

# **Development of a Dynamic Traffic Assignment and Simulation Model for Incident and Emergency Management Applications in the Birmingham Region**

## **Research Proposal**

### **Principal Investigators**

**Virginia P. Sisiopiku, PhD and Andrew Sullivan, BSCE**  
Civil, Construction, and Environmental Engineering  
University of Alabama at Birmingham  
Birmingham, AL

### **Co-Investigators**

**Fouad H. Fouad, PhD and Wilbur Hitchcock, PhD**  
Civil, Construction, and Environmental Engineering  
University of Alabama at Birmingham  
Birmingham, AL

**Burcu B. Keskin, PhD and Sharif H. Melouk, PhD**  
Information Systems, Statistics, & Management Science  
University of Alabama  
Tuscaloosa, AL

**Kyriacos Mouskos, PhD**  
Universal Transportation Model Simulation Center  
City College of New York  
New York, NY

**Athanasios Ziliaskopoulos, PhD**  
Mechanical and Industrial Engineering  
University of Thessaly  
Volos, Greece

**Curtis Barrett and Tom Vick**  
Vista Transportation Group (VTG, Inc.)  
Evanston, IL

**Daniel Turner, PhD**  
Civil, Construction, and Environmental Engineering  
University of Alabama  
Tuscaloosa, AL

### **Collaborators**

**Saiyid Hassan Sikder, PhD**  
Civil, Construction, and Environmental Engineering  
University of Alabama at Birmingham  
Birmingham, AL

**David Brown, PhD**  
Computer Science  
University of Alabama  
Tuscaloosa, AL

**Michael Anderson, PhD**  
Civil & Environmental Engineering  
University of Alabama in Huntsville  
Huntsville, AL

**Neville Parker, PhD**  
Universal Transportation Model Simulation Center  
City College of New York  
New York, NY

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### **BACKGROUND**

Traffic incidents and natural or man-made disasters can impose significant safety risks and disruptions on traffic flows. Moreover, congestion resulting from such occurrences may impede the ability of EMS to provide timely response to those in need of medical attention. There is a need to understand how traffic will be impacted in a large metro area in such an event for three reasons:

- (i) to manage the traffic so that it does not impede emergency operations,
- (ii) to manage the evacuation of populations under threat and divert pass-through traffic out of harm's way, and
- (iii) to manage the flow of first responders to the site of the incident.

In general, the research community has not studied the interactions among these three (3) flows generated almost instantly after a major disaster. Traffic engineers seem to understand fairly well how traffic flow behaves under normal conditions (usually User Equilibrium behavior is assumed). Enforcement and emergency management operators can route and coordinate first responders to a emergency site but although they recognize that the typical background traffic could impede with the emergency vehicles, they are not in a position to manage this traffic except when drastic measures (such as closures of access roads) are taken by law enforcement. When, in addition to the above, there is also a sizeable area or high density corporate, educational or government campus that needs to be evacuated, then this flow generates highly complex interactions with the previous two flows that has not been adequately addressed in the literature or practice.

A need has been recognized for models that can capture the fast evolving dynamic conditions taking into consideration the realities of the above mentioned three (3) flows, in addition to the management measures (street closures, traffic signal control alterations, informational messages) and infrastructure failures. Needless to say that a catastrophe is an extraordinary event and the drivers confronted with it are not expected to behave in the User Equilibrium and System Optimum behavior (as commonly accepted in transportation planning), which makes existing models not directly applicable. Finally, the impact of a major emergency may impact very large parts of the network, which requires the availability of models that can function on large scale regional networks yet maintain reasonable computational time. Currently, no tools exists in the market that can model dynamically large network traffic operations under emergency conditions.

### **PROJECT PURPOSE AND SCOPE**

To address the needs highlighted above the proposed work focuses on the development of a comprehensive regional model of the Birmingham region to be used as a training and evaluation test bed. The tool will allow stakeholders to examine the impact of, and develop response strategies to, major incidents and emergencies with a potential to minimize the impact of

emergencies on traffic operations and the safety of the traveling public. Special attention will be placed on optimizing decision-making, and addressing needs of vulnerable populations including the injured and disabled. The benefit of the holistic preparedness planning approach proposed in this research is that it leads into better management of all assets of the transportation system, which in turn greatly assists planners and emergency responders to select and implement strategies that serve best the needs of the traveling public.

## **THE VISTA MODELING ENVIRONMENT**

The model development and testing for this research will be performed within the VISTA (Visual Interactive System for Transportation Algorithms) environment. VISTA is a next generation mesoscopic model with a Dynamic Traffic Assignment (DTA) capability that was developed at Northwestern University and has been successfully used on transportation projects across the nation. VISTA can simulate the movements of multiple modes across large networks and incorporate the effects of Intelligent Transportation Systems (ITS) and traveler information systems into driver behavior. The principal innovative characteristics of VISTA are:

- The ability to achieve a dynamic user equilibrium (DUE). This means that every traveler assigned to the network will travel on their optimal path; no traveler can switch to another path to reach their destination more quickly. DUE allows modelers to determine the best-case assignment and results for any type of scenario being studied.
- One unique feature of the VISTA model is that it is accessible over the Internet. Once built, the model is hosted and run on a cluster of computers accessible by any authorized user at any time anywhere Internet access is available. This eliminates the need for having new software installed on individual computers. This also eliminates the need to upgrade computers to handle the increased demands of running a simulation model. Any authorized user can modify their model, run the model, and obtain the results using a typical web browser. It also ensures consistency in analysis because all users have access to the same networks and model results. The proliferation of mobile devices (laptops, PDAs) provides an added incentive for users to have up to date VISTA data wherever they are located.
- The VISTA system offers a framework for conducting incident management and emergency analyses in a seamless manner since most of the algorithms that it involves – DTA models, time-dependent route planning algorithms – are already included into the system. The route planning algorithms are necessary for modeling emergency service operations such as ambulance, fire, towing, police, and security-related agencies. Under Incident Management, all entities (police officers, security officers, fire department officers, transport agencies operators, towing services) will be able to receive VISTA data/results on the scene, providing a tool for real time optimization/coordination on route diversions, roadway closures, signal timing changes, etc. The VISTA emergency and evacuation modules can be used for off-line emergency analyses, real-time implementation, and training exercises.

Another powerful attribute of the VISTA model is that it allows the incorporation of real-time traffic count data into model runs for refinement and forecasting purposes. For each model, a calibration procedure can be designed that will be based on data collected automatically by roadway detection devices and in-vehicle devices. More specifically, VISTA allows for a real-time incident management/evacuation module to be designed that will be able to run faster than real time, such that any changes due to the effect that specific set of dynamic events have on the

roadway capacity (roadway flooding, fallen trees, signal blackout, roadway closures due to security concerns, other) and operation can be emulated and a set of alternatives could be evaluated in real-time.

## RESEARCH TEAM

The University of Alabama at Birmingham has assembled a multi-disciplinary team of experts from several departments in four (4) research institutions to perform the research described herein. These include faculty in the Departments of Civil, Construction, and Environmental Engineering at the University of Alabama at Birmingham (UAB); Civil and Environmental Engineering at the University of Alabama in Huntsville (UAH), and the City College of New York (CCNY), as well as faculty in the Departments of Information Systems, Statistics, and Management Science; Civil, Construction, and Environmental Engineering; and Computer Science at the University of Alabama (UA). The VISTA Transport Group (VTG Inc.) will be also a project partner for the duration of the project and will provide technical support with the VISTA model development, application, maintenance, and training.

Research team members have established expertise in traffic operations and safety, transportation planning, large scale simulation modeling, homeland security, emergency management and applied optimization for decision support and have collaborated in the past in funded research activities. A list of project PIs, co-PIs and collaborators follows. Brief bios of the team members are available in APPENDIX A – RESEARCH TEAM.

**TABLE 1. RESEARCH TEAM MEMBERS**

<b>Name</b>	<b>Title</b>	<b>Department</b>	<b>Agency</b>
Fouad H. Fouad, co-PI	Professor and Chair	Civil, Construction, & Environmental Engineering	UAB
Wilbur Hitchcock, co-PI	Professor	Civil, Construction, & Environmental Engineering	UAB
Saiyid Hassan Sikder	Research Engineer	Civil, Construction, & Environmental Engineering	UAB
Virginia Sisiopiku, PI	Associate Professor	Civil, Construction, & Environmental Engineering	UAB
Andrew Sullivan, PI	Research Engineer	Civil, Construction, & Environmental Engineering	UAB
David Brown	Professor	Computer Science	UA
Burcu B. Keskin, co-PI	Assistant Professor	Information Systems, Statistics, & Management Science	UA
Sharif H. Melouk, co-PI	Assistant Professor	Information Systems, Statistics, & Management Science	UA
Daniel Turner, co-PI	Professor	Civil, Construction, & Environmental Engineering	UA
Michael Anderson	Associate Professor	Civil & Environmental Engineering	UAH
A. Ziliaskopoulos, co-PI	President	Research and Development	VTG Inc.
Curtis Barrett, co-PI	Software Engineer	Research and Development	VTG Inc.
Tom Vick, co-PI	Vice President	Transportation Planning	VTG Inc.
Kyriacos Mouskos, co-PI	Associate Director	Universal Transportation Model Simulation Center	CCNY/ VTG Inc.
Neville Parker	Director	Universal Transportation Model Simulation Center	CCNY

In addition, graduate students will be funded through the project. Student participation in this project compliments the PI's and Co-PI's efforts to recruit graduate students and actively involve them with programs of UTC. Women and minority students will be given priority when considered as candidates for the graduate student assistantship funded through this project. It is also anticipated that this research could enhance the institution's desire to increase international student exchange and collaborative research efforts.

UAB-Civil, Construction, and Environmental Engineering will serve as the lead institution and will have the overall project coordination and management responsibility. The multi-disciplinary research partnership approach in this program is expected to be highly effective and is in line with the UAB-UTC's human resources goal to "foster and promote intra- as well as inter-campus cooperation".

### **PRIOR EXPERIENCE**

The research team is well positioned to meet the goals and objectives of this research proposal and has demonstrated expertise closely related to the research aims described in this document. For example, a 2005 grant from the Federal Transit Administration through the Great Urban Serving Universities Program funded Drs. Sisiopiku, Mouskos, and Parker to study dynamic traffic assignment applications for transit in the Birmingham region. This work can lay the foundation for the modeling of transit operations for evacuation of special-need populations in case of emergencies as described in this proposal.

Moreover, in a recent study funded by the Alabama Department of Transportation (ALDOT) Dr. Sisiopiku and Mr. Sullivan used VISTA to assess hurricane evacuation operations (from Mobile/Gulf Coast to Selma/Montgomery). The study focused on modeling interstate I-65 and other evacuation corridors in VISTA and evaluating contra flow operations. As part of the study, existing and alternate reversal plans were tested to assess the impacts of modifications to existing plans and recommendations were developed on best practices.

Several members of the research team have been involved in a number of recently completed or on-going projects sponsored by the University Transportation Center for Alabama (UTCA) that complement nicely the scope of the proposed research. The proposed project will build upon the expertise gained and the results obtained from the UTCA-supported work. Table 2 lists a sample of relevant UTCA-sponsored projects.

For instance, UTCA project 08112 currently underway under the direction of Dr. Turner will provide another excellent model for the proposed work. In this effort UA is teaming with the University of North Carolina Charlotte (UNCC) to prepare enhanced evacuation plans for two coastal cities, Mobile, Alabama and Wilmington, North Carolina. This will allow a more rigorous identification of the affected population (those without vehicles), determination of the proportion that will require transit evacuation (the most difficult step in the planning process), development of protocols for registering them and maintaining contact with them, identification of suitable intermediate marshalling areas and staging areas, and other steps in the process. Both UA and UNCC are fully engaged with the local and state emergency management agencies

on this project and the expertise gained from this study is directly transferable to the proposed project.

**TABLE 2. UTCA-SPONSORED PROJECTS RELATED TO THE PROPOSED WORK**

<b>Project No.</b>	<b>Project Title</b>	<b>Investigators</b>
01461	UTCA Crash Analysis Information Division	Brown (UA), Ray (UA), Parrish (UA)
01464	Application of Information Technology to Traffic Safety in Alabama	Brown (UA), Dixon (UA), Parrish (UA)
03226	Regional Emergency-Traffic Simulation	Sisiopiku (UAB), Jones (UA)
06202	Transportation Facilities Emergency Management	Sisiopiku (UAB), Peters (UAB)
07408	Development of a Dynamic Traffic Assignment Model Evaluate Lane Reversal Plans for I-65	Sisiopiku (UAB), Sullivan (UAB), Mouskos (CCNY), Parker (CCNY), Barrett (VTG, Inc)
08112	Transit Evacuation Planning: Two Case Studies	Turner (UA), Hardin (UA)
08103	Transit Modeling and Mitigating Traffic Congestion	Melouk (UA), Keskin (UA), Componation (UAH), Harris (UAH), Farrington (UAH), Anderson (UAH), Sisiopiku (UAB)

Earlier work by Drs. Kamga and Mouskos (2006) demonstrated that the impact of an incident is non-trivial and only a DTA model can produce accurate estimates of incident delay. One of the main outcomes of this research is that an incident may increase the Origin-Destination (O-D) travel time for some travelers - usually upstream of the incident location, and improve the O-D travel time for other travelers – usually downstream of the incident location. Further, an incident may increase, decrease or have no effect on the total network travel time. The research further illustrated the need for a 24-hour analysis time period. It is further emphasized that the current practice of estimating the incident delay refers to only the *temporal delay* caused by the incident to the travelers just upstream of the incident location – this temporal delay is usually referred to as the incident delay which is statistically incorrect as it does not take into account the overall O-D trip of each traveler – as a DTA model does.

Drs. Ziliaskopoulos and Mouskos (2007) implemented a prototype VISTA-DTA model for the City of Saarbrücken, Germany under the Monitor Integrated Safety System (MISS) European Union sponsored project to support emergency operations. The prototype model demonstrated that the VISTA DTA would be most beneficial in providing emergency vehicle routing under incident conditions. Given an incident, the VISTA DTA predicts the traffic conditions and provides a set of potential routes for each emergency vehicle to its destination – given that in a metropolitan area a set of incidents are occurring at different places in a continuous manner - in a time-dependent manner. Once an operational calibrated model is established for a metropolitan area, it can be used for real-time traffic forecasting, real-time emergency vehicle routing to

various destinations, real-time travelers routing, off-line emergency services training, off-line route diversion planning, and off-line traffic control optimization (signal timing, lane designation, vehicle class restrictions, turn prohibitions etc).

Under a recent MISS EU project, members of the team used VISTA to produce estimates of traffic flows at 15-minute time intervals for the Province of Bologna network and produce estimated accident rates in million-vehicle-kilometers. The use of the VISTA provided a means for estimating accident rates for roadway links and intersection movements while ensuring that all traffic flows follow the flow conservation constraint which is often not present in accident rates computed only through traffic counts (since such counts are collected/retrieved at different days and time periods for different locations).

VISTA is also being used in a related effort in Chicago, IL led by Mr. Vick and Dr. Ziliaskopoulos where the scenario of a potential traffic incident involving a hazardous material is being considered. The knowledge and tools developed under that project will be made available to the research team with prior approval by the Chicago Metropolitan Agency for Planning (CMAP) and the Illinois Department of Transportation (IDOT), so that development effort can be reduced.

## **APPROACH**

We are proposing a research program consisting of five (5) separate but interrelated projects to address various aspects of incident and emergency management research and training needs. Following is a listing of the proposed projects along with lead investigating units and project contributors.

- **Aim 1. Capacity Building, Education, and Technology Transfer Program.**  
Lead Investigator: Sisiopiku, UAB  
Contributors: UAB (Fouad, Sullivan, Sikder), VGT Inc. (Mouskos, Ziliaskopoulos), CCNY (Parker), UA (Turner)  
Estimated Duration: 24 months
- **Aim 2. Development, Calibration, and Testing of the Birmingham Prototype Model.**  
Lead Investigator: Sisiopiku, UAB  
Contributors: VGT Inc. (Barrett), UAB (Sullivan, Sikder)  
Estimated Duration: 9 months
- **Aim 3. Development and Testing of a Decision Support Tool for Optimization of EMS Response Time.**  
Lead Investigator: Sullivan, UAB;  
Contributors: UA (Keskin, Melouk); VGT Inc. (Barrett, Vick, Mouskos), UAB (Sikder)  
Estimated Duration: 18 months
- **Aim 4. Evaluation of Incident, and Emergency Management Options in the Birmingham Region.**  
Lead Investigator: Sisiopiku, UAB  
Contributors: VTG, Inc. (Ziliaskopoulos, Barrett, Vick), UAB (Sikder), UAH (Anderson), UA (Brown)  
Estimated Duration: 18 months

- **Aim 5. The Role of Transit in Safe Evacuation of the Elderly and Disabled in Emergencies and Disasters.**  
Lead: Sullivan, UAB  
Contributors: UAB (Hitchcock, Sisiopiku, Sikder), UA (Turner), UAH (Anderson), VGT Inc. (Mouskos)  
Estimated Duration: 18 months

More specifically,

- **Aim 1** focuses on the development and delivery of a comprehensive research, education, and training plan aiming at advancing the knowledge and practice in incident and emergency management
- **Aim 2** is charged with the development, calibration, and refinement of the Birmingham test bed and is a precondition for the successful execution of the following three research projects as described in Aims 3 through 5
- **Aim 3** utilizes an integrated simulation-optimization technique to enhance emergency vehicle response and transport time
- **Aim 4** develops a framework that integrates physical infrastructure, transportation demand, and crash data and tests incident and emergency management scenarios and response actions, and
- **Aim 5** studies issues related to the evacuation of individuals without personal vehicles and models the transit evacuation scenarios during small and large-scale evacuations.