MAUTC THEME

MAUTC's theme, *Technology for Integrated Transportation Systems Operation and Performance*, 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. 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.
- Multimodal mission that addresses passenger and freight transportation, highway, transit, and intermodal facilities.

MANAGEMENT STRUCTURE

Penn State has been the lead university and grantee for the University Transportation Centers (UTC) Program since 1986. MAUTC is administered through the Thomas D. Larson Pennsylvania Transportation Institute (Institute).

The MAUTC executive director and principal investigator, Dr. Martin T. Pietrucha, delegates day-to-day responsibility for MAUTC partner activities to each partner university: University of Maryland, University of Virginia, Virginia Polytechnic Institute and State University, and West Virginia University.

Dr. Paul Jovanis, professor, civil engineering, and director, Transportation Operations Program, represents the Institute's faculty interests in MAUTC activities.

Ms. Janice Dauber, MAUTC coordinator, is responsible for MAUTC's technology transfer activities, publicity, and report preparation.

Ms. Mara Poorman, staff assistant, provides clerical support for the overall MAUTC administrative effort as well as for Penn State's MAUTC projects and programs. Additional Institute staff support MAUTC as needed.

MAUTC FUNDING AND EXPENDITURES

MAUTC meets the U.S. Department of Transportation's 1:1 match requirement through state and local agencies, private companies, and universities. Maryland, Pennsylvania, Virginia, and West Virginia departments of transportation provide the majority of matching funds. (See figures 1 and 2.)

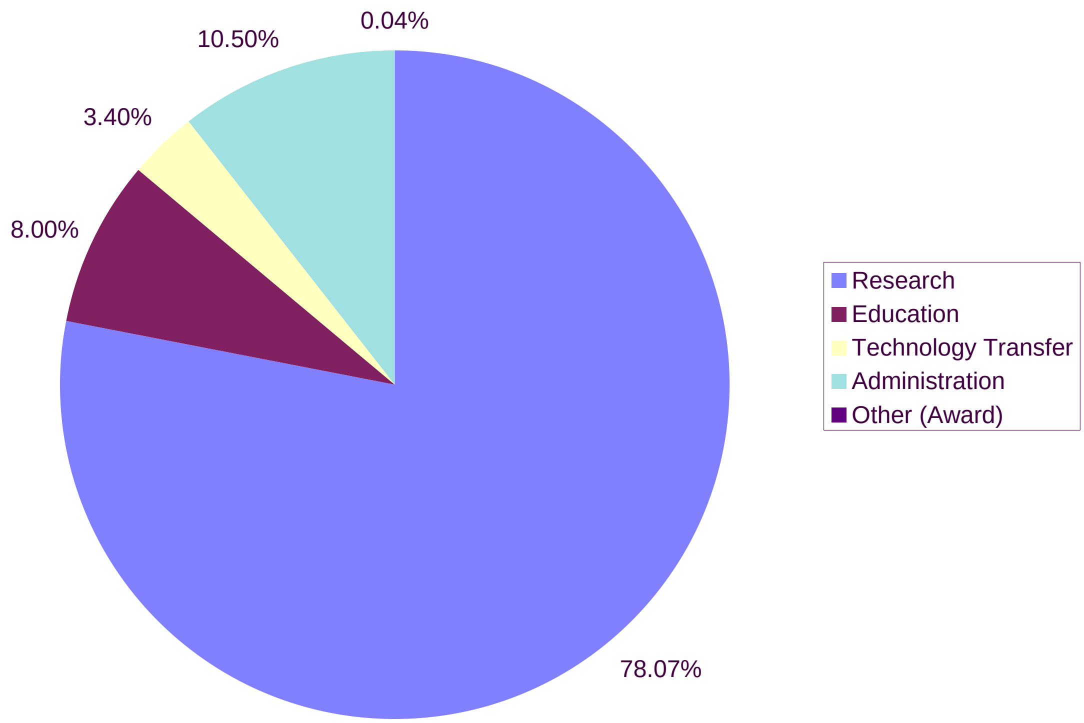

Figure 1 Expenditures by Activity

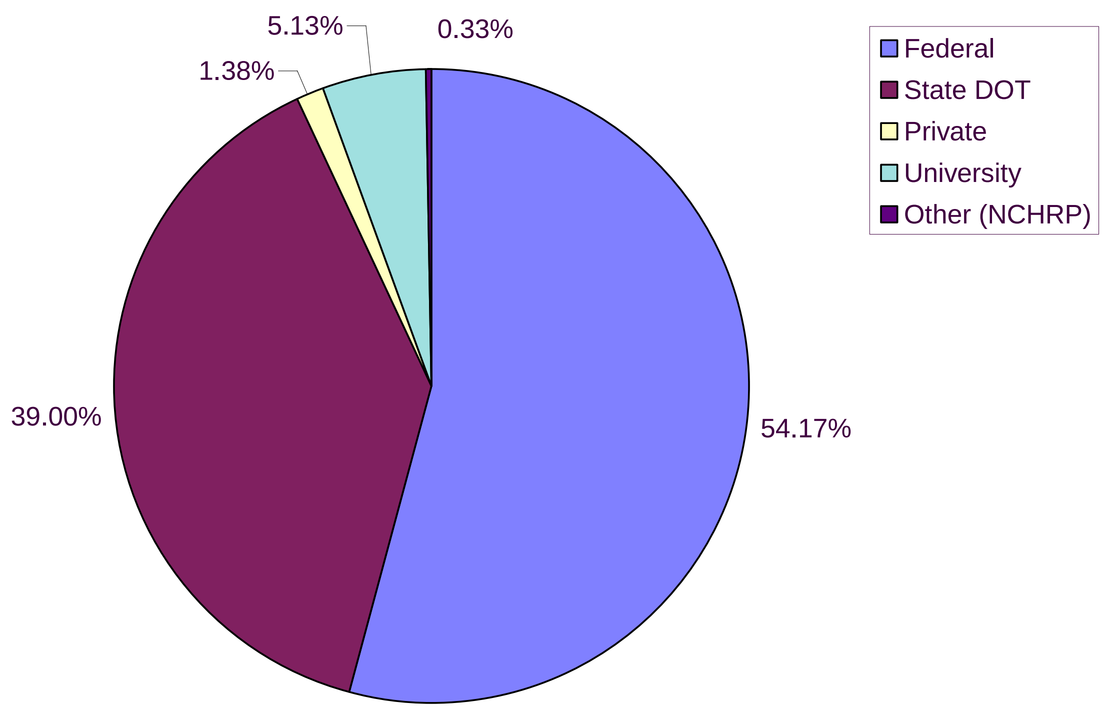

Figure 2 Expenditures by Source

Figure 3. Larson Institute

The Thomas D. Larson Pennsylvania Transportation Institute is one of the nation's leading university transportation centers. Since its first days in 1968, the Institute has pursued a mission of interdisciplinary research that today involves laboratories, departments, and colleges throughout Penn State and numerous state, federal, and private collaborators. The Institute supports University faculty and students by providing interdisciplinary educational and research opportunities that complement and enhance the University's undergraduate and graduate education programs.

The Institute is the locus for transportation-related research conducted by Penn State faculty from more than 14 colleges and research centers. Many of these faculty hold joint appointments with the institute and Penn State's academic colleges and schools; areas of specialization include civil, computer, electrical, industrial, and mechanical engineering as well as agriculture, information sciences and technology, supply chain management, architectural engineering, economics, geography, psychology, and statistics. Through its multidisciplinary structure and supportive research environment, the Institute provides a unique focal point of collaboration for faculty from many different areas of the University.

Three programs comprise the Institute: Transportation Infrastructure Program, the Transportation Operations Program, and Vehicles Systems and Safety Program. Faculty, researchers, and students from all three programs contribute to and benefit from the research projects funded under the auspices of MAUTC.

University of Maryland

The University of Maryland (UMD) became a partner in 2007 when MAUTC re-competed for the Region 3 University Transportation Center. Professor Elise Miller-Hooks serves as MAUTC director for UMD.

The University of Maryland transportation research effort benefits from the new Intelligent Transportation Systems Laboratories in the recently completed state-of-the-art Engineering Research Building. New laboratories for transportation research include: Real-time Traffic Management Systems Research and Education Laboratory, Collaborative Decision-Making Laboratory for Large-Scale Distributed Dynamic Systems, Traffic Safety and Operations Laboratory, and Intelligent Transportation Systems Planning Laboratory. Direct connections exist from the various cameras and sensors installed along the freeway and highway system under the Maryland CHART traffic management center to provide live quasi-continuous feeds to the ITS Laboratories. Access to all archived CHART traffic data is also available through the University of Maryland laboratories. The Collaborative Decision-

Making Laboratory provides unique capability to conduct interactive simulation-based experiments with multi-agent transportation decision systems.

The University of Maryland offers transportation-related undergraduate and graduate degrees in civil engineering and mechanical engineering.

University of Virginia

The transportation program at UVA has expanded since its inception in the late 1940s when the University of Virginia School of Engineering and Applied Sciences began an ongoing partnership with Virginia Transportation Research Council (VTRC), the research branch of the Virginia Department of Transportation. The Center for Transportation Studies (CTS) was established to organize the existing academic program and research activities and to lay the groundwork for future growth.

The Center is located within the Civil Engineering Department on the grounds of the University of Virginia. With offices and laboratory facilities located on two floors, including the Smart Travel Lab, the Center also shares the resources, laboratories and library of the VTRC facility, a 100-employee research complex at the University of Virginia. The academic and research programs of the Center are closely associated with the Virginia Transportation Research Council. Through this partnership, faculty hold joint appointments, VTRC research scientists teach specialized courses, and graduate student work is supported through a Graduate Research Assistantship Program. The Research Council also supports the Virginia Technology Transfer Center, the Smart Travel Lab, shared computational facilities, and the largest transportation library in the State of Virginia.

Today the Center oversees a flourishing program that includes education, research, and public service. Its faculty, which span the departments of Civil Engineering and Systems and Information Engineering at the University, are highly regarded both as teachers and as researchers. They have been the recipients of University teaching awards and include two members of the National Academy of Engineering.

Thanks to the extensive, longstanding ties with such organizations as VTRC, MAUTC, as well as the Federal Highway Administration and the Institute of Justice, the center has a stable, flourishing research program, covering such areas as transportation and land use, traffic simulation, highway safety, freight operations, and traffic operations.

Virginia Polytechnic Institute and State University

Virginia Technology and Transportation Institute (VTTI) was established in August 1988 in response to the U.S. Department of Transportation's University Transportation Centers Program and in cooperation with the Virginia Department of Transportation. VTTI pursues its mission by encouraging research, attracting a multidisciplinary core of researchers, and educating students in the latest transportation technologies through hands-on research and experience. The institute is both an FHWA/FTA ITS Research Center of Excellence and a Mid-Atlantic Universities Transportation Center.

VTTI is housed in a 30,000-square-foot building located in Blacksburg, Virginia. It was built at the western end of Virginia's Smart Road, a road designed specifically for testing new transportation technology. The building accommodates the Smart Road Control Center, where researchers monitor and control data collection, weather-generation, lighting, power grids, and roadway surveillance cameras. The building is equipped with office and laboratory space for VTTI, VDOT's Christiansburg Residency, and companies that contract for use of the facility. Additionally, it holds a fully staffed garage and shop for experimental vehicles.

VTTI is used by more than 90 researchers and faculty. In addition, approximately 80 students have access to the facility as well as its laboratories and equipment.

West Virginia University

Harley O. Staggers National Transportation Center

The Staggers Center at West Virginia University (WVU) is a comprehensive transportation research institute that has served regional and national transportation research, education, and technology transfer needs since 1977. The center includes nearly 20 core faculty and staff members currently conducting nearly $2 million of research, education, and technology transfer activities. As part of a large university, the center can bring the necessary expertise to bear on virtually any client's problem. The Staggers Center has five primary research areas: Infrastructure Management, Planning and Economics, Transportation Design and Operations, Energy and Environmental Impacts, and Transportation Structures.

Public service is one of the center's primary missions, in concert with WVU's role as the land grant institution for the state. The center strives to ensure that benefits of research extend beyond the solving of technical problems. Through the technology transfer center, routine training sessions are held for transportation engineering and maintenance personnel. Faculty and researchers serve as technical and educational support to state agencies, legislature, municipalities, and private citizens. In addition, the research program provides the primary support for graduate students while they pursue their studies, a tremendous investment in the future of transportation engineering.

RESEARCH

The Pennsylvania State University

Geocomposite Interlayer Testing

Placing a structural asphalt overlay atop existing pavements is one of the conventional methods used in pavement rehabilitation. However, reflective cracking in the new overlay has presented a serious challenge associated with pavement rehabilitation. Reflective cracking involves the development of cracks in the new overlay that mirror the cracks and/or joints in the old, existing pavement. Traffic loading and environmental effects are the primary external causes of reflective cracking.

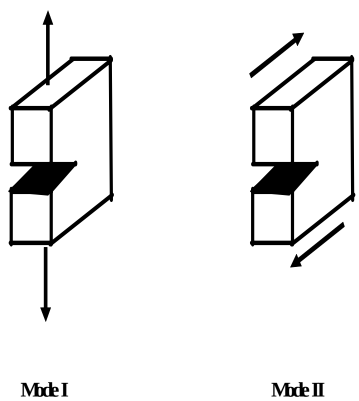

Figure 4 Two modes of crack propositioning, I. Opening mode; II. Shearing mode

Under daily temperature variations or rapid temperature changes, the shrinkage and expansion of the underlying pavement layers result in the opening and closure of cracks. Bending moments from traffic loading can also lead to crack development.

A geocomposite interlayer combining a high-modulus geogrid with a lightweight non-woven geotextile may help delay and reduce reflective cracking by providing reinforcement and strain relief. Researchers are investigating mechanisms of the geocomposite interlayer for mitigating crack propagation.

Quantification of the reinforcement will provide a better understanding of the interlayer's effectiveness and offer an opportunity to identify important factors that affect the reinforcing performance.

Hydrogen Plant Module (HPM) and Vehicle Fueled by Same

Hydrogen is a leading alternative fuel candidate for transportation because it is clean and can be acquired from a wide variety of renewable and conventional energy feed-stocks offering greater energy independence for the country going forward.

There are major barriers and challenges to widespread hydrogen deployment as a transportation fuel. One of the most significant barriers to fuel cell vehicle commercialization is on-board storage.

The ideal hydrogen storage technology would be low cost, small, light weight, high capacity, low pressure, reasonable temperature, non-toxic, safe, one-way, and efficient from well to wheels. None of the existing hydrogen storage technologies possesses all of these attributes.

This project, a collaboration between Alloy Surfaces Company, Inc. and Penn State, seeks to develop an aluminum alloy and water-based chemical energy carrier technology to deliver hydrogen on-board vehicles, which could potentially surpass previous technologies in system performance to the above metrics.

Technology Evaluation in Characterization of the Air Void System in Concrete

The objective of this project was to evaluate current technologies that have the capability of characterizing the air void system in concrete within the first several hours of placement. Early detection of these parameters can significantly improve the quality control of concrete pavements at an early construction stage. The research work was supported and funded by the Pennsylvania Department of Transportation (PennDOT).

Researchers first conducted a comprehensive technology assessment and literature review. Based on this assessment, two technologies were identified by PennDOT as candidates for a laboratory evaluation: ultrasound, using Rayleigh waves, and thermography, using an FLIR infrared camera. Both technologies demonstrated the potential to characterize the air void system in concrete within the first several hours of placement.

The ultrasound tests were able to show that the Rayleigh wave speed is influenced by the air void system in fresh concrete. A significant difference was found on the measured Rayleigh wave speeds for concrete with and without entrained air. These measurements were made as early as four hours after concrete placement, thus they reflect properties of the fresh concrete state. The equipment used was portable and therefore can be implemented in field evaluations.

Thermography tests were able to effectively recognize concrete with and without entrained air by comparing measured spatial thermal gradients. These differences were consistent both at the fresh and hardened state and indicate a possible correlation with the air void system. Finite element simulations confirmed that the concrete air void structure affects the heat conduction. Experimental measurements were successfully taken as early as two hours after concrete placement but could be taken immediately, proving that fresh concrete can be characterized. In addition, the portable features of the equipment used are suitable for field applications.

Study of Bead Gun Angle when Applying Glass Beads on Waterborne Paint

PennDOT asked researchers to investigate the application angle of glass beads on waterborne paint to determine which angle(s) and the optimal speed for the application of pavement markings provided the highest retroreflectivity and visibility.

To evaluate pavement marking performance as a function of truck speed and glass bead gun angle, the research team applied pavement markings to a section of the Larson Institute Test Track Facility that is used in a bus testing program. The application of the paint was recorded by a high-speed digital camera. Buses passed over the markings approximately 3,125 times a month for one year.

Human factors evaluations were conducted twice at the test track to determine the "just noticeable difference" of the pavement markings at night time, three months and nine months after applying the markings. Thirty-six research volunteers, varying in age, participated in the experiment.

In addition, during the application process 36 test plates were fastened to the pavement to collect samples of the 18 pavement markings for use in laboratory evaluation. The test plates were subjected to accelerated-wear and weathering tests with the MMLS3.

The results of the laboratory and field testing indicate a strong correlation between end detection distance measured in the nighttime driving experiment and pavement marking retroreflectivity. Researchers concluded that a 12 mph/-20 degree bead gun angle provided the best speed/angle combination.

University of Maryland

Tools to Support Greenhouse Gas (GHG) Emissions Reduction: A Regional Effort

This is a regional, collaborative project being jointly conducted by the University of Maryland and Virginia Tech.

The transportation sector plays a very significant role in Greenhouse Gas emis- sions in the United States. According to the U.S. Environmental Protection Agency (EPA), approx- imately 27% of GHG production in the United States (as of 2003) can be attributed to this sector. With weak economic growth and steady national support for reducing our carbon footprint, this is an ideal time to take action that fosters mitigation efforts to reduce the transportation-related environmental impacts from GHG emissions through improved monitoring, technology development and personal accountability. Construction and maintenance of our roadways contribute, as well, to the nation's carbon footprint through emissions produced by deforestation, heavy equipment usage, pollutants resulting from on-site production and use of large quantities of off-gassing materials (such as asphalt and concrete), and resulting traffic delays. This regional effort seeks to develop tools to support GHG emissions reduction.

To reduce fuel consumption and emissions, significant effort is required to enhance vehicle technologies. Several research efforts have quantified the impact of aggressive driving on fuel consumption and emission rates. Figure 5 demonstrates that CO emissions vary considerably as a function of vehicle speed and acceleration levels. Additionally, as a consequence of high engine-load conditions, only a small percentage of the total trip contributes to the majority of trip-related CO emission. Consequently, a reduction of high-emitting driving behavior can significantly improve air quality. In this effort, eco-driving strategies, including strategies that involve combining energy and emission models with navigation programs, will be developed that can reduce vehicle fuel consumption levels. Such strategies provide consumers with feedback on the impact of aggressive acceleration maneuvers and permit them to consider traffic congestion and other factors in "greener" route selection. The impact on the network-wide efficiency will be quantified and the potential for integrating system efficiency with environmental measures will be investigated.

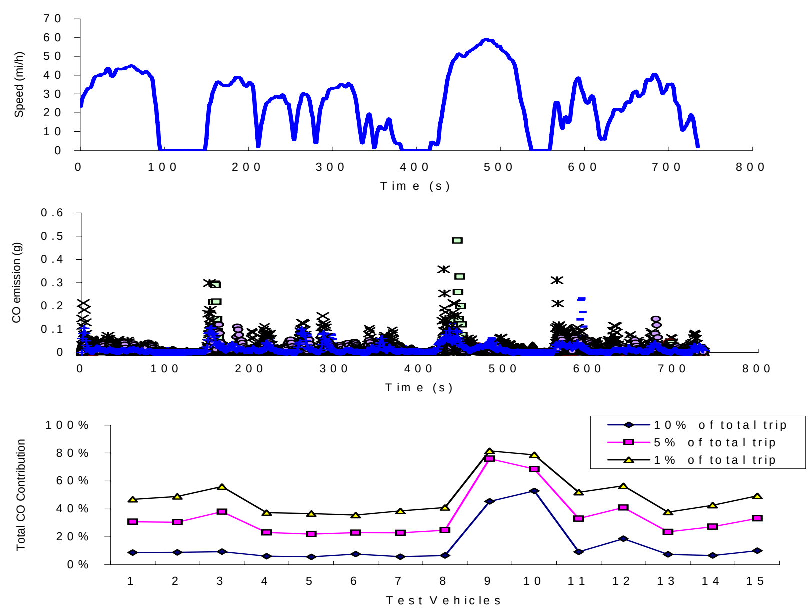

Figure 5 CO Emissions for the ARTA Cycle

Agencies such as state departments of transportation (DOTs) manage and fund enormous construction projects. Contractors compete for these projects based on estimated costs, project duration, and reputation. These firms may be required to follow pre-specified guidelines to reduce emissions, such as the Non-road Diesel Tier System developed by the EPA, requiring that no more than a small percentage of all equipment present on a construction site fall under one of several high-emission tiers. Rarely is environmental impact considered in choosing the winning bid. A set of tools is under development to support (1) the measurement of carbon footprint of transportation construction projects, including impacts from both deforestation and reforestation, and (2) decision-making tools to aid contractors in trading off project cost, duration and resulting emissions in bid creation. These tools will: support carbon footprint estimation of an entire roadway construction project by the contractor, state DOT or environmental agency; support contractors in making green construction decisions and proposing bids that simultaneously consider cost, project duration and resulting emissions; allow state DOTs to consider emissions in addition to cost and duration in assessing bids; support current standards and anticipate new regulations; allow state agencies to monitor companies in accordance with recent GHG reduction laws at state and federal levels; and account for recent laws that might affect construction, including the EPA Tier System and possible future carbon tax or cap and trade programs. This effort will result in a prototype carbon footprint estimator and set of decision tools with applicability to the transportation construction sector. These tools will be demonstrated in a case study involving a 7-mile portion of Maryland's Intercounty Connector (ICC), currently under construction.

Integrated Urban Systems Model with Multiple Transportation Supply Agents

Transportation agencies at federal, state, and local levels, as well as private road authorities in some cases, all participate in transportation supply and investment decision-making with mobility, accessibility, welfare, and/or profitability objectives. For instance, transportation investment in the Washington, DC-Baltimore region involves three state DOTs, two large MPOs, six small MPOs, more than a dozen counties, several state and regional transit agencies, and toll road authorities. Due to this multi-jurisdictional and multimodal institutional structure, the allocation of transportation revenue to various needs has become a complex process that depends on both agency internal procedures and inter-agency dynamics.

From a systems operation and planning perspective, it is desirable that all investment decisions are made coordinately to maximize the overall transportation system effectiveness. This goal would be much more achievable if the transportation system in a region is completely controlled by an efficient centralized agency. However, transportation and planning agencies in the real world often have dissimilar and sometimes competing objectives, and their self-interests may not always lead to desirable system outcomes. This type of marginalization or even ignorance of system-wide objectives by individual decision-makers is a common problem in integrated systems management.

This project summarizes and analyzes the decision rules and processes currently adopted by various agencies (see Figure 6) in the Washington, DC and Baltimore region, and how these decisions translate into transportation facilities on the ground. Interviews have been conducted with staff members at the county, metropolitan, state, and regional transportation and planning agencies. The key research questions are how multimodal highway and transit investment decisions are made in this region, how transportation funds are allocated to different modes, different jurisdictions, and different projects, and how agencies at different levels of government interact with each other. Figures and tables are developed to visually present the research findings and the actual investment process. Findings suggest that policy initiatives, political factors, and technical evaluation intertwine in the decision-making process, and conflicts often arise when regional and local interests collide. Agencies have developed qualitative and quantitative methods to handle competing objectives and various considerations. Analyzing the existing transportation planning and investment process is the first step toward the comparison of alternative investment processes (e.g., more centralized or decentralized processes) and toward modeling future transportation system states under current and alternative investment processes. A prototype quantitative model of transportation investment decision-making has also been developed in this project based on the interview findings. The model is currently being tested for the Washington, DC area.

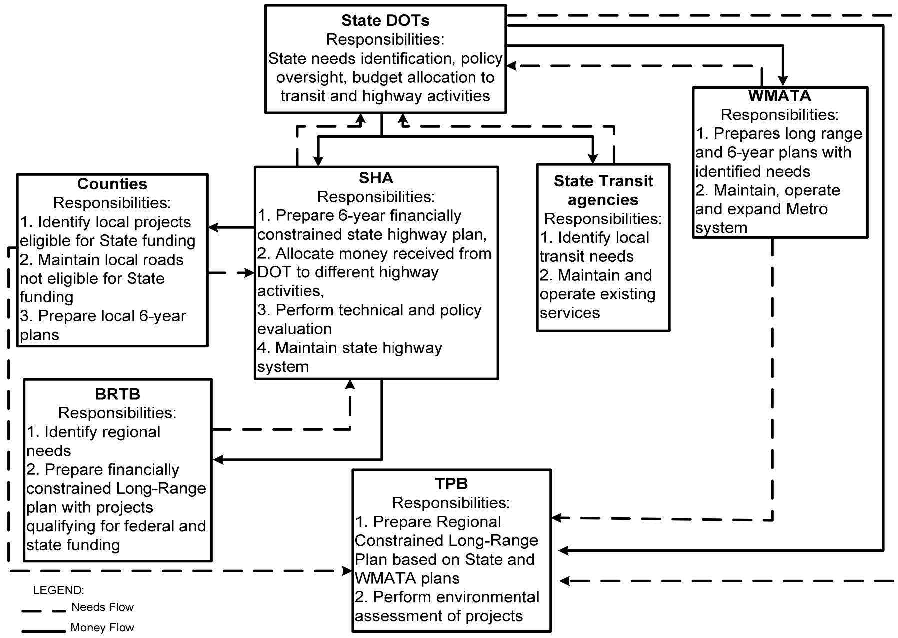

Figure 6 Multimodal and Multi-Jurisdictional Transportation Investment Processes in the Washington DC–Baltimore Region

Supply Chain Management in Disaster Response

The global increase in the number of natural disasters highlights the need for better planning and operation of responding agencies. During emergencies various aid organizations often face significant problems of transporting large amounts of many different relief commodities including food, clothing, medicine, medical supplies, machinery, and personnel from different points of origin to different destinations in the disaster areas. The transportation of supplies and relief personnel must be done quickly and efficiently to maximize the survival rate of the affected population and minimize the cost of such operations. The major devastations of hurricanes Katrina and Rita in the Gulf Coast of the United States followed by inadequate response from FEMA, is an example that shows the need for and importance of this research.

It is difficult, if not impossible, to efficiently operate such a complex structure without comprehensive mathematical models. Unfortunately, there is no research in the academic literature that considers a humanitarian supply chain in compliance to FEMA's structure. Offering a centralized, comprehensive model that describes the specifics of disaster supply chains is the main goal of this research. The aim is to

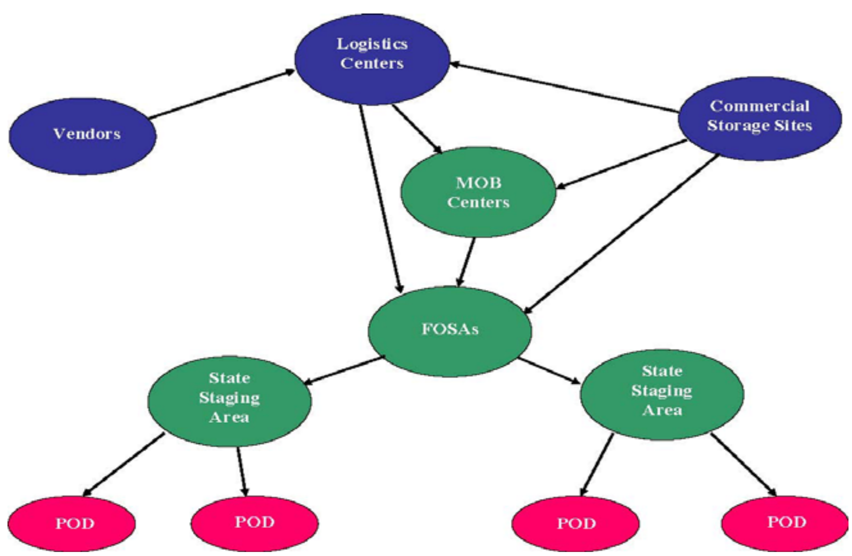

Figure 7 FEMA's Supply Chain Structure

develop a system of computer and mathematical models that can track the operational details of large-scale disaster response operations and find the optimal allocation of scarce resources to the most critical tasks to minimize loss of life and human suffering.

This project provided a compendium of previous research in this area and analyzed the advantages and disadvantages of the other works available in the literature. Also for the first time, this project has provided a systematic view of FEMA's complicated supply chain structure that shows the relationship between the components of the chain and is suitable for network modeling and freight transportation studies. Figure 7 shows this structure in general form. The results of this research extend the state of the art by presenting an integrated model at the operational level that describes the details of supply chain logistics in major emergency management agencies such as FEMA, in response to the immediate aftermath of a large-scale disaster.

Among the US DOT objectives, this research aims at improving the safety and security of the general public in the event of natural or man-made disasters.

The results of this project will be incorporated into undergraduate and graduate-level UMD transportation courses.

Applying the proposed model to a series of imaginary case studies verified the model and showed its capabilities to handle large-scale problems. Using the proposed model provided a high level of transparency and control over the disaster response operations that was not available before. Figure 10 shows a map of federal and state-level facilities for an imaginary scenario similar to hurricane Katrina that is used for numerical analysis. Development of fast and efficient solution algorithms and heuristics for the proposed model will be the other major contribution of this research

Analysis and Design of Vehicle Sharing Systems

Vehicle sharing programs have been gaining ground around the world for providing an environment-friendly, socially responsible, and economical mode of transport. These programs involve a fleet of vehicles positioned strategically at stations across the transportation network. Users are free to lease vehicles to complete a trip and drop the vehicle at a station close to their destination. The shared vehicle fleet can be comprised of cars, electric vehicles, or bicycles (see Figure8). Such systems offer innovative solutions to the larger mobility problem and can have positive impacts on the transportation system as a whole by reducing urban congestion.

By transferring control of vehicles to the user, the system becomes vastly more flexible, offering more choices with regard to departure time, destinations, and transit routes. However, this user flexibility places exceptional logistical challenges on operators, who must ensure adequate vehicle stock at each station to service all

Figure 8 A Bike sharing station in Washington D.C. (photo: Rahul Nair)

demand. Balking users strike at the heart of the viability of the system. In research done this past year, strategies to better manage fleets under demand uncertainty were developed. These strategies involve anticipative fleet redistribution that operators initiate to correct short-term demand asymmetry (since flow from one station to another is seldom equal to flow in the opposite direction). When these strategies were tested on the Singapore car-sharing program, the system operated at higher reliability levels and serviced more demand than would be possible without capital improvements to the system.

Future research on such systems will involve looking at their interface with transit by providing "last-mile" connections. Additional work will examine several design decisions that are critical for the success of such systems (pricing, station locations, fleet composition and size).

UNIVERSITY OF VIRGINIA

Investigation of Connectivity between Major Freight Handling Facilities

This study investigates the location and connectivity issues of critical major freight handling facilities in Virginia. These facilities include distribution centers, ports, intermodal terminals, modal terminals, and major industrial centers. A GIS framework will be incorporated to include point facilities, the transportation system, and major commodity flows. Forecasts will be made to anticipate future bottlenecks in the system and strategies will be recommended for their mitigation.

Access Management Performance Measures, Phase 2

Due to the high political and monetary expenses associated with access management strategies, stakeholders in the highway improvement process want a way to measure the effectiveness of these strategies.

The Virginia Department of Transportation's (VDOT) dashboard provides diverse information about Virginia's highway system such as the number of roadway fatalities, the cost of recent improvements, and the condition of the pavement. Although important, these existing performance measures do not provide the information needed to judge the effectiveness of access management strategies, which are beginning to receive emphasis from the Department.

The purpose of this project is to identify performance measures that can be used to evaluate access management programs and, if appropriate, to develop a method of integrating these measures into VDOT's dashboard. The project will focus on the selection of appropriate performance measures and the validation of their applicability and usefulness.

Modeling Single Occupant Vehicle Behavior in High-Occupancy Toll (HOT) Facilities

High-occupancy toll lanes are being proposed and implemented in many major metropolitan areas. The basic concept of HOT lanes is to allow single-occupant vehicles (SOVs) to pay a toll to use high-occupancy vehicle (HOV) lanes. The toll is dynamically set at a level to ensure the HOV lanes continue to offer a high level of service. Therefore, in order to operate and model HOT facilities effectively, there is a need to understand SOV behavior in an HOT environment.

While there have been theoretical decision models developed in an attempt to address this need, no models currently exist which are based on empirical data. This project will focus on the use of a large set of field data collected on I-394, a HOT facility in Minneapolis, MN known as MnPASS. Using both traffic and tolling data from MnPASS, the research