REPORT OF THE
VIRGINIA MODELING, ANALYSIS
AND SIMULATION CENTER (VMASC) OF
OLD DOMINION UNIVERSITY

Interim Report: Expanding the Commonwealth of Virginia's Public Transportation System

TO THE GOVERNOR AND
THE GENERAL ASSEMBLY OF VIRGINIA

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Preface

The 2006 State of Virginia Appropriations Act, Item 180, directed that the Virginia Modeling, Analysis and Simulation Center (VMASC) of Old Dominion University (ODU) utilize modeling, simulation, analysis and visualization research methods to study, analyze and make recommendations for optimizing the Commonwealth's modes of public transportation in the Route 1 corridor of Fairfax County, and surrounding high population density areas, including rail and bus and to provide an interim report on this effort no later than 1 November 2006. This study is in-progress and includes the following members from Old Dominion University:

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Executive Summary

The 2006 State of Virginia Appropriations Act, Item 180, directed that the Virginia Modeling, Analysis and Simulation Center (VMASC) of Old Dominion University (ODU) utilize modeling, simulation, analysis and visualization research methods to study, analyze and make recommendations for optimizing the Commonwealth's modes of public transportation in the Route 1 corridor of Fairfax County, and surrounding high population density areas, including rail and bus and to provide an interim report on this effort no later than 1 November 2006. VMASC's review of ongoing northern Virginia traffic studies reveals that BRAC recommendations will significantly contribute to automobile traffic in an already congested area while simultaneously reducing public transit options for many impacted employees whose jobs will be relocated to either Fort Belvoir or Quantico.

A number of potential strategies have been identified to mitigate traffic congestion due to BRAC recommendations and by state and local agencies involved in studying and modeling the impacts to the transportation system. Several organizations are utilizing well-accepted, discrete event, longitudinal flow models to model traffic in the northern Virginia transportation network. VMASC can also address the traffic congestion problem from this approach, however, it is not expected that additional support from VMASC along this traditional line of analysis will add significant value to the work already underway.

An area of interest that is not currently being addressed – one where VMASC could make a significant contribution – is modeling High Occupancy Toll (HOT) lanes in Northern Virginia along the US Route 1 / I-95 Corridor. Accordingly, it is suggested that the Commonwealth Legislature concur with VMASC's recommendation to shift its analytical focus from "optimizing" a US Route 1 transportation system to modeling and analyzing the feasibility a "HOT lane" alternative for this region.

In addition to the HOT lane modeling proposal, VMASC will also develop a new simulation capability for studying congested traffic areas that incorporates modern simulation methods utilizing human driving behaviors. Traditionally, studies of traffic patterns in highly populated areas relied on generalized traffic behavior patterns to represent driving patterns of regional commuters. This approach is static in nature and does not account for the behavior of commuters when faced with known route delays, destination changes or public transit options available to travelers for getting to various destinations. These traditional traffic models do not incorporate human decision making and behaviors into engineering-level transportation flow models. This makes them ill-suited to modeling and analyzing dynamic, complex decision situations where traffic behavior depends on situational conditions that change over time. To model this type of situation requires a different approach based on adaptive behaviors. This approach will allow state-level decision makers and transportation planners to take a new, comprehensive look at commuter behaviors and traffic patterns. VMASC proposes to develop a simulation that incorporates human behaviors into traffic flow models in order to study how this behavior influences the choice of transportation modes and routes. By incorporating human behaviors into the family of traffic and transportation models, we will be able to more effectively design and implement employ public transportation systems in highly congested, highly populated areas.

1 BACKGROUND

In July 2006, the Virginia General Assembly directed that the Virginia Modeling, Analysis, and Simulation Center (VMASC) of Old Dominion University (ODU) undertake the requirement to address several problems related to transportation mobility in the Commonwealth. Specifically, VMASC was tasked to:

1) Use modeling, simulation and visualization to study and recommend alternatives for optimization of Virginia's public transportation system, including rail and bus. Specifically, VMASC was asked to study and analyze ways to economically expand Virginia's public transportation system into high population density area and locations of high traffic congestion.

2) Examine the public transit requirements throughout the Route 1 corridor in Fairfax County due to the recommendations of the Base Realignment and Closure (BRAC) commission at Fort Belvoir.

The Fairfax County Route 1 corridor transportation problem is very dynamic due to interactions of social, political, economic, environmental, and human behavior factors affecting the area that vary by time of the day and season of the year. The complexity of the environment makes it highly unlikely that an 'optimal' transportation system can be identified that can accommodate dynamics and temporal factors. It is possible, however, to apply models and simulations to examine the factors listed above in order to determine how they influence transportation modes operating in the corridor, and to evaluate the viability, suitability and sustainability of public transportation alternatives for the Route 1 corridor.

The problem, and corresponding system under consideration here, has been bounded by the legislature to public transportation requirements along Route 1. This narrowly defined focus is amenable to detailed analyses. This study is complimentary to a number of other on-going studies specifically focusing on related Route 1 corridor transportation issues such as how to mitigate the impact of recommendations by the Base Realignment and Closure (BRAC) Commission and the impact of continued community growth on the existing transportation network.

This report covers two major areas. First, we summarize results of VMASC's review of US Route 1 and I-95 corridor transportation analyses to date. Second, we describe the methodology that VMASC proposes to address important issues related to mobility in Northern Virginia and public transportation throughout the Commonwealth.

2 ONGOING MODELING ACTIVITIES OF FORT BELVOIR

On November 9, 2005, BRAC Commission recommendations were approved that will result in the redistribution of approximately 21,000 Department of Defense jobs to Fort Belvoir, located in Fairfax County, Virginia, and another 5,000 jobs to the U.S. Marine Corps Base at Quantico, Virginia. The personnel who currently fill these jobs will be reassigned from leased space in Alexandria, Arlington, and other northern parts of Fairfax County (see Northern Virginia Regional Commission, 2005). This represents a major shift in employment in the area and has the potential to significantly impact an already congested transportation system in the areas around Fort Belvoir and Quantico.

In response to BRAC Commission recommendations, the Commonwealth directed that VMASC to apply its modeling, simulation and analysis capabilities to study the problem. VMASC's first step was to conduct a preliminary review of relevant past and ongoing state transportation studies. Background research identified four major efforts that were reviewed and assessed. Findings revealed that various state agencies are studying and analyzing the problem using models and analytical tools that cover a wide range of techniques from sophisticated high-resolution models to 'back-of-the-envelope' analysis relying on expert judgment. The sections below summarize findings with respect to previous and ongoing studies.

2.1 Base Case Estimates of Traffic Condition

A timely study by the Northern Virginia Transportation Authority (NVTA), called TransAction 2030 (see Northern Virginia Transportation Authority, 2006), proposed a transportation plan for Northern Virginia for the year 2030. This study, which is still in draft, used a mathematical model to forecast traffic congestion in the northern Virginia area out to the year 2030. This analysis did not include the impact of base realignment and closure recommendations on regional transportation system. Although the impact of job realignments on northern Virginia is not explicitly examined, the NVTA study provides a mathematically sound baseline for estimating future traffic congestion on the regions transportation facilities.

The traffic estimates were generated using land use forecasts and travel demand provided by the Metropolitan Washington Council of Governments (MWCOG). Model results show significant congestion along the US 1/I-95 corridor in 2030. The TransAction 2030 plan recommended over $2 billion in road, transit, and pedestrian/bicycle access improvements to deal with the projected traffic congestion levels. The increased traffic in-and-around Fort Belvoir and Quantico due to BRAC will require additional expansion of transportation modes beyond what is recommended in the TransAction 2030 study.

2.2 MWCOG Analysis of BRAC Recommendations

Prior to the final adoption of recommendations by the BRAC Commission, MWCOG attempted to analyze potential transportation impacts (see Metropolitan Washington Council of Governments, 2005). The Metropolitan Washington Council of Governments, in partnership with George Mason University, constructed a rate-based growth projection model based on household and employment factors to forecast and analyze traffic in northern Virginia. The projections were based on census data available as of the summer of 2005. The projections were subsequently incorporated into the MWCOG travel forecasting models to estimate traffic conditions for the years 2010 and 2025 assuming no traffic congestion mitigation strategies. The models estimate the number of vehicle trips, vehicle miles of travel, and emissions. These forecasts are then used to predict future transportation requirements as a basis for making transportation system changes to accommodate future requirements. Major findings are summarized in the table below.

Trip Type & Year*	Estimated Change from Today
Daily Transit Trips	
2010	- 18,528 trips / day
2020	- 6,097 trips / day
Daily Vehicle Trips	
2010	+ 26,790 trips / day
2020	+ 84,932 trips / day

* Baseline data: approximately 24M trips daily by approximately 4M people

The impact of increased traffic attributable to these findings on specific facilities was not explicitly identified by the study. Additionally, their impact on US 1 and I-95 cannot be determined from the report.

2.3 Northern Virginia BRAC Working Group Findings

In 2005, then Governor Mark Warner created a working group called the Northern Virginia BRAC Working Group to examine the BRAC recommendations. The members included local business leaders and state politicians with U.S. Congressmen and Senators serving as non-voting ex officio members. The Working Group met four times during October and November 2005. Local governments provided transportation information to the group. A final report was submitted by the Working Group in December 2005 (see Northern Virginia Regional Commission, 2005). Notable highlights included the following:

- Virginia Department of Transportation (VDOT) studies in 2002 and 2003 had projected significant traffic increases along US Route 1 by 2025 without considering the BRAC realignment;
- Population realignment due to BRAC has the potential to significantly add to current traffic congestion since many employees would be moving from a Metro-accessible employment location to locations at Quantico and Fort Belvoir where this mode of travel does not exist;
- Increases in traffic are expected to be greatest in the I-95/US Route 1 corridor;
- A significant increase in traffic congestion is expected between Fort Belvoir and the Pentagon.
- By 2025, traffic was projected to increase by 94 percent and 71 percent along the Prince William and Fairfax sections of US Route 1, respectively.

Based on forecasted changes in traffic levels and behaviors due to BRAC, the Working Group recommended that an additional $258 million in transportation improvements be programmed to respond to the changes brought on by the BRAC recommendations. The proposed projects included roadway improvements to increase access to Fort Belvoir and Quantico and improvements to transit access as well as longer-term projects to address traffic congestion problems.

2.4 Ongoing Work by Fort Belvoir

Independent of the Commonwealth traffic analysis, Fort Belvoir and its consultants are investigating the potential impacts of the BRAC recommendations. In particular, the Department of Defense is required to conduct an environmental impact study and submit an Environmental Impact Statement (EIS) based on the environmental impacts of many traffic alternatives under consideration for dealing with base realignment. An initial scoping meeting for the EIS was held during the summer 2006. A draft EIS is expected in December 2006. Initial analysis by the Fort Belvoir consultant yielded the following findings (see Virginia Department of Transportation, 2006a):

- Most new employees assigned to Fort Belvoir already reside in the metropolitan area and are not expected to move;
- Based on a zip code analysis, 41 percent of the employees expected to be reassigned to Fort Belvoir will travel on northbound routes, 28 percent will travel on southbound routes, 17 percent will travel on westbound routes, and 14 percent will use eastbound routes. These numbers could

change when the BRAC recommendations are actually implemented due to discrepancies with current and future employee residences.

Potential alternatives under consideration include:

- Complete the Fairfax County Parkway;
- Establish a shuttle bus service from the Franconia-Springfield Metro Station to Fort Belvoir;
- Extend the Metro Blue and Yellow lines to Fort Belvoir;
- Improve high occupancy vehicle (HOV) access including HOV access off of I-95 at Newington;
- Improve Virginia Railway Express (VRE) access; and
- Offer opportunities to employees to telecommute.

Options that are construction-intensive would require additional funding and take a number of years to complete. At this time, funding sources for these improvements are unclear. The U.S. Army has acknowledged that it expects to fund some traffic mitigation efforts. The environmental impact study will model the impact of alternatives that change to traffic at Fort Belvoir as well as the impact of other mitigation strategies. The EIS will include recommended alternatives and accompanying implementation strategies for each recommended alternative pertaining to traffic changes to and around Fort Belvoir.

2.5 Virginia Department of Rail and Public Transportation (VDRPT)

In August 2006, VMASC personnel met with members from the Virginia Department of Rail and Public Transportation (VDRPT) to discuss the changes at Fort Belvoir. VDRPT representatives stated that the VDRPT consultant firm, Mitretek, would be tasked to perform analyses of the US Route 1 and I-95 corridor for this project and that VMASC services would not be needed by VDRPT. No further contact or coordination has taken place between VMASC and VDRPT on the Fort Belvoir analysis.

2.6 Summary

The analysis performed to date shows that the BRAC recommendations will add additional automobile traffic to an already congested transportation system, while also simultaneously making public transit a less feasible option for many of the impacted employees. A number of potential mitigation strategies have been identified, and a number of entities are involved in modeling the impacts to the transportation system. It appears that several groups are applying traditional, well-accepted transportation models in an attempt to address the changes at Fort Belvoir.

3 Transportation Modeling Opportunities in Northern Virginia

As noted above, a number of state and federal organizations involved in modeling and analyzing the implications of base realignment on transportation in the US Route 1 and I-95 corridor. While VMASC can also address this problem, the contribution of VMASC's analysis may not add significant value to the work already underway. However, one area of interest that is not being modeled at this time – one where VMASC could make a significant contribution – is modeling the establishment of High Occupancy Toll (HOT) lanes in Northern Virginia.

3.1 High Occupancy Toll (HOT) Lane Background

The concept of HOT lanes has been successfully implemented in several locations throughout the United States; most notably on I-5 in San Diego and on SR 91 in Orange County, California (see Parsons Brinkerhoff and Texas Transportation Institute, 2003). With HOT lanes, vehicles are not required to meet a high occupancy vehicle (HOV) ridership requirement. Drivers simply pay for the service. Non-HOV vehicles rates and fees are established for 'HOT' HOV lanes vary during the day and are based on the level of congestion in the general purpose lanes with higher rates set during congested periods. The HOT lane strategy relies on service for fee to regulate use of existing HOV capacity. By allowing non-HOV vehicles to travel on HOV facilities with excess capacity, this alternative will manage demand through pricing while simultaneously providing a valuable revenue stream that can be used to maintain roads and pay for transportation system improvements. Vehicles that meet the HOV occupancy requirements would use the facilities under rules that exist today (for free) or at reduced cost.
Currently, two HOT lane projects are in varying stages of development in Northern Virginia. One on I-495 is awaiting approval one the EIS report is completed. The I-495 alternative recommends a 12-lane wide high occupancy toll road (see Virginia Department of Transportation, 2006a). This project would extend west from the I-95 and I-395 Springfield interchange to the Maryland state line. The second HOT lane project in northern Virginia was undertaken in October 2006 when VDOT entered into a public-private partnership with Fluor and Transurban to investigate HOT lanes on I-95 and I-395 (Virginia Department of Transportation, 2006b). The proposed limits of this project extend from the 14^{th} Street Bridge to Massaponax. That proposal indicates that the existing HOV lanes would be expanded from 2 to 3 lanes and with the incorporation of one or more HOT lanes.

3.2 Current Modeling Approach

The northern Virginia HOT lane approach has the potential to significantly impact regional travel in the northern Virginia and Washington, D.C. areas. In August 2006, at the annual meeting of the Institute of Transportation Engineers Mr. Ron Kirby, Director of the Transportation Planning Department of MWCOG presented an excellent summary of the transportation and traffic modeling and analysis framework being used to analyze the I-495 HOT lanes. The modeling approach presented by Mr. Kirby appeared to be appropriate for high-level planning. However, it is based on a number of simplifying assumptions that could have significant impacts on the overall accuracy of the model that make it suitable for detailed analyses of traffic and transportation system alternatives required for decision making.
Specifically, there are unanswered questions about how the model addresses the behavioral decision to enter or leave the HOT lanes as well as the accuracy of the environmental geometry that was modeled. In the model, drivers are apparently free to enter and leave the HOT lanes whenever there were significant changes between linked tolls. The drivers leaving the HOT lanes exited at cross streets and would reenter the I-495 general-purpose lanes from arterial roads. This behavior would not be very likely, however, under rules that required drivers to exit onto the highly access roads, such as SR 7 in Tyson's Corner, before reentering I-495. This somewhat unrealistic and disadvantageous simplification appeared to generate unlikely traffic behavior due to vehicles entering and leaving HOT lanes along the Beltway. This example is only meant to illustrate that the rules incorporated into the model currently being used to simulate driver behavior might be improved upon with further HOT lane research.

4 Modeling High Occupancy Toll Lanes in Northern Virginia

The proposed HOT lane projects have the potential to create significant impacts on regional mobility and travel patterns in Northern Virginia. Improvements to simulations used to model HOT lanes before analytical results can be used as a basis for making decisions to proceed with the projects. This research will help to ensure that:

- The HOT lanes are having a positive mobility impact;
- Tolling levels are set appropriately; and
- The HOT lanes projects are economically viable.

The additional research will include overcoming the apparent limitations of the current MWCOG model. As an independent, state source of expertise in transportation modeling and simulation studies, VMASC is well suited to making improvements to existing transportation modeling methodologies and to delivering a modeling paradigm that will more accurately simulate driver behavior and to analyzing the impact on traffic operations. Specific tasks involved in developing this simulation are briefly laid out below.

Task 1. Gather Data Required to Develop Model

The first step will be to collect relevant data to develop the new HOT lanes model. VMASC will leverage previous work by MWCOG and other agencies to obtain relevant information including:

- A copy of the exiting MWCOG model;
- Relevant traffic data and projections;
- Relevant roadway inventory data; and
- Relevant socioeconomic data.

Specific information related to the proposed geometric design of the HOT lanes will also be collected to build as accurate a model as is possible.

Task 2. Develop HOT Lanes Model

VMASC will begin HOT Lane Model development by reviewing relevant past studies of HOT lane operations and performance. These empirical results will provide valuable insight into driver behavior and decision making processes involved with HOT lane operation, and help narrow the potential modeling approaches that could be used to simulate HOT lanes.

All feasible modeling approaches will be reviewed as viable candidates to determine which methodology appears to be most likely to create significant improvements in HOT lane modeling processes. Outside experts and state stakeholders will be consulted in this process. This review will dictate whether a new model needs to be developed or whether an existing, commercial transportation model can be modified to accurately model the performance of the HOT lanes. If possible, existing models that are widely available will be modified to help ensure that the results of this research can easily be implemented by VDOT and metropolitan planning organizations.

Once a modeling approach has been selected, a HOT lane model will be developed and tailored to the northern Virginia area that can be used to support state leaders in making decisions about HOT lane project alternatives. The model will allow for the following variables to be examined, at a minimum:

- Amount of HOT lane tolls;
- Locations of entry and exit points to the HOT lanes;
- Socioeconomic characteristics of drivers; and
- Levels of background traffic.

The HOT lane model will be subject to the following requirements:

- The HOT lanes must operate a minimum speed of 50 mph, roughly equally to *Highway Capacity Manual* Level of Service E (TRB, 2000). This restriction will be used to ensure that the HOT lanes are still operating at an acceptable speed and that they do not become congested;
- Path assignment will be performed based on user equilibrium requirements; and
- Revenue from the HOT lanes should be maximized given the other constraints.

Task 3. Compare New Model to MWCOG Model
The final task will be the application of the model and model output in a comparative analysis of competing feasible HOT lane alternatives and comparing results with outcomes from the existing MWCOG model. A sensitivity analysis will be performed to look at the impact of different assumptions of socioeconomic characteristics and levels of traffic. Different alternatives for entering and exiting the HOT lanes will also be examined. This analysis will help bound the potential performance of the HOT lanes.

Although it is not possible to formally validate the model until the HOT lanes are installed, the comparison will serve to illustrate whether there are potentially significant differences between the new model and the MWCOG model. Should differences exist, this will provide an indication that the Commonwealth may want to closely examine any analysis that was performed using the MWCOG model. Specific measures that will be examined will include:

- Total system delay;
- Individual link delays;
- Individual link flows; and
- Total revenue generated.

5 Modeling Approach to Study Public Transportation Optimization in Other High Population Density Areas

Previous studies of transportation patterns in highly populated areas centered on efforts to understand aggregated origins and destination patterns of regional commuters. This approach is static in nature in that it does not account for the behavior of commuters when faced with known route delays, emergent destination changes, or other available public travel options known to travelers for getting to a destination. In other words, human behaviors are not incorporated into these types of engineering-level models. This makes engineering-level models unsuited to modeling and analyzing what are primarily complex decision-making situations where the situation depends on conditions that change over time. This type of complex system requires a modeling approach that can account for this adaptive behavior to provide for a more comprehensive look at commuter patterns (Rindt, Marca, & McNally, 2002).

To provide the ability to study this type of complex adaptive system in relation to public transportation utilization, we will develop a simulation that incorporates human behavior to study how this behavior influences the choice of transportation modes and routes. By simulating more realistic human behavior choices we may be able to uncover ways to better design or employ public transportation systems to help alleviate or reduce traffic congestion in these higher population density areas. The specific tasks to develop this simulation are outlined and briefly described below.

Task 1. Review transportation literature regarding human behavior patterns
The first step in this effort will be to identify previous studies that have documented human behavior patterns related to transportation mode choices. This effort may also include surveying commuters on their transportation decisions based on developed scenarios and use cases. This task will also include

identification of any models already developed for this purpose, their characteristics, and their applicability to this project.

Task 2. Develop complex adaptive behavior model

This task will use the results of task 1 to develop a model and subsequent simulation that will enable the project to study the results of including human behavior on a transportation system including the possible ways commuters may use public transportation to optimize their commute times.

Task 3. Compare the complex adaptive behavior model to the traditional engineering model

This comparison will serve as a way to understand the possible different results that may be obtained between these two models and what the magnitude of those differences may be.

Task 4. Employ the model to study public transit optimization strategies

Once developed, the model will be used to look at strategies that will enhance the optimum use of public transportation and to understand the larger behavior patterns that may emerge as a result of including these behavioral aspects into transportation modeling.

6 References

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Virginia Department of Transportation (2006a). *Final Environmental Impact Statement Section 4(f) Evaluation*.

Virginia Department of Transportation (2006b). *Interim Agreement to Develop and/or Operate the I-95/I-395 HOT Lanes Project in Virginia*.

Appendix A   Legislative Mandate

The Virginia Modeling, Analysis and Simulation Center (VMASC) is directed to utilize modeling and simulation and visualization research methods to study matters related to the optimization of the Commonwealth's modes of public transportation, including rail and bus. In conducting the study, the VMASC shall consider issues such as the most economical and efficient methods of expanding the Commonwealth's public transportation systems to areas possessing the highest population density or most severe automotive traffic congestion, and other issues as may arise. Included in this evaluation shall be an examination of the public transit needs in the Route 1 corridor in Fairfax County relating to the base realignment actions impacting Fort Belvoir. The VMASC shall provide personnel and materials to conduct the study, and shall consult with the Secretary of Transportation, the Department of Rail and Public Transportation, the Virginia Transportation Research Council and other entities suggested by the Chairmen of the House and Senate Committees on Transportation. VMASC shall provide an interim report to the Chairmen of the House and Senate Transportation Committees no later than November 1, 2006 and a written final report to the respective Chairmen no later than November 1, 2007.