribution of traffic. The exact nature and magnitude of these changes are currently unknown, yet certainly hold the potential to impair traffic flow and bring congestion to neighborhoods. While grocery shopping generates only a small portion of all traffic, recent developments are changing its relationship to telecommunications, information, and travel, and they are indicative of potentially major impacts for the transportation industry.

A great deal of study will be required to accurately forecast the net effect on traffic that these changes will have. Models must be developed to forecast the usage of grocery delivery services that different grocery industries offer. Furthermore, as household replenishment and consumer direct develop, studies should be undertaken to measure their effects upon the traffic network. Time use and time allocation analysis may be required to determine how time freed from grocery shopping will be used, if grocery delivery will create more travel, and if delivery will change activity patterns spatially or temporally. Analytical studies may be needed to determine the traffic network effects of delivery services in terms of trip rates, vehicle kilometers traveled, and traffic volumes (number of vehicles flowing per unit of time), as well as to quantify the effect of trip chaining and load consolidation. These studies are urgently needed to guide long range transportation plans and traffic forecasting efforts across the nation.

Finally, some attention should be given to transportation policy that could affect the development, adoption, and practice of household replenishment and consumer direct. If the cumulative impact of household replenishment and consumer direct is negative, an examination



of transportation and land-use policy and tools available, and how they could be used to shape and redirect this business trend, would also be important.

In this project, the critical factors defining the design and implementation of household replenishment and consumer direct will be considered first in a conceptual framework that is currently under development by the research team led by Dr. Goulias. This framework will be used to derive a model system that explicitly depicts and predicts changes in business and household behavior with the adoption of household replenishment and consumer direct. Then, the potential impact of these two strategies upon transportation systems will be simulated under a variety of organizational and policy scenarios. Finally, simulations will be used to identify optimal strategies and design details that are more likely to minimize social costs.

**Project:** Evaluation of Pennsylvania Turnpike ATIS  
**Principal Investigator:** Konstadinos Goulias  
**University:** The Pennsylvania State University  
**Sponsor:** Pennsylvania Department of Transportation

Researchers associated with the Center for Intelligent Transportation Systems (CITranS) at The Pennsylvania Transportation Institute at Penn State have joined a team headed by Frederic R. Harris, Inc., to assist the Pennsylvania Turnpike Commission during the implementation of its Phase III Advanced Traveler Information System (ATIS) on the turnpike. CITranS will fill the role of independent evaluator of the project. Specifically, CITranS will measure the resultant benefits in three key areas: user perceptions, traffic flow/operations, and optimal emergency protocol design and use. The evaluations will be based on the perceptions of both turnpike users and managers. Additionally, CITranS will evaluate the turnpike's entire ITS system in terms of its interoperability with other ITS systems that are in place and planned for Pennsylvania.

The first component of the MAUTC side in this project was the review and theoretical framework used in evaluating ITS technologies and services. Researchers used an activity-base approach and total-survey design, as well as notions from traffic flow theory, to define an evaluation plan. In addition, the project generated a plethora of data that can be used to develop and test a variety of theories about information provision and use by traffic managers and travelers. Moreover, the traffic impacts of roadside information provision in terms of traffic flow (e.g., weaving behavior and traffic flow characteristics) can be evaluated by performing field experiments.

**Project:** Addressing I-81 Transportation Issues  
**Principal Investigator:** Hesham Rakha  
**University:** Virginia Polytechnic Institute & State University  
**Sponsor:** MAUTC

The mountainous topography, together with the large number of trucks that travel along Virginia's major highways, has resulted in capacity reductions along uphill highway sections. The 2000 Highway Capacity Manual (HCM) produces charts that indicate how a 200 lb/hp

vehicle's speed varies as a function of the length of travel along an upgrade section. However, the HCM does not analyze what the impact of a slowly moving bottleneck has on the general traffic, nor does it study the interaction of multiple moving bottlenecks (a truck overtaking another truck on a grade). Research in the area of grade impacts on truck performance and on the formation of shockwaves upstream of slowly moving bottlenecks is underway at Virginia Polytechnic Institute & State University, as discussed below.

This effort involves a combination of research and educational efforts. The research efforts involve a number of tasks.

1. An evaluation of the safety hazard of I-81 relative to other interstate highways in the United States, which was completed.
2. Identifying critical safety-hazard locations along I-81, investigating the causes of vehicle crashes there, and performing a comprehensive analysis of the I-81 crash database.
3. Developing time-to-collision models for estimating rear-end crash rates.
4. Characterizing truck traffic along the I-81 corridor in terms of the weight and power characteristics of the trucks, which was completed.
5. Developing and validating vehicle-dynamics models for the modeling of truck performance on grade sections.
6. Updating the HCM truck-performance curves for the design of grade sections.
7. Estimating truck-equivalency factors for uncongested and congested regimes.
8. Quantifying the impact of trucks on the surrounding traffic, especially along upgrade sections.

The educational effort involves developing a joint graduate course to be offered at the MAUTC universities. The course will cover trucking issues, including truck logistics, truck dynamics and traffic flow behavior, and the impact of trucks on the pavement.

<b>Project:</b>	Characterizing Vehicle Dynamics for the Enhancement of Traffic Simulation Models
<b>Principal Investigator:</b>	Hesham Rakha
<b>University:</b>	Virginia Polytechnic Institute & State University
<b>Sponsor:</b>	MAUTC

The assessment of intelligent transportation systems (ITS) requires sophisticated evaluation tools that capture the intricacies of vehicle-to-vehicle and vehicle-to-control interaction. Furthermore, the assessment of the fuel consumption and emission impacts of ITS applications requires models that are sensitive to vehicle dynamics. Consequently, the assessment of the energy and

emission impacts of alternative investments can be viewed as a two-level process. At the first level, the microscopic dynamics of traffic, such as car-following, lane-changing, and acceleration-deceleration behavior, must be captured. The car-following models, together with the lane-changing models, capture the steady-state behavior of traffic (no acceleration or deceleration), while the acceleration and deceleration models capture the transition behavior between steady states (non-steady state). At the second level, the energy and emissions must be computed based on the instantaneous speed and acceleration estimates that were computed in the first level.

The Transportation Systems and Operations Group (TSOG) at the Virginia Tech Transportation Institute (VTTI) is establishing itself as one of the leading agencies in transportation and traffic modeling. The TSOG is involved in the modeling of signal priority along the Columbia Pike Boulevard using the INTEGRATION and VISSIM simulation models. In addition, TSOG will be evaluating the I-77/I-81 overlap in Wytheville using the INTEGRATION and CORSIM models.

The development and enhancement of microscopic simulation tools requires systematic data collection efforts. The Smart Road facility, together with the fully equipped vehicles at VTTI, provides a unique environment for the systematic collection of traffic data for the validation of these tools.

The objective of this research effort is to utilize GPS detection technology, together with fully equipped vehicles, to characterize vehicle behavior in order to provide data that will allow for the enhancement of microscopic simulation tools. To achieve this objective, data are being collected along the Smart Road, as well as along typical urban-arterial and freeway sections. The data will include a vehicle's speed, acceleration, throttle level, braking indicator, fuel consumed, and emissions every second.

This research project includes a number of tasks:

1. Develop a fully instrumented test vehicle for conducting field tests.
2. Collect field data on maximum vehicle-acceleration levels when not constrained by surrounding traffic.
3. Develop vehicle dynamics models that capture unconstrained, maximum vehicle-acceleration levels.
4. Collect field data on typical vehicle-acceleration levels when vehicles are not constrained by surrounding traffic.
5. Develop vehicle dynamics models that capture unconstrained, typical vehicle-acceleration levels.

6. Collect field data on typical vehicle-acceleration levels of vehicles in platoons.
7. Develop vehicle dynamics models that capture constrained, typical vehicle-acceleration levels.
8. Collect field data from typical, on-road driving-conditions to characterize typical vehicle-deceleration and vehicle-acceleration behavior.
9. Validate vehicle-dynamics models against field data.

It is anticipated that the research effort will put VTTI in a unique position in terms of providing field data for the validation of microscopic simulation models.

**Project:** Addressing Urban Network Transportation Issues  
**Principal Investigator:** Hesham Rakha  
**University:** Virginia Polytechnic Institute & State University  
**Sponsor:** MAUTC

The majority of transportation problems occur within urban environments. Tools are required not only to model the traffic flow within an urban environment but also to provide an optimum type of control. Various types of control are emerging, including transit signal priority, adaptive signal control, ramp metering, toll roads, etc.

The objective of this research effort is to develop traffic flow theory and control to address the unique issues of urban networks. A number of tasks were identified:

1. Delay estimation at isolated, under-saturated and over-saturated signalized intersections for uniform and random vehicle-arrivals.
2. Stop estimation at under-saturated and over-saturated, signalized-intersection approaches.
3. Capacity, delay, and stop estimation at two-way-stop, all-way-stop, and roundabout approaches.
4. Identification of optimum isolated-intersection control, depending on network configuration, traffic demand, and demand level.
5. Identification of effective transit-priority strategies that can result in overall, network-wide benefits to transit and regular vehicles.
6. Identification of effective, adaptive traffic-signal control for system-wide traffic benefits.
7. Addressing of traffic-demand-inducement issues.

**Project:** Electronic Payment Systems  
**Principal Investigator:** John Collura  
**University:** Virginia Polytechnic Institute & State University  
**Sponsor:**

Addressing the traffic congestion problem in urbanized areas involves two general approaches. The first of these approaches involves supply enhancement measures that could involve the construction of new roadways, the widening of existing roadways, or the enhancement of roadway capacity using intelligent transportation systems (ITS). The second approach involves demand reduction measures that include road pricing, increased vehicle ridership (HOV), and other measures.

This effort involves research in the area of Electronic Payment Systems (EPS), including toll roads, parking, and transit services. Further research will be conducted in the latter phase of the project to model toll roads and High Occupancy and Toll (HOT) lanes. The thrust of this research effort will be EPS performance evaluation, with an emphasis on EPS user acceptance and the economics of EPS, including capital and operating costs and savings to agencies. Broadening the scope would allow Virginia Tech to include the evaluation of traffic flow impacts (e.g., throughput, diversion).

A number of tasks were identified:

1. Review of the state of knowledge in the areas of transit TFC evaluation, the economics of public transit operations, and fare collection practices and technologies, which was completed.
2. Development of a systematic approach to define and describe alternative TFC systems, which was completed and suggested that the major TFC system determinants are payment media, fare media, TFC equipment, and transit technology (mode).
3. Formulation of measures of effectiveness to evaluate alternative TFC systems, which was completed.
4. Formulation of a conceptual evaluation framework and a plan to assess the operating costs of current TFC systems in transit.
5. Analysis of the operating expenses associated with current TFC systems on heavy rail and motorbus transit in the United States, with the aid of the evaluation framework and plan.

**Project:** Developing a Fully Instrumented Test Facility  
**Principal Investigators:** Hesham Rakha, Ray Pethtel, Alejandra Medina, and Francois Dion  
**University:** Virginia Polytechnic Institute & State University

**Sponsor:**

MAUTC

There is an urgent need to develop tools for the evaluation of the efficiency, energy, environmental, and safety impacts of traffic-flow-improvement projects, including those involving intelligent transportation systems (ITS) and intelligent vehicle initiatives (IVI). This research effort will address this need by developing a comprehensive data-collection environment for the development, validation, and testing of these evaluation tools, one that may also be used as a test bed for emerging communication, traffic management, and traveler information systems.

The goal of the project is to develop a comprehensive, instrumented test-bed in Blacksburg to:

- (1) Serve as a test facility for the evaluation and enhancement of traffic flow theory.
- (2) Be utilized to develop a database of field data for conducting research on alternative means of disseminating real-time traveler-information to the public.
- (3) Serve as a test facility for enhancing and developing tools for the evaluation of network-wide, energy and environmental impacts of operational-level transportation projects.
- (4) Serve as a test facility for enhancing and developing tools for quantifying the noise impacts of operational-level transportation projects.
- (5) Serve as a test facility to evaluate emerging ITS technologies that can benefit transit operations.
- (6) Serve as a test facility for the evaluation of emerging surveillance and communication technologies.
- (7) Serve as a unique educational tool that will allow practitioners, undergraduate students, and graduate students to access and analyze traffic data.

The research will involve the following tasks:

1. Acquire all instrumentation.
2. Install and calibrate field instrumentation.
3. Develop communication systems to transmit data to the traffic control center.
4. Develop the traffic control center.
5. Develop a repository for the field data.

6. Develop web-based applications for the field data.
7. Perform preliminary investigations of field data.

**Project:** The Development of TRANSIMS Modeling Capabilities  
**Principal Investigator:** Antoine Hobeika  
**University:** Virginia Polytechnic Institute & State University  
**Sponsor:** Federal Highway Administration

TRANSIMS is a new software package under development by FHWA to overcome concerns and issues surrounding traditional demand-forecasting methods. Technical features of TRANSIMS will address planning issues such as congestion pricing, alternative development patterns, transportation control measures, motor vehicle emissions, and intelligent transportation systems (ITS).

TRANSIMS major technical feature will be that the identity of individual travelers can be maintained throughout the simulation and analysis architecture. All synthetic travelers will be generated as part of the development of synthetic population for a specific metropolitan region by using a variety of data sources. Activity times and locations will be computed for individuals. The intermodal route plans generated by the planner module will maintain individual identities, as will the microsimulation. The resulting simulation output will provide a detailed, second-by-second history of every traveler in the system during a 24-hour period. A variety of impact analyses can be conducted by using these results.

The research endeavors on TRANSIMS at Virginia Tech are continuing with work on coding the Blacksburg network as a small-scale application of TRANSIMS and on the modules on emissions and feedback.

Work on the Population Synthesizer Module, Activity Generator Module, Route Planner Module, and Traffic Simulator Module has been completed.

Dr. Antoine Hobeika taught TRANSIMS during spring semester 2001, as part of the Transportation System Planning course. It was the first time that such a course was taught in the United States. It was well received by the students. Dr. Hobeika attended several workshops on TRANSIMS during the year.

**Project:** Fatigue Modeling of SUPERPAVE HMA  
**Principal Investigator:** Imad-Al Qadi  
**University:** Virginia Polytechnic Institute & State University  
**Sponsor:** MAUTC

In the current mechanistic-empirical (M-E) design procedures for flexible pavements, the primary transfer functions are those that relate maximum tensile strain in the hot-mix asphalt (HMA) surface layer to fatigue cracking and compressive strain at the top of the subgrade layer

to rutting at the surface. These functions, called fatigue and rutting equations, are usually derived from statistically based correlations of pavement condition with laboratory-specimen performance, full scale road-test experiments, or both methods. HMA fatigue behavior is an important component of a M-E design procedure; unfortunately, most of the models do not reflect field fatigue behavior. This is manifested in the fact that HMA fatigue failure is achieved much faster under a laboratory setting than in a field environment. This difference has been typically accounted for with the use of a single shift factor based mainly on engineering experience.

The flexible pavement portion of the Smart Road facility includes 12 flexible pavement designs. Each section is approximately 100 m long. The sections are instrumented with pressure cells, strain gages, time-domain reflectometry probes, thermocouples, and frost probes. The instruments were embedded as layers were built. Laboratory fatigue tests of field cores and field-mixed, laboratory-compacted specimens, along with measured response from the instrumented pavement sections at the facility, were used to quantify the differences between laboratory and field environments.

Four shift factors were identified to correlate field and lab fatigue behavior: stress-state, material-difference, traffic-wander, and healing. Field-measured critical strains and strain energy exerted during truck loading were both used to determine the stress-state shift factor. Strain measurements of truck-loading distribution (wander) were used to determine the wander shift factor. Finally, results from laboratory fatigue tests on cores and laboratory-compacted specimens were used to evaluate a shift factor to account for the difference in compaction procedures. While the derived shift factors utilized the measured stresses and strains at the Smart Road facility, calculated strains and stresses, based on appropriate pavement and loading modeling, may also be used.

The research involved conducting laboratory fatigue tests of field cores and field-mixed, laboratory-compacted specimens; quantifying of the differences between laboratory and field environments; and identifying shift factors to correlate field and lab fatigue behavior.

**Project:** MAUTC Scholarship  
**Principal Investigator:** Hesham Rakha, Alejandra Medina, and Francois Dion  
**University:** Virginia Polytechnic Institute & State University  
**Sponsor:** MAUTC

There is an urgent need to attract and sponsor high quality students to conduct research in the transportation field.

This project involves providing a one-year scholarship towards a student's degree for conducting research in the area of transportation infrastructure and systems engineering .

**Project Title:** ITS Alternatives Analysis: Evaluating Parking Management  
**Principal Investigator:** Lester A. Hoel



**University:**  
**Sponsors:**

University of Virginia  
Virginia Department of Transportation and MAUTC

An important component of the success of major transportation facilities, such as busways and rail transit lines, is access to the facility via automobile. An investigation of existing intelligent transportation systems (ITS) technologies and their potential for improving the operation of parking facilities, combined with a methodology for evaluating the application of these technologies in various situations, would be valuable to transportation planners. University of Virginia researchers have investigated the application of ITS technologies in parking facilities and are in the process of developing a methodology for selecting appropriate technologies for a particular area. The methodology will likely consist of evaluating the various alternatives based on measurement criteria to determine candidate technologies. The techniques of the methodology should be transferable to parking systems at other transportation facilities.

**Project Title:** Evaluation of Traveler Diversion Due to En-Route Information  
**Principal Investigator:** Michael J. Demetsky  
**University:** University of Virginia  
**Sponsors:** Virginia Department of Transportation and MAUTC

Since the introduction of intelligent transportation systems (ITS), the transportation engineering community has tried to identify the benefits of these systems in concrete terms. One of these ITS strategies is the dynamic message sign (DMS). This project determined the effect a DMS system had on driver behavior at a site selected in the Hampton Roads area of Virginia. The scenario studied was the choice a traveler has to change his or her route from the Hampton Roads Bridge Tunnel to the Monitor Merrimac Bridge Tunnel based on messages displayed on the DMS system. Data was collected on the DMS system, and volume data was obtained using loop detectors, from August 1998 to July 1999. Data analysis was performed on recent data after a change was made in the usage of the DMS system. The data were processed, and the difference between the percentage of drivers turning towards the Hampton Roads Bridge Tunnel when the DMS system was and was not in use was calculated. This difference is referred to as the diversion percentage. The average diversion percentage calculated was very low. Reasons for this result included the “weak” message displayed on the system, the unwillingness of drivers to divert, and the distance from the secondary route. Sensitivity analyses performed on the data showed that certain variables affected diversion percentage. Drivers were more likely to divert during Thursdays and Fridays, summer months, off-peak times, and instances when high traffic volumes existed. A secondary analysis was performed on recent data after a change was made in the usage of the DMS system. The secondary analysis suggested that the newer messages created a larger amount of diversion, although this could not be proved because of the small amount of data. Another secondary analysis compared two different methodologies for determining diversion. The results from this report were limited to the scenario studied and should not be applied to other situations where a DMS system is used to divert drivers.

**Project Title:** Ozone Formation Attributable to Emissions from Rural Interstate Traffic  
**Principal Investigator:** Michael J. Demetsky  
**University:** University of Virginia  
**Sponsors:** Virginia Transportation Research Council and MAUTC

The formation of low-level ozone is dictated by a complex chemical process involving ozone precursors and meteorological factors. Oxides of nitrogen (NO<sub>x</sub>) are important precursors to ozone formation. Recent studies have revealed that ozone formation over rural areas in much of the eastern United States is limited primarily by the availability of NO<sub>x</sub>. Mobile sources emit approximately 32 percent of the total nationwide NO<sub>x</sub> emissions. The majority of NO<sub>x</sub> emissions from mobile sources are associated with vehicles accelerating or cruising at high speeds. Such driving performance is characteristic of interstate traffic in rural areas. Many rural interstates exhibit heavy truck-traffic that may account for as much as 30 percent of total traffic volumes. Traffic volumes along such heavily traveled corridors often exceed 80,000 vehicles per day. Studies have shown that trucks account for greater NO<sub>x</sub> emissions per vehicle than

gasoline-powered passenger cars due to the relatively high combustion temperatures and pressures associated with diesel engines. As alluded to previously, vehicles on rural interstates generally exhibit high speeds (> 60 mph). Thus, large traffic volumes traveling at relatively high speeds on rural interstates can contribute significant NO<sub>x</sub> emissions to the local atmosphere. The research will examine the role these mobile source emissions play in the production of low-level ozone in the rural atmosphere. Particular attention will be given to the emissions attributable to vehicles traveling along a rural interstate. A photochemical model will be developed to simulate ozone formation conditions. Interstate I-81 and its environs will be used to develop and test the model. The results of the research will provide important information on the impacts of rural interstates on local environments as well as the amount of pollution generated by these facilities.

During the past year considerable progress was made in this research effort. Heavy-duty-vehicle emissions data were obtained from the Colorado Institute for Fuels and High Altitude Engine Research at the Colorado School of Mines. These data were used to calibrate the emission estimation methodology used in the freeway operations simulation package, FRESIM. FRESIM was used to estimate emissions for traffic data collected in the Tuscarora Mountain Tunnel on the Pennsylvania Turnpike. The estimated emissions were compared to actual emissions measured in the tunnel by a research team from the Desert Research Institute at the University of Nevada, Reno. The results of the updated FRESIM methodology agreed well with the measured data and were shown to be more consistent with actual emissions measured in other studies than were results from the original FRESIM methodology. The emission estimates were then put into a preliminary version of the photochemical modeling procedure being developed in this research. The model was used to simulate the ozone formation attributable to the rural interstate traffic by studying several test scenarios with varying traffic and chemical parameters. The preliminary runs indicated that NO<sub>x</sub> emissions from interstate traffic, particularly heavy-duty vehicles, contribute to significant ozone production near the interstate. The preliminary results and methodology were presented in January at a poster session at the American Meteorological Society 11<sup>th</sup> Joint Conference on the Applications of Air Pollution Meteorology with the Air & Waste Management Association in Long Beach, California.

The emissions estimation methodology will be refined to allow a more detailed description of the emissions chemistry. Tasks to be completed include: modifying the chemical mechanism in the photochemical model, simulating traffic conditions and emissions along other interstates (e.g., I-81), producing a final report summarizing the study efforts and detailing findings and conclusions.

**Project Title:** An Investigation of Web-Based Technologies for the Peninsula Transportation District Commission  
**Principal Investigator:** Brian L. Smith  
**University:** University of Virginia  
**Sponsors:** Pentran and MAUTC

Providers of public transportation find themselves in a very competitive marketplace. In order to maintain market share, and to grow, transit agencies are eager to take advantage of opportunities offered by new and emerging technologies. Pentran is beginning an effort to use the World Wide Web as a tool in retaining riders, increasing market share, improving customer service, and increasing public awareness of its services in the Hampton Roads region. In this effort, Pentran will use the power of the web in improving communications with current and potential customers.

However, experience has proven that the web is not a panacea. As is the case with other communications devices, such as signing, printed material, television, radio, and telephone, it has its strengths and weaknesses. On the positive side, the web has the potential to automate information dissemination, is an interactive instrument, offers information that can be updated quickly and at a low cost, can provide easy to follow graphics, and reaches a growing market. Unfortunately, the web market is currently limited mostly to persons who have access to a computer. Furthermore, the ability to update information quickly places pressure on a provider to constantly maintain a well designed and current website; failure to do so often results in a negative public impression.

Among the public and private sector there is a rush to have a presence on the web. Yet development of a website has costs: initial page design and layout, server space rental, and maintenance of the site information. Most important, the reputation of the organization responsible for the site is at stake. Furthermore, an opportunity to enhance customer service could be missed if the capabilities of the web are not tailored to meet Pentran's needs.

To support the investigation of the web's applicability to achieving Pentran's goals, the research team developed a prototype web-based application, a transit trip planner. This prototype application provided substantive insights on the use of the web in public transportation. A final report was completed for the project. In addition, a paper discussing the design of trip planners was published in the *Journal of Public Transportation*.

**Project Title:** Reliability-Based Monitoring of Bridge Structures  
**Principal Investigator:** C. E. Orozco  
**University:** University of Virginia  
**Sponsors:** Virginia Department of Transportation and MAUTC

Given the deterioration of a good many of the approximately 600,000 bridges in the United States, there is a continual need to improve the efficiency of maintenance, repair, and inspection operations for bridge structures. The objective of this project is to develop a real-time, reliability-based bridge monitoring system that will feed information to a given bridge management system. The bridge monitoring system will use state-of-the-art, reliability-based techniques to estimate probabilities of failure of bridge structures. This information will be fed to a bridge management system to trigger maintenance, repair, and inspection operations. An algorithm will be developed to constantly update probabilities of failure given current and historical stress and strain data. The algorithm will also detect unusual bridge response behavior that could indicate dangerous overload situations. The possibility of using ideas borrowed from early warning systems (EWS) used successfully to predict the onset of earthquakes will also be explored. It is envisioned that there will be a network of instrumented bridges that will feed information to the bridge monitoring system. A second stage of the project will address the actual instrumentation process and the design of the network of instrumented bridges.

**Project Title:** Undergraduate Research Experience  
**Principal Investigator:** Edward K. Morlok  
**University:** University of Pennsylvania  
**Sponsor:** 21<sup>st</sup> Century Project for the Undergraduate Experience, UPS Foundation Fund, and MAUTC

A major goal of the University of Pennsylvania is to increase the involvement of undergraduates in research. This initiative is directed toward involving students in transportation and logistics research. This is being done in three ways. One is to have students work part-time on projects with faculty and graduate students. A second is to have students work on topics of interest that are related to specific research projects. This is accomplished through independent study courses arranged with individual faculty members. The third is to have students work on design projects in the field of transportation and logistics, and ideally, with firms with which we have a close research relationship. Examples of projects completed in the past year include the design of a new port terminal for Dependable Distribution, Inc.; a review of models of maintenance of track and structure costs for Amtrak; and development of a simulation model of a U.S. Postal Service terminal that will become part of a larger simulation model of the entire bulk mail (parcel) network. The terminal design project is illustrative of the close working relationship that often characterizes these projects. In the effort, the students met frequently with the officers of the client company, and were also advised by both faculty and persons in a related consulting firm. Their design will enable the firm to use bulk handling instead of bags, reducing costs and enabling expansion of cargo through the Port of Philadelphia. Their conceptual design is now in the detailed-design-planning phase, ready for implementation.

**Project Title:** Transportation and Logistics Networks Research Program  
**Principal Investigator:** Edward K. Morlok  
**University:** University of Pennsylvania  
**Sponsors:** Conrail, "K" Line, Manugistics, Inc., UPS Foundation Fund, United Parcel Service of America, and MAUTC

Globalization, e-commerce, mass customization, and other trends are changing the demand for transportation in fundamental ways. In this environment we feel the best use of our limited MAUTC funds is to provide seed money to initiate projects that are truly research in nature and to support projects that will have a substantial, long-term impact and that can be supported by other sources once started. In addition, the funds are targeted specifically to the logistics area.

Three related topics are being supported: simulation and optimization of nested carrier networks, with application to bulk mail, parcel, and other systems; real-world truck routing and scheduling problems with optimization-based, heuristic solution methods; and impacts of congestion on urban goods movement, with possible solutions.

**Project Title:** Traffic Engineering Education Plan  
**Principal Investigator:** John A. Anderson  
**University:** The Pennsylvania State University  
**Sponsors:** Pennsylvania Department of Transportation and MAUTC

The role of traffic engineering in today's transportation field is changing and expanding. Society and transportation legislation are mandating less construction of new facilities and more efficiency from the existing system. State and local governments are beginning to place greater emphasis on transportation operations and system management. There is also an increasing use of advanced technologies to collect, transmit, and apply information to improve the capacity of existing facilities. These trends require greater education and training of professionals involved in traffic engineering.

In response to a PENNDOT initiative to enhance the knowledge of individuals involved in the traffic engineering function, MAUTC researchers developed a traffic engineering education plan that outlines the framework for a traffic engineering education program. The plan specifies the technical content and time frame needed to prepare PENNDOT's traffic engineering function for the challenges of the new century. The technical content is divided into 23 knowledge modules representing distinct areas of traffic engineering. The knowledge modules are subdivided into levels to organize the content for employees with varying levels of experience and responsibility. The first phase of the program involved developing the first six knowledge modules, which cover transportation engineering, transportation planning, design concepts, traffic characteristics, work areas/advanced topics, and advanced signal concepts. The six modules were developed into self-paced study guides, the technical content of which may be adapted and taught through short courses, CD ROM, or interactive computer programs.

Due to the success of this long-term project, Penn State is developing education plans for PENNDOT's design and construction management and maintenance programs.

**Project Title:** Support of the ITS Statewide Steering Committee  
**Principal Investigator:** John M. Mason, Jr.  
**University:** The Pennsylvania State University  
**Sponsors:** Pennsylvania Department of Transportation, U.S. Department of Transportation, and MAUTC

The advancement of intelligent transportation systems (ITS) is a vital aspect of the Pennsylvania Department of Transportation's mission. This project provided the resources necessary for MAUTC to support Pennsylvania's Statewide ITS Steering Committee and PENNDOT during the planning for and deployment of ITS systems and programs in the state; to assist the department in the development of strategic plans for ITS implementation in Pennsylvania; and to conduct evaluations and assessments of PENNDOT's ITS programs and activities as requested by PENNDOT and the Statewide ITS Steering Committee.

MAUTC, in cooperation with the Statewide ITS Steering Committee and PENNDOT, used this project to plan for, evaluate, and assess the deployment and operation of ITS-related technologies, systems, and programs. The following three primary activities were conducted in accordance with the project:

MAUTC personnel provided staff support for Pennsylvania's Statewide ITS Steering Committee by making arrangements for committee meetings and notifying committee members, serving as recorder at the meetings, and producing and distributing meeting minutes. MAUTC personnel identified, located, acquired, developed, and distributed ITS-related resource materials as requested by the steering committee, and performed other ITS related activities requested by the committee.

MAUTC staff participated in the various activities related to the development of Strategic and Business Plans for the implementation of ITS in Pennsylvania. Initially, MAUTC participation included activities such as conducting background research, development of resource materials, participation in strategic and business planning activities, organization of meetings, and document production. An example of activities under this project was the development of a Strategic Plan for Rural ITS in Pennsylvania.

At the direction of the ITS Steering Committee via PENNDOT, MAUTC personnel developed the methodology by which to evaluate the success ITS technology implementation had on field operations. For each evaluation, Penn State developed an evaluation plan, performed the evaluation, and provided a draft and final report on the evaluation results. Presentations of evaluation results were provided to the ITS Steering Committee and PENNDOT upper management.

**Project Title:** Center for Intelligent Transportation Systems Research

**Principal Investigator:** Konstadinos Goulias  
**University:** The Pennsylvania State University  
**Sponsors:** U.S. Department of Transportation and MAUTC

The Center for Intelligent Transportation Systems (CITranS) was established in January 1994 to provide a means for Penn State to take a more active part in intelligent transportation systems (ITS) research. A multidisciplinary research initiative administered through Penn State's Pennsylvania Transportation Institute (PTI), CITranS encompasses all forms of surface transportation and serves as a focal point for advanced technologies research at Penn State.

In addition to coordinating the university's broad interdisciplinary ITS research efforts, CITranS provides guidance in four critical, ITS-related research areas: human factors and safety; large vehicle dynamics; transportation planning and demand management; and systems architecture, modeling, and integration. One element of the center's two-part mission focuses on successfully combining Penn State's diverse capabilities to pursue relevant ITS research opportunities and to coordinate strong interdisciplinary responses. The other main element focuses on actively promoting professional development in ITS subject matter through university-level course work and technology transfer activities.

CITranS is affiliated with several Penn State research areas, including the College of Engineering, which has designated CITranS as one of its Centers of Excellence; MAUTC; and the Applied Research Laboratory.

In January 1996, CITranS personnel began assisting the Pennsylvania Department of Transportation in developing a strategic plan for implementing ITS in Pennsylvania. The plan will help ensure that ITS implementation benefits as many Pennsylvania citizens as possible by enhancing personal mobility, improving transportation safety, mitigating environmental impacts, and promoting economic vitality. The ongoing project is part of the PENNDOT/MAUTC Partnership and has received \$220,000 in funding.

In addition to providing financial support to several graduate students participating in ITS-related research, CITranS is participating in the Disadvantaged Driver Initiative. The initiative is a vehicle for addressing issues associated with using ITS to enhance the mobility of special-user groups such as the elderly, the disadvantaged, and the operators of specialized use vehicles. Researchers have already determined that the redeployment of advanced technologies from the defense sector can provide ITS benefits to these special-user groups at a greatly reduced cost. The project is a joint effort involving CITranS, PTI, ARL, the Gerontology Center, the Alliance for Transportation Research, the University of Minnesota, and the Surface Transportation Policy Project.

CITranS also maintains a specialized ITS Information Clearinghouse to serve as a central repository for faculty and students interested in furthering their knowledge of ITS and in developing proposals for funded ITS research. The clearinghouse, which is located at PTI, contains specialized information such as current ITS-related requests for proposals and



previously submitted proposals, journals, reports, research papers, and conference proceedings. The clearinghouse is maintained and expanded as part of ongoing activities at CITranS.

**Project Title:** Climate Survey Development and Organizational Assessment (1999-2000)  
**Principal Investigator:** Robert J. Vance  
**University:** The Pennsylvania State University  
**Sponsors:** Pennsylvania Department of Transportation and MAUTC

A climate survey can be an important component of an organization's quality improvement efforts. An employee opinion survey for the Pennsylvania Department of Transportation, called the PENNDOT Organizational Climate Survey (OCS), was designed by PENNDOT and Penn State and implemented from 1995 through 1999.

The OCS assessed opinions on 17 topics with 100 survey items plus three background questions. Topics included climate for participation, individual participation in decision making, organizational commitment, outlook for change, innovation, stress, teamwork, safety, quality of communication, customer service, job satisfaction, and more.

OCS Feedback Reports were produced for all units within PENNDOT. Feedback Reports provided results at the scale level using a bar chart format, and at the item level using a numerical format. From the outset of the OCS process within PENNDOT, support was provided by the Penn State research team in the form of user manuals, workshops, individual consultation for managers and quality coordinators, and additional analyses and reports when requested. The most recent innovation was an OCS website. The website:

- Supports PENNDOT managers and Quality Coordinators on use and interpretation of OCS Feedback Reports.
- Receives requests for customized OCS Feedback Reports. For example, a manager might request a comparison of his work unit with another work unit in selected OCS items for 1995 and 1999. To meet this request, the website would provide a series of report design screens that allow users to select the desired items, work unit comparisons, and time periods. Reports would be created by the server computer. These can be printed locally in color or black and white.
- Answers FAQ (Frequently Asked Questions), where users may post questions about the OCS process and receive answers and suggestions within a short period of time from Penn State researchers, PENNDOT officials, and other users.
- Provides a forum for sharing best practices in OCS use, interpretation, and problem resolution.

Penn State researchers developed a flow chart that illustrates the OCS survey and feedback reporting process. A notebook computer and monitor was used to demonstrate the OCS website to interested parties.

**Project Title:** PENNDOT's Intelligent Transportation Systems (ITS) Strategic Plan  
**Principal Investigator:** John M. Mason, Jr.  
**University:** The Pennsylvania State University  
**Sponsors:** The Pennsylvania Department of Transportation and MAUTC

The development of a strategic plan for the implementation of intelligent transportation systems (ITS) in Pennsylvania will benefit the Commonwealth's citizens by enhancing personal mobility, improving transportation safety, mitigating environmental impacts, and promoting economic vitality by positioning PENNDOT to take advantage of the opportunities ITS provides.

MAUTC and PENNDOT worked together to develop an ITS strategic plan. The project was divided into three phases: assessment of the ITS environment, development of an ITS strategic plan, and development of an ITS implementation plan.

**Project Title:** Roadside Vegetation Management  
**Principal Investigator:** Thomas L. Watshke  
**University:** The Pennsylvania State University  
**Sponsors:** The Pennsylvania Department of Transportation, U.S. Department of Transportation, and MAUTC

PENNDOT's Bureau of Maintenance and Operations is responsible for maintaining roadside vegetation in a manner that will preserve the functionality of the roadway. To do this most effectively, PENNDOT roadside specialists must be aware of developments in low-maintenance ground-cover establishment and maintenance, and in the materials and methods of managing undesirable vegetation.

The researchers on this project, through Penn State's College of Agricultural Sciences, will evaluate available vegetation management techniques and systems, and provide an outreach function to assist in the implementation of improved methods. This will be accomplished through activities in four different tasks, during a four-year period. Although the task structure will be retained from year to year, specific activities within each task may change.

**Project Title:** Probing Motorists' Perceptions of Highway Quality  
**Principal Investigator:** James H. Miller  
**University:** The Pennsylvania State University  
**Sponsors:** Pennsylvania Department of Transportation and MAUTC

As part of its ongoing drive toward improved service quality and customer satisfaction, PENNDOT has undertaken large-scale mailed surveys of licensed drivers during the past three years to gauge their rating of interstates, numbered traffic routes, and secondary roads on the state highway system. Approximately 6,700 completed surveys were returned, providing data for each PENNDOT county maintenance unit with some level of statistical reliability.

Therefore, this effort both predates and surpasses a survey conducted as part of the National Quality Initiative and those undertaken subsequently by other states. Thus, this annual survey can serve as a valuable tool for monitoring customer feedback over time and can help assess the overall effectiveness of PENNDOT's highway maintenance program.

However, exactly what these data represent is not clear at this point. Initial research shows only modest correlations between the motorists' ratings of the quality of the roads and more objective measures such as the International Roughness Index (IRI) or the maintenance backlog per mile across the 67 counties. Indeed, in some cases the direction of the statistical relationship is counterintuitive, e.g., the motorists' ratings of interstate highway quality tend to be somewhat higher in those counties where IRI measures are also higher. Customer satisfaction ratings should be complementary to the more traditional measures, adding a new dimension rather than correlating perfectly with IRI and maintenance backlogs. PENNDOT needs to have a clearer understanding of the basis on which motorists evaluate highway quality for such survey feedback to be truly useful for county maintenance managers and higher level program managers.

**Project Title:** Increasing the Pool of Highway Construction Subcontractors and Construction Personnel  
**Principal Investigator:** James H. Miller  
**University:** The Pennsylvania State University  
**Sponsors:** Pennsylvania Department of Transportation and MAUTC

A Highway/Bridge Construction Subcontractors' Manual and a Highway Construction Vocational and Technical (Vo-Tech) Manual that presents heavy highway construction as a career choice for high school students will be produced. The manual will incorporate instruction on the Disadvantaged Business Enterprise (DBE) certification process as input from successful DBE subcontractors.

The project will include researching the best practices used in producing similar manuals and educational materials, and researching PENNDOT's current needs that might be met by subcontractors and future needs that might be met by today's high school students. Primary research will incorporate interviews with contractors, PENNDOT central office and district personnel, and educators. Current manuals, procedural guidelines, and lesson plans will be reviewed, updated, and incorporated into a new subcontractors' manual and new vo-tech modules for students in the construction trades. The manual will include PENNDOT procedures, business basics, and advice from "people in the know." The transportation construction modules will include input from similar sources along with input from experienced vocational educators in high school vocational.

**Project Title:** Pennsylvania's Quality Initiative: Synthesis of Customer Satisfaction and Information Requirements  
**Principal Investigator:** James H. Miller  
**University:** The Pennsylvania State University  
**Sponsors:** Pennsylvania Department of Transportation, U.S. Department of Transportation, and MAUTC

Customer satisfaction is at the heart of the Pennsylvania Quality Initiative (PQI), which was formed to create a close partnership among all the stakeholders in the process of building, maintaining, and operating Pennsylvania's highway system. In order to assure that government and the highway industry can respond to customers' needs, creative and effective ways of gauging these needs and expectations are required. Thus, PQI and PENNDOT are committed to using market research to gauge customer needs and expectations.

During the past few years, various organizations have conducted surveys of highway users in Pennsylvania, focusing on different issues and employing a variety of samples and survey approaches. The PQI Customer Service Subcommittee needs to be familiar with the synthesized "voice of the customer" as it can be distilled from these surveys. To provide a customer focus for other PQI initiatives, it will also be critical to identify additional information requirements regarding customer satisfaction and to develop an agenda for further market research in the area of customer satisfaction.

This project consisted of three tasks: a review of highway customer satisfaction surveys in Pennsylvania, interviews with key stakeholders in the PQI process, and a report that synthesized the results of the surveys and interviews and presented an agenda for further market research to address additional information needs regarding customer satisfaction with Pennsylvania highways.

Numerous customer surveys conducted during the past several years were reviewed and synthesized into a "voice of the highway customer" in Pennsylvania. These surveys included the following: Pennsylvania Highway Information Association (PHIA) Survey, 1994; National Cooperative Highway Research Program (NCHRP) Focus Groups, 1995; *Overdrive Magazine* Survey, 1995; American Automobile Association (AAA) Survey, 1995; Penn State University QUIK Surveys, 1995 and 1997; Pennsylvania Turnpike Survey, 1995; and PENNDOT County Maintenance Customer Service Surveys, 1994 to 1997.

Semi-structured interviews were conducted with key stakeholders in the PQI process to learn more about their concerns and interests with respect to customer perspectives and expectations regarding highway services. In addition to several PENNDOT senior officials, those interviewed included representatives of the following organizations: Federal Highway Administration; Tony DePaul and Son; Consulting Engineers Council of Pennsylvania; Pennsylvania Asphalt Pavement Association; Pennsylvania Aggregate and Concrete Association; American Concrete Pavement Association; Pennsylvania Turnpike Commission; and American Public Works Association, Pennsylvania Chapter. In addition, interviews with representatives of user groups, such as the American Automobile Association, truckers' associations, and shippers' associations, were conducted if deemed advisable.

Based on the results of tasks 1 and 2, a report was prepared that synthesized the "voice of the customer" to date and provided an agenda for further market research into customer satisfaction. The report includes a synthesis of the highway user surveys conducted to date, a compilation of the results of the individual interviews conducted in task 2, identification of remaining information needs regarding customer satisfaction with Pennsylvania highways, and an agenda for further market research to address customer satisfaction.

**Project Title:** Construction and Materials Training and Education Plan  
**Principal Investigator:** John A. Anderson  
**University:** The Pennsylvania State University  
**Sponsors:** Pennsylvania Department of Transportation and MAUTC

The Construction Training Steering Committee, comprised of representatives from PENNDOT, the Pennsylvania Turnpike Commission, Associated Pennsylvania Constructors (APC), Consulting Engineers Council (CEC), and the Federal Highway Administration (FHWA), has identified a need to substantially update the technical knowledge base in the highway materials and construction community. A developmental training plan addressing necessary technical knowledge and skills for Pennsylvania's agencies, commissions, constructors, and engineering consultants will be established to define future education and training activities for all training partners. The training activities will position the Pennsylvania construction and materials community at the forefront of the nation during the next five years.

**Project Title:** Evaluation of Backcalculation Algorithms through Dynamic Modeling of Falling Weight Deflectometer (FWD) Test  
**Principal Investigator:** Samir Nabih Shoukry  
**University:** West Virginia University  
**Sponsors:** West Virginia Division of Highways, U.S. Department of Transportation, and MAUTC

The availability of information on pavement moduli profile is essential for mechanistic design and rehabilitation decisions of new and distressed pavements. The Falling Weight Deflectometer (FWD) Test is in use by many states for monitoring variability of pavement materials and seasonal changes in material properties, and for providing data for overlay thickness design. Experience has shown that different backcalculation programs produce different results when applied to the same pavement.

In this project, dynamic finite element models of flexible, rigid, and composite pavements were developed to produce deflection basins that closely match those measured during FWD tests. The pavement moduli profiles predicted by several major backcalculation programs for the same pavement structure will be compared with the moduli profile used in the finite element model. The backcalculation algorithm that produces a moduli profile closest to the one used in the model will be identified. The effect of thermal warping of concrete slabs and layers interface bond on the backcalculated moduli were studied.

**Project Title:** Identification of Critical Stress Concentration Around Dowel Bars  
**Principal Investigator:** Samir N. Shoukry  
**University:** West Virginia University  
**Sponsors:** West Virginia Department of Transportation and MAUTC

During the past four years, West Virginia University (WVU) researchers have taken steps toward developing a mechanistic approach for studying different types of pavements. Explicit, nonlinear, three-dimensional, finite-element modeling (3D-FEM) was used to simulate the dynamic response of different types of pavement structures to impact loads. The 3D-FEM results showed excellent correlation with the experimental results. Models were developed to investigate the response of rigid, flexible, and composite pavement response to a Falling Weight Deflectometer (FWD) load. The response of a thermally warped slab to FWD load was also modeled. Preliminary results obtained for the Y-stress distribution around the dowel bars indicated that techniques could be developed to prevent the concentration of stresses at the interfaces between the dowels and the supporting concrete. The improvement could be achieved through improving the load transfer between the dowels and the surrounding concrete. Thus, without significant increase in the construction cost, pavement joints could be designed to last longer, maintenance cost could be reduced, and the ride quality maintained for a longer time period.

In this project, nonlinear, 3D-FEM was designed to identify the distribution of critical stresses surrounding doweled transverse joints subjected to thermal and moving traffic loads. Alternative dowel and transverse joint design was developed to eliminate the points of high stress concentration, which lead to joint failure, thus improving load transfer efficiency and reducing maintenance cost.

**Project Title:** Fitting Falling Weight Deflectometer with SASW Measurement Capability  
**Principal Investigator:** Samir N. Shoukry  
**University:** West Virginia University  
**Sponsors:** West Virginia Department of Transportation, U.S. Department of Transportation, and MAUTC

The Falling Weight Deflectometer (FWD) Test results are influenced by loading, climate, and pavement condition. Acoustic testing techniques that are based on the mechanism of stress wave propagation in structural materials have been applied for the evaluation of material properties. The Spectral Analysis of Surface Waves (SASW) is typically used for the nondestructive moduli profiling of pavements and soil sites. In this study an automated computer program for pavement moduli evaluation using the SASW was developed. The practicality and limitation of the approach was investigated. Plans for fitting this type of measurement to FWD will be prepared. The major finding of the project was that SASW did not perform as expected and was found to be affected by traffic noise.

**Project Title:** SUPERPAVE HMA Mixes  
**Principal Investigator:** Imad Al-Qadi  
**University:** Virginia Polytechnic Institute & State University  
**Sponsors:** Virginia Department of Transportation and MAUTC

Traditionally, the performance of hot-mix asphalt (HMA) has been studied through the remaining life concept given by Miner's Law. This highly underestimates the life of the pavement, which is reflected in the use of shift factors up to 100. Other performance models use measures that may include roughness, rutting, and percent cracking, among others. These measured criteria or indices, functional and structural, are based on distress surveys of in-service pavements. Such models may only be valid for pavements that have some structures and are subjected to similar traffic and environmental loadings. A performance model that uses a more mechanistic measure, such as the modulus of the HMA, may yield better assessment of the pavement life.

A proposed method was based on using a damage evolution model that monitors the change in modulus over the life of the material. Indirect tensile fatigue testing of HMA was required to develop the parameters for the model. By subjecting the HMA to a repetitive stress (similar to that used in the resilient modulus determination), and by monitoring the elastic resilient strain until failure, a laboratory performance model can be established. Data collected from the Smart Road facility will provide means to relate the laboratory performance to the field performance through mechanistically determined shift factors. These will be based on strain energy calculations using strain-gauge and pressure-cell response due to different loading conditions.

**Project Title:** Addressing Transportation Issues in the I-81 Corridor  
**Principal Investigator:** Hesham Rakha  
**University:** Virginia Polytechnic Institute & State University  
**Sponsors:** Virginia Department of Transportation and MAUTC

The I-81 Corridor extends 328 miles through the valley of Virginia, located between the Blue Ridge and Allegheny Mountains. The I-81 highway acts as a common economic asset to these areas, and provides a strategically important transportation link to major economic centers and major eastern markets. This project will contribute to enhancing the movement of people and commerce in and through the corridor by addressing transportation, economic development, and electronic education.

The research will focus on developing a calibrated microscopic model of a portion of the I-81 freeway in Virginia. This microscopic model will serve as a tool that evaluates alternative construction staging strategies; evaluates alternative intelligent transportation systems (ITS) applications (e.g., changeable message signs, ramp metering); evaluates alternative climbing-lane scenarios; and provides a better understanding of changes in travel routing behavior during congestion and construction-related closures. The INTEGRATION microscopic simulation and traffic assignment model will serve as the simulation tool because of its unique routing capabilities.



Enhancements to the INTEGRATION model are being developed in order to capture the microscopic equilibrium of tractive and resistance forces (air, road surface friction, and grade) associated with the motion of a vehicle. These enhancements should allow the INTEGRATION model to capture the unique impacts of the mountainous terrain, which are typical of I-81, on the traffic performance.

A one-day workshop on Innovative Freeway Management and Control Strategies for I-81 was organized jointly with the Virginia Department of Transportation (VDOT). In preparation for this workshop, an extensive literature review was conducted to identify potential ITS solutions regarding variable speed limits, incident management systems, travel time estimation, variable message signs, etc. As a result of the workshop a special I-81 Committee was created. The Virginia Tech Transportation Institute is part of this committee. In addition, the Transportation Systems and Operations Group visited I-81 weigh stations and retrieved data from the weigh stations to establish daily, monthly, and yearly truck characteristics along I-81. Members also met with representatives of the VDOT traffic Division, Salem District, to set the framework to analyze accident data for I-81 to identify typical types of accidents, causes of accidents, sections of the highway with higher incidents rates, and possible solutions.

**Project Title:** Quantifying the Impact of Average Speed, Speed Variability, Level of Deceleration, and Level of Acceleration on Vehicle Fuel Consumption and Emissions

**Principal Investigator:** Hesham Rakha

**University:** Virginia Polytechnic Institute & State University

**Sponsors:** Virginia Department of Transportation and MAUTC

Hydrocarbon, carbon monoxide, and nitrogen oxides are three primary pollutants associated with motor vehicles. State-of-practice in estimating vehicle emissions is based only on the average speed, and it has been found insufficient in emissions estimates.

Highway vehicles consume almost half of the petroleum in the United States. Improvement in fuel efficiency will not only reduce the extent of the nation's dependence on foreign oil, but also reduce carbon oxide emission, the principal greenhouse gas.

The objective of this research project was three-fold. First, the study was to demonstrate that the use of average speed alone for estimating vehicle fuel consumption and emissions is inadequate. Specifically, the study was to quantify the level of error associated with the use of average speed as a single explanatory variable. Second, the study was to identify the most critical variables that impact vehicle fuel consumption and emissions of hydrocarbon (HC), carbon monoxide (CO), and oxides of nitrogen (NO<sub>x</sub>). Eight variables were considered in this study: the average speed, speed variability, the level of deceleration defined as deceleration noise, the level of acceleration defined as acceleration noise, total noise, and number of stops, kinetic energy, and powers. Third, the study was to develop statistical models that computed the vehicle fuel consumption and emissions based on the explanatory variables that were identified in the second objective. These models were applied and validated against field data, with very good results.

As a result of this project, a master's thesis, "Quantifying the Impact of Average Speed, Speed Variability, Level of Deceleration, and Level of Acceleration on Vehicle Fuel Consumption and Emissions," was completed.

**Project Title:** Urban Network Transportation Issues  
**Principal Investigator:** Hesham Rakha, John Collura  
**University:** Virginia Polytechnic Institute & State University  
**Sponsors:** Virginia Department of Transportation and MAUTC

Delay is one of the key parameters that are utilized in the optimization of traffic signal timings. Furthermore, delay is a key parameter in computing the level of service provided to motorists at signalized intersections. Delay, however, is a parameter that is difficult to estimate because it includes the delay associated with decelerating to a stop, the stopped delay, and the delay associated with accelerating from a stop. While many methods are currently used to estimate the delay incurred by motorists on intersection approaches, very little research has been conducted to assess the consistency of delay estimates among the various analytical and simulation approaches. In an attempt to systematically evaluate and demonstrate the assumptions and limitations of different delay estimation approaches, this project compared the delay estimates from numerous models for an under-saturated signalized intersection, considering uniform and random arrivals.

Specifically, this project compared a theoretical, vertical, queue-analysis model; the queue-based models used in the 1994 and 2000 versions of the Highway Capacity Manual; the queue-based model in the 1995 Canadian Capacity Guide for Signalized Intersections; a theoretical, horizontal queuing model derived from shock wave analysis; and the delay estimates produced by the INTEGRATION microscopic traffic simulation software. The model demonstrated the validity of estimating delay based on car-following behavior without the need for an explicit delay formula, and established the potential of a validated simulation software to evaluate conditions that are beyond the scope of analytical formulations. In addition, real data were collected to analyze traffic delay. The collected data included total traffic volumes, bus volume and headways, geometry, signal timing plans, and other information.

As a result of this project, a Ph.D. dissertation, "Delay Stop and Queuing Estimation at Fixed-Time Signalized Intersections," was completed.

**Project Title:** Development of a Macroscopic Model for Evaluating the Impact of Emergency Vehicle Signal Preemption on Traffic  
**Principal Investigator:** Wei Hua Lin and John Collura  
**University:** Virginia Polytechnic Institute & State University  
**Sponsor:** MAUTC

Models developed in the past to study the signal preemption problem for emergency vehicles (EVs) are mostly either microscopic or analytical simulations. This research developed a

macroscopic model for examining the effect of signal preemption for EVs on traffic control measures, roadway capacity, and vehicles on side streets. The model was based on the cell transmission model, which is consistent with the hydrodynamic theory of traffic flow. A special component that handles EVs was developed in the model. Several test scenarios were constructed to demonstrate the capabilities of the model for studying the impact of signal preemption on an arterial with multiple intersections under various traffic demand levels and varying frequencies of the arrival of EVs. Performance measures, such as average vehicle delay, maximum delay, and variance of delay to traffic in all approaches, were obtained. Traffic dynamics associated with the presence of EVs, a feature currently unavailable in the existing models, was captured by a moving bottleneck.

An advantage of the model is that the space equations used in the model can be easily incorporated into a mathematical programming problem. By coupling with a desired objective function, the model can be solved analytically. Optimal solutions can be generated to obtain insights into the development of traffic control strategies in the presence of Evs.

## **II.C. MAUTC TECHNOLOGY TRANSFER**

**Project Title:** MAUTC Annual TRB Research Showcase  
**Principal Investigator:** Ann Marie Hutchinson  
**University:** The Pennsylvania State University  
**Sponsors:** Pennsylvania Department of Transportation and MAUTC

In January, MAUTC faculty and more than 100 researchers participate in the annual MAUTC Student Research Showcase in Washington, D.C., held in conjunction with the Transportation Research Board Annual Meeting. Participating students meet and review each other's work via research exhibits, which are also reviewed by members of the MAUTC Partners Roundtable and officials from the U.S. Department of Transportation, Pennsylvania Department of Transportation (PENNDOT), and other transportation organizations. In 2001, PENNDOT co-hosted the event with MAUTC. The event provides a forum for participants to network with researchers from state departments of transportation, federal agencies, universities, consulting firms, and research institutes. More than 400 transportation professionals attend this event annually.

**Project Title:** 1999 Transportation Engineering and Safety Conference  
**Principal Investigator:** Walter P. Kilareski  
**University:** The Pennsylvania State University  
**Sponsors:** Pennsylvania Department of Transportation, U.S. Department of Transportation, and MAUTC

The 1999 Transportation Engineering and Safety Conference, held at The Penn Stater Conference Center at Penn State, attracted transportation professionals from across

Pennsylvania, the mid-Atlantic states, and the country. The conference featured speakers and workshops that fostered discussion and encouraged questions.

The responsibility of transportation professionals for improved safety, efficiency, and capacity is expanding as more demands are placed on existing transportation systems. Constantly changing legislative requirements also have increased the responsibility of the transportation professional beyond design and operation, into areas of air quality, systems management, and intelligent transportation systems. Hence, there is a need for programs to increase the knowledge within the profession so that these new responsibilities can be adequately met. It was the intent of this conference to fulfill this need in a dynamic and enlightening setting.

David N. Wormley, Dean of the College of Engineering at Penn State, welcomed more than 400 attendees and emphasized the importance of the conference to the transportation community and of transportation research to the new millennium. PENNDOT Deputy Secretary for Planning Larry M. King addressed current issues faced by transportation professionals and provided perspective on upcoming transportation legislation.

**Project Title:** International Symposium on the Use of Nonlinear Finite Element Modeling in Pavement Analysis and Design  
**Principal Investigator:** Samir Nabih Shoukry  
**University:** West Virginia University  
**Sponsors:** West Virginia Division of Highways and MAUTC

The first symposium was attended by 110 participants. Participants requested that this symposium be held annually. The Second International Symposium was held in Charleston, West Virginia October 11 to 13, 2000. It was sponsored by the Federal Highway Administration, Federal Aviation Administration, West Virginia Department of Transportation, American Association of State Highway and Transportation Officials, Transportation Research Board, TRL (Transportation Research Laboratory, United Kingdom), University of Delf in the Netherlands, West Virginia University, and MAUTC.

**Project Title:** Professional Capacity Building in Transportation  
**Principal Investigator:** Hesham Rakha  
**University:** Virginia Polytechnic Institute & State University  
**Sponsors:** Virginia Department of Transportation and MAUTC

On one hand, researchers are generally criticized for not applying their research to real-life problems. On the other hand, practitioners are generally criticized for not applying the latest research developments in solving their problems. The objective of this project is to bridge the gap between research and practice in the area of traffic operations by providing short courses and workshops to Virginia Department of Transportation (VDOT) employees and traffic engineers in general.

Traffic engineers at the Virginia Tech Transportation Institute have developed six related short courses in the areas of traffic flow and simulation fundamentals, traffic signal operations, and

freeway management and three short courses in transportation planning in the areas of site impact analysis, demand models, and environment. Each course consists of a series of lectures and complementary computer demos. Three, three-day short courses were offered in 1999.

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PROJECT STATUS LIST