UAB UTC Annual Report

2010-2011

Philip R. (Russ) Fine, PhD, MSPH,
Founding Director & Principal Investigator

Contact Information

Dr. Russ Fine, Founding Director and Principal Investigator
rfine@uab.edu
205.934.1448

Mr. Jeffrey Foster, Associate Director for Administration & Finance
fosterau@uab.edu
205.996.6086

Dr. Gerald McGwin, Jr., Associate Director for Research & Scientific Oversight
mcgwin@uab.edu
205.975.3036

Dr. Kathleen Bolland, Education and Outreach Advisor
kbolland@sw.ua.edu
205.348.3926

Dr. Andrea Underhill, Research Scientist / Consultant
moonpie@uab.edu

Dr. Despina Stavrinos, Research Scientist
dstavrin@uab.edu
205.934.7861

Ms. Crystal Franklin, Program Administrator
crynklin@uab.edu
205.934.1643

Mailing Address:
CH19 Suite 401
1530 3rd Avenue South
Birmingham, AL 35294-2041

A Note from the Director

It is likely this is the last Director's Note I will ever write for a UAB UTC Annual Report. Coming to grips with this reality is sobering, but as limnologists have taught us, lakes renew themselves when they "turn over." They become refreshed and are often more productive than in the past, even if historically they have been vibrant and healthy. And, so it will be with future transportation research at UAB. We've been very productive in the past. But, I am supremely confident UAB's next generation of transportation-related research leaders will be even more productive than we have been; and, we've really "cranked it out."

As I think back about the many and varied contributions the UAB UTC has made to highway and traffic safety, it is important to acknowledge and thank **United States Senator Richard Shelby** for having made it possible. The UAB University Transportation Center *owes its very existence* to Senator Shelby whose historic commitment to our nation's highway, transit, traffic and motor vehicle safety programs is without peer. There is no way to accurately estimate the number of people who are alive today because of the challenges UAB has been privileged to pursue and the accomplishments we have been able to make to the field of highway and traffic safety. That which we can say with certainty is that we've done these things because Senator Shelby made it possible for us to have a seat at the table; but, we had to produce and produce *big time*.

Sen. Richard Shelby

Our theme, **Traffic Safety and Injury Control** essentially identified itself because of our experience, resources and capacity; and, because our chosen theme supported: (1) USDOT's vision of safer, simpler and smarter transportation; (2) the first goal of FTA's strategy plan of safety and security; (3) NHTSA's goal of addressing the most significant traffic and motor vehicle safety issues; and, (4) FHWA's goal of reducing the number of highway-related fatalities and injuries. In addition, the UAB UTC's activities targeted more than one mode of transportation, addressing issues and challenges associated with private motor vehicles, commercial carriers and transit.

Even in retrospect, it is of more than casual interest the UAB UTC was the first and – to our knowledge – the **only UTC ever to be established in a School of Medicine**. This one-of-a-kind operating platform enabled UAB to bring a unique perspective to the study of medically-related transportation issues such as (1) the impact of congestion on motor vehicle crash-related (MVC) injury outcome as a function of the "golden hour"/first-responder access; (2) prevention and reduction of commercial vehicle crashes as a function of operator health status; (3) crash injury prevention and control as a function of the operator-vehicle-environment interface; and, (4) achieving a statistically significant reduction in injuries and deaths associated with MVCs occurring in medically underserved, rural areas.

Although the UAB UTC's *beginning-to-end life-span* was short, in less than 60 months we developed, conducted and have completed an ambitious, wide-reaching research agenda encompassing three research domains and 11 individual projects. The research domains were: **Domain I: Emergency Medical Services and Congestion**; **Domain II: Development of a Dynamic Assignment and Simulation Model for Incident and Emergency Management Applications in the Birmingham Region**; and, **Domain III: Distracted Driving and Small Projects**. More detailed information and formal Final Reports on the specific projects appear elsewhere in this document .

We were able to accomplish this ambitious agenda by partnering with researchers from a wide variety of disciplines. For example, with the affiliation of **Karen Heaton, RN, PhD**, we established an important collaborative relationship with UAB School of Nursing (SON). Dr. Heaton, a co-principal investigator of the UTC's **NTRCI***-sponsored project, *Impact of Distraction and Health on Commercial Driving Performance,* is an assistant professor in the SON's Department of Community Health, Outcomes, and Systems as well as the Occupational Health Nursing Program Director for the National Institute of Occupational Safety and Health (NIOSH) funded Deep South Center for Occupational Safety and Health. More detailed information and formal Final Reports on the specific projects appear elsewhere in this Annual Report. (*National Transportation Research Center, Inc.)

Beyond our research agenda, the UAB UTC also had many significant accomplishments in education and training. For example, the UAB UTC and the UAB School of Engineering's Department of Civil, Construction & Environmental Engineering, led by **Dr. Fouad Fouad,** established a **Certificate in Transportation Safety and Injury Control Engineering** and a **Certificate in Transportation Engineering**. The certificate programs – a marriage between engineering, public health and the emerging discipline of injury control – are enabling engineering students and other transportation professionals to acquire advanced training and experience in the public health and injury control aspects of transportation research.

Additionally, the UAB UTC, in cooperation with the UAB Injury Control Research Center (ICRC), has been underwriting and conducting **Epidemiology 603: Injury – Epidemiologic Principles and Prevention Strategies**, a graduate course in the UAB School of Public Health for more than twenty years. Since motor vehicle crashes are the leading cause of injury and death in the US for persons under the age of 45, there has always been a transportation emphasis in the course. However, since the UAB UTC assumed organizational, financial and administrative responsibility for the course after ICRC funding ended, it has taken on an even more prominent transportation focus, reflecting the growing importance of transportation research at UAB, catalyzed by the establishment of the UAB UTC.

There is another example of a training activity of which we are quite proud: Three years ago, the UAB UTC partnered with the **Jefferson County Youth Transportation Program*** (JCYTP), a campus-based minority enrichment effort managed by **UAB's Office of Equity and Diversity** and underwritten, in large part, by the Alabama Department of Transportation (ALDOT). Subsequently, the **UAB UTC's Minority Enrichment Transportation Internship** emerged; and, we believe it is unique among internships. For example, Instead of the intern working for the UAB UTC, the UAB UTC works for the intern. Based on the student's interests, UTC leadership secures engagement opportunities within various summer workshops and schedules appointments for the intern to meet with practicing professionals from a wide variety of transportation-related disciplines. The UAB UTC minority enrichment internship provides hands-on experience as well as a glimpse of what professionals in transportation-related fields actually do. The UAB UTC Minority Enrichment Transportation Internship has proven to be an invaluable resource for students by providing them with a glimpse of real-world transportation-related career choices. This internship opportunity represents another example of how the UTC has leveraged local, state and federal programs in our effort to help contribute to the transportation work force of the future. (*) Additional information about the JCYTP is available at < http://www.uab.edu/utc/JCYTP/JCYTP.html >

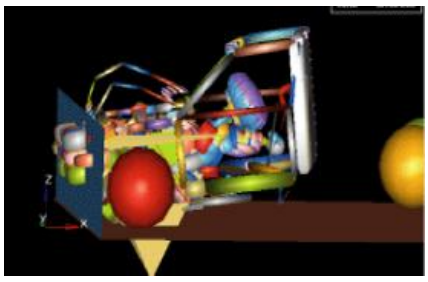
Dr. Despina Stavrinos is an outstanding example of the UAB UTC's education and training efforts to help bring new, highly-skilled professionals to the transportation work-force. Soon after beginning her training as the UAB UTC's first Post-Doctoral Fellow in 2009, **Dr. Despina Stavrinos** established the **Translational Research for Injury Prevention (TRIP) Laboratory® at the UAB UTC**.

The TRIP® Lab's mission is to provide a scientific environment that promotes the generation of knowledge intended to increase our understanding of the behavioral aspects of distracted driving among teens and young adults and then translate those findings into injury prevention and control practice.

Since its establishment, 30 graduate and undergraduate students have been affiliated the TRIP Laboratory. In less than 30 months, Dr. Stavrinos and her students submitted 26 abstracts to scientific meetings, professional gatherings and competitions. Six oral and 20 poster presentations resulted from those submissions and there have been eight competitive poster winners from her group. That remarkable accomplishment has been complemented by publication of four scientific manuscripts in peer-reviewed journals and the submission of four additional manuscripts that are presently under Editorial Consideration by peer-reviewed journals.

Beyond our research, education and training activities, the UAB UTC emphasized technology transfer and, despite modest resources, it also emphasized meaningful outreach and community service. A prime example of this type of activity is the **Alabama Distracted Driving Summit**. In early December 2009, the **UAB UTC** invited the **University Transportation Center for Alabama** (UTC-A) to co-sponsor, with us, the **Alabama Distracted Driving Summit**. This was the nation's first statewide meeting on distracted driving; and, we put it together and pulled it off a mere 61 days after **Secretary of Transportation Ray LaHood**'s Washington, D.C. Summit. Alabama's Summit brought together more than 300 transportation leaders, elected officials, safety advocates, law enforcement representatives and private sector representatives, as well as transportation and public health scientists from throughout the nation to discuss how to reduce motor-vehicle crashes resulting from distracted driving through legislation, enforcement, public awareness and education. The Alabama Summit was especially significant due to the presence of Secretary LaHood, who in his keynote address praised both Alabama UTCs for their initiative and leadership in hosting the event: "*The University of Alabama at Birmingham's Summit – the first of its kind outside Washington – helps continue the national conversation on distracted driving and will put more good ideas on the table to prevent needless deaths. I hope other states will follow its lead.*" We are gratified and honored that the Alabama Distracted Driving Summit served to re-energize the somewhat scattered and poorly organized statewide anti-distracted-driving activities previously underway in various places throughout Alabama. Because of the UAB UTC sponsored Summit, many more people, private-sector entities as well as government agencies, have become better informed about the distracted driving problem and involved in efforts to reduce, if not eliminate, this problem. Moreover, there is no question the Summit measurably increased awareness of the distracted driving efforts outlined by **Alabama's Strategic Highway Safety Plan**. There are many additional examples of the UAB UTC's "scope and reach." We understood the importance of Technology Transfer and have addressed it through regularly recurring **Research in Progress Seminars and Webinars**, a large number of meaningful publications, presentations, public forums, public and private sector outreach activities and considerable *pro bono* technical assistance.

Left to Right: Dr. Jay Lindly (UTCA), Sec. Ray LaHood, and Dr. Russ Fine at the Alabama Distracted Driving Summit



Two classic examples of the latter include Dr. Jeff Crandall, a UAB UTC sponsored scientist and head of the Center for Applied Biomechanics at the University of Virginia, is consulting with leading scientists and government officials as moves Japan moves toward implementing a national *Accident Crash Notification System*.

In May 2010, Dr. Crandall traveled to Tokyo and presented his UAB UTC-sponsored research, *Potential Improvements in Medical Treatment and EMS Through Real-Time Injury Assessment of Occupants Involved in Car Crashes* at The Tokyo Joint Symposium. That high profile meeting was organized by the Japanese Association for the Surgery of Trauma, the Japan Society of Automotive Engineers, the Japan Automobile Research Institute, the Institute for Traffic Accident Research and Data Analysis and the General Insurance of Association of Japan.

Another example of important "grass roots" technology transfer – this time much closer to home – involved providing technical assistance and guidance to a citizen-driven, anti-texting while driving movement known as **Alabamians Against Distracted Driving.** In addition, our distracted driving-related educational and community service activities have provided much needed data and direction to several municipalities throughout the Greater Birmingham Region, as well as elsewhere in Alabama, that have lead to the adoption of the local ordinances banning texting while driving. Among these of which we are most proud is the City of Birmingham, whose texting ban includes the UAB Campus.

While the spectrum of activities addressed in this narrative is substantial; it is not 100% inclusive. I could cite many additional activities and accomplishments but this Director's Note is already approaching the length of an Executive Summary. Time to stop.

It is my opinion – and one supported by hard data – that the UAB UTC did an exceptionally good job during its all-too-short lifespan despite being among a tiny group of Title III UTCs receiving the lowest amount of annual federal support in the entire 60+ member UTC network. Our success and our efficiency did not happen serendipitously. We have been efficient and successful because my coworkers and I embraced a strict standard: *Provide the taxpayers with the highest possible return on their investment*. Today, I know with certainty, that we did this and we did it well.

Finally, while I am very proud of the many products of our research, education, training and outreach efforts, I have been equally gratified when, on several occasions during the past six years, three highly-regarded transportation leaders: **Dr. Ray Mundy,** Director of the Center for Transportation Studies and the Barriger Endowed Professor of Transportation and Logistics at the University of Missouri – St. Louis; **Mr. Joseph Petrolino**, UTC Center Director and Vice President of Heavy Vehicle R&D at the National Transportation Research Center, Inc (NTRCI) in Knoxville, Tennessee; and, **Dr. Curtis Tompkins**, Director of USDOT's UTC program – publicly expressed their admiration at how much the UAB UTC accomplished, year in and year out, given the very modest amount of funding it received.

Thank you, Ray, Joe and Curt. You were very perceptive.
Yes, the UAB UTC did "*a whole lot with not very much.*"

Dr. Russ Fine
Founding Director and Principal Investigator
The UAB University Transportation Center

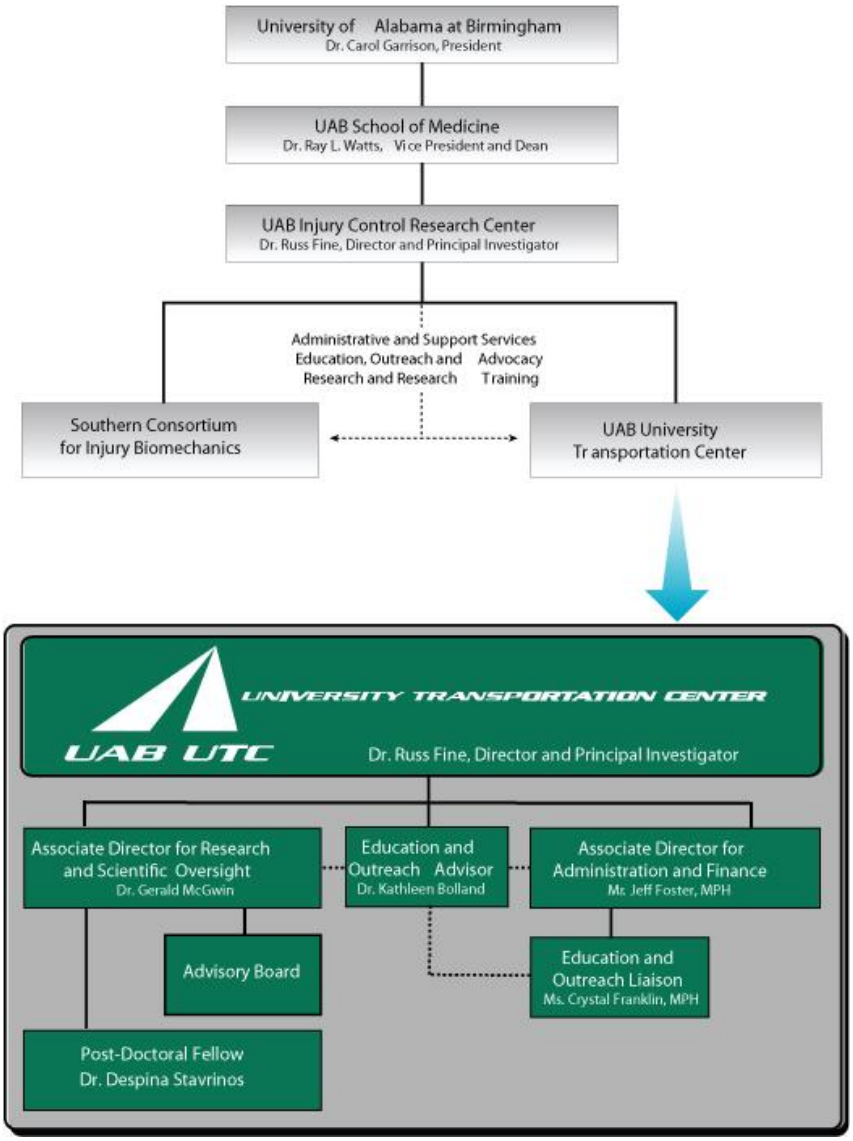
Center Theme

The UAB UTC's theme, *Traffic Safety and Injury Control* was an excellent fit for the UAB Injury Control Research Center's (ICRC) faculty, because it complemented the ICRC's Mission, which was: *"To help the nation achieve a significant reduction in the rate of injuries and their resulting deaths and disabilities, especially in the southeastern United States."* In the United States in 2008, there were nearly 122,000 unintentional injury deaths in persons less than 1 year of age through older than 85 years of age. Of these deaths, approximately 32% were motor vehicle related. However, this figure and proportion increased substantially when four additional transportation-related categories, (1) Other Land Transport, (2) Other Transport, (3) Pedestrian and (4) Pedal Cyclist, were added to the mix. The UAB UTC Theme and the activities conducted in its support applied to more than one mode of transportation. To this end, the research, education and technology transfer activities of the UAB UTC were designed to address problems, issues and challenges associated with private motor vehicles, commercial carriers and transit. Since the UAB UTC was the first – and, to our knowledge, the only – UTC ever to be established within a School of Medicine, the UAB UTC chose to address medically related issues such as (1) the impact of congestion on motor vehicle crash-related (MVC) injury outcome as a function of the "golden hour"/first-responder access; (2) traffic management and emergency preparedness via development of a dynamic traffic assignment and simulation model for incident and emergency management applications; (3) and the distracted driving epidemic; with the goal to achieve a statistically significant reduction in morbidity and mortality associated with MVCs occurring in medically underserved, rural areas of a large Southern state.

Management Structure & Principal Center Staff

The UAB Injury Control Research Center (UAB ICRC), Dr. Russ Fine, Director and Principal Investigator, was the designated entity to which the UAB UTC was awarded. Thus, the integrated approach to the UTC's management was both efficient and highly cost-effective (see page 36, Funding Sources & Expenditures). For example, the ICRC's management paradigm addressed all the functions and programs of the Center, whether research, education, training or service (Figure 1).

Figure 1.



The Director and two Associate Directors, Mr. Jeff Foster and Dr. Gerald McGwin comprised the Center's final Leadership Committee. The Leadership Committee formulated the operating policies and administrative procedures that were used to guide UTC activities. [Note: Dr. McGwin succeeded Dr. Jay Goldman, the UAB UTC's first Associate Director for Research and Scientific Oversight. Dr. Goldman retired in 2008].

Leadership Responsibilities

The UAB UTC Director, Dr. Russ Fine, had global responsibility for operations of the Center. He provided leadership, vision and cohesiveness, and nurtured centeredness through experienced, daily, ongoing engagement rather than simply serving as manager of an array of loosely aggregated activities and workers. Dr. Fine fostered relationships with intra- and extra-mural personnel, agencies institutions, schools, departments, divisions and centers by delegating specific aspects of his overall responsibilities to two Associate Directors.

The Associate Director for Research and Scientific Oversight coordinated and supervised the UTC's research efforts and research support personnel, provided guidance for intramural and extramural research project selection and external review processes, and interfaced with various UAB school and research entities. Dr. Gerald McGwin who succeeded Dr. Jay Goldman as Associate Director for Research and Scientific Oversight is an internationally known and highly regarded injury epidemiologist who, since the UTC's research program was launched, was the Principal Investigator of one of the UTC's three major research domains: Emergency Medical Services and Congestion.

The Associate Director for Administration and Finance, Mr. Jeffrey Foster, was responsible for managing and coordinating all day-to-day operations and support activities of the UAB UTC. This included working closely with Drs. Fine, Goldman and McGwin on matters pertaining to the UTC visioning, policy promulgation, implementation and monitoring, as well as nurturing and promoting relationships with a host of extramural and intramural departments, agencies, organizations and individuals. In addition, Mr. Foster was the UTC's day-to-day interface with our DOT-based RITA Project Officer. Mr. Foster was named the UTC's Associate Director for Administration and Finance in January 2010 when the former Associate Director for Administration and Finance, Dr. Andrea Underhill retired from full-time employment secondary to moving her research and training activities to the State of Georgia.

The UAB UTC's Principal Staff

Director & Principal Investigator – Philip R. (Russ) Fine, PhD, MSPH
Dr. Fine was the founding director and principal investigator of the UAB UTC, the UAB Injury Control Research Center (1988) and The Southern Consortium for Injury Biomechanics (2000). Dr. Fine is Professor of Medicine in the Department of Medicine. He has been on the UAB Faculty of Medicine since 1975 and earned, for UAB, nearly $50 million in research grants, contracts or other types of funding awards during his career. He is the author or co-author of more than 100 contributions to the scientific literature and a member of numerous professional, scientific societies and organizations.

Associate Director for Research & Scientific Oversight – Gerald McGwin, Jr., PhD, MS
Dr. McGwin has been associated with the UAB UTC as a Principal Investigator and Research Domain director since 2007. He is the Associate Director for the UAB Center for Injury Sciences as well as professor and vice-chairman of the School of Public Health's Department of Epidemiology. Dr. McGwin is director of the Center for Clinical and Translational Science (CCTS) Design and Biostatistics Program. He is an associate editor for the American Journal of Epidemiology and regular reviewer for more than a dozen scientific journals. He has authored or co-authored more than 330 peer-reviewed manuscripts.

Associate Director for Administration & Finance – Jeffrey Foster, MPH
Mr. Foster has worked with the UAB UTC since its inception. In addition to his key UTC role and responsibilities, he is an experienced investigator and is rapidly becoming a highly effective scientific administrator. He serves, also, as the Associate Director of the UAB Southern Consortium for Injury Biomechanics. Mr. Foster earned his MPH in Epidemiology from the University of Alabama at Birmingham in 2005. His experience includes transportation research in both heavy and light vehicles, laboratory and field- data collection and testing as well as research project participant recruitment.

Education & Outreach Advisor – Kathleen Bolland, PhD
Dr. Bolland served as the Education and Outreach Advisor to the UAB UTC. In addition to UTC duties, Dr. Bolland is the Assistant Dean for Educational Programs and Student Services in the School of Social Work at The University of Alabama. As a professional staff member in the Evaluation and Assessment Laboratory in the College of Education at The University of Alabama, Dr. Bolland designed and conducted evaluations for 15 years before joining the UA faculty in the School of Social Work.

Program Administrator – Crystal Franklin, MPH
Ms. Franklin, a former UTC student intern, joined the staff full-time in 2010. She provided support to the UTC Leadership in a variety of Center-related activities including grant writing, administrative duties, webinar planning and research assistance. She works closely with Dr. Stavrinos, on a day-to-day basis, functioning as a skilled research associate, which she has become since joining the UTC group.

The Advisory Board

UAB UTC Advisory Board Standing Left to Right: Russ Fine, Fouad Fouad, Andy Sullivan, John Campbell, Richard Burleson, Peter Behrman, Michael Andrews, Despina Stavrinos, Gerald McGwin, Joy Fleisher, Richard Gonzalez, Jay Goldman. Seated Second Row Left to Right: Joe Petrolino, Bill Foisy, Mark Bartlett, Russell Griffin, Jeff Foster. Seated Front Row Left to Right: Ray Mundy, Walter Kulyk, Virginia Sisiopiku, Sharif Melouk, Kathy Bolland

Beginning in 2006 with our first Advisory Board the UAB UTC's Advisory Board played a key role in helping guide UTC activities, formulating research concepts, identifying emerging research and education needs, and in selecting research projects.

In addition to the UTC Advisory Board Members, numerous civic and political leaders (e.g. Birmingham Mayor William Bell) as well as other representatives from the academic sector, numerous transportation professionals would turn out to network, trade ideas, make recommendations and learn more about the activities of the UAB UTC and the RITA program. Some of the UAB UTC's most successful research and education initiatives grew out of our Advisory Board meetings and include our work in the realm of distracted driving and transit worker health education initiative. For more historic information on the UAB UTC's Advisory Board meetings please visit our website www.uab.edu/utc.

Advisory Board members were often treated to a special keynote address from local leaders on topics ranging from the use of mass transit as a tool for public health and emergency management (not just as means for the disadvantaged to travel from Point A to Point B), to the effect of congestion on health outcomes, to technological advancements of active safety systems in motor vehicles. The UAB UTC's diversity in research and education activities was in no small part due to the encouragement and "out of the box" appreciation that our Advisory Board provided.

The UAB UTC Advisory Board was made up of leaders from throughout the State and Nation representing a number of high-profile entities and organizations whose varying missions contribute positively to the goals and objectives of the UAB UTC.

Dr. Ray Mundy and Dr. Russ Fine

Members of the UAB UTC's Most Recent and Final Advisory Board

Joe Acker, EMT-P, MPH (*ex officio*) *Executive Director* *Birmingham Regional Emergency Medical Services System*	**Walter Kulyk, PE** *Director, Office of Mobility Innovation* *Federal Transit Administration*
D. Michael Andrews, JD *Attorney, Beasley, Allen, Crow, Methvin, Portis & Miles, PC*	**Michael Howell-Moroney, PhD** *Director, Master of Public Administration Program* *University of Alabama at Birmingham*
Mark Bartlett, PE *Division Administrator, Federal Highway Administration*	**Robert Kimberly, MD** *Senior Associate Dean for Research, UASOM* *University of Alabama at Birmingham*
Peter Behrman *Executive Director, Birmingham Jefferson County Transit Authority*	**Fouad Fouad, PhD** *Professor and Chairman, Civil, Construction & Environmental Engineering University of Alabama at Birmingham*
David Brown, PhD *Deputy Director, Center for Advanced Public Safety The University of Alabama*	**Richard Gonzalez, MD** *Professor, Department of Surgery* *University of South Alabama*
Frank K. Filgo, CAE *President & CEO, Alabama Trucking Association*	**Ordrell Smith** Director, Jefferson County Youth Transportation Program University of Alabama at Birmingham
Richard Burleson, MBA *Director, Injury Prevention Branch Alabama Department of Public Health*	**Virginia Sisiopiku, PhD** *Associate Professor, Civil, Construction & Environmental Engineering University of Alabama at Birmingham*
Glenn Cummings, MBA/HCM, RN *Coordinator, Trauma Services University of South Alabama*	**Loring Rue, MD** *Chief, Section of Trauma, Burns & Surgical Critical Care, University of Alabama at Birmingham*
John Campbell, MD *EMS Medical Director, Alabama Department of Public Health*	**Henry Wang, MD, MPH, MS** *Associate Professor & Vice Chairman for Research, Department of Emergency Medicine, University of Alabama at Birmingham*
David Meaney, PhD *Associate Director, Penn Center for Brain Injury & Repair Professor of Bioengineering University of Pennsylvania*	**Spencer Collier** *Director, Homeland Security – Alabama*
Ray A. Mundy, PhD – UAB UTC Advisory Board Chairman *Director, Center for Transportation Studies Barriger Endowed Professor of Transportation & Logistics University of Missouri, St. Louis*	**Joseph A. Petrolino, MS** *Vice President, Heavy Vehicle R&D National Transportation Research Center, Inc*
Dan Turner, PhD, PE *Emeritus Professor of Engineering, The University of Alabama*	**Don Vaughn, PE** *Deputy Director & Chief Engineer, Alabama Department of Transportation*

Experience is the Best Teacher

UAB UTC leadership always believed that while classroom education is indispensable, *experience* is often the best teacher. This belief is evidenced through the numerous students the UAB UTC took "under its wings" as Student Assistants, Interns or Minority Enrichment Students. Over the last several years, we published many newsletter and annual report articles highlighting the activities and accomplishments of these students. To regular reader of our publications, names such as Despina Stavrinos, David Cutter, Crystal Franklin, Jennifer Jones, Nichele Cantrell, Dominique Foster, JoShea Carson and Scott Crawford are likely familiar. Moreover, each research project funded through the UAB UTC was encouraged to provide students with opportunities to gain valuable experience through participating in various research projects. The number of students trained through UAB UTC-funded research varied by project, but ranged from one to approximately 20 students per academic semester. Virtually all of these students made positive contributions to various research projects while learning how to design and conduct experiments and learning how to analyze data. The contributions and accomplishments of UAB UTC-affiliated student researchers were many and varied. And, it should be underscored that without the help of both graduate and undergraduate student researchers, many projects would not have been possible. So, while they may not have received the same level of recognition as students working with the UTC's Administrative Unit, project affiliated student researchers were out there juggling academic course work, work on the project and, oftentimes, a part-time job, just like those students who worked for the Administrative Unit.

While it is not practical to document the contributions and accomplishments of all the students, there are several students working with UAB UTC-funded research who particularly stand out: Ms. Ozge Cavusoglu, under the supervision of Dr. Virginia Sisiopiku; Dr. Russell Griffin, under the supervision of Dr. Gerald McGwin; and Dr. Annie Artiga Garner, under the supervision of Dr. Despina Stavrinos. All three students have been honored for their accomplishments within the transportation field by being named UAB UTC Students of the Year. It is more than noteworthy that before becoming a mentor to Dr. Garner, Dr. Despina Stavrinos was a UAB UTC graduate student assistant and was named 2007 – 2008 UAB UTC Student of the Year for her work in pedestrian safety. Later, Dr. Stavrinos became the UAB UTC's first Post-Doctoral Fellow, secured research funding from the UAB UTC and other sources and founded the **UAB Translational Research for Injury Prevention (TRIP) Laboratory** where she now mentors a dozen or more students each semester.

Dr. Russ Fine with UAB SOY recipients (L to R) Annie Garner (2010), Ozge Cavasoglu (2008), Russell Griffin (2009), and Despina Stavrinos (2007)

The UAB UTC's commitment to helping build the transportation infrastructure demands that we foster interest in transportation-related careers for young men and women. We endeavor to do this through a combination of formal coursework and experiential learning. The UAB UTC knows the value of experience as a teacher and we strive to provide both graduate and undergraduate students with ample opportunities for experiential learning through both our Administrative Unit and our research projects. Hands-on experience is an excellent way to kindle a curiosity for transportation-related work in students from non-traditional transportation fields, thereby recruiting more individuals into the transportation-related workforce.

Education Core

Continuation of Popular Injury Epidemiology Course in UAB School of Public Health Made Possible by UAB UTC Leadership

In 1989, the UAB Injury Control Research Center conceptualized, designed, developed and began offering the first and only graduate course focusing specifically on injury. The catalog name for the course was Injury: Epidemiologic Principles and Prevention Strategies (EPI 603) and it was offered through UAB's Department of Epidemiology in the School of Public Health. Since its inception, the course has been based on state-of-the-science information describing the etiology of injury as well as *best-practice* control measures. EPI 603 is offered primarily to graduate students from the UAB School of Public Health, but students have also come from the School of Medicine, the School of Engineering, the School of Nursing and other disciplines across campus. The injury course has always been immensely popular with students, due to its unique subject matter and somewhat novel class style. Also, it is the core course component required for completion of the UAB UTC driven Certificate in Transportation Safety and Injury Control Engineering in the UAB School of Engineering.

Since motor vehicle crashes are the leading cause of injury and death in the US for persons under the age of 45, there has always been a strong transportation emphasis in the course. However, when CDC inexplicably terminated funding of the UAB ICRC in 2007, the UTC stepped in and assumed financial responsibility for continuing the course. Since then, EPI 603 has taken on an even stronger transportation focus which is largely the result of the growing importance of transportation research at UAB, made possible by the UAB UTC.

Examples of lectures focusing primarily on transportation include:

• An epidemiologic overview of the Injury Phenomenon in the United States with Special emphasis on the leading cause of Unintentional morbidity and mortality: motor vehicle crashes [two consecutive introductory lectures spanning three hours by Dr. Russ Fine, Professor of Medicine and Director of the UAB University Transportation Center; the Southern Consortium for Injury Biomechanics; and, The UAB Injury Control Research Center]

• Causes and Prevention of motor vehicle crashes (MVCs): class discussion and debate [by Dr. John Waterbor, Associate Professor of Epidemiology, UAB UTC and UAB ICRC Senior Scientist]

• Causes and Prevention of MVCs among elderly drivers [by Dr. Cynthia Owsley, Professor of Ophthalmology, Director of the Clinical Research Unit in the Department of Ophthalmology, Co-Director of the Center for Research on Applied Gerontology]

• Studies of distracted drivers and driving [by Dr. Despina Stavrinos who was the first UAB UTC Post-Doctoral Fellow; and, who is now on the Faculty of Medicine where she continues to serve as Director of the Translational Research for Injury Prevention Laboratory, which she established while on her UTC Fellowship]

• Public policy interventions and motor vehicles fatalities [Dr. Michael Morrisey, Professor of Health Care Organization and Policy, Director of the Lister Hill Center for Health Policy]

UAB UTC's Final Student of the Year: Annie Artiga Garner

On January 22, 2011 Annie Artiga Garner, a PhD student at UAB, was recognized, nationally, as the UAB UTC's Student of the Year by the Council of University Transportation Centers during their Annual Awards Banquet in Washington, DC.

Annie was formerly a UAB UTC Research Assistant studying transportation from the perspective of a non-traditional discipline, psychology. She defended her doctoral dissertation project "Parental influences on driving behavior in adolescents with Attention Deficit Hyperactivity Disorder (ADHD)" in August 2011. Her highly innovative research project examined the role of parenting practices and parental psychopathology on driving behaviors of adolescents with ADHD, a group shown to be at increased risk of becoming involved in motor vehicle crashes. Currently, Annie is completing her internship in clinical psychology at the world-famous Cincinnati Children's Hospital. Although her internship is primarily clinical in nature, Dr. Garner will continue her transportation-related research throughout the internship by continuing to collaborate on projects with UAB UTC scientists.

Dr. Annie Garner receiving her SOY award with her husband, Mr. Kevin Garner, and Dr. Russ Fine.

Since receiving the UTC's Student of the Year Award, Dr. Garner was also awarded the 2011 Gregg Steele Outstanding Graduate Student in Medical/Clinical Psychology Award; the Overall Outstanding Graduate Student in Psychology Award; and most recently, she was one of three recipients of the 2011 Dean's Award for the Outstanding Graduate Student in UAB's College of Arts and Sciences. Previous UAB UTC Students of the Year included Dr. Despina Stavrinos, Dr. Russell Griffin and Ms. Ozge Cavusoglu.

UAB UTC Internship Program

As part of its array of educational opportunities for students representing a variety of academic disciplines, the Translational Research for Injury Prevention (TRIP) Laboratory® at the UAB UTC established both graduate assistant and internship opportunities. This past summer, Mr. Scott Crawford joined the TRIP lab staff as an intern. Scott, a native of Greensboro, North Carolina obtained a bachelors degree in psychology from UAB in 2008. Subsequently, he worked as a research assistant at the Birmingham Veterans Administration's Center for Surgical, Medical Acute care Research and Transitions (C-SMART). In the fall of 2009, he matriculated in UAB's School of Public Health where he is pursuing an MPH with a specialization in epidemiology. He is on track to graduate in December, 2011. While in graduate school, Scott was also employed by the UAB Department of Health Behavior where he assisted in the study of behavioral economics and addiction.

Mr. Scott Crawford

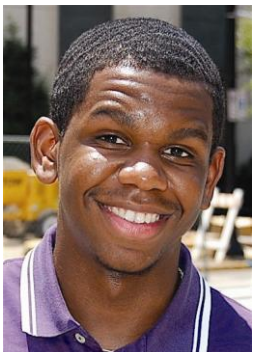
As the TRIP Lab's second intern, Scott worked under the supervision of Dr. Despina Stavrinos to initiate development of a behavioral economics model of distracted driving. Currently, Dr. Starvinos and Scott have partnered with scientists from UAB's Departments of Psychology and Psychiatry to study how impulsivity and temporal discounting affect an individual's decision to use hand-held devices while driving. Following graduation, Scott plans to continue this line of research with the TRIP Lab through the spring of 2012 while he determines the most appropriate route for continuing his education.

Minority Enrichment Program

Soon after the UTC was established we partnered with the Jefferson County Youth Transportation Program (JCYTP), a UAB campus-based minority enrichment effort managed by the University's Office of Equity and Diversity and underwritten, in large part, by the Alabama Department of Transportation (ALDOT). Since that time, we have ample evidence that our Summer Minority Enrichment Program had a profound impact on the lives of the three young people who have been our UAB UTC Interns. The Minority Transportation Internship is unique among internships. Instead of the intern working for the UAB UTC, the UAB UTC works for the intern. Based on the student's interests, UTC leadership secures engagement opportunities within various summer workshops and schedules appointments for the intern to meet with practicing professionals from a wide variety of transportation related disciplines. The UAB UTC minority enrichment internship provides hands-on experience as well as a glimpse of what professionals in transportation-related fields actually do. The UAB UTC Minority Enrichment Transportation Internship is proving to be an invaluable resource for students by providing them with a glimpse of real-world transportation related career choices. This internship opportunity is another example of how the UTC leveraged local, state and federal programs in our effort to help contribute to the transportation work force of the future.

Mrs. Nichelle Cantrell

Our first intern was **Ms. Nichelle Cantrell** who is presently a third year student at Indiana University Purdue University Indianapolis (IUPUI) majoring in biomedical engineering. She is planning to pursue a PhD in chemical engineering and has not ruled out the possibility of medical school after completing her graduate education. During a recent telephone conversation she recounted her post-high school summer internship with the UTC as having been a "great and important experience during which my eyes were opened to the huge number of opportunities that would be available to a person interested in becoming an engineer."



Mr. Dominique Foster

Our second intern, **Mr. Dominique Foster** is a second year student at Tuskegee University. Upon the recommendation of JCYTP leadership, Mr. Dominique Foster, a 2010 graduate of Bessemer City High School in Bessemer, AL, was selected for the second two-month internship. Dominique enrolled as a freshman at Tuskegee University in mid-August, 2010. Dominique had a full schedule of workshops, short courses and one-on-one meetings. He met with a variety of UAB faculty and staff working in a wide range of academic disciplines including Medicine, Engineering, Biostatistics, Business, Public Health, Accounting and Hospital Administration. Outside of UAB, Dominique met with Birmingham-Jefferson County Regional Transportation Authority Executive Director Mr. Peter Behrman and Transportation Manager Mr. Soloman Wilson. The highlight of Dominique's internship was his participation in the prestigious National Science Foundation sponsored Visualization Workshop offered through the UAB School of Engineering and directed by Dr. Alan Shih. This two week long workshop provided Dominique with an overview of computer graphics and scientific visualization. He learned about engineering simulation software and applied what he learned to acquire hands-on visualization experience using 3D imaging and various forms of field manipulation.

Mr. JoShea Carson

Our third intern was Mr. Joshea Carson, a 2011 graduate of Birmingham's historic Woodlawn High School. Mr. Carson's exposure experience was similar in many ways to that of his predecessors Ms. Cantrell and Mr. Foster with the exception of an opportunity to work *one-on-one* with Mr. Ben McManus, a post-baccalaureate research assistant and part-time UTC staff member on the UAB UTC Database Project. This particular initiative was described in the approved Strategic Plan. Its purpose was to create a public access database enabling any user to identify and track pending transportation-related legislation in Alabama. Data elements included the name and number of the proposed legislation, sponsors, committees, status of bill, links to complete text of bill, etc. Mr. Carson, who is very knowledgeable in computer science, was able to assist Mr. McManus with the database design and population. In addition, Mr. Carson met with a spectrum of UAB faculty from the schools of Engineering, Medicine, Liberal Arts and Sciences, and Dentistry. In addition, he was accompanied by UAB UTC leadership to the Mercedes automobile manufacturing plant in Tuscaloosa, Alabama and to the Hyundai automobile manufacturing plant in Montgomery, Alabama where he participated in plant tours arranged by Dr. Fine and Mr. Foster. One of the highlights of Mr. Carson's summer experience was an arranged "hands on" experience at the Porsche Driving School located at the Barber Motorsports Park in Birmingham. Because of a long-standing relationship between Dr. Fine and Mr. George Barber, owner of the world class motor racing facility, Mr. Carson received "in vehicle" driving instructions from a professional road racing instructor in two of their state-of-the-art Porsche race cars where he was allowed to drive "at speed" for several laps. Since Mr. Carson hopes to become an engineer who works in some aspect of the automotive industry, he described his experience as *"the best day of my life."*

Ms. Nichelle Cantrell and Dr. Fine

Mr. JoShea Carson and Dr. Fine

Dr. Fine, Mr. Dominique Foster and UAB UTC Scientist Dr. Alan Shih

Technology Transfer

From 2006-2011 and in conjunction the UAB Injury Control Research Center (ICRC), the Southern Consortium for Injury Biomechanics (SCIB), and the Children's Hospital of Alabama, the UAB UTC conducted and co-sponsored frequent educational presentations under the organizational banner of the Research In Progress Seminar Series (RIPSS). These seminars and webinars provided a forum for research scientists and allied professionals to describe their activities, progress, problems, provisional interpretation of data as well as provisional findings and conclusions. Of equal, if not greater, importance is the fact that these forums provide opportunities for the investigators making the presentations to acquire feedback, guidance and advice from those in attendance – typically a diverse group of faculty, staff, students and other vested parties from throughout the state– whether in person or via the internet.

Many of the RIPSS hosted by the UAB UTC were archived and can be accessed via our website at www.uab.edu/utc . A comprehensive list of RIPSS presentations appears below.

2010-2011	
Brock Long & Ginger Boling	Dynamic Evacuation Clearance Time Tool
Timothy M. Hale & Kelsey Eliasson	Ride Safe- How Information on Safety and Health is Shared in an Online Motorcycle Community: Preliminary Findings and Methodological Challenges
Melissa McBrayer	Grad School Preparation: Personal Statements
Jeffrey Graveline	Copyright and you: A primer for researchers
Lee Schulz	SmartDrive Safety
Adam Scott	Baby Safety Showers Bring Safe May Flowers
Community Member Roundtable	Transit Asset Management in Birmingham: Discussion
TRB	Strategic Highway Research Program-2 webinar: S08 briefing
Dr. Lesley Ross	Driving, health, and the impact of licensing regulations on older adults: Using data harmonization to address complex driving issues
Dr. Drew Davis	Pediatric Acquired Brain Injury: Acute care perspectives for mild, moderate and severe injury
Dr. Karen Heaton	Health Factors related to critical safety events in commercial driving
multiple speakers	UAB UTC Annual Advisory Board Meeting
Don Labbe	Factors Associated With Return to Driving and Driving Behavior Following Traumatic Brain Injury
Chijioke Ulasi	ASPH/NHTSA Public Health Fellowship Program: My experiences as an Injury Prevention Fellow at NHTSA
2009-2010	
Captain Duane Cox & Tonya Webb	Pedestrian Safety Initiative
multiple speakers	Alabama Distracted Driving Summit
Annie Garner	Parental Influences on Driving Behavior
Ozge Cavusoglu	Transit Practices for Evacuation Preparedness and Response for Vulnerable Populations
multiple speakers	UTC Advisory Board Meeting
Cheng Zhong	Crash Prediction on Rural Roads
Peter Behrman	Birmingham-Jefferson County Transit Authority Peer Review Summary

2008-2009	
Dr. Virginia Sisiopiku	Traffic Management Strategies for Hurricane Evacuations in the Southeastern United States
Dr. Virginia Sisiopiku	UAB UTC VISTA software training webinars (4 separate occasions)
Nita Hestevold	A Current Review of Traffic Safety for Parents and Teens
multiple speakers	UTC Advisory Board Meeting
Russell Griffin	The Effectiveness of Recent Developments in Automobile Safety
Dr. John Putzke	Outcomes Research Informatics: Helping Investigators Publish Data
Stephanie Watson	Analysis of the Effects of Aging Transportation Infrastructure on Heavy Construction Projects
Marnie Sutton	The Effects of Gender and Affect on Risky Driving Behavior in Adolescents
Dr. Ben Barton	Developmental Influences on Children's Pedestrian Safety*
multiple speakers	*Disaster Preparedness From Multiple Perspectives*
Dr. Akhlaque Haque	GIS and Google Earth: Socioeconomic Surveillance and Public Policy Making
2007-2008	
Michelle Ackerman	The Impact of Feedback on Self-Rated Driving Ability and Self-Regulation Among Older Adults
Dr. Karlene Ball	Understanding Crash Risk Among Older Drivers
Katherine Byington	The Effect of Cell Phone Distraction on Pediatric Pedestrian Injury Risk
Dr. Thomas Novack	Return to Driving Following Traumatic Brain Injury
Dr. Nancy Rhodes	Positive Affect and Risk Perception in Youth Risky Driving
Dr. Alan Shih	The Efforts in Creating Pediatric Computational Models for Automobile Crash Simulations
Drs. Bharat Soni and Alan Shih	Creating A Digital Child for Use in Simulated Automobile Crashes
2006-2007	
Dr. Jodie Plumert	Preventing injury among child cyclists: a roundtable discussion
Dr. Jodie Plumert	How do immature perceptual and cognitive skills put child cyclists at risk for injury?
Julie Cole Farmer	Child passenger safety in Alabama
Dr. Nancy Rhodes	Behavioral study to reduce DUI and risky driving
Despina Stavrinos	The effect of distraction on pedestrian injury risk
Dr. Joel Schumacher	Assessment and brief intervention of impaired driving among college students: DriveStraight.com
Dr. Claudia Marin	Comprehensive school-based intervention to reduce teen crashes in Birmingham, Alabama

UAB UTC Productivity

UTC-affiliated researchers have produced a number of peer-reviewed publications and have presented research results at local, regional, national and international venues. Below is a comprehensive list of those publication and presentations.

UAB University Transportation Center
Center Supported & Center Related Publication and Presentations
August 2006 – July 2011

In Press

Schwebel DC, Davis AL, O'Neal EE. Child pedestrian injury: A review of behavioral risks and preventive strategies. *Am J Lifestyle Med*. In press.

Schwebel DC, Stavrinos D, Byington KW, Davis T, O'Neal EE, de Jong D. Distraction and pedestrian safety: How talking on the phone, texting, and listening to music impact crossing the street. *Accid Anal Prev.* In press.

2011 Publications

Stavrinos D, Biasini FJ, Fine PR, Hodgens JB, Khatri S, Mrug S, Schwebel DC. Mediating factors associated with pedestrian injury in children with ADHD. *Pediatrics*. In press.

Bose D, Crandall JR, McGwin G, Goldman J, Foster J, Fine PR. Computational methodology to predict injury risk for motor vehicle crash victims: A framework for improving Advanced Automatic Crash Notification systems. Transportation Research Part C: Emerging Technologies. 2011;19:1048-1059.

Gonzalez RP, Cummings GR, Rodning CB. Rural EMS en route IV insertion improves IV insertion success rates and EMS scene time. Am J Surg. 2011 Mar;201(3):344-7.

Owsley C, McGwin G Jr. Vision and driving. Vision Res. 2010 Nov 23;50(23):2348-61.

Owsley C, McGwin G Jr, Seder T. Older drivers' attitudes about instrument cluster designs in vehicles. Accid Anal Prev. 2011 Nov;43(6):2024-9.

Parker WT, McGwin G Jr, Wood JM, Elgin J, Vaphiades MS, Kline LB, Owsley C. Self-reported driving difficulty by persons with hemianopia and quadrantanopia. Curr Eye Res. 2011 Mar;36(3):270-7.

Sisiopiku VP, Sullivan A, Foster J, Fine PR. Emergency response and traffic congestion: The dispatcher's perspective. Proceedings of the Disaster Management and Human Health: Reducing Risk, Improving Outcomes Conference. Orlando, FL. 2011.

Stavrinos D, Byington KW, Schwebel DC. (2011). Distracted walking: Cell phones increase injury risk for college pedestrians. J Safety Res. 2011;42:101-107.

2011 Presentations

Amin A, Chenoweth JB, Kapoor P, McManus B, Welburn SC, Franklin CA, Fine PR, Stavrinos D. Cell phone application use and types among young distracted drivers. Poster presented at the 2011 University of Alabama at Birmingham Summer Expo for Undergraduate Research. Birmingham, AL. July 2011. [First place prize in student poster competition]

Dr. Despina Stavrinos and Dr. Russ Fine present at the 2011 UAB EXPO

Amin A, Garner AA, Franklin CA, Fine PR, Stavrinos D. Assessing the role of sociability in distracted driving. Poster presented at the 2011 University of Alabama at Birmingham Expo for Undergraduate Research. Birmingham, AL. April 2011. [Third place prize for student poster competition]

Avis KT, O'Neal EE, McCartney LM, Balzer R, Schwebel DC. Does obstructive sleep apnea affect children's pedestrian safety? Poster presented at the annual Sleep, Health, and Safety meeting of the National Sleep Foundation. Washington, DC. March 2011.

Bose D, Crandall JR, Griffin R, McGwin G, Foster J, Fine PR. Potential benefits of an automatic injury notification system in reducing motor vehicle crash fatalities. Poster presented at the 139th APHA Annual Meeting. Washington, DC. October 2011.

Byington KW, Renfroe M, Fetterer M, Schwebel DC. Multitasking among college pedestrians: Mobile internet use and perception of safety. Poster presented at the annual convention of the Alabama Psychological Association. Orange Beach, AL. June 2011.

Capar I, Melouk S, Keskin B. Emergency response: Models, formulations, and insights. Presented at the Production and Operations Management Society Conference. Reno, Nevada. April 2011.

Denny S, Garner AA, Franklin CA, Fine PR, **Stavrinos D.** Effect of intelligence and text length on distracted driving performance. Poster presented at 2011 University of Alabama at Birmingham Summer Expo for Undergraduate Research. Birmingham, AL. July 2011. [Third place prize in student poster competition]

Denny S, Garner AA, Franklin CA, Fine PR, Stavrinos D. Exploring differences in cognitive abilities between adolescents with and without Attention Deficit Hyperactivity Disorder. Poster presented at the 2011 University of Alabama at Birmingham Expo for Undergraduate Research. Birmingham, AL. April 2011. [First place prize for student poster competition]

Garner AA, Fine PR, Hyndman L, Stavrinos D. Positive illusory bias in distracted teen drivers with ADHD. Poster presented at the 27th Annual UAB Department of Medicine Trainee Research Symposium, Birmingham, AL. March 2011.

Guthrie WB, O'Neal EE, McCartney LM, Schwebel DC. The role of intelligence in child pedestrian safety. Poster presented at the annual meeting of the American Psychological Association. Washington, DC. August 2011.

UAB UTC Intern Ayushi Amin

Jones JL, Franklin CA, Fine PR, Stavrinos D. Can individual differences predict distracted driving performance in young adults? Poster presented at the 27th Annual UAB Department of Medicine Trainee Research Symposium, Birmingham, AL. March 2011.

Jones JL, Franklin CA, Fine PR, Stavrinos D. Factors influencing parental decisions on teen licensure. Presented at the 2011 UAB Graduate Student Research Day Competition. Birmingham, AL. February 2011.

Jones JL, Franklin CA, Fine PR, Stavrinos D. Factors influencing parental decisions on teen licensure. Poster presented at the 2011 Joint Annual Meeting of the Safe States Alliance and Society for Advancement of Violence and Injury Research (SAVIR). Iowa City, IA. April 2011.

Mangieri S, Garner AA, Franklin CA, Fine PR, Stavrinos D. It's not just distracted driving! Poster presented at the 2011 University of Alabama at Birmingham Expo for Undergraduate Research. Birmingham, AL. April 2011. [Third place prize for student poster competition]

Martin AN, Franklin CA, Fine PR, Stavrinos D**.** Misperceptions of distracted driving ability and risk among teens with or without ADHD. Poster presented at the 2011 University of Alabama at Birmingham Summer Expo for Undergraduate Research. Birmingham, AL. July 2011.

McCartney LM, Byington KW, Guthrie WB, O'Neal EE, Schwebel DC. Mobile internet use among college students: Epidemiology and links to motor vehicle safety. Poster presented at the annual meeting of the American Psychological Association. Washington, DC. August 2011.

McGwin G, Griffin R, Bose D. Domain 1: Emergency medical services and congestion. Presented at the 2011 UAB UTC Annual Advisory Board Meeting, Birmingham, AL. May 2011.

McManus B, Garner AA, Franklin CA, Fine PR, Stavrinos D. Enhancing productivity and work efficiency in a research laboratory. Poster presented at the 2011 University of Alabama at Birmingham Expo for Undergraduate Research. Birmingham, AL. April 2011.

Schwebel DC, Davis AL, O'Neal EE. Child pedestrian safety: A systematic review. Paper presented at the 2011 Joint Annual Meeting of Safe States, SAVIR and CDC Core I & II State Injury Grantees. Coralville, IA. April 2011.

Sisiopiku V. Domain 2: Development of a dynamic assignment and simulation model for incident and emergency management applications in the Birmingham region. Presented at the 2011 UAB UTC Annual Advisory Board Meeting, Birmingham, AL. May 2011.

Sisiopiku V. Modeling incidents and emergencies in the Birmingham area using VISTA. Presented at the Transportation Research Board 90th Annual Meeting, ANB10 (4) – TRB Subcommittee on Emergency Evacuation. Washington, DC. 2011.

Sisiopiku VP, Sullivan A, Foster J, Fine PR. Emergency response and traffic congestion: The dispatchers perspective. Presented at the Conference on Disaster Management and Human Health: Reducing Risk, Improving Outcomes. Orlando, FL. 2011.

Standing Left to Right: Mr. Scott Crawford, Mr. Barnett Chenoweth, Ms. Ayushi Amin, Ms. Sharon Welburne, UTC Program Administrator Ms. Crystal Franklin, Ms. Parul Kapoor. Left to Right Kneeling: Mr. Joshea Carson and Mr. Ben McManus

Stavrinos D, Garner AA, Franklin CA, Griffin R, Fine PR. Piloting a cognitive intervention for adolescent drivers with and without ADHD. Poster presented at the 27th Annual UAB Department of Medicine Trainee Research Symposium, Birmingham, AL. March 2011.

Stavrinos D. A pilot study for distracted driving in teens with and without ADHD. Presented at the 2011 UAB UTC Annual Advisory Board Meeting, Birmingham, AL. May 2011.

Sutton ML, McCallum DM, Rhodes N. The effects of unmitigated agency and moral disengagement on risky driving behavior of adolescent drivers. Presented at the annual meeting of the Society for Personality and Social Psychology. San Antonio, TX. January 2011.

Sutton ML, McCallum DM, Rhodes N. Unmitigated agency as a moderator of the effect of sex on risky driving behavior in adolescents and young adults. Presented at the annual meeting of the Alabama Psychological Association. Orange Beach, AL. June, 2011.

Sutton ML, McCallum DM. The effects of video game exposure and moral disengagement on risky driving behavior in adolescent and young adult drivers. Presented at the annual meeting of the Association for Psychological Science. Washington, DC. May 2011.

Welburn SC, Garner AA, Franklin CA, Fine PR, Stavrinos D. Psychometric validity of Questionnaire of Assessing Distracted Driving (QUADD). Poster presented at the 2011 University of Alabama at Birmingham Expo for Undergraduate Research. Birmingham, AL. April 2011. [First place prize for student poster competition]

Williams L, Garner AA, Franklin CA, Fine PR, Stavrinos D. Effect of distracted driving on visual attention. Poster presented at the 2011 University of Alabama at Birmingham Expo for Undergraduate Research. Birmingham, AL. April 2011. [Third place prize for student poster competition]

2010 Book Chapters

Fine PR, Foster J, Underhill AT, Harper KT. The prevention of spinal cord injury. In: Lin VW, ed. Spinal Cord Medicine: Principles and Practice. New York: Demos Medical Publishing, Inc; 2010.

2010 Publications

Arregui-Dalmases C, Ash JH, Del Pozo E, Kerrigan JR, Crandall J. Characterization of the transverse and spinous vertebral processes: fracture forces under quasi-static and dynamic loading - biomed 2010. Biomed Sci Instrum. 2010;46:154-9.

Arregui-Dalmases C, Ash JH, Del Pozo E, Kerrigan JR, Crandall J. Failure of the lumbar pedicles under bending loading - biomed 2010. Biomed Sci Instrum. 2010;46:148-53.

Ash JH, Kerrigan JR, Arregui-Dalmases C, Del Pozo E, Crandall J. Endplate indentation of the fourth lumbar vertebra - biomed 2010. Biomed Sci Instrum. 2010;46:160-5.

Ball K, Edwards JD, Ross LA, McGwin G Jr. Cognitive training decreases motor vehicle collision involvement of older drivers. J Am Geriatr Soc. 2010 Nov;58(11):2107-13.

Booth JN 3rd, Davis GG, Waterbor J, McGwin G Jr. Changing paradigms of seat belt and air bag injuries. J Am Coll Surg. 2010 Jul;211(1):147-8.

Elgin J, McGwin G, Wood JM, Vaphiades MS, Braswell RA, DeCarlo DK, Kline LB, Owsley C. Evaluation of on-road driving in people with hemianopia and quandrantanopia. Am J Occup Ther. 2010 Mar-Apr;64(2):268-78.

Hu J, Chou C, Yang K, King A. Occupant injury mechanism in rollover crashes - diving or roof crush. SAE 2010 World Congress and Expo. 2010.

Griffin R, Maclennan P, McGwin G Jr. Griffin R, Maclennan P, McGwin G Jr. Hyperthermia deaths among children in parked vehicles: an analysis of 231 fatalities in the United States, 1999-2007. Forensic Sci Med Pathol. 2010 Jun;6(2):99-105.

Kerrigan JR, Bose D, Li Z, Arregui-Dalmases C, Pozo ED. Response of the sternum under dynamic 3-point bending - biomed 2010. Biomed Sci Instrum. 2010;46:440-5.

Kimpara H, Lee JB, Yang KH, King AI. Effects of body weight, height, and ribcage area moment of inertia on blunt chest impact response. J Traffic Inj Prev 2010; 11:207-214.

Lessley D, Shaw G, Parent D, Arregui-Dalmases C, Kindig M, Riley P, Purtsezov S, Sochor M, Gochenour T, Bolton J, Subit D, Crandall J, Takayama S, Ono K, Kamiji K, Yasuki T. Whole-body response to pure lateral impact. Stapp Car Crash J. 2010 Nov;54:289-336.

Li Z, Kindig MW, Kerrigan JR, Untaroiu CD, Subit D, Crandall JR, Kent RW. Rib fractures under anterior-posterior dynamic loads: experimental and finite-element study. J Biomech. 2010 Jan 19;43(2):228-34.

Schwebel DC, McClure LA. Using virtual reality to train children in safe street-crossing skills. Inj Prev. 2010;16:e1-e5.

Sisiopiku VP, Chemmannur J, Brown J. Conversion of one- to two-way streets in birmingham downtown: A feasibility study. SimAUD 2010.

Turner D, Evans W, Kumlachew M, Wolshon B, Dixit V, Sisiopiku VP, Islam S, Anderson M. Issues, practices, and needs for communicating evacuation information with vulnerable populations. Transportation Research Record: Journal of the Transportation Research Board, No. 2196, Network Modeling 2010, Transportation Research Board of the National Academies, Washington, DC. December 2010:159-167.

Turner D, Wolshon B, Dixit V, Evans W, Sisiopiku VP, Islam S, Anderson M, Teklewold M. Transportation-oriented communications with vulnerable populations during major emergencies: Current challenges and best practices. J Transportation Res Board. 2010.

Turner D, Wolshon B, Dixit V, Evans W, Sisiopiku VP, Islam S, Anderson M. Transportation-oriented communications with vulnerable populations during major emergencies: Current challenges and best practices. Proceedings of the 89th Transportation Research Board Annual Meeting. Washington, D.C. 2010.

2010 Presentations

Bose D, Crandall J, Trowbridge M, McGwin G, Foster J, Goldman J, Fine R, O'Connor R. Multibody modeling method for predicting occupant injury risk: a framework for automatic injury notification system. Presented for a joint symposium titled "What is the best way to implement an Accident Crash Notification System (ACNS) in Japan?" organized by the JAST (Japanese Association for the surgery of Trauma), JSAE (Japan Society of Automotive Engineers), JARI (Japan Automobile Research Institute), ITARDA (Institute for Traffic Accident Research and Data Analysis), and GIAJ (General Insurance of Association of Japan), May 2010.

Cavusoglu O, Sisiopiku V. Impacts of traffic incidents and disasters on traffic network operations and emergency response. Presented at the 2010 Huntsville Simulation Conference. Huntsville, AL. 2010.

Cavusoglu O. Transit practices for evacuation preparedness and response for vulnerable populations. Presented at UAB ICRC and UAB UTC Research in Progress Seminar, Birmingham, AL. February 2010.

Cummings G. Center for the study of rural vehicular trauma. Presented at the 2010 UAB UTC Annual Advisory Board Meeting, Birmingham, AL. May 2010.

Garner A. Parental influences on driving behavior. Presented at the UAB University Transportation Center, Birmingham, AL. February 2010.

Garner AA, Hyndman L, Fine PR, Stavrinos D. Positive illusory bias in distracted teen drivers with ADHD. Poster presented at the 22nd Annual CHADD International Conference on ADHD. Atlanta, GA. November 2010

Garner AA, Stavrinos D. Influence of parental distracted driving on teens with and without ADHD. Poster presented at the 2010 Simpson Ramsey Symposium, Civitan International Research Center, Birmingham, AL. First Place Prize. April 2010.

Jhala K, Garner AA, Welburn S, Fine PR, Stavrinos D. Effect of effortful control on driving in adolescents with ADHD. Poster presented at the 22nd Annual CHADD International Conference on ADHD. Atlanta, GA. November 2010.

King R, O'Neal EE, Schwebel DC. Safety of using hands-free headsets while driving. Poster presented at the annual meeting of the American Psychological Association. San Diego, CA. August 2010.

Mizzell J, Byington KW, Renfroe M, O'Neal E, Schwebel DC. Text-messaging and driving: Epidemiological data and implications for prevention. Poster accepted for presentation at the annual meeting of the Society for Behavioral Medicine, Seattle, WA. April 2010.

O'Neal E, Schwebel DC, Davis T. College-aged drivers: Internet technology on phones may pose new driving risks. Poster accepted for presentation at the annual meeting of the Southeastern Psychological Association, Chattanooga, TN. March 2010.

Renfroe M, Stavrinos D, Mizzell J, de Jong D, Schwebel DC. Pedestrian safety while listening to music. Poster accepted for presentation at the annual meeting of the Society for Behavioral Medicine, Seattle, WA. April 2010.

Dr. Despina Stavrinos and UAB UTC Intern Shannon Denny

Schuster R, O'Neal EE, Dominguez G, Schwebel DC. Does socioeconomic status relate to children's pedestrian route selection safety? Poster presented at the biennial Kansas Conference in Clinical Child and Adolescent Psychology. Lawrence, KS. October 2010.

Schwebel D. Teaching young children pedestrian safety skills in virtual reality. Presented at the 2010 UAB UTC Annual Advisory Board Meeting, Birmingham, AL. May 2010.

Siegel JH, Belwadi A, Smith JA, Shah C, Yang KH. Analysis of the mechanism of lateral impact aortic isthmus disruption in real-life motor vehicle crashes using a computer-based finite element numeric model with simulation of prevention strategies. Presented at the Eastern Association for the Surgery of Trauma (EAST), 23rd Annual Scientific Assembly in Collaboration with the Society of Trauma Nurses (STN), Phoenix, AZ. January 2010.

Sisiopiku V, Sullivan A. Emergency dispatching and congestion. Presented at the National Evacuation Conference. New Orleans, LA. 2010.

Sisiopiku V. Development of a dynamic traffic assignment and simulation model for incident and emergency management applications in the Birmingham region. Presented at the 2010 UAB UTC Annual Advisory Board Meeting, Birmingham, AL. May 2010.

Sisiopiku V. Emergency response and traffic congestion: Dispatchers' perspectives. Presented at the National Evacuation Conference, New Orleans, LA. 2010.

Sisiopiku V. A holistic approach to incident management. Presented at the INFORMS 2010 Southern Regional Conference, Huntsville, AL. 2010.

Sisiopiku V. A holistic approach to incident management. Invited presentation to the INFORMS 2010 Southern Regional Conference. Huntsville, AL. 2010.

Sisiopiku V. Contra flow operations for hurricane evacuation: Lessons learned from an Alabama case study. National Evacuation Conference, New Orleans, LA. 2010.

Stavrinos D, Franklin CA. Racial disparities in distracted driving. Presented at the 2011 UAB Health Disparities Research Symposium. Birmingham, AL. April 2011.

Stavrinos D. Distracted driving in teens. Presented at the 2010 UAB UTC Annual Advisory Board Meeting, Birmingham, AL. May 2010.

Stavrinos D. Individual differences in perception of distracted driving ability in teenage drivers. Poster presented at the 26th Annual UAB Department of Medicine Trainee Symposium, Birmingham, AL. March 2010.

Sutton ML, McCallum DM. Video game exposure as a predictor of risky driving in adolescent male drivers. Presented at the annual meeting of the Society of Southeastern Social Psychologists. Charleston, SC. October 2010.

Trowbridge MJ. Building healthier streets for healthier neighborhoods (expert panelist, emergency response planning & built environment). Presented at the Congress for New Urbanism Annual Conference. Atlanta, GA. May 2010.

Turner D, Wolshon B, Dixit V, Evans W, Sisiopiku VP, Islam S, Anderson M, Teklewold M. Transportation-oriented communications with vulnerable populations during major emergencies: Current challenges and best practices. Presented at the Journal of the Transportation Research Board, Transportation Research Record (TRR). January 2010.

Turner D, Wolshon B, Dixit V, Evans W, Sisiopiku VP, Islam S, Anderson M. Transportation-oriented communications with vulnerable populations during major emergencies: Current challenges and best practices. **Proceedings of the** 89th Transportation Research Board Annual Meeting, Washington, D.C. 2010.

Welburn S, Garner AA, Jhala K, Fine PR, Stavrinos D. Distracted driving in adolescents with ADHD. Poster presented at the 22nd Annual CHADD International Conference on ADHD. Atlanta, GA. November 2010.

Welburn SC, Garner AG, Schwartz M, Stavrinos D. Developing a self-report measure of distracted driving in young adults. Poster presented at the 2010 UAB Expo, Birmingham, AL. April 2010.

2009 Publications

Aekbote K, Chou CC, Cheng J, Yang KH, Cavanaugh JM, Rouhana SW, Belwafa J. Development of transfer functions between ES-2re and SID-IIs dummies using rigid wall sled tests. INFATS 2009; Paper # AAI3369657:7:303-310.

Aekbote K, Zhao L, Maltarich M, Cheng J, Chou CC, Yang KH. A door sub-system sled test methodology for simulation of occupant responses in FMVSS 214 side impact oblique pole test. Int J Vehicle Safety 2009; 4:230–256.

Aekbote1, K.; Cheng, J.; Zhao, L.; Chou, C.C.; Yang, K.H. and Maltarich, M. Development of sub-system sled test methodologies for evaluation of side impact countermeasures. INFATS 2009; 7:314-323.

Chen HB, Yang KH, Wang ZG. Biomechanics of whiplash injury. Chin J Traumatol 2009; 12:305-314.
Chou CC, Wagner C, Yang KH, King AI. A review of tripped rollover test methodologies. Int J Vehicle Safety 2009; 4:185–229.

Guan F, Belwadi A, Han X, Yang KH. Application of optimization methodology on vehicular crash reconstruction. ASME IMECE 2009.

Hyatt E, Griffin R, Rue LW 3rd, McGwin G Jr. The association between price of regular-grade gasoline and injury and mortality rates among occupants involved in motorcycle- and automobile-related motor vehicle collisions. Accid Anal Prev 2009; 41:1075-9.

Kim JE, Kim Y-H, Li Z, Eberhardt AW, Soni BK. Evaluation of traumatic brain injury using multi-body and finite element models. Math Comput Simul. 2009 Sep 18;42(13):2191-5.

McGwin G, Nunn AM, Mann JC, Griffin R, Davis GG, MacLennan PA, Kerby JD, Acker JE, Rue LW. Reassessment of the tri-modal mortality distribution in the presence of a regional trauma system. J Trauma 2009; 18: 184-186.

Schwebel DC, McClure LA. Using virtual reality to train children in safe street-crossing skills. Inj Prev **16:**e1-e5.

Schwebel DC, Pitts D, Stavrinos D. The Influence of carrying a backpack on college student pedestrian safety. Accid Anal Prev 2009; 41: 352-356.

Schwebel DC, Stavrinos D, Kongable EK. Attentional control, high intensity pleasure, and risky pedestrian behavior in college students. Accid Anal Prev. 2009; 41: 658-661.

UAB UTC Associate Director Dr. Gerald McGwin

Segui-Gomez M, Lopez-Valdes F J, Crandall J. Characterizing the distribution of injury and injury severity for belted front-seat occupants involved in frontal crashes. Annual Intl Res Council on the Biomechan Inj Conf, York, UK. 2009; 155.

Sisiopiku VP, Acharya A, Anderson M, Turner D. Evaluation of traffic signal performance under oversaturated conditions using VISTA. Trans Simulation Symp 2009; 165.

Sisiopiku VP, Cavusoglu O, Fadel G. Active traffic management opportunities and challenges for implementation. 2009 ITE Technical Conference and Exhibit Compendium of Technical Papers, Phoenix, AZ.

Sisiopiku VP, Cavusoglu O, Sikder S. High occupancy vehicle lane performance assessment through operational, environmental impacts and cost-benefit analyses. EAIA 2010.

Sisiopiku VP, Germin F. Analysis of impacts from temporary left- and right- shoulder lane use as an active traffic management strategy. Huntsville Simulation Conference 2009.

Stavrinos D, Byington KW, Schwebel DC. The effect of cellphone distraction on pediatric pedestrian injury risk. Pediatrics 2009; 123: e179-185.

Trowbridge MJ, Gurka MJ, O'Connor R. Urban sprawl and delayed ambulance arrival in the United States. Amer J Prev Med 2009; 37:428-32.

Trowbridge MJ, Kent R. Rear seat motor vehicle travel: Using national data to define a population at-risk. Amer J Prev Med 2009; 37:321-323.

Wood JM, McGwin G, Elgin J, Vaphiades MS, Braswell RA, Decarlo D, Kline LB, Meek C, Searcey K, Owsley C. On-road driving performance by persons with hemianopia and quadrantanopia. Invest Ophthalmol Vis Sci. 2009; 50: 577-85.

Zhang L, Franklyn M, Yang KH. Head injury prediction: Accident reconstruction of real-world crash cases. WACBE World Congress on Bioengineering 2009; 330.

2009 Presentations

Guan F, Belwadi A, Han X, Yang KH. Application of optimization methodology on vehicular crash reconstruction. Presented at the ASME 2009 International Mechanical Engineering Congress & Exposition, IMECE2009, Lake Buena Vista, Florida. November 2009.

Luck JF, Nightingale RW, Bass CD, Song Y, Kait J, Myers BS. Pediatric PMHS neck Biomechanics. Presented at the National Highway Traffic Safety Administration Yearly Briefing. September 2009.

Sisiopiku V. Active traffic management opportunities and challenges for implementation. Presented at the 2009 ITE Technical Conference and Exhibit, Phoenix, AZ. 2009.

Sisiopiku V. Analysis of impacts from temporary left- and right- shoulder lane use as an active traffic management strategy. Presented at the Huntsville Simulation Conference, Huntsville, AL. 2009.

Stavrinos D. Definitions, data and research results. Panel moderator at the Alabama Distracted Driving Summit, Birmingham, AL. December 2009.

Trowbridge MJ, Gurka MJ, O'Connor RO. Emergency response and the built environment: does urban sprawl delay ambulance arrival? Presented at the American Public Health Association (APHA) Annual Meeting, Philadelphia, PA. November 2009.

2008 Book Chapters

Kerby J, Underhill AT, Foster J, Fine P. Drugs, alcohol, and injury prevention In: Flint L, Meredith JW, Schwab CW, Trunkey DD, Rue L, eds. Trauma: Contemporary Principles and Therapy. Philadelphia, PA: Lippincott Williams & Wilkins; 2008:121-132.

Schwebel DC. Safety and childproofing. In MM Haith & JB Benson, eds. Encyclopedia of infant and early childhood development. San Diego, CA: Academic Press; 2008: 43 – 54.

2008 Publications

MacLennan PA, Marshall T, Griffin R, Purcell M, McGwin G, Rue LW. Vehicle rollover risk and electronic stability control systems. Inj Prev. 2008;14:154-8.

McGwin G Jr, McCartt AT, Braitman KA, Owsley C. Survey of older drivers' experiences with Florida's mandatory vision re-screening law for licensure. Ophthalmic Epidemiol 2008; 15:121-7.

McGwin G, Modjarrad K, Duma S, Rue LW. Association between upper extremity injuries and side airbag availability. J Trauma 2008; 64:1297-301.

McGwin G, Zoghby JT, Griffin R, Rue LW. Incidence of golf cart-related injury in the United States. J Trauma. 2008; 64:1562-6.

Morrongiello BA, Schwebel DC. Gaps in childhood injury research and prevention: What can developmental scientists contribute? Child Development Perspectives. 2008;2(2):78-84.

Schwebel DC, Gaines J, Severson J. Validation of virtual reality as a tool to understand and prevent child pedestrian injury. Accid Analysis and Prevent 2008; 40: 1394-1400.

UAB UTC Intern Ms. Jenny Jones

2008 Presentations

Anderson M, Sisiopiku VP, Jones S. Traffic signals on oversaturated corridors. Presented at the 49th Annual Transportation Research Forum. Fort Worth, TX. 2008.

Byington KW, Stavrinos D, Norris HR, Davis T, Schwebel DC. The effect of cell phone distraction on child pedestrian safety. Presented at the National Conference in Child Health Psychology. Miami Beach, FL. April 2008.

Fanaei K, Stavrinos D, Craig L, Byington KW, Pitts DD, Schwebel DC, The UAB Youth Safety Lab. Epidemiology of cell phone use in 10- to 12-year-olds, and implications for child safety. Presented at the National Conference in Child Health Psychology. Miami Beach, FL. April 2008.

Frascogna N, Nichols M, Lycans S, Monroe K, King WD. Accessing the knowledge of ATV safety for children among Alabama pediatricians. Presented at the Southern Society for Pediatric Research. New Orleans, LA. February 2008.

Gaines J, Schwebel DC, Severson J, Schikore M, Bruse C, Vanderleest R. Validation of virtual reality as a means to study pedestrian behavior. Presented at the biennial conference of the International Society for Child and Adolescent Injury Prevention (ISCAIP). Mérida, Mexico. March 2008.

McCallum DM, Reynolds SJ, Conaway MB, Givens SM. Patterns of ATV use among children in rural communities: 2002-2007. Paper presented at the 2008 meeting of the National Institute for Farm Safety. Lancaster, PA. June 2008.

Norris HR, Byington KW, Stavrinos D, Kongable L, Schwebel DC. The role of temperamental differences on pediatric pedestrian safety. Presented at the National Conference in Child Health Psychology. Miami Beach, FL. April 2008.

Pitts DD, Stavrinos D, Byington KW, Fanaei K, Schwebel DC. Epidemiology of walking in 10-to 12-year olds. Presented at the National Conference in Child Health Psychology. Miami Beach, FL. April 2008.

Schwebel DC, Gaines J, Kinchen S, Cuccaro PM, Elliott MN, Franzini L, Mumford G, Parcak S, Schuster MA. Use of satellite imagery to study neighborhood effects on disparities in unintentional adolescent pedestrian injury. Presented at the 9th World Conference on Injury Prevention and Safety Promotion. Mérida, Mexico. March 2008.

Sisiopiku VP. Development of a dynamic traffic assignment model to evaluate lane reversal plans for hurricane evacuations on I-65. Presented at the 2008 SDITE Annual Meeting. Charleston, SC. 2008.

Stavrinos D, Ackerman M, Schwebel DC, Ball KK. Developmental differences in visual processing skills. Presented at the Association of Psychological Science. Chicago IL. May 2008.

Waid JC, Sisiopiku VP, Sullivan AJ, Mouskos K, Barrett C, Conner G. Lane reversal operations for hurricane evacuations. Presented at the 10th International Conference on Application of Advanced Technologies in Transportation (AATT). Athens, GR. 2008.

2007 Publications

Barton BK, Schwebel DC, Morrongiello BA. Brief report: Increasing children's safe pedestrian behaviors through simple skills training. J Pediatr Psychol. 2007 May;32(4):475-80.

Barton BK, Schwebel DC. A contextual perspective on the etiology of children's unintentional injuries. Health Psychology Review. 2007; 1: 173-185.

Barton BK, Schwebel DC. The influences of demographics and individual differences on children's selection of risky pedestrian routes. J Pediatr Psychol. 2007 Apr;32(3):343-53.

Barton BK, Schwebel DC. The roles of age, gender, inhibitory control, and parental supervision in children's pedestrian safety. J Pediatr Psychol. 2007 Jun;32(5):517-26.

DeVivo MJ. Epidemiology of pediatric spinal cord injury: Yesterday, today, and tomorrow. J Spinal Cord Med. 2007;30:173.

Franklyn M, Peiris S, Huber C, Yang KH. Pediatric material properties: A review of the human childand animal surrogates. Crit Rev Biomed Eng. 2007; 35: 197-342.

Grabowski DC, Morrisey MA. Systemwide implications of the repeal of the national maximum speed limit. Accident Analysis and Prevention. 2007;39:180-189.

Hussain A, Brown D. Land use patterns, urbanization and deer-vehicle crashes in Alabama. *Human-Wildlife Conflicts*. 2007;1(1):89–96.

Jones SL, Sisiopiku VP. Safety at isolated high-speed signalized intersections: Synthesis. ASCE Journal of Transportation Engineering. 2007;133(9):523-528.

Quinn KP, Lee KE, Ahaghotu CC, Winkelstein, BA. Structural changes in the cervical facet capsular ligament: potential contributions to pain following subfailure loading. Stapp Car Crash J. 2007; 51:169-187.

Quinn KP, Winkelstein BA. Cervical facet capsular ligament yield defines the threshold for injury and persistent joint-mediated neck pain. J Biomech. 2007;40(10):2299-306.

Quinney BE, Kerby JD, Rue, LW 3rd, Cross JM. Closure of the Mississippi Firefighters Memorial Burn Center: The implications for burn care in Alabama. J Burn Care Res. 2007;28(6;Suppl 2):S190.

Ratcliff JJ, Greenspan AI, Goldstein FC, Stringer AY, Bushnik T, Hammond FM, Novack TA, Whyte J, Wright DW. Gender and traumatic brain injury: Do the sexes fare differently? Brain Injury 2007;21:1023-1030.

Schwebel DC, Ball KK, Severson J, Barton BK, Rizzo M, Viamonte SM. Individual difference factors in risky driving among older adults. J Safety Res. 2007;38:501-509.

Schwebel DC, Gaines J. Pediatric unintentional injury: Behavioral risk factors and implications for prevention. J Dev Behav Pediatr. 2007;28:245-254.

Schwebel DC, Yocom JS. How personality and reward relate to automobile drivers' judgment of affordances using their own vehicles. Ecological Psychology. 2007;19(1):49-68.

Left to Right: Ms. Shandrea Pendleton; Ms. Meagan Knauss, and Dr. David Schwebel present at the 2008 SAVIR Conference

Sisiopiku VP, Byrd JE, Chittoor A. Application of level of service methods for the evaluation of operations at pedestrian facilities. Journal of the Transportation Research Board, Transportation Research Record (TRR). 2007;2002:117-124.

Sisiopiku VP, Li X, Mouskos KC, Kamga C, Barrett C, Abro AM. Dynamic traffic assignment modeling for incident management. Journal of the Transportation Research Board, Transportation Research Record (TRR). 2007;1994:110-116.

Sisiopiku VP. Application of traffic simulation modeling for improved emergency preparedness planning. ASCE Journal of Urban Planning. 2007;133(1):51-60.

2007 Presentations

Akin D, Sisiopiku VP. Modeling interactions between pedestrians and turning vehicles at signalized crosswalks operating under combined pedestrian-vehicle interval. Presented at the 86th Transportation Research Board Annual Meeting. Washington, DC. 2007.

Akin D, Sisiopiku VP. Pedestrian crossing compliance characteristics at-grade signalized crosswalks: Case study in a downtown-university campus environment. Presented at the 86th Transportation Research Board Annual Meeting. Washington, DC. 2007.

Atay SM, Bayly PV. Magnetic resonance elastography of the mouse brain in vivo. Presented at the ASME 2007 Summer Bioengineering Conference. Keystone, CO. 2007.

Davis AL, Gaines J, Stavrinos D, Schwebel DC. A study of walking speed at a crosswalk. Presented at the annual meeting of the Association of Psychological Science. Washington, DC. May 2007.

DeVivo MJ. Epidemiology of pediatric SCI: Past, present & future. Presented at the International Meeting on Upper Limb in Tetraplegia. Philadelphia, PA. September 2007. (Invited Keynote Presentation)

DeVivo MJ. Epidemiology of pediatric spinal cord injury: yesterday, today, and tomorrow. Presented at the 33rd Annual Scientific Meeting of the American Spinal Injury Association. Tampa, FL. May 2007.
Feil SM, Gaines J, Schwebel DC. Demographic differences in subjective perception of virtual reality simulator realism. Presented at the annual meeting of the American Psychological Association. San Francisco, CA. August 2007.

Feil SM, Gaines J, Schwebel DC. Demographic differences in subjective perception of virtual reality simulator realism. Presented at the annual meeting of the American Psychological Association. San Francisco, CA. August 2007.

Foster J. Glucose tolerance and commercial truck crashes. Poster accepted for presentation at the Transportation Research Board's Research Issues in Freight Transportation — Congestion and System Performance Conference. Washington, DC. October 2007.

Frascogna N, Nichols M, Lycans S, Monroe K, King WD. Accessing the knowledge of ATV safety for children among Alabama pediatricians. Presented at the Injury Free Coalition for Kids. Fort Lauderdale, FL. November 2007.

Goldman J. ICRC Transportation Related Injury Prevention and Control Activities. Presented to the National Center for Injury Prevention and Control, Centers for Disease Control and Prevention. Atlanta, GA. August 2007.

Li Z, Kim JE, Alonso JE, Davidson JS, Eberhardt AW. Contralateral boundary conditions affect the biomechanical response of the pubic symphysis during pelvic side impacts. Presented at the ASME 2007 Summer Bioengineering Conference. Keystone, CO. 2007.

McCallum DM, Reynolds SJ, Conaway MB, Givens SM. Evaluation of a farm safety day program. Presented at the 2007 Summer Conference of the National Institute for Farm Safety. Penticton, BC. June 2007.

Morrisey MA, Grabowski DC. Beer taxes, gasoline prices, GDL programs and effects on teen auto fatalities. Presented at the Robert Wood Johnson Foundation, Substance Abuse Policy Research Program Annual Meeting. Amelia Island, FL. December 2007.

Rhodes N, Edison A. You Drink, You Drive, Then What? The effectiveness of anti-drinking and driving appeals. Presented at the annual meeting of the International Communication Association. San Francisco, CA. May 2007.

Rhodes N, Edison A. You Drink, You Drive, Then What? The effectiveness of anti-drinking and driving appeals. Presented at the annual meeting of the International Communication Association. San Francisco, CA. May 2007.

Rhodes N. Focus on parents: Teens' perceptions of parental safety messages. Workshop presentation at the 2007 Lifesavers Conference. Chicago, IL. March 2007.

Rhodes N. Teens' risky driving. Presented at the National Center for Injury Prevention and Control, Center's for Disease Control and Prevention. Atlanta, GA. August 2007.

Schwebel DC. Pediatric pedestrian safety in virtual reality. Presented at the National Center for Injury Prevention and Control, Centers for Disease Control and Prevention. Atlanta, GA. August 2007.

Shah CS, Hardy WN, Yang KH, Van Ee CA, Morgan RM, Digges KH. Investigation of the traumatic rupture of the aorta (TRA) by simulating real-world accidents. Presented at the 2007 IRCOBI conference. 2007.
Sisiopiku VP, Chaukar A, Hitchcock W. Transit system operations under emergency conditions. Presented at the Transport Chicago 2007 Conference. Chicago, IL. 2007.

Sisiopiku VP, Li X, Mouskos KC, Kamga C, Barrett C, Abro AM. Dynamic traffic assignment modeling for incident management. Presented at the 86th Transportation Research Board Annual Meeting. Washington, DC. 2007.

Sisiopiku VP. Comparison of traffic simulation delay to actual delay. Presented at the Huntsville Simulation Conference. Huntsville, AL. 2007.

Sisiopiku VP. Dynamic traffic assignment and the VISTA model. Presented at the Alabama Chapter of the American Planning Associations (APA) Annual Conference. Auburn, AL. 2007.

Sisiopiku VP. Pedestrian crossing compliance characteristics at-grade signalized crosswalks: Case study in a downtown-university campus environment. Presented at the 86th Transportation Research Board Annual Meeting. Washington, DC. 2007.

Sisiopiku VP. Transit system operations under emergency conditions. Presented at the Transport Chicago 2007 Conference. Chicago, IL. 2007.

Stavrinos D, Gaines J, Severson J, Schwebel DC. Developmental trends in pedestrian safety: How children choose traffic gaps. Presented at the annual meeting of the Association of Psychological Science. Washington DC. May 2007.

Stavrinos D, Schwebel DC, Biasini F. Relations between executive function and increased pedestrian injury risk. Presented at the annual meeting of the Society for Public Health Education. Alexandria, VA. November 2007.

Underhill A. The UAB University Transportation Center. Presented at the National Center for Injury Prevention and Control, Centers for Disease Control and Prevention. Atlanta, GA. August 2007.

Yang K, King A, Huber C. Numerical and empirical investigations of automotive related aortic injury. Presented at the 2007 Southern Consortium for Injury Biomechanics Conference. Birmingham, AL. December 2007.

2006 Publications

Morrisey MA, Grabowski DC, Dee TS, Campbell C. The strength of graduated drivers license programs and fatalities among teen drivers and passengers. *Accid Anal Prev*. 2006;38:135-141

Schwebel DC, Severson J, Ball KK, Rizzo M. Individual difference factors in risky driving: The roles of anger/hostility, conscientiousness, and sensation-seeking. *Accid Anal Prev*. 2006;38(4):801-10.

2006 Presentations

Bowling EB, Patil S, Grimes G, Schwebel DC. Virtual reality as a mechanism to understand and teach pedestrian safety. Abstract accepted to the National Conference on Child Health Psychology. Gainesville, FL. April 2006.

Brown D, Rhodes N. Risky driving behavior. Paper presented at the Safe Home Alabama Traffic Safety Summit, Montgomery, AL. June 2006.

Davis A, Stavrinos D, Gaines J, Schwebel DC. Comparing laboratory walking speed to actual street-crossing speed: Validation for virtual reality research. Poster submitted for presentation at the annual Alabama Psychological Association fall convention. November 2006.

Rhodes N, Edison A, Roskos-Ewoldsen D. The accessibility of drinking and driving attitudes and norms. Presented at the annual meeting of the Association for Psychological Science. New York, NY. May 2006.

Rhodes N. Accessibility is as accessibility does. Abstract to be presented at the annual meeting of the International Communication Association. Dresden, Germany. June 2006.

Schwebel DC, Severson J, Ball KK, Rizzo M. Individual difference factors in risky driving: The roles of anger, conscientiousness, and sensation-seeking. Poster accepted for presentation at the 8th World Conference on Injury Prevention and Safety Promotion. Durban, South Africa. April 2006.

Schwebel DC, Severson J. Development of virtual reality to understand and teach pediatric pedestrian safety. Abstract submitted to the International Society for Child and Adolescent Injury Prevention. Durban, South Africa. April 2006.

Products, Technologies, and Research Results

It is a source of significant pride that meaningful regulatory contributions have already resulted from data analysis and subsequent educational / translational efforts following the Alabama Distracted Driving Summit conducted in December, 2009. By adopting ordinances to ban texting while driving within their local police jurisdictions after the Alabama Legislature failed to pass state-wide legislation, 16 municipalities including Birmingham, Mobile, Montgomery and Huntsville benefitted from the important role the UAB UTC played in bringing attention to the magnitude of the distracted driving problem and by providing irrefutable data enabling proponents to "prove their case."

Furthermore the UAB UTC takes great pride in work our Center scientists completed on (a) congestion mitigation and improving EMS "Golden Hour" response times; and (b) the recently completed injury prediction algorithm (described elsewhere in this Final Annual Report). We posit that the work products of these two projects, taken together, will enable future first-responders to arrive quicker and for AACN systems to play a more active and precise role in the delivery of the most appropriate emergency response.

Although the UAB UTC was quite small from a staff size perspective; and, despite the fact UAB was also among those with the smallest amount of funding, our efforts had an overwhelming positive impact on traffic safety and injury control.

Specific Accomplishments

Since we became a bona fide UTC, the Specific Accomplishments sections of our Annual Reports have invariably been the most challenging. We are proud of the activities of the UAB UTC and strive for all our actions to strongly support state and national transportation goals. However, we realize that not everything we do can go in the Specific Accomplishment Section.

With that in mind, we would like to begin this section with a disclaimer, of sorts. The items included herein are those of which we are most proud or are otherwise close to our hearts. We hope that you, the reader, will not neglect the other sections of our Annual Report, as you will find noteworthy accomplishments throughout the document.

2009 Alabama Distracted Driving Summit

Left to Right: Dr. Despina Stavrinos, US Secretary of Transportation Hon. Raymond LaHood, and Dr. Russ Fine at the 2009 Distracted Driving Summit

On Dec. 3, 2009, the UAB University Transportation Center (www.uab.edu/utc) joined forces with the University Transportation Center for Alabama (http://utca.eng.ua.edu) to sponsor the **Alabama Distracted Driving Summit**. This first (and to our knowledge still the only) statewide summit on distracted driving was conducted a mere 61 days after Secretary of Transportation Ray LaHood's Washington, D.C., summit. The purpose of this one-day event was: (1) to bring together researchers, educators, public policy and decision makers, and private citizens from across our state to describe the scope and nature of the distracted driving problem; (2) to identify meaningful ways to increase public awareness of the safety issues associated with distracted driving; and (3) to identify and review legislative and regulatory approaches/options for addressing distracted driving in Alabama.

Modeled after the US Secretary of Transportation's National Distracted Driving Summit, the Alabama summit brought together more than 300 transportation leaders, elected officials, safety advocates, law enforcement representatives and private sector representatives, as well as transportation and public health scientists to discuss how to reduce motor-vehicle crashes resulting from distracted driving through legislation, enforcement, public awareness and education.

In April 2011 Mr. Jeffrey Foster, MPH, UAB UTC Associate Director, and Ms. Crystal Franklin, MPH, UAB UTC Program Administrator, represented the Center at the first joint meeting of the nation's two leading injury and violence prevention organizations: the Society for the Advancement of Violence and Injury Research (SAVIR) and the Safe States Alliance, formerly doing business as the State and Territorial Injury Prevention Directors Association or STIPDA. The meeting's theme, Progress Through Partnership, was hosted by the University of Iowa Injury Prevention Research Center. Federal partners for the conference include the National Institute for Occupational Safety and Health (NIOSH) and the Centers for Disease Control and Prevention.

A key goal of the joint meeting was exploration of the injury prevention field's potential as a platform for interdisciplinary research using technology, bringing together diverse fields, and conducting rigorous scientific projects with community partners. It has been well documented that motor vehicle crashes are the number one killer of persons aged 1-44 in this country, the most productive personal and economic life years. Given the Centers for Disease Control lack of funding in this area for the last 10 years, the burden to fund much needed transportation related injury research and education has fallen to centers like ours. UAB is uniquely positioned to bridge communication gaps between those in the injury prevention and transportation fields with our UTC background work and our continuing work in

emergency medicine management and biomechanics, and this national conference is one example, of many, where the UAB UTC took advantage of opportunities to expose "traditional" injury prevention professionals to the injury prevention work being done by those in the transportation field. It also provided an opportunity to engage and educate decision makers of the effects of transportation related morbidity and mortality on our country and the need for multiple disciplines to play a role in addressing the problem. Multi-disciplinary communication reduces redundant research efforts that limit the effectiveness of taxpayer dollars and Mr. Foster and Ms. Franklin's participation in this meeting is further evidence of that.

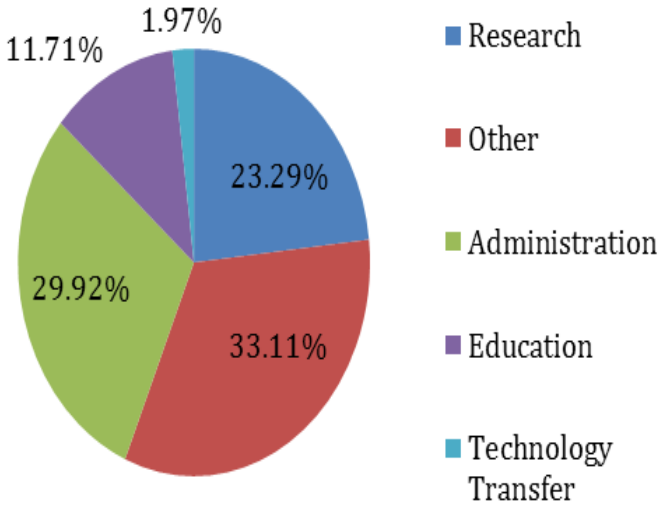
On May 19th and 20th, 2011, the UAB UTC and UAB School of Nursing conducted a Health Fair for employees of the Birmingham-Jefferson County Transit Authority (BJCTA). This activity was another important UTC-driven education, training, and outreach initiative providing health screening services to transit workers. The May event focused on cardiovascular risk reduction among local transit employees, a group shown to be highly vulnerable, at risk workers. The scope of health screening services being provided by faculty from the UAB School of Nursing's (SON) Department of Occupational Health Nursing included blood pressure measurement and counseling; Body Mass Index (BMI) measurement, obesity/nutrition counseling; sleep apnea screening; smoking cessation counseling; and, medical referrals based on the Good Health Program® screening guidelines for hypertension and /or sleep apnea. The Health Fair was conducted at the BJCTA primary fleet terminal and was provided free charge not only to drivers, but all Birmingham-Jefferson County Transit employees. The UAB UTC believes that healthier drivers are safer drivers and creating an awareness of the importance of health and healthy choices is an important and often overlooked component of safe driving.

Left to Right: Mr. Jeff Foster, BJCTA Dir. Peter Behrman, Dr. Thomas Kekes-Szabo and Dr. Russ Fine at the UAB UTC/BJCTA Health Fair

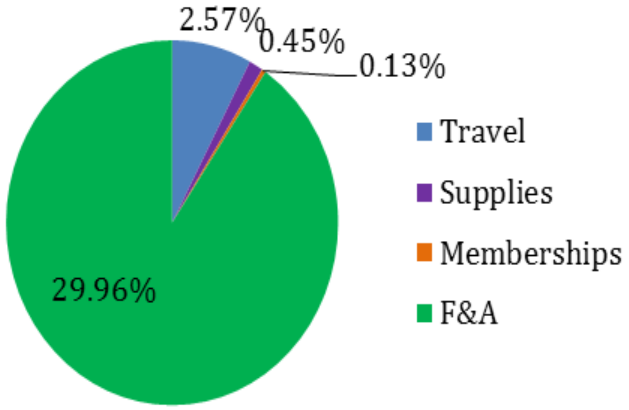
Finally, UAB UTC leadership accepted and embraced the fiduciary responsibility associated with using tax dollars for research and we held our researchers to the highest standards, and encouraged collaboration and innovative multi-disciplinary research projects from the very beginning. The work and efforts of our faculty and staff provided benefits, both directly and indirectly, to the taxpayers supporting this work; and to us that is our greatest accomplishment.

Funding Sources and Expenditures

Total Expenditures



Other



UAB UTC

Research Domains

Domain 1
Project 1

Urban Sprawl and Pre-hospital Emergency Care Time

Final Report

Emergency Medical Services and Congestion:
Urban Sprawl and Pre-hospital Emergency Care Time

University of Alabama at Birmingham
University Transportation Center
Grant No. DTRT06-G-0048

UAB UTC

Principal Investigator: Matthew Trowbridge, MD, MPH

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein. This document is disseminated under the sponsorship of the Department of Transportation University Transportation Centers Program, in the interest of information exchange. The U.S. Government assumes no liability for the contents or use thereof.

Urban Sprawl and Delayed Ambulance Arrival in the U.S.

Matthew J. Trowbridge, MD, MPH, Matthew J. Gurka, PhD, Robert E. O'Connor, MD, MPH

Background: Minimizing emergency medical service (EMS) response time is a central objective of prehospital care, yet the potential influence of built environment features such as urban sprawl on EMS system performance is often not considered.

Purpose: This study measures the association between urban sprawl and EMS response time to test the hypothesis that features of sprawling development increase the probability of delayed ambulance arrival.

Methods: In 2008, EMS response times for 43,424 motor-vehicle crashes were obtained from the Fatal Analysis Reporting System, a national census of crashes involving ≥1 fatality. Sprawl at each crash location was measured using a continuous county-level index previously developed by Ewing et al. The association between sprawl and the probability of a delayed ambulance arrival (≥8 minutes) was then measured using generalized linear mixed modeling to account for correlation among crashes from the same county.

Results: Urban sprawl is significantly associated with increased EMS response time and a higher probability of delayed ambulance arrival (p=0.03). This probability increases quadratically as the severity of sprawl increases while controlling for nighttime crash occurrence, road conditions, and presence of construction. For example, in sprawling counties (e.g., Fayette County GA), the probability of a delayed ambulance arrival for daytime crashes in dry conditions without construction was 69% (95% CI=66%, 72%) compared with 31% (95% CI=28%, 35%) in counties with prominent smart-growth characteristics (e.g., Delaware County PA).

Conclusions: Urban sprawl is significantly associated with increased EMS response time and a higher probability of delayed ambulance arrival following motor-vehicle crashes in the U.S. The results of this study suggest that promotion of community design and development that follows smart-growth principles and regulates urban sprawl may improve EMS performance and reliability.

(Am J Prev Med 2009;37(5):428–432) © 2009 American Journal of Preventive Medicine

Introduction

Urban sprawl is an increasingly prevalent development pattern in the U.S., typified by low-density construction, poor street connectivity, and single-use zoning that separates residential housing from civic and commercial districts.[1] These characteristics result in longer trip distances,[2] increased traffic congestion and trip time variability for commuters,[1,3] and higher rates of traffic and pedestrian fatalities.[4]

Emergency medical service (EMS) response time is one of the key measurements for prehospital system performance, with rapid response being highly desirable in situations involving serious trauma or cardiac arrest.[5] Many of the features of sprawl that make personal automobile trips longer, more dangerous, and less time efficient also likely affect ambulance dispatch, potentially leading to delayed arrival. However, the relationship between urban sprawl and EMS response time has not been quantified.

Using national data, this study sought to measure the relationship between county-level urban sprawl and EMS response time in the U.S. It was hypothesized that sprawling counties would be associated with longer response time and increased probability of delayed ambulance arrival relative to counties exhibiting "smart growth" characteristics (i.e., less sprawl) such as higher-density residential development and connected street networks.[3] Confirmation of sprawl's association with

From the Department of Emergency Medicine (Trowbridge, O'Connor), and Department of Public Health Sciences (Gurka), University of Virginia School of Medicine; and Center for Applied Biomechanics (Trowbridge), University of Virginia School of Engineering, Charlottesville, Virginia

Address correspondence and reprint requests to: Matthew J. Trowbridge, MD, MPH, Department of Emergency Medicine, University of Virginia Health System, P.O. Box 800699, Charlottesville VA 22908-0699. E-mail: mtrowbridge@virginia.edu.

© 2009 American Journal of Preventive Medicine • Published by Elsevier Inc.
0749-3797/09/$–see front matter
doi:10.1016/j.amepre.2009.06.016

Table 1. Distribution of EMS response time and motor-vehicle crash site characteristics[a,b]

Crash site characteristic	All crashes	EMS response time (minutes) <8	EMS response time (minutes) ≥8
n	43,424	22,688	20,736
Presence of construction near crash	1,146 (2.6%)	579 (2.6%)	567 (2.7%)
Crash occurred at night	22,146 (51.1%)	11,597 (51.2%)	10,549 (51.0%)
Wet road surface	7,229 (16.7%)	3,479 (15.4%)	3,750 (18.1%)
M (±SD) sprawl index	102.4±16.9	104.7±16.0	99.9±17.6

[a]Crash data including EMS response time obtained from 2000–2002 Fatal Analysis Reporting System (FARS)
[b]Except for sprawl index, data are reported in frequencies (columnwise percentages in parentheses).
EMS, Emergency and Medical Services

increased EMS response time would have important implications for EMS and emergency preparedness planning in metropolitan areas.

Methods

Data Sources

Emergency medical service response time data were obtained from the Fatal Analysis Reporting System (FARS), a nationwide motor-vehicle crash data collection program sponsored by the U.S. Department of Transportation[6,7] that provides a complete census of crashes in which at least one fatality occurs within 30 days of the crash. It includes extensive data regarding the circumstances of each crash, including location, road conditions, EMS notification time, and time of arrival by EMS at the scene. Many of the built environment measures used to develop the urban sprawl measure used in this analysis are based on 2000 census data. Therefore, FARS data from roughly the same time period (2000–2002) were used to calculate EMS response time following U.S. motor-vehicle crashes.

County-level sprawl was measured using index scores previously developed by Ewing et al.[3] This validated continuous index represents a composite of factors incorporating measures of residential density, segregation of land use, strength of metropolitan centers, and accessibility of the street network and has been widely used in the public health and urban planning literature.[1,2,4,8]

The sprawl index is available for most census-defined metropolitan counties (n=954); some exceptions are the District of Columbia and independent cities in Virginia. The SI also does not apply to rural areas. Available SI values are centered on a value of 100 and range from 55 (Jackson County, Topeka KS) to 352 (Manhattan–New York County, New York NY). Higher index values indicate counties with development more consistent with smart-growth principles.

Study Sample Characteristics

Data from 113,879 motor-vehicle crashes were obtained from the 2000–2002 FARS databases. Where possible, sprawl index values were assigned to each crash based on the county and state in which it occurred. Sprawl index values were available for 77,382 of these crashes (68%); most of the crashes without an index measure occurred in rural areas where the sprawl index does not apply. To focus on more typical metropolitan regions, crashes that occurred in counties with sprawl index values >200 (>97th percentile, n=1086) were excluded. These included the Queens, Bronx, Kings, and New York Counties in New York, and San Francisco County in California. Finally, crashes with incomplete or invalid EMS response time data were also excluded (n=32,872). The final sample included 43,424 motor-vehicle crashes occurring in 46 states and 797 counties.

Analysis

As a measure of EMS response time (dependent variable), the time from notification to ambulance arrival at the crash scene for each motor-vehicle crash in FARS was calculated. Use of mean response time as a quality metric for EMS is generally discouraged given its sensitivity to outliers.[9] Current guidelines by the National Association of EMS Physicians instead suggest the use of fractile response metrics that measure the percentage of EMS responses that meet established time criteria.[9] This approach is intended to reflect and emphasize the importance of EMS response time reliability in the context of medical emergencies.

Incorporating this perspective, the primary outcome measure (EMS response time) used in this study was analyzed as a dichotomized threshold value. Published response time criteria specific to motor-vehicle trauma are not currently available. Therefore, a "delayed" ambulance arrival was defined as ≥8 minutes based on the performance goal of 90% response within 8 minutes that is often used as a quality metric for ambulance dispatch systems.[10] Preliminary analysis demonstrated that ambulance arrival was delayed for approximately 48% of motor-vehicle crashes in the analytic sample (≥8 minutes=20,736, <8 minutes=22,688; Table 1).

The association between delayed ambulance arrival (≥8 minutes) and county-level sprawl was then measured using generalized linear mixed models within the PROC GLIMMIX procedure of SAS, version 9. This approach was chosen to account for the clustered nature of the data because traditional regression techniques would not adjust for correlation among EMS responses that occur within the same county.[11]

Odds of delayed EMS response were modeled as a function of the sprawl index while controlling for crash-level covariates determined to be significant predictors of response time in preliminary analyses. These included time of day, road surface conditions, and presence of construction at the crash site. Given that the relationship between sprawl and odds of delayed response was initially assessed as a quadratic function, the sprawl index was centered (about 100) when included in the model to avoid collinearity. Predicted probability of delayed EMS response at three sprawl index values chosen to approximate average, sprawling, and smart-growth counties was then calculated by subgroup (road surface condition, road construction status, and time of crash).

Table 2. Significant predictors of delayed ambulance arrival (≥8 minutes) following motor-vehicle crashes in the U.S.

Model covariate	OR estimate	95% CI	*p*-value
Presence of construction near crash	1.17	(1.03, 1.33)	0.0195
Wet road surface	1.23	(1.16, 1.30)	<0.0001
Crash occurred at night	1.06	(1.02, 1.11)	0.0042
Sprawl index[a]	Not applicable[b]		<0.0001
(Sprawl index)[a]	Not applicable[b]		0.0346

[a]County sprawl index centered around 100
[b]Relationship between probability of delayed ambulance response and county sprawl index modeled as a quadratic function

This project was approved by the University of Virginia IRB. All analyses were conducted in 2008.

Results

Urban sprawl was found to be significantly associated with increased EMS response time and a higher probability of delayed ambulance arrival (≥8 minutes) following motor-vehicle crashes in the U.S. (p=0.03, Table 2). This probability decreases quadratically (Figure 1) as the county sprawl index increases (signifying less sprawling development) while controlling for nighttime crash occurrence, wet road surface, and presence of construction. This decrease in the probability of a delayed ambulance arrival appears to stabilize in counties with prominent smart-growth characteristics (i.e., high sprawl index values); however, definitive conclusions are not possible because relatively few counties in the sample met these criteria.

To further quantify the relationship between sprawl and EMS response time, the predicted probability of a delayed EMS response was calculated for three specific sprawl index values while accounting for other significant predictors (Table 3). These index values were chosen to approximate counties with average, sprawling, and smart-growth development patterns. Overall, the probability of a delayed EMS response was higher in sprawling counties compared with compact counties. For example, the probability of a delayed EMS response for daytime crashes in dry conditions without construction was 69% (95% CI=66%, 72%) in Fayette County GA (sprawl index=75; sprawling) compared with 31% (95% CI=28%, 35%) in Delaware County PA (sprawl index=125; smart growth).

Discussion

This study demonstrates an association between urban sprawl and increased EMS response time as well as a higher probability of delayed ambulance arrival following motor-vehicle crashes in the U.S. The probability of a delayed ambulance arrival is nearly twice as high in counties with prominent features of sprawl, such as low-density construction, limited street connectivity, and segregation of residential development from civic and commercial districts compared with counties exhibiting smart-growth characteristics.[3]

The public health effects of urban sprawl on health issues such as pediatric obesity[8] and traffic injury risk[1,2,4] are well documented and frequently discussed, yet the potential impact of unregulated sprawling development on the performance, efficiency, and cost of EMS is often ignored. Efforts to integrate population density[12] and emergency event location[13,14] into predictive models to guide EMS resource allocation are ongoing. However, the results of this analysis suggest that integration of more comprehensive land-use metrics, such as measures of urban sprawl, into EMS dispatch algorithms may improve resource utilization and potentially response reliability.

Confirmation of sprawl's association with increased EMS response time supports previous calls for increased consideration of land use and its potential impact on emergency care. In his January 2007 *Annals of Emergency Medicine* commentary,[15] William Millard points out that medical infrastructure frequently lags behind residential development in sprawling suburban and ex-urban areas, placing these communities distant from major trauma and tertiary care centers. Lower home prices in sprawling ex-urban areas have also attracted lower-income populations, including the elderly, who are at higher risk for emergent medical

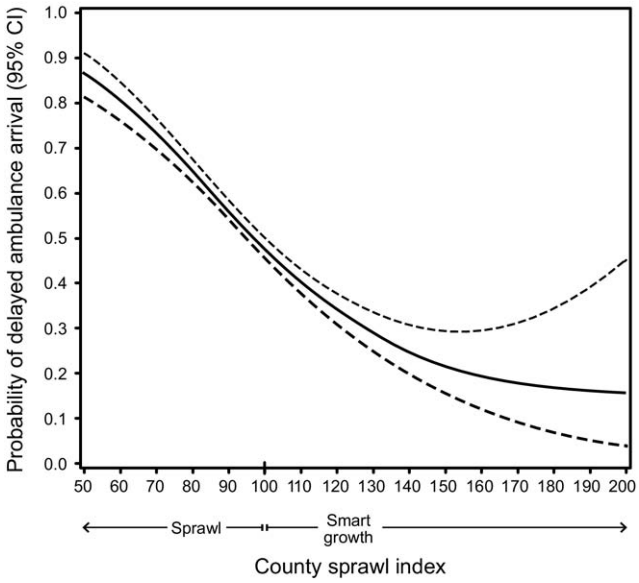


Figure 1. Model-estimated probability of delayed ambulance arrival (≥8 minutes) by county sprawl index[a,b,c]
[a]Relationship between probability of delayed ambulance arrival and county-level sprawl index modeled as a quadratic function (p=0.0346)
[b]Probability calculated for a crash that occurred on a dry road during the day with no construction present
[c]Dashed lines indicate the 95% CI around the model-predicted probabilities

Table 3. Model-predicted probability of delayed ambulance arrival (≥8 minutes) for select U.S. counties[a]

Road surface condition	Construction present	Time of day	Fayette County GA: sprawling (sprawl index=75)	San Benito County CA: average (sprawl index=100)	Delaware County PA: smart growth (sprawl index=125)
Dry	No	Day	0.69 (0.66, 0.72)	0.48 (0.46, 0.50)	0.31 (0.28, 0.35)
Dry	No	Night	0.70 (0.68, 0.73)	0.49 (0.47, 0.51)	0.33 (0.29, 0.36)
Dry	Yes	Day	0.72 (0.68, 0.76)	0.52 (0.48, 0.55)	0.35 (0.30, 0.40)
Dry	Yes	Night	0.74 (0.70, 0.77)	0.53 (0.49, 0.57)	0.36 (0.31, 0.41)
Wet	No	Day	0.73 (0.71, 0.76)	0.53 (0.50, 0.55)	0.36 (0.32, 0.40)
Wet	No	Night	0.75 (0.72, 0.77)	0.54 (0.52, 0.57)	0.37 (0.33, 0.42)
Wet	Yes	Day	0.76 (0.73, 0.80)	0.57 (0.53, 0.61)	0.39 (0.34, 0.45)
Wet	Yes	Night	0.77 (0.74, 0.81)	0.58 (0.54, 0.62)	0.41 (0.36, 0.46)

[a]Counties chosen based on their sprawl index value to represent sprawling, average, and smart-growth areas (i.e., mean sprawl index value±1 SD)

issues and EMS utilization.[16] As a result, demand for EMS service is often increased per capita in the same sprawling areas where it is more difficult and expensive to provide. Recent declines in housing prices and clustering of foreclosures in sprawling suburban areas[17] threaten to further delay investment in healthcare facilities for outlying metropolitan areas, potentially intensifying stress on suburban emergency response systems.

Strengths and Limitations

The primary strengths of this study are its use of national EMS data, a continuous multicomponent measure of urban sprawl,[3] and the incorporation of multilevel analysis techniques to adjust for correlation between EMS runs occurring within the same county.[11] Previous studies investigating the impact of sprawl on EMS response in ex-urban areas have been limited by their use of broad development categories (urban, rural, ex-urban) to analyze variability in the built environment.[18,19] The current study uses a comprehensive specific measure of urban sprawl[3] that incorporates multiple land-use metrics and is widely used in both urban planning and public health.[1,2,4,8]

At the same time, this analysis is based solely on EMS response following motor-vehicle crashes; national EMS response time data for other health emergencies are currently unavailable. While the American Ambulance Association recommends the response interval of less than 8 minutes used in this study for all emergency call types including trauma,[10] the medical necessity of this response interval for serious injury remains debatable.[5] This limits interpretation of sprawl's potential impact on patient outcome due to delayed ambulance arrival from the current analysis. Availability of comprehensive national EMS data inclusive of emergent conditions with well-defined response-time criteria would allow quantification of potential negative health outcomes due to sprawl-related inefficiencies in prehospital care delivery. For example, hypoxic emergencies, such as cardiac or respiratory arrest, require initiation of treatment within 4–6 minutes to prevent permanent disability or death.[9] Building the capacity to directly measure the impact of urban sprawl and other built environment features on EMS performance and subsequent patient outcomes will be critical to successful land-use reform, particularly in rapidly expanding metropolitan areas.

Motor-vehicle crash databases, such as the FARS data set used in this analysis, also do not include information necessary to measure system-level variability in call processing time from notification to actual ambulance dispatch. In many communities, emergency calls are initially picked up by police and then routed to EMS, potentially introducing response delays that are independent of ambulance travel time. There is no obvious indication that these unmeasured delays systematically biased the results of the current analysis. However, development of EMS data systems that allow specific segments of the EMS response interval to be distinguished and measured will be very valuable.

Finally, the use of a county-level sprawl measure also limited the current analysis of EMS response to a regional geographic scale. It is likely that neighborhood-level design factors (e.g., "loop and lollipop" subdivisions prioritizing cul-de-sacs[1] versus more traditional grid neighborhoods) exert substantial effects on EMS response time, particularly in the context of hypoxic emergencies, where even short delays may have important implications for patient outcomes. The public health benefits of increased street network connectivity, including emergency response, are becoming increasingly well recognized. Certain states, including Virginia,[20] are beginning to mandate reductions in cul-de-sacs and limited-access neighborhoods through transportation and land-use legislation.[21] Future research will be needed to guide these efforts and measure their impacts on EMS response reliability.

Conclusion

Urban sprawl is significantly associated with increased EMS response time and higher probability of delayed ambulance arrival following motor-vehicle crashes in the U.S. The results of this study suggest that promo-

tion of community design and development that follows smart-growth principles and regulates urban sprawl may improve EMS performance and reliability.

This research was supported by Grant No. DTRT06-G-0048 from the U.S. Department of Transportation's Research and Innovative Technology Administration to the University of Alabama Injury Research Center.

No financial disclosures were reported by the authors of this paper.

References

1. Frumkin H, Frank L, Jackson R. Urban sprawl and public health: designing, planning, and building for healthy communities. Washington DC: Island Press, 2004.
2. Trowbridge MJ, McDonald NC. Urban sprawl and miles driven daily by teenagers in the United States. Am J Prev Med 2008;34(3):202–6.
3. Ewing R, Pendall R, Chen D. Measuring sprawl and its transportation impacts. Travel Demand Land Use 2003;(1831):175–83.
4. Ewing R, Schieber RA, Zegeer CV. Urban sprawl as a risk factor in motor vehicle occupant and pedestrian fatalities. Am J Public Health 2003; 93(9):1541–5.
5. Myers JB, Slovis CM, Eckstein M, et al. Evidence-based performance measures for emergency medical services systems: a model for expanded EMS benchmarking. Prehosp Emerg Care 2008;12(2):141–51.
6. National Center for Statistics and Analysis, National Highway Traffic Safety Administration. Fatal Analysis Reporting System (FARS); www-fars.nhtsa.dot.gov/.
7. National Highway Traffic Safety Administration. 2007 FARS coding and validation manual. Washington DC: U.S. Department of Transportation, 2007.
8. Ewing R, Brownson RC, Berrigan D. Relationship between urban sprawl and weight of United States youth. Am J Prev Med 2006;31(6):464–74.
9. Bailey ED, Sweeney T. Considerations in establishing emergency medical services response time goals. Prehosp Emerg Care 2003;7(3):397–9.
10. American Ambulance Association. Contracting for emergency ambulances services. A guide to effective system design. Sacramento CA: American Ambulance Association, 1994.
11. Desai M, Begg MD. A comparison of regression approaches for analyzing clustered data. Am J Public Health 2008;98(8):1425–9.
12. Vukmir R. The influence of urban, suburban, or rural locale on survival from refractory prehospital cardiac arrest. Am J Emerg Med 2004;22(2): 90–3.
13. Lerner EB, Billittier AJ, Sikora J, Moscati R. Use of a geographic information system to determine appropriate means of trauma patient transport. Acad Emerg Med 1999;6:1127–33.
14. Peleg K, Pliskin JS. A geographic information system simulation model of EMS: reducing ambulance response time. Am J Emerg Med 2004;22: 164–70.
15. Millard WB. Suburban sprawl: where does emergency medicine fit on the map? Ann Emerg Med 2007;49(1):71–4.
16. Svenson JE. Patterns of use of emergency medical transport: a population-based study. Am J Emerg Med 2000;18(2):130–4.
17. Katz B, Bradley J. The suburban challenge. Newsweek 2009, Jan 26. Available from URL: http://www.newsweek.com/id/180028.
18. Lambert TE, Meyer PB. Ex-urban sprawl as a factor in traffic fatalities and EMS response times in the Southeastern United States. J Econ Issues 2006;XL:941–53.
19. Lambert TE, Meyer PB. New and fringe residential development and emergency medical services response times in the United States. State Local Govert Rev 2008;40(2):115–24.
20. Weiss E. In Va., vision of suburbia at a crossroads: targeting cul-de-sacs, rules now require through streets in new subdivisions. Washington Post 2009, Mar 22:A01.
21. General Assembly of Virginia. Requirements for taking new streets into state secondary highway system. Virginia Acts of Assembly, 2007;Chap. 382(Sect. 33.1–70.3).

What's new online?

Visit **www.ajpm-online.net** today to find out how you can stay updated on key articles with saved searches and table of content e-mail alerts.

Domain 1
Project 2

Characterization of EMS Providers' Perspectives and Experiences with Congestion

Emergency Medical Service Providers' Experiences with Traffic Congestion

Background: The population's migration from urban to suburban areas has resulted in a more dispersed population and increased traffic flow, possibly resulting in longer emergency response times. While studies have examined the effect of response times on time to definitive care and survival, no study has addressed the possible causes of slowed response time among emergency medical service first responders.

Objectives: Assess the variables most commonly associated with increased emergency response time as described in the opinions and views of emergency medical service first responders.

Methods: A total of 500 surveys were sent to randomly selected individuals registered as first responders with the Alabama Department of Public Health, and 112 surveys were returned completed. The survey included questions regarding roadway design, response to emergency calls, in-vehicle technology aimed at decreasing travel time, and public education regarding emergency response.

Results: Respondents reported travelling on city streets most often during emergency calls, and encountering traffic more often on interstates and national highways. Traffic congestion, on average, resulted in nearly 10 minutes extra response time. Most agreed that the more effective in-vehicle technology in reducing response time was a pre-emptive green device; however, very few reported availability of this device in emergency vehicles. Public education regarding how to react to approaching emergency vehicles was stated as having the greatest potential impact on reducing emergency response time.

Conclusion: The results of the survey suggest that the best methods for reducing emergency response times are those that are easy to implement (e.g., public education).

Keywords: emergency; response; time; traffic; survey

Introduction

In the late 20th century, the United States witnessed an increased in the number of vehicles on the road (1). By 2001, nearly 25% of households owned 3 or more vehicles (1). This was accompanied by an increase both in the number of trips taken daily, as well as the average length of the trips. Combined with outdated roadway designs that cannot handle the increased traffic volume, the increase in the number of vehicles has resulted in slower travel speeds and longer trips (2,3,4). This increase in traffic volume has led research to be conducted to examine the impact of the increased volume of emergency response. In particular, one study suggested an increase in the probability of delayed (i.e., ≥ 8 mins) ambulance arrival to the scene as a result of the effects of the more spread out population (5). This delay may impact patient survival. While the literature is mixed on whether more timely emergency response affects cardiac arrest survival, research suggests that use of emergency response services allows stroke patients to receive quicker treatment and increases survival among trauma patients (6-16).

To date, while studies have attempted to quantify the delays in emergency medical service (EMS) response due to urban sprawl, no study has addressed the concerns of those with direct knowledge (i.e., EMS responders) of the effects of delayed response time and the most effective methods of decreasing the delay (5). The purpose of this study is to assess the impact of roadway design and traffic congestion on EMS response (particularly response time) per the opinions and experiences expressed by EMS providers.

Materials and Methods

Survey Development

A series of focus groups were conducted with personnel from fire departments and ambulance services to elicit content for a survey instrument regarding the impact of traffic congestion on EMS response. After initial development, the survey was pilot tested with a local fire department in order to ensure that question wording was appropriate, and that the length of the survey was acceptable. The final survey included questions on training received regarding how to navigate through traffic congestion. The survey also included questions regarding the types of roads (i.e., interstates or highways, county roads, and city streets) travelled during emergency response and experience with traffic congestion on each road type. Additional questions collected information regarding response and patient transport times to the scene and to the final destination (e.g., hospital) and the impact of traffic congestion on these times. Information was collected regarding the accuracy and timeliness of information provided by dispatchers, including whether information regarding road construction and traffic was provided. The survey also contained a series of questions regarding of the role roadway design, including the impact of safety measures such as continuous median barriers on response time and the impact of other roadway design features (e.g., electronic highway signs warning of traffic delays and high-occupancy vehicle lanes) on response time. Information regarding the use and impact of in-vehicle technology (e.g., low frequency sirens, GPS devices, pre-emptive green light devices, automatic crash notification [ACN]) on emergency response times was elicited. Finally, the survey included questions regarding the impact of public education on drivers' reactions to approaching emergency vehicles.

Study Participants

A list of licensed EMS providers was obtained from the Alabama Department of Public Health from which 500 were randomly selected to participate in the study. The selected participants were sent a letter describing the objectives of the study along with a copy of the survey instrument. The letter also indicated that the survey could be completed online, and that all respondents would be entered into a drawing for $1,000. A reminder letter was sent two months from the initial mailing of the survey for those who had yet to respond. A total of 112 surveys were completed from November 2009 to February 2010, and 39 were returned due to incorrect addresses. Our institution's Institutional Review Board approved the study.

Results

The mean age of respondents was 40.4 years, 91% were male, 95% were white, and a majority had either some college or trade school education (49.1%) or completed college or trade school education (44.5%) (Table 1). The majority (67.6%) of respondents reported being firefighters, although many were also paramedics (51.8%) or EMTs (40.7%). Two-thirds of respondents served a mostly urban population.

Response to Emergency Calls

City streets were the most frequently travelled roadway during response while travel on other types of roads was also frequent (Table 2). Emergency responders encounter and are impeded by traffic more often on interstates or national highways and city streets compared to state highways and county roads. The average response time to the scene was 6.4 minutes and to the final destination was 14.9 minutes, although this varied by urban or rural status (Table 3). The average reported delay due to traffic congestion was nearly twice as great for travel to the

destination (5.8 minutes) compared to the scene (2.5 minutes). This did not differ by urban or rural status. More than half (58.5%) of respondents are made aware of road construction prior to responding to an emergency call, but most do not receive traffic information (Table 4).

Overall, respondents agreed to some extent that information regarding the location was conveyed accurately and quickly from 9-1-1 callers to the agency, from the agency to dispatchers, and from the dispatchers to emergency service providers (Table 5). It should be noted, however, that respondents felt that missteps in the relay of emergency call information were more likely to come from the 9-1-1 callers or dispatchers than from the 9-1-1 agencies.

Roadway Design

A vast majority of respondents agreed that continuous median barriers save lives by preventing motor vehicle collisions caused by vehicles crossing highway medians; however, nearly 75% agreed that the barriers increase response time by preventing emergency vehicles from being able to cross the median, with slightly over half (52.4%) reported being impeded by a continuous median barrier during an emergency call (Table 6). Overall, 56.6% of respondents felt that electronic highway signs warning of traffic-related problems have a beneficial impact on emergency response times, and nearly 70% believed that high-occupancy lanes have a beneficial impact on emergency response times (Table 7).

In-Vehicle Technology

Low frequency sirens were the most often utilized in-vehicle technology (67.0%), followed by GPS devices (42.0%) (Table 8). Interestingly, while pre-emptive green devices were the least likely to be used in emergency vehicles (14.3%), over 85% of respondents believed that these devices have a beneficial impact on emergency response time.

Public Education

Most respondents (94.3%) agreed that public education about how to provide accurate information to emergency services (e.g., location of the incident, severity of incident) will decrease response times, and 95.3% agreed that public education about how to react to an approaching emergency vehicle on a roadway will help to decrease response times.

Discussion

This is the first study to assess the opinions and experience of EMS responders regarding factors affecting response times. While the current study presents a plethora of information, the following are the main points of the study results: Respondents reported that interstates and city streets were the most often travelled roads, and the roads in which traffic was most often present. Traffic more greatly affected time to final destination compared to travel to the scene. While slightly over half of respondents were given information regarding road construction prior to emergency response, a majority reported not being given traffic information. A majority agreed that information regarding the emergency was accurately and rapidly conveyed by callers, 9-1-1 agencies, and dispatchers. Respondents agreed that median barriers save lives by preventing vehicles from crossing median during a collision, but felt that these barriers increase response time by preventing emergency vehicles from crossing the median. Further related to roadway design, a majority of respondents believed that high-occupancy vehicle lanes will have the greatest impact on decrease response time. Regarding in-vehicle technologies, respondents reported that pre-emptive green devices and automatic crash notification systems have the greatest impact on decreasing response time, but these technologies are minimally prevalent. Finally, many EMS responders felt that the best opportunity to decrease response time can be

derived from public education regarding how to provide accurate information to emergency responders and how to react to approaching emergency vehicles.

Because this is the first study on this topic, it is difficult to place the results in context; however, there is ample literature regarding EMS response in relation to initiation of medical treatment. While literature has suggested no association between EMS transport and timing of the reception of care among trauma patients, multiple studies have reported that those needing emergency care due to illness (e.g., cardiac arrest, stroke) receive quicker treatment when using EMS transport (12,17-24). Specifically, patients complaining of chest pain arrived at the hospital quicker when using private transport, but received definitive care much more rapidly when using EMS transport due to care beginning at the time of EMS arrival (23). A similar finding was reported in a recent study of acute myocardial infarction patients (24). Among stroke patients, those arriving by EMS transport were more 70% less likely to have a delayed emergency department arrival (i.e., ≥ 3 hours from symptom onset), and were seen quicker by a physician once arriving at the emergency department (12). Studies examining differences in time to emergency department arrival by type of transport have reported between an 84% (2.4 vs. 14.8 hours) and a 30% decrease in delay time (2.85 vs 4.03 hours) (20,22).

Conversely, research examining the association between EMS response time and survival has reported mixed results. Studies including trauma and non-trauma emergency calls have observed no association between survival and response time (6, 25). However, other studies have reported contrary results (26). In studies including only trauma patients—who account for an estimated 41% of ambulance transports to emergency departments—a survival benefit with shorter EMS response time is observed (14,16,27). Similar to studies including all types of emergency calls, this association may be limited to very rapid response times (i.e., under four

minutes) (28). Feero et al. examined the mortality risk among 848 trauma patients in the Portland, Oregon area and reported that shorter response times were associated with unexpected survival, with total EMS response time (i.e., time from notification of emergency call to arrival at the hospital) nearly ten minutes shorter for survivors compared to non-survivors (14). Additionally, the time-to-scene was nearly half as long for survivors (3.5 minutes) compared to non-survivors (5.9 minutes), and was the only portion of EMS response that was significantly different between survivors and non-survivors. In the current study, respondents reported that, on average, traffic congestion increased time-to-scene by 2.5 minutes and time-to- destination (e.g., hospital) by 5.8 minutes, for a total increase of 8.3 minutes. Previous research has suggested that the risk of death for trauma patients increases by 5% for every minute between the occurrence of an injury to the arrival to a hospital (15). Extrapolating this to the current results, traffic congestion may contribute to a 48% increase in the expected mortality risk.

These studies highlight the importance of taking measures to ensure the most rapid EMS response and transport as possible. According to the survey respondents, the most beneficial impact on response time can be derived from methods that are relatively straightforward to implement. These include public education regarding how to provide accurate information to EMS services and how to react to an oncoming EMS vehicle and installation of in-vehicle technologies such as GPS and pre-emptive green devices (i.e., devices that allow change traffic lights to green as EMS vehicles approach them, ensuring an open intersection through which the vehicle can pass). Interestingly, while respondents reported that in-vehicle technologies would be highly beneficial in reducing EMS response time, less than half reported having GPS units installed in EMS vehicles, and only 15% reported having pre-emptive green devices installed in the vehicles. While no research exists regarding the effect of pre-emptive green devices on

response time, GPS devices have been shown to be effective in reducing EMS response time for emergency calls in rural areas (29). Additionally, high-occupancy lanes were reported to be equally as beneficial in decreasing response times; however, the installation of these lanes may not be feasible for many areas due to resource constraints.

Limitations

The results of the current study should be viewed in light of certain strengths and limitations. First and foremost, the current study was strengthened by the fact that, through the use of random sampling, respondents were from both urban and rural areas and travelled all types of roads during emergency calls. A variety of questions were asked regarding roadway design, in-vehicle technologies, and public education; however, we were not able to determine which would be the most effective in reducing EMS response time, which could be due to the fact that the response time variables represent estimates of response time rather than actual measurements. This study is limited by a low response rate, with only 20% of surveys returned; as a result, it is possible that the sample is not representative of the entire population of EMS responders. That is, those responding to the survey could have possibly been the most affected by delays in response time, resulting in their answers representing the most extreme circumstances of the EMS responder population. During the development of the survey, no question was included to determine the frequency in which respondents in rural areas transported patients to urban areas; however, given that the majority of respondents of the survey were from urban areas, we do not feel this significantly impacted the results. Additionally, the current study is limited by a lack of generalizability, as it is possible that the experience of EMS responders in this state is not representative of the experience in other states.

Conclusion

The results of this study suggest that factors which EMS providers believe have the greatest impact on emergency response time are those in which changes can be relatively feasible to implement (i.e., public education and in-vehicle technology). Future studies should use objective data in order to determine whether changes in this factors (e.g., interventions on how to react to oncoming emergency vehicles, installment of technologies such as GPS devices and pre-emptive green light devices) affect EMS response times.

References

1. Hu PS, Reuscher TR. Summary of Travel Trends: 2001 National Household Travel Survey. U.S. Department of Transportation. Available at: http://nhts.ornl.gov/2001/pub/STT.pdf [Accessed May 19, 2011].

2. Frumkin H. Urban sprawl and public health. *Public Health Rep*. 2002; 117(3): 201–217.

3. Frank LD, Pivo G. Impacts of mixed use and density of utilization on three modes of travel: single-occupants vehicle, transit, and walking. *Transportation Res Rec* 1995;1466:44-52.

4. Trowbridge MJ, McDonald NC. Urban sprawl and miles driven daily by teenagers in the United States. *American Journal of Preventive Medicine*. 2008;34(3):202-6.

5. Trowbridge MJ, Gurka MJ, O'Connor RE. Urban sprawl and delayed ambulance arrival in the U.S. *Am J Prev Med*. 2009;37(5):428-432.

6. Pons PT, Haukoos JS, Bludworth W, et al. Paramedic response time: does it affect patient survival? *Acad Emerg Med*. 2005;12(7):594-600.

7. O'Keeffe C, Nicholl J, Turner J, Goodacre S. Role of ambulance response times in the survival of patients with out-of-hospital cardiac arrest. *Emerg Med J*. 2010. Available at: http://www.ncbi.nlm.nih.gov/pubmed/20798090 [Accessed January 12, 2011].

8. Salisbury HR, Banks BJ, Footitt DR, Winner SJ, Reynolds DJ. Delay in presentation of patients with acute stroke to hospital in Oxford. *QJM*. 1998;91(9):635-640.

9. Wester P, Rådberg J, Lundgren B, Peltonen M. Factors associated with delayed admission to hospital and in-hospital delays in acute stroke and TIA: a prospective, multicenter study.Seek- Medical-Attention-in-Time Study Group. *Stroke*. 1999;30(1):40-48.

10. Morris DL, Rosamond W, Madden K, Schultz C, Hamilton S. Prehospital and emergency department delays after acute stroke: the Genentech Stroke Presentation Survey. *Stroke*. 2000;31(11):2585-2590.

11. Schroeder EB, Rosamond WD, Morris DL, Evenson KR, Hinn AR. Determinants of use of emergency medical services in a population with stroke symptoms: the Second Delay in Accessing Stroke Healthcare (DASH II) Study. *Stroke*. 2000;31(11):2591-2596.

12. Lacy CR, Suh DC, Bueno M, Kostis JB. Delay in presentation and evaluation for acute stroke: Stroke Time Registry for Outcomes Knowledge and Epidemiology (S.T.R.O.K.E.). *Stroke*. 2001;32(1):63-69.

13. Sampalis JS, Lavoie A, Williams JI, Mulder DS, Kalina M. Impact of on-site care, prehospital time, and level of in-hospital care on survival in severely injured patients. *J Trauma*. 1993;34(2):252-261.

14. Feero S, Hedges JR, Simmons E, Irwin L. Does out-of-hospital EMS time affect trauma survival? *Am J Emerg Med*. 1995;13(2):133-135.

15. Sampalis JS, Denis R, Lavoie A, et al. Trauma care regionalization: a process-outcome evaluation. *J Trauma*. 1999;46(4):565-579; discussion 579-581.

16. Sánchez-Mangas R, García-Ferrrer A, de Juan A, Arroyo AM. The probability of death in road traffic accidents. How important is a quick medical response? *Accid Anal Prev*. 2010;42(4):1048-1056.

17. Demetriades D, Chan L, Cornwell E, et al. Paramedic vs private transportation of trauma patients. Effect on outcome. *Arch Surg*. 1996;131(2):133-138.

18. Cornwell EE, Belzberg H, Hennigan K, et al. Emergency medical services (EMS) vs non-EMS transport of critically injured patients: a prospective evaluation. *Archives of Surgery (Chicago, Ill.: 1960)*. 2000;135(3):315-9.

19. Salisbury HR, Banks BJ, Footitt DR, Winner SJ, Reynolds DJ. Delay in presentation of patients with acute stroke to hospital in Oxford. *QJM*. 1998;91(9):635-640.

20. Wester P, Rådberg J, Lundgren B, Peltonen M. Factors associated with delayed admission to hospital and in-hospital delays in acute stroke and TIA: a prospective, multicenter study.Seek- Medical-Attention-in-Time Study Group. *Stroke*. 1999;30(1):40-48.

21. Morris DL, Rosamond W, Madden K, Schultz C, Hamilton S. Prehospital and emergency department delays after acute stroke: the Genentech Stroke Presentation Survey. *Stroke*. 2000;31(11):2585-2590.

22. Schroeder EB, Rosamond WD, Morris DL, Evenson KR, Hinn AR. Determinants of use of emergency medical services in a population with stroke symptoms: the Second Delay in Accessing Stroke Healthcare (DASH II) Study. *Stroke*. 2000;31(11):2591-2596.

23. Hutchings CB, Mann NC, Daya M, et al. Patients with chest pain calling 9-1-1 or self-transporting to reach definitive care: which mode is quicker? *Am. Heart J*. 2004;147(1):35-41.

24. Song L, Yan H, Hu D. Patients with acute myocardial infarction using ambulance or private transport to reach definitive care: which mode is quicker? *Intern Med J*. 2010;40(2):112-116.

25. Blackwell TH, Kline JA, Willis JJ, Hicks GM. Lack of association between prehospital response times and patient outcomes. *Prehosp Emerg Care*. 2009;13(4):444-450.

26. Blackwell TH, Kaufman JS. Response time effectiveness: comparison of response time and survival in an urban emergency medical services system. *Acad Emerg Med*. 2002;9(4):288-295.

27. Burt CW, McCaig LF, Valverde RH. Analysis of ambulance transports and diversions among US emergency departments. *Ann Emerg Med*. 2006;47(4):317-326.

28. Pons PT, Markovchick VJ. Eight minutes or less: does the ambulance response time guideline impact trauma patient outcome? *J Emerg Med*. 2002;23(1):43-48.

29. Gonzalez RP, Cummings GR, Mulekar MS, Harlan SM, Rodning CB. Improving rural emergency medical service response time with global positioning system navigation. *J Trauma*. 2009;67(5):899-902.

Table 1. Demographic and occupation-related characteristics of survey respondents

Demographics	
Age	
Mean ± std	40.4 ± 10.8
Range	19.0-67.0
Gender	
Male	100/110 (90.9%)
Female	10/110 (9.1%)
Race	
Black	6/110 (5.4%)
White	104/110 (94.6%)
Education	
High school or GED	7/110 (6.4%)
Some college or trade school	54/110 (49.1%)
College or trade school	49/110 (44.5%)
Occupation	
Type	
EMT	44/108 (40.7%)
Firefighter	73/108 (67.6%)
Paramedic	56/108 (51.8%)
Other	14/108 (13.0%)
Setting	
Urban	73/109 (67.0%)
Rural	36/109 (33.0%)

Table 2. Questions regarding roadway travel during response to emergency calls

	Interstates or national highways	State highways	County roads	City streets
Do you travel on the following roadways during an emergency response?	98/105 (93.3%)	96/105 (91.4%)	95/105 (90.5%)	101/105 (96.2%)
How often do you encounter traffic on the following roads during an emergency response?				
Always	11/106 (10.4%)	12/105 (11.4%)	2/100 (2.0%)	14/104 (13.5%)
Often	27/106 (25.5%)	18/105 (17.1%)	7/100 (7.0%)	26/104 (25.0%)
Sometimes	45/106 (42.4%)	48/105 (45.7%)	42/100 (42.0%)	40/104 (38.5%)
Rarely/Never	23/106 (21.7%)	27/105 (25.7%)	49/100 (49.0%)	24/104 (23.1%)
How often have you been impeded by traffic during an emergency response on the following roads?				
Always	3/103 (2.9%)	5/104 (4.8%)	2/98 (2.0%)	3/103 (2.9%)
Often	18/103 (17.5%)	14/104 (13.5%)	4/98 (4.1%)	23/103 (22.3%)
Sometimes	50/103 (48.5%)	47/104 (45.2%)	32/98 (32.7%)	37/103 (35.9%)
Rarely/Never	32/103 (31.1%)	38/104 (36.5%)	60/98 (61.2%)	40/103 (38.8%)

Table 3. Mean travel time to scene and destination by self-reported urbanality

	Overall		Urban		Rural	
	Mean ± std	**Range**	**Mean ± std**	**Range**	**Mean ± std**	**Range**
Mean travel time						
To scene	6.4 ± 3.4	1.25-22.5	5.4 ± 2.6	1.25-17.5	8.6 ± 3.9	0.0-22.5
To destination	14.9 ± 8.5	1.0-45.0	12.6 ± 7.8	1.0-45.0	19.9 ± 7.9	6.0-37.0
Mean travel time increase due to traffic congestion						
To scene	2.5 ± 2.5	0.0-15.0	2.4 ± 2.1	0.0-12.5	2.9 ± 3.2	0.0-15.0
To destination	5.8 ± 5.1	0.0-30.0	5.7 ± 5.2	0.0-30.0	6.1 ± 5.1	0.0-20.0

Table 4. Information provided by dispatch that could affect the emergency response route

	N (%)
Does your area utilize a centralized dispatch?	
Yes	85/106 (80.2%)
No	21/106 (19.8%)
Are you made aware of road construction prior to responding to an emergency	
Yes	62 (58.5%)
No	44 (41.5%)
How do you receive road construction information?	
Dispatch	65 /111 (58.6%)
Other personnel within your department	25/111 (22.5%)
Personnel from other departments	27/111 (24.3%)
Media (e.g., television, radio)	33/111 (29.7%)
Other	7/111 (6.3%)
Are you provided with traffic information by the dispatch?	
Yes	30/106 (28.3%)
No	76/106 (71.7%)
Does your department utilize Alabama Department of Transportation traffic webcams to determine if certain routes are blocked by traffic congestion?	
Yes	12/107 (11.2%)
No	95/107 (88.8%)
Would knowledge of the severity of the motor vehicle accident affect your route	
Yes	54/107 (50.5%)
No	53/107 (49.5%)
When encountering traffic congestion, have you called in a request for another unit to be dispatched?	
Yes	43/105 (40.9%)
No	62/105 (59.1%)
How often do you accurately receive information regarding the location of an emergency?	
Always	9/107 (8.4%)
Mostly	78/107 (72.9%)
Sometimes	18/107 (16.8%)
Rarely/Never	2/107 (1.9%)

Table 5. Opinions regarding information provided by callers to emergency services and dispatch

	Fully agree	Somewhat agree	No opinion	Disagree
Callers to emergency services provide accurate information regarding the location of the emergency (n=106)	7.6%	70.7%	5.7%	16.0%
Emergency 9-1-1 agencies quickly convey emergency information to dispatchers (n=106)	24.5%	55.7%	12.3%	7.5%
Dispatchers accurately convey information from callers to emergency services (n=106)	23.6%	50.9%	9.4%	16.1%
The current dispatch system used in my area allows quick response to emergency scenes (n=107)	48.6%	40.2%	4.7%	6.5%
The closest (geographically) emergency response team is sent to the scene for each emergency call	53.3%	29.0%	6.5%	11.2%
There is communication among emergency departments in my area (n=107)	37.4%	35.5%	10.3%	16.8%
Communication among emergency departments decreases response time to the scene (n=106)	31.1%	21.7%	23.6%	23.6%
The use of a centralized dispatch center helps in reducing response times by selecting the closest emergency response team to the scene (n=106)	52.8%	27.4%	15.1%	4.7%

Table 6. Opinions of experience with continuous median barriers (e.g., Jersey barriers, steel cable barriers, and rail barriers) during emergency response

	N (%)
Continuous median barriers save lives by preventing crossover motor vehicle collisions.	
Fully agree	56/105 (53.3%)
Somewhat agree	41/105 (39.1%)
No opinion	7/105 (6.7%)
Disagree	1/105 (0.9%)
Continuous median barriers increase emergency response time by preventing emergency vehicles from crossing the median.	
Fully agree	36/105 (34.3%)
Somewhat agree	41/105 (39.1%)
No opinion	14/105 (13.3%)
Disagree	14/105 (13.3%)
Have continuous median barriers ever impeded your response to an emergency?	
Yes	55/105 (52.4%)
No	50/105 (47.6%)

Table 7. Opinions of experience with roadway design during emergency response

	N (%)
Does your area currently use electronic highway signs warning of traffic-related problems?	
Yes	38/105 (36.2%)
No	67/105 (63.8%)
How well do electronic highway signs provide accurate, timely traffic-related info?	
Overall	
Well	37/96 (38.5%)
Somewhat well	50/96 (52.1%)
Not well at all	9/96 (9.4%)
Among those whose area uses electronic highway signs	
Well	16/38 (42.1%)
Somewhat well	18/38 (47.4%)
Not well at all	4/38 (10.5%)
What kind of impact do you feel that electronic signs warning you of traffic-related problems will have on emergency response times?	
Overall	
Beneficial	60/106 (56.6%)
No impact	45/106 (42.5%)
Negative	1/106 (0.9%)
Among those whose area uses electronic highway signs	
Beneficial	20/38 (52.6%)
No impact	18/38 (47.4%)
Negative	0/38 (0.0%)
What kind of impact do you feel that a designated lane for high-occupancy vehicles will have on emergency response times?	
Beneficial	74/106 (69.8%)
No impact	32/106 (30.2%)
Negative	0/106 (0.0%)

Table 8. Prevalence and impact of use of recent in-vehicle technologies

	N (%)
Which of the following devices does your department/service use in its emergency vehicles?	
GPS device	47/112 (42.0%)
Low frequency sirens	75/112 (67.0%)
Pre-emptive green device	16/112 (14.3%)
Have you had training in how to use a GPS device?	
Yes	28/47 (59.6%)
No	19/47 (40.4%)
What kind of impact do you think pre-emptive green devices have on emergency response time?	
Beneficial	87/102 (85.3%)
No impact	13/102 (12.7%)
Negative	2/102 (2.0%)
What kind of impact do you think Automatic Crash Notification systems (e.g., OnStar®) have on emergency response time?	
Beneficial	91/106 (85.9%)
No impact	12/106 (11.3%)
Negative	3/106 (2.8%)

Survey Instrument

DEMOGRAPHICS
We will begin the survey by asking a few quick questions about you. Remember that the information you put in this survey is confidential.

1. What is your age in years?

_____ years

2. What is your gender?

☐ Male ☐ Female

3. Which of the following would you say best represents your racial or ethnic group? [Mark only one]

☐ White ☐ Black ☐ Hispanic ☐ Asian

☐ American Indian ☐ Other (please specify) _____

4. What is the highest grade or year in school you completed? [Mark only one]

☐ Eighth grade or less ☐ Some high school

☐ High school or GED ☐ Some college or trade school

☐ College or higher

YOUR JOB
Questions 5-14 are in regards to your job as an EMS responder. Please do not provide information for any job in which you are not an EMS responder.

5. Describe your occupation. [Check all that apply]

☐ Paramedic ☐ Firefighter ☐ EMT

☐ Other (please specify) _____

6. In what city and county do you work?

City _____

County _____

7. Do you serve a mostly urban or rural population?

☐ Urban ☐ Rural

8. For how many emergency response departments/paramedic services do you work?

☐ 1 ☐ 2 ☐ 3 or more

9. For which fire department/paramedic service(s) do you work?

1.

2.

3.

4.

10. How many shifts do you usually work per week?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

11. How many hours per shift do you usually work?

	<9	9-12	13-16	17-20	21-24
Shift #1	☐	☐	☐	☐	☐
Shift #2	☐	☐	☐	☐	☐
Shift #3	☐	☐	☐	☐	☐
Shift #4	☐	☐	☐	☐	☐
Shift #5	☐	☐	☐	☐	☐
Shift #6	☐	☐	☐	☐	☐
Shift #7	☐	☐	☐	☐	☐

12. How many hours of sleep do you get per shift?

_____ hours

13. On a typical shift, to how many calls do you usually respond?

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 or more

14. Do you ever drive an emergency vehicle to respond to a call?

☐ No (Skip to question 24) ☐ Yes (Continue to question 15)

DRIVER QUESTIONS
Questions 15-23 will ask you about information regarding your experience as a driver of an emergency response vehicle.

15. For how many calls per shift on average are you the driver?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 or more

16. Have you ever had training in driving an emergency vehicle?

☐ No (Skip to question 22) ☐ Yes (Continue to question 17)

17. How long ago did you receive your first training?

☐ Less than 1 year ☐ 1 year ☐ 2 years ☐ 3 or more years

18. Did any part of the training include how to deal with traffic-related problems (e.g., rush-hour congestion or congestion related to a motor vehicle accident)?

☐ No (Skip to question 20) ☐ Yes (Continue to question 19)

19. How well did this training prepare you for dealing with traffic-related problems?

☐ Very well ☐ Well ☐ Somewhat well ☐ Not well at all

20. In your opinion, what could have been done in order for the training to better prepare you for traffic-related problems?

_____

_____

_____

_____

_____

_____

21. Have you ever taken a refresher course in driving an emergency vehicle?

☐ No (Skip to question 23) ☐ Yes (Continue to question 22)

22. Did the refresher course include training on how to deal with traffic-related problems?

☐ No ☐ Yes

23. Have you ever been involved in a motor vehicle accident while on a call?

☐ No ☐ Yes

If yes, were you at fault?

☐ No ☐ Yes

RESPONSE TO CALLS
Questions 24-31 pertain to travel during responses to calls. Please respond whether you were the driver or passenger of the emergency vehicle.

24. During calls, do you ever travel on the following types of roads?

	No	Yes
Interstates or U.S. Highways	☐	☐
State highways	☐	☐
County roads	☐	☐
City streets	☐	☐

25. If possible, list the names of the following road types on which you travel most often.

Interstates or U.S. Highways (e.g., I-65, I-759, US-31): _____

State highways (e.g., AL-3, AL-10, AL-17): _____

County roads: _____

City streets (only list the streets you travel the most): _____

26. During calls, how often do you travel on the following types of roads?

	Always	Most of the time	Some of the time	Rarely
Interstates or U.S. Highways	☐	☐	☐	☐
State highways	☐	☐	☐	☐
County roads	☐	☐	☐	☐
City streets	☐	☐	☐	☐

27. How often during calls do you encounter traffic congestion on the following road types?

	Always	Most of the time	Some of the time	Rarely
Interstates or U.S. Highways	☐	☐	☐	☐
State highways	☐	☐	☐	☐
County roads	☐	☐	☐	☐
City streets	☐	☐	☐	☐

28. How many minutes is your average travel time?

From dispatch to scene: _____ minutes

From scene to final destination (e.g., hospital): _____ minutes

29. How often during calls has your travel time been impeded by traffic congestion on the following road types?

	Always	Most of the time	Some of the time	Rarely
Interstates or U.S. Highways	☐	☐	☐	☐
State highways	☐	☐	☐	☐
County roads	☐	☐	☐	☐
City streets	☐	☐	☐	☐

30. What are the most frequent times of the day (up to 3) that traffic congestion has impeded your travel time on the following road types?

Interstates or U.S. Highways	From _____ AM/PM	to	_____ AM/PM
	From _____ AM/PM	to	_____ AM/PM
	From _____ AM/PM	to	_____ AM/PM
State highways	From _____ AM/PM	to	_____ AM/PM
	From _____ AM/PM	to	_____ AM/PM
	From _____ AM/PM	to	_____ AM/PM
County roads	From _____ AM/PM	to	_____ AM/PM
	From _____ AM/PM	to	_____ AM/PM
	From _____ AM/PM	to	_____ AM/PM
City streets	From _____ AM/PM	to	_____ AM/PM
	From _____ AM/PM	to	_____ AM/PM
	From _____ AM/PM	to	_____ AM/PM

31. By how many minutes on average does traffic congestion increase your travel time?

From dispatch to scene: _____ minutes

From scene to final destination (e.g., hospital): _____ minutes

DISPATCH
Questions 32-41 will ask questions regarding your experience and opinions about information received from the dispatch.

32. How much do you agree with the following statements?

	Fully Agree	Somewhat agree	No opinion	Somewhat disagree
Callers to emergency services provide accurate information regarding the location of the emergency	☐	☐	☐	☐
Emergency 9-1-1 agencies quickly convey emergency information to dispatchers	☐	☐	☐	☐
Dispatchers accurately convey information from callers to emergency services	☐	☐	☐	☐

33. Does your area currently utilize a centralized dispatch system for all emergency response departments?

☐ No ☐ Yes

34. Are you made aware of road construction prior to responding to an emergency call?

☐ No ☐ Yes

35. How do you receive road construction information? [Check all that apply]

☐ Dispatcher

☐ Other personnel within your department

☐ Personnel from other departments

☐ Media (e.g., newspapers, television, radio)

☐ Other (please specify) _____

36. Are you provided with traffic information by the dispatch?

☐ No ☐ Yes

37. Does your department utilize Alabama Department of Transportation traffic webcams to determine if certain routes are blocked by traffic congestion?

☐ No ☐ Yes

38. Would knowledge of the severity of the motor vehicle accident (e.g., number of vehicles involved, if a rollover is involved, severity of damage to the vehicles) affect your route choice?

☐ No ☐ Yes

39. How much do you agree with the following statements?

	Fully Agree	Somewhat agree	No opinion	Somewhat disagree
The current dispatch system used in my area allows quick response to emergency scenes.	☐	☐	☐	☐
The closest (geographically) emergency response team is sent to the scene for each emergency call	☐	☐	☐	☐
There is communication among emergency departments in my area	☐	☐	☐	☐
Communication among emergency departments decreases response time to the scene	☐	☐	☐	☐
The use of a centralized dispatch center helps in reducing response times by selecting the closest emergency response team to the scene.	☐	☐	☐	☐

40. How often do you accurately receive information regarding the location of an emergency? [Check one]

☐ Always ☐ Mostly ☐ Sometimes ☐ Rarely ☐ Never

41. When encountering traffic congestion, have you called in a request for another unit to be dispatched?

☐ No ☐ Yes

ROADWAY DESIGN
Questions 42-48 are in regards to roadway design, and how the design affects your response time to emergency calls.

42. How much do you agree with the following statements about continuous median barriers (e.g., Jersey barriers, steel cable barriers, and rail barriers)?

	Fully Agree	Somewhat agree	No opinion	Somewhat disagree
Continuous median barriers save lives by preventing crossover motor vehicle accidents.	☐	☐	☐	☐
Continuous median barriers increase emergency response time by preventing emergency vehicles from crossing the median.	☐	☐	☐	☐

43. Have continuous median barriers (e.g., Jersey barriers, steel cable barriers, and rail barriers) ever impeded your response to an emergency?

☐ No ☐ Yes

44. Do you feel that electronic signs warning you of traffic-related problems will have a beneficial, negative, or no impact on the timeliness of EMS response?

☐ Beneficial ☐ Negative ☐ No impact

45. Does your area currently use electronic highway signs warning of traffic-related problems?

☐ No ☐ Yes

46. How well do electronic highway signs provide accurate, timely traffic-related info?

☐ Very well ☐ Well ☐ Somewhat well ☐ Not well at all

47. Do you feel that a designated lane for high-occupancy vehicles will have a beneficial, negative, or no impact on timeliness of EMS response?

☐ Beneficial ☐ Negative ☐ No impact

48. How much cooperation exists between the following agencies and emergency services in regards to roadway design?

	Complete cooperation	Some cooperation	No cooperation
Alabama Department of Transportation	☐	☐	☐
County Department of Transportation	☐	☐	☐
City Department of Transportation	☐	☐	☐

IN-VEHICLE TECHNOLOGY
Questions 49-53 assess your experience and opinions on the use of in-vehicle technology during the course of your time as an EMS provider.

49. Which of the following devices are in use in your emergency vehicle?

(check all that apply)

☐ Low frequency sirens (e.g., Federal Signal Rumbler siren, Whelen Howler siren)

☐ GPS device

☐ Pre-emptive green light device (e.g., Opticom)

50. If you currently have a GPS device in one of your emergency vehicles, have you had any training in how to use it properly?

☐ No ☐ Yes

51. Do you feel that traffic signal pre-emptive devices (e.g., Opticom) will have a beneficial, negative, or no impact on the timeliness of EMS response?

☐ Beneficial ☐ Negative ☐ No impact

52. Do you feel that Automatic Crash Notification systems (e.g., OnStar) will have a beneficial, negative, or no impact on the timeliness of EMS response?

☐ Beneficial ☐ Negative ☐ No impact

53. <u>Using each number only once</u>, please rank the following in the order from least beneficial (1) to most beneficial (10) in regards to decreasing time of EMS response.

	1	2	3	4	5	6	7	8	9	10
Automatic crash notification (e.g., OnStar)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Cooperation between the Department of Transportation and emergency services	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
High-occupancy vehicle lane	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Lights and sirens	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Low-frequency sirens	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Pre-emptive green light devices	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Public education regarding providing information to 9-1-1 and how to reach to approaching emergency vehicles	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Synchronized traffic lights	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Traffic web cams	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

PUBLIC KNOWLEDGE

54. How much do you agree with the following statements?

	Fully Agree	Somewhat agree	No opinion	Somewhat disagree
Public education about how to provide accurate information to emergency services will help to decrease response time to emergency scenes	☐	☐	☐	☐
Public education about how to behave when an emergency vehicle approaches will help to decrease response time to emergency scenes	☐	☐	☐	☐

COMMENTS

55. We have provided this space for you to make any additional comments about your experience with traffic congestion and roadway design as an EMS provider.

_____

_____

_____

56. Thank you for taking the time to complete this survey. If you would like to enter the drawing for $1000, please enter the study ID given to you in the first page of this packet.

Study ID: _____

Domain 1
Project 3

The Role of Within-Vehicle Technology for Improving EMS Response Time

Abstract

Background – Automatic collision notification (ACN) systems, such as OnStar®, have the ability to provide public safety answering points (PSAPs) with near-instant notification regarding the occurrence and location of motor vehicle collisions (MVCs) thereby decreasing emergency medical service (EMS) response time and potentially improving patient survival.

Methods – All MVCs involving OnStar®-equipped vehicles in a seven-county area served by a regional trauma system from 2005-2009 were eligible for inclusion in this study. Two elapsed times were calculated: (1) the time from MVC occurrence to the receipt of an electronic OnStar® crash notification message at the regional trauma communications center and (2) the time from MVC occurrence to the first Public Safety Answering Point (PSAP) (i.e., 9-1-1) voice notification call. For each MVC the difference between these elapsed times was calculated. Negative difference values would be indicative of a time savings with OnStar crash notification messages arriving at PSAPs prior to the receipt of an associated 9-1-1 call.

Results – There was a statistically significant time savings associated with OnStar® ACN systems ($p<0.0001$), which was similar in magnitude for both urban (1 minute 11 seconds, $p<0.0001$) and rural (1 minute 18 seconds, $p=0.0146$) crashes.

Conclusion – ACN systems have the ability to notify PSAPs more rapidly regarding the occurrence of MVCs and as a result they may aid in decreasing EMS response time in both urban and rural settings, thereby potentially improving patient outcomes.

Introduction

It has long been observed that the majority of deaths due to trauma, including those attributed to motor vehicle collisions (MVCs), occur within the first one to two hours following injury (1-6). This observation fostered the concept of the "Golden Hour" which exemplifies the need to minimize the time between injury and initiation of treatment. Trauma centers and systems were developed around this concept and attempt to provide appropriate care in a timely manner, thereby improving survival. Research has demonstrated that this premise appears to be true (7-14).

Automatic collision notification (ACN) systems represent an opportunity to enhance prehospital trauma care by early identification of a MVC. These systems utilize collision sensors and wireless technology to detect and transmit information regarding the occurrence of a MVC, and have been recognized for their potential contribution towards preventing MVC-related morbidity and mortality (15-17). While all ACN systems provide the time and location of MVCs, advanced ACN (AACN) systems provide more detailed information including collision severity, airbag deployment, and vehicle position (e.g., overturned).

At the present time, with few exceptions (e.g., state of Idaho), ACN systems are not integrated with emergency medical services (EMS), rather the information is sent from the vehicle to ACN service providers (e.g., OnStar®) who, in turn, may, depending on the situation, contact public safety answering points (PSAPs) (i.e., 9-1-1 call centers) in the geographic area wherein the MVC occurred. Currently, this is done via phone. However, the messages received at OnStar are in electronic format, and could be forwarded to PSAPs electronically. (Note: some PSAPs are receiving a limited amount of electronic data through the Priority Access system). Thus, ACN systems have the potential to decrease EMS response time, which may be especially

important in rural areas where MVCs may go unobserved with long discovery times. To date, though several studies have quantified the potential benefit of ACN systems, these estimates have been largely theoretical and not based upon actual ACN-related MVCs (15-17). The objective of the current study is to quantify—based upon real-world ACN collisions—the potential time reductions in crash notification associated with ACN systems if ACN crash messages are sent directly to PSAPs.

Methods

Birmingham Regional Emergency Medical Services System (BREMSS)

The data for this study were collected from vehicles equipped with OnStar® that were involved in a MVC from 2005 to 2009 in the region of Alabama served by the Birmingham Regional EMS System (BREMSS). The BREMSS region consists of seven counties (Blount, Chilton, Jefferson, St. Clair, Shelby, Walker, and Winston). This region is home to approximately 1.1 million people, and encompasses approximately 4,000 square miles. The BREMSS region includes approximately 180 emergency medical service agencies, over 2,000 emergency medical technicians, and over 21 PSAPs.

While BREMSS has been in operation since the early 1970s, in October 1996 a voluntary trauma system was established within the region. Of the 24 hospitals in the region, 10 agreed to participate (18). At its inception, three of these hospitals were designated Level I trauma centers, six were Level III centers, and one was a Level IV trauma center. During the period of the current study, one of the Level I centers was downgraded to a Level III – leaving two with a Level I trauma center designation (one a pediatric trauma center and one an adult trauma center) – and the Level IV center has been upgraded to a Level III, resulting in eight region Level III trauma centers.

All trauma centers in the region are linked to the BREMSS Trauma Communications Center (TCC) which monitors hospital resource availability via secure dedicated connections. The TCC is staffed 24 hours-a-day by trained paramedics. If a patient meets trauma system triage criteria, pre-hospital personnel at the crash scene contact the BREMSS TCC and are directed to transport the patient to the most appropriate hospital, defined according to the real-time availability of trauma care resources (e.g., ICU beds, operating rooms, surgeon availability). These resources are monitored by TCC paramedics using a real-time software system called LifeTrac® with trauma centers updating the status of specific trauma care resources as they become available or unavailable. The LifeTrac® system is also utilized to collect patient information from the field including triage criteria satisfaction, demographic information (e.g., age, sex), and clinical characteristics (e.g., systolic blood pressure, respiratory rate, Glasgow Coma Scale score); this data is then electronically forwarded to the receiving hospital. The BREMSS TCC also dispatches aero-medical resources when needed; it does not dispatch ground ambulances.

BREMSS/OnStar® Integration

Since 2005 ACN and AACN messages emanating from OnStar® equipped vehicles involved in MVCs in Alabama have been sent electronically to the BREMSS TCC. These messages are forwarded to the BREMSS TCC using a data routing infrastructure developed under a joint Federal Highway Administration (FHWA) / Minnesota Department of Transportation (MnDOT) field operational test (FOT) (19). One focus of the FHWA / MnDOT FOT was to evaluate standards-based communication infrastructure and protocols for forwarding telematics data to secondary emergency response agencies such as EMS agencies.

The communications infrastructure put in place during the FHWA / MnDOT FOT automatically forwarded crashes that occurred in Alabama to the BREMSS TCC. This electronic data transmission was triggered by OnStar operators as soon as they verified the crash and need for emergency response. This verification is done by speaking with vehicle occupants using a phone connection that is automatically setup by the ACN equipment in the car. If OnStar is unable to speak with vehicle occupants, for whatever reason, they immediately forward the electronic message transfer.

OnStar® crash messages are received at the TCC by a software component called the Intelligent Information Integration Broker (I3B) that securely receives the collision message data from the OnStar® data routing infrastructure. The I3B determines if the collision has occurred in the BREMSS region and if so, uses the open standard communication protocols to send the collision message data to the BREMSS / LifeTrac® system. When a collision message is received the LifeTrac® system presents an alert and displays the ACN/AACN data. The paramedics (known as communicators) at the TCC then associate the OnStar® message with the patient record – should one exist – based on discussions with EMTs on the scene. Not all OnStar® crash messages received by the TCC will be associated with a trauma system patient, in fact, such situations are rare. This is because the majority of MVCs are minor and therefore the occupants do not warrant entry into the trauma system. It is also possible that more than one patient is involved, and thus multiple patient records are sometimes associated with an OnStar® crash. Regardless of whether or not TCC communicators link an OnStar® crash message to none, one, or more trauma system patients, they will contact via telephone the appropriate PSAP serving the region in which the MVC took place to collect PSAP timeline data. Based upon the details (e.g., time, location) of the MVC contained within the OnStar® crash message TCC

communicators obtain information regarding the time of the first voice notification call received by the PSAP associated with each OnStar® MVC. The time voice calls were received from OnStar® are also recorded, but not analyzed as part of this study.

It is important to note that neither the TCC nor the PSAPs depend upon the ACN/AACN messages for primary alerting or dispatching purposes. The routing of OnStar® crash messages to the TCC is for demonstration and evaluation purposes, with the TCC serving as a model for receipt of such messages at individual PSAPs. In accordance with the agreement with their subscribers, OnStar® continues to contact the appropriate 9-1-1 agency directly by phone to initiate the emergency medical services response when appropriate.

Variable Definitions

For each MVC, information was collected regarding the time of the MVC, time at which the BREMSS TCC received the OnStar® electronic crash message and time at which the first voice notification call was received by the PSAP (Figure 1). Specifically, the following data were collected.

- Time of MVC. For technical reasons, the time of the MVC was estimated based on when the crash message was received at the OnStar communications center. This time was estimated as one minute before when the crash message was received at the OnStar communications center. This approximation was necessary because the actual MVC time was not available to the study. One minute was found to be a good approximation of the time it takes to set up a cellular call and connect to a receiving data system (20). Since the focus of the analysis for this study was to compare the difference between when electronic

crash messages were received at the BREMSS TCC and when the first 911 voice notification call was received at a PSAP, exact crash times were not important.

- Elapsed time to voice notification. For purposes of this study, the time to first voice notification call was defined as the difference between the time of the MVC and the time the first voice notification call was received at a PSAP. Two times to voice notification variables were calculated: one including voice notification calls made by OnStar® and one excluding voice notification calls made by OnStar®. In the later case, without the OnStar voice notification call, 9-1-1 calls from the public were the primary source. Voice calls to the PSAP from OnStar were received via regular phone lines at the PSAP rather than via the dedicated 9-1-1 system.
- Time to OnStar® data. This was defined as the difference between the time of the crash and the time at which the BREMSS TCC received the electronic OnStar® data message (the time at which the data was received by the BREMSS TCC server, in the current study, is a proxy for a PSAP receiving the electronic data).

It should be noted that the time to first voice notification call was reported by the respective PSAP to BREMSS paramedics verbally. As a result, it is possible that the reported times could be biased due to non-synchronization of the clocks. To correct for this, the clock time in both locations was reported, and a correction factor was calculated as the difference between the times.

MVCs were classified as to whether they occurred in an urban or rural area using definitions supplied by the U.S. Census (21). For MVCs in which at least one involved vehicle had AACN, the vehicle's estimated change in velocity (ΔV) during the MVC was provided.

This measurement is commonly used in MVC-related research as a measure of crash severity, with values ≥ 15 miles per hour considered severe enough to cause airbag deployment.

Statistical Analysis

The median difference between time to OnStar® data arrival at the BREMSS TCC and receipt at the PSAP of the first voice notification call was calculated. The median was chosen over the mean due to the skewness of the data (i.e., the mean was greater than the median, suggesting a normal distribution was not present). To determine whether the difference was statistically different from zero (i.e., the time to OnStar® data and time to first voice notification call were equal), a sign test was used. Since it is possible that this time difference may be affected by whether the MVC occurred in an urban or rural area, median time differences were compared between urban and rural MVCs using a Wilcoxon signed ranks test.

Results

From 2005 to 2009, there were 417 MVCs in the BREMSS region involving OnStar®-equipped vehicles. Ninety-five MVCs had multiple crash data messages sent causing errors in the data, and one MVC had no crash data messages sent; these were excluded from analysis. Of the remaining 321 MVCs, 85 had an associated 9-1-1 voice notification call and 74 had an OnStar voice notification call. Forty-five had both an associated OnStar voice call and a 9-1-1 call.

The median time from collision to OnStar® data reaching the BREMSS TCC was 1-minute 36 seconds (Table 1), with a majority of OnStar® data reaching the BREMSS TCC between 1 minute 30 seconds and 1 minute 45 seconds (Figure 2). The median time to the first voice notification call (including OnStar calls) was 2 minutes 10 seconds, with a minimum of 3 seconds and a maximum of 1 hour 15 minutes 48 seconds; however, when voice notification

calls made by OnStar® were excluded, this time increased to 2 minutes 47 seconds. Interestingly, median time to first voice notification call was shorter in rural areas compared to urban areas (1 minute 54 seconds vs. 2 minutes 15 seconds) when including OnStar® calls, and longer in rural areas compared to urban (3 minutes 02 seconds vs. 2 minutes 42 seconds) when excluding OnStar® calls. These differences, however, were not statistically significant.

For all MVCs, the median time for receipt of ACN crash data was 33 seconds faster than the first voice notification call (including OnStar® voice notification calls) ($p=0.0018$) (Table 2). While this time savings was significant for urban areas (34 seconds, $p=0.0016$) and not significant for rural area (21 seconds, $p=0.4177$), there was no difference in time savings between urban and rural areas ($p=0.6013$). When OnStar® voice notification calls were excluded from the analysis, the overall time savings increased to 1 minute 13 seconds ($p<0.0001$). A similar savings was observed for both urban (1 minute 11 seconds, $p<0.0001$) and rural (1 minute 18 seconds, $p=0.0146$) areas, but again no difference in time savings between these areas was observed ($p=0.5829$). Examining the overall distribution of time savings (excluding OnStar® voice calls), a majority of MVCs were associated with measurable time savings averaging about 2 minutes (Figure 3).

Discussion

The results of the current study indicate that PSAPs could be notified regarding MVC occurrence by more than a minute (~75 seconds) if ACN systems with electronic data delivery were added to traditional methods of notification (i.e., voice calls from bystanders or passersby). This time savings is smaller (~30 seconds) when compared against current methods that include voice notification calls from ACN providers like OnStar, which is the current state of affairs (at

least for vehicles equipped with ACN equipment). This study indicates an added benefit of electronic transfer of ACN messages.

As this is the first study to examine potential time savings associated with ACN systems, there is no previous research to which to compare the current results. However, studies suggesting that the risk of death for trauma patients increases with increasing time since injury (22, 23), underscore the need to provide timely care through rapid EMS notification and response. In this manner, the current study suggests that ACN can possibly increase chances of survival by decreasing the time between injury occurrence and EMS notification. Based on a study of patients with major trauma, it is estimated that the risk of dying increases 5% for each minute that passes between injury occurrence and arrival to a hospital (24). Extrapolating this to the current study's results, ACN systems – by notifying EMS personnel quicker – can decrease the risk of death for a major trauma patient by slightly over 6%

While there was no observed difference between urban and rural MVCs in regards to time savings associated with ACN, it should be noted that a significantly increased time to EMS notification has been observed for rural MVCs in other studies. Specifically, there have been multiple studies that have reported a marked difference in mortality and EMS response times for traumas occurring in rural compared to urban areas (24-27), particularly for MVC-related injuries (28, 29). This increase in rural MVC-related mortality is due to increases in response time (30) and MVC severity (31, 32). Thus, ACN may provide an important contribution to survival for rural MVCs, particularly when there is a large delay between crash occurrence and first 9-1-1 call (e.g., a severe, unwitnessed, single-vehicle MVC that incapacitates the passengers).

ACN systems are only one of many in-car technologies that can decrease emergency response. For example, in-vehicle global positioning satellite (GPS) units now allow emergency responders to receive real-time traffic information. These systems have also been shown to help emergency responders to find their destinations more effectively, resulting in an average decrease of approximately 1 minute for response time (33). The savings are greater for rural MVCs in which the emergency responders have a longer distance to travel, resulting in a time savings of approximately 4 minutes (34). These studies, combined with the current study, suggest that the use of these technologies in emergency vehicles along with ACN systems in MVC involved vehicles may be beneficial to patient survival by increasing the ability for patients to receive timely trauma care, particularly for rural MVCs.

There are several issues to consider regarding the integration of ACN systems into pre-hospital care. If ACN messages are sent directly to PSAPs, there must be some manner of deciding whether pre-hospital care is needed. That is, the PSAP must be able to discern the severity of the MVC based on the information received from the ACN message. Currently, ACN providers such as OnStar accomplish this by providing AACN information supplemented with information obtained verbally through contact with the vehicle passengers. In first generation ACN systems, ACN messages only relayed whether an airbag deployment had occurred, and did not relay information regarding the severity of the MVC. Current AACN systems, however, can relay MVC severity information including the type of impact (i.e., front, rear, or side), measures of crash severity (e.g., ΔV), and whether rollover occurred in addition to the detection of airbag deployment. If directly sent to PSAPs, the time savings combined with the severity information provided by AACN systems can facilitate timely and appropriate emergency care to be given to injured individuals.

In addition to decreased notification times, ACN, and more importantly AACN, data may prove an important resource for predicting injury likelihood (35). The application of this data to algorithms developed to predict overall and body region specific injury likelihood may allow first responders to be better prepared to care for victims through knowledge of the type of equipment needed, and would allow hospital teams to prepare for the arrival of the injured patient.

The results of this study should be interpreted in light of certain strengths and limitations. Because of the BREMSS centralized trauma system, we were able to gather accurate information regarding the time of PSAP voice notification; however, it was not possible to obtain 9-1-1 voice notification times for a number of OnStar® MVCs. This may introduce bias, particularly if those MVCs missing 9-1-1 calls are distinct from those with 9-1-1 calls; however, crash severity (measured by ΔV) was similar for those missing and not missing 9-1-1 calls, therefore causing the estimated time savings to be biased towards the null (i.e., 0 minutes). In reporting OnStar® crash message and 9-1-1 call times, the clocks used to report the times between agencies may not have been synchronized; however, at the time of recording time data, the time given by the agency clocks at the time of data collection was recorded. The difference between the PSAP and BREMSS clocks was then used to adjust time intervals. Additionally, the current results are limited in generalizability due to the use of only General Motors vehicles and data from one region of one state.

Conclusion

ACN systems are a valuable tool in providing timely trauma care for individuals injured in MVCs. While the current study was able to report how time savings associated with ACN systems may increase the chance of survival, further studies are needed to provide a more

complete picture of the effect of ACN systems on survival following MVC-related injuries.

Table 1. Times with reporting of motor vehicle collision via ACN and 9-1-1 call by rural/urban status

	Median (Min,Max) (Minutes:Seconds)	p-value*
Time from collision to:		
Arrival of ACN data message to BREMSS TCC	**01:36 (01:00,2:25)**	
Rural area (n=95)	01:36 (01:00,02:06)	0.2691
Urban area (n=196)	01:35 (01:06,02:25)	
Receipt of first voice notification call (including voice call from OnStar)	**02:10 (00:03,1:15:48)**	
Rural area (n=40)	01:54 (00:03,1:15:48)	0.6126
Urban area (n=74)	02:15 (00:07,50:17)	
Receipt of first voice notification (excluding voice call from OnStar) (i.e., 9-1-1 call)	**02:47 (00:03,1:21:46)**	
Rural area (n=27)	03:02 (00:03,1:21:46)	0.5919
Urban area (n=58)	02:42 (00:07,50:17)	

*P-value compares median time savings between rural and urban areas, and is calculated from a Wilcoxon signed ranks non-parametric test

Table 2. Time differences associated with ACN messages* by rural/urban status

	Median (Min,Max) (Minutes:Seconds)	p-value$_0$†	p-value$_{diff}$‡
Time savings associated with ACN data messages:			
Including voice notification calls from OnStar			
Overall	**00:33 (-01:40,1:14:15)**	**0.0018**	
Rural area (n=38)	00:21 (-01:40,01:14:15)	0.4177	0.6013
Urban area (n=69)	00:34 (-01:21,48:43)	0.0016	
Excluding voice notification calls from OnStar			
Overall	**01:13 (-01:40,1:20:13)**	**<0.0001**	
Rural area (n=25)	01:18 (-01:40,1:20:13)	0.0146	0.5829
Urban area (n=53)	01:11 (-01:12,48:43)	<0.0001	

* Calculated as the difference between reception of ACN crash message at TCC and first voice notification call. A negative number denotes the ACN message arrived slower to TCC than the voice notification call

† P-value tests whether the median change is different from 0, and is calculated from a sign test for median values

‡ P-value compares median time savings between rural and urban areas, and is calculated from a Wilcoxon signed ranks non-parametric test

Figure 1. Time line denoting times of interest between crash occurrence and EMS team notification

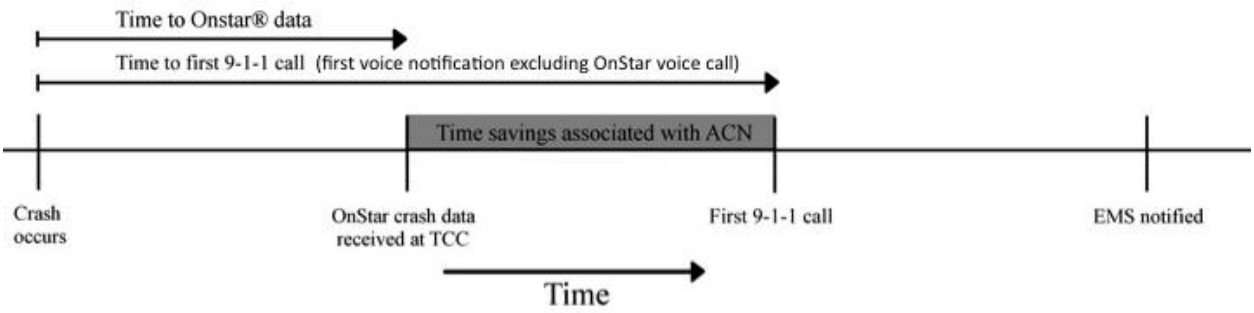


Figure 2. Frequency of time from motor vehicle collision to receipt of ACN crash data message at TCC

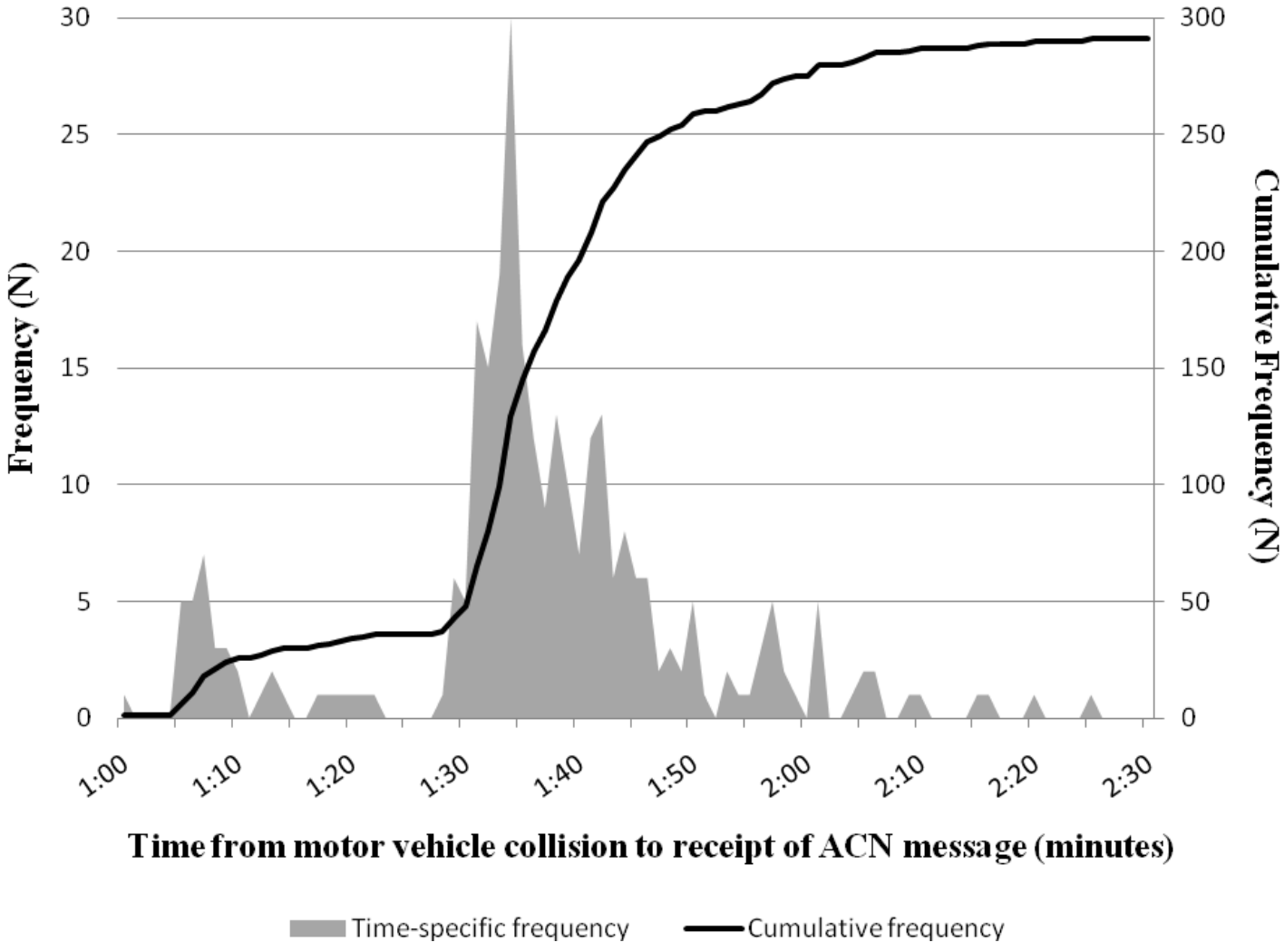
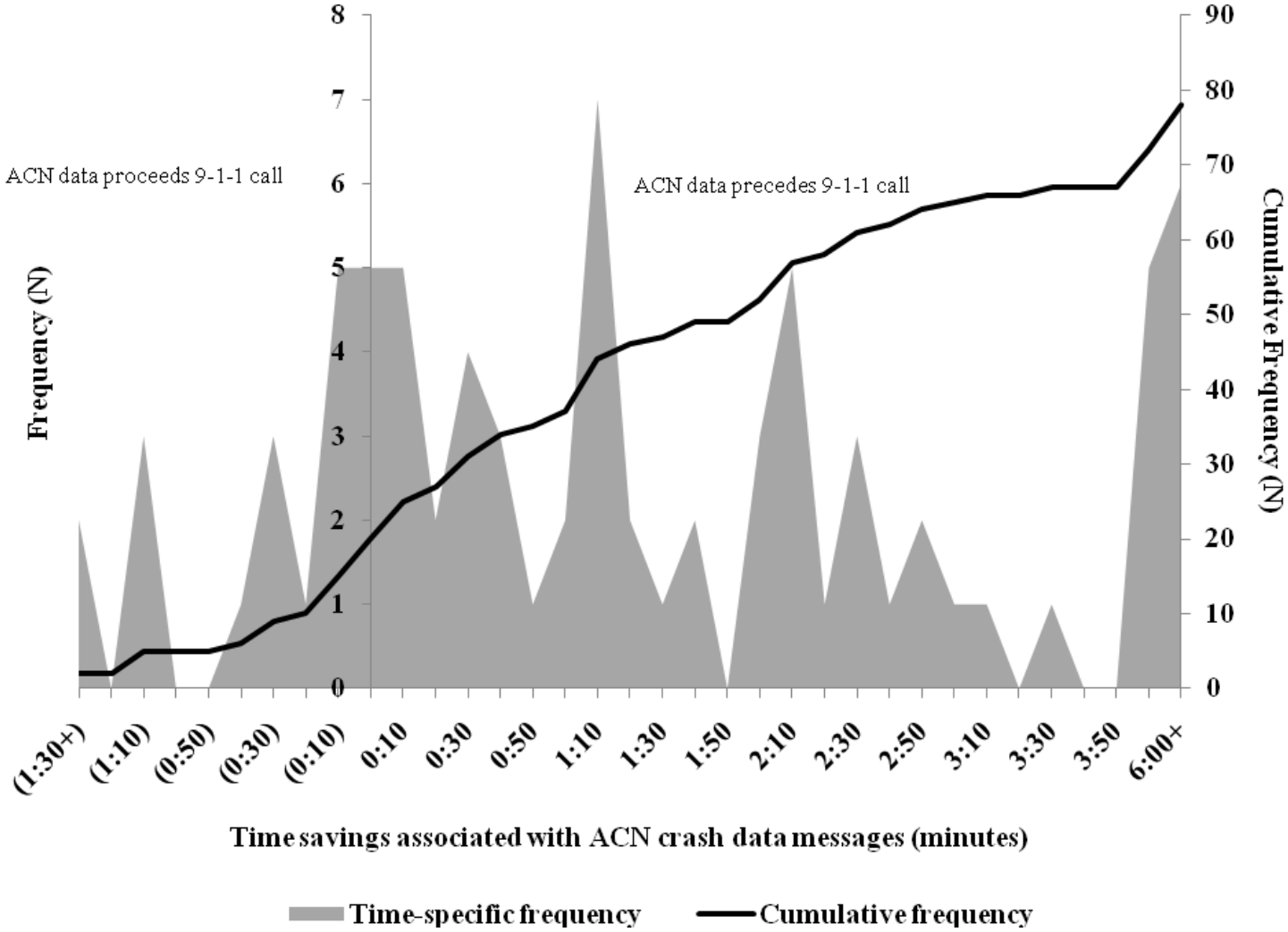


Figure 3. Distribution of time savings associated with the arrival of ACN data messages to TCC compared to first 9-1-1 voice notification (excluding voice notification calls from OnStar)



REFERENCES

1. Baker CC, Oppenheimer L, Stephens B, et al. Epidemiology of trauma deaths. *Am. J. Surg*. 1980;140(1):144-150.

2. Trunkey DD. Trauma. Accidental and intentional injuries account for more years of life lost in the U.S. than cancer and heart disease. Among the prescribed remedies are improved preventive efforts, speedier surgery and further research. *Sci. Am*. 1983;249(2):28-35.

3. Sauaia A, Moore FA, Moore EE, et al. Epidemiology of trauma deaths: a reassessment. *J Trauma*. 1995;38(2):185-193.

4. Meislin H, Criss EA, Judkins D, et al. Fatal trauma: the modal distribution of time to death is a function of patient demographics and regional resources. *J Trauma*. 1997;43(3):433-440.

5. Olson CJ, Brand D, Mullins RJ, et al. Time to death of hospitalized injured patients as a measure of quality of care. *J Trauma*. 2003;55(1):45-52.

6. McGwin G, Nunn AM, Mann JC, et al. Reassessment of the tri-modal mortality distribution in the presence of a regional trauma system. *J Trauma*. 2009;66(2):526-30.

7. Mullins RJ, Veum-Stone J, Helfand M, et al. Outcome of hospitalized injured patients after institution of a trauma system in an urban area. *JAMA*. 1994;271(24):1919-24.

8. Mullins RJ, Veum-Stone J, Hedges JR, et al. Influence of a statewide trauma system on location of hospitalization and outcome of injured patients. *J Trauma*. 1996;40(4):536-45; discussion 545-6.

9. Mullins RJ, Mann NC, Hedges JR, et al. Preferential benefit of implementation of a statewide trauma system in one of two adjacent states. *J Trauma*. 1998;44(4):609-16; discussion 617.

10. O'Keefe GE, Jurkovich GJ, Copass M, et al. Ten-year trend in survival and resource utilization at a level I trauma center. *Ann Surg*. 1999;229(3):409-15.

11. Cornwell EE, Chang DC, Phillips J, et al. Enhanced trauma program commitment at a level I trauma center: effect on the process and outcome of care. *Arch Surg*. 2003;138(8):838-43.

12. Scarborough K, Slone DS, Uribe P, et al. Reduced mortality at a community hospital trauma center: the impact of changing trauma level designation From II to I. *Arch Surg*. 2008;143(1):22-7; discussion 27-8.

13. Peleg K, Aharonson-Daniel L, Stein M, et al. Increased survival among severe trauma patients: the impact of a national trauma system. *Arch Surg*. 2004;139(11):1231-6.

14. MacKenzie EJ, Rivara FP, Jurkovich GJ, et al. A national evaluation of the effect of trauma-center care on mortality. *N. Engl. J. Med*. 2006;354(4):366-378.

15. Clark DE, Cushing BM. Predicted effect of automatic crash notification on traffic mortality. *Accid Anal Prev*. 2002;34(4):507-513.

16. Pieske O, Lob G, Messner G, et al. ACN (Automatic Collision Notification)--reducing fatalities in traffic accidents by automated accident reporting. *Kongressbd Dtsch Ges Chir Kongr*. 2002;119:546-548.

17. Lahausse JA, Fildes BN, Page Y, et al. The potential for automatic crash notification systems to reduce road fatalities. *Annu Proc Assoc Adv Automot Med*. 2008;52:85-92.

18. Abernathy JH, McGwin G, Acker JE, et al. Impact of a voluntary trauma system on mortality, length of stay, and cost at a level I trauma center. *Am Surg*. 2002;68(2):182-192.

19. Battelle, The Melcher Group. Evaluation of the MAYDAY / 911 Field Operational Test. Prepared for the Federal Highway Administration (FHWA) and National Traffic Safety Administration (NHTSA). 19 July 2006.

20. Funke, D, Bellis E, Donnelly B, Blatt A, McClellan R, and Wilson G. Automated Collision Notification (ACN) Field Operational Test Final Report. National Highway Traffic Safety Administration (NHTSA), USDOT HS 809 303. 31 October 2000.

21. Womack J. Agriculture: A glossary of terms, programs, and laws, 2005 edition. 2005. Available at: http://ncseonline.org/nle/crsreports/05jun/97-905.pdf. Accessed August 16, 2010.

22. Sampalis JS, Lavoie A, Williams JI, et al. Impact of on-site care, prehospital time, and level of in-hospital care on survival in severely injured patients. *J Trauma*. 1993;34(2):252-261.

23. Feero S, Hedges JR, Simmons E, et al. Does out-of-hospital EMS time affect trauma survival? *Am J Emerg Med*. 1995;13(2):133-135.

24. Sampalis JS, Denis R, Lavoie A, et al. Trauma care regionalization: a process-outcome evaluation. *J Trauma*. 1999;46(4):565-579; discussion 579-581.

25. Esposito TJ, Maier RV, Rivara FP, et al. The impact of variation in trauma care times: urban versus rural. *Prehosp Disaster Med*. 1995;10(3):161-166; discussion 166-167.

26. Rogers FB, Shackford SR, Hoyt DB, et al. Trauma deaths in a mature urban vs rural trauma system. A comparison. *Arch Surg*. 1997;132(4):376-381; discussion 381-382.

27. Peek-Asa C, Zwerling C, Stallones L. Acute traumatic injuries in rural populations. *Am J Public Health*. 2004;94(10):1689-1693.

28. Grossman DC, Kim A, Macdonald SC, et al. Urban-rural differences in prehospital care of major trauma. *J Trauma*. 1997;42(4):723-729.

29. Gonzalez RP, Cummings GR, Phelan HA, et al. Does increased emergency medical services prehospital time affect patient mortality in rural motor vehicle crashes? A statewide analysis. *Am. J. Surg*. 2009;197(1):30-34.

30. Gonzalez RP, Cummings G, Mulekar M, et al. Increased mortality in rural vehicular trauma: identifying contributing factors through data linkage. *J Trauma*. 2006;61(2):404-409.

31. Brown LH, Khanna A, Hunt RC. Rural vs urban motor vehicle crash death rates: 20 years of FARS data. *Prehosp Emerg Care*. 2000;4(1):7-13.

32. Muelleman RL, Wadman MC, Tran TP, et al. Rural motor vehicle crash risk of death is higher after controlling for injury severity. *J Trauma*. 2007;62(1):221-225; discussion 225-226.

33. Ota FS, Muramatsu RS, Yoshida BH, et al. GPS computer navigators to shorten EMS response and transport times. *Am J Emerg Med*. 2001;19(3):204-205.

34. Gonzalez RP, Cummings GR, Mulekar MS, et al. Improving rural emergency medical service response time with global positioning system navigation. *J Trauma*. 2009;67(5):899-902.

35. Champion HR, Augenstein JS, Blatt AJ, et al. New tools to reduce deaths and disabilities by improving emergency care: urgency software, occult injury warnings, and air medical services database. Available at: http://www.cubrc.org/centir/docs/new_tools.pdf. Accessed August 12, 2010.

Domain 1
Project 4

Potential Improvements in Medical Treatment and EMS through Real-time Injury Assessment of Occupants Involved in Crashes

Author's personal copy

Transportation Research Part C 19 (2011) 1048–1059

Contents lists available at ScienceDirect

Transportation Research Part C

journal homepage: www.elsevier.com/locate/trc

Computational methodology to predict injury risk for motor vehicle crash victims: A framework for improving Advanced Automatic Crash Notification systems

D. Bose [a,*], J.R. Crandall [a], G. McGwin [b], J. Goldman [b], J. Foster [b], P.R. Fine [b]

[a] University of Virginia, Center for Applied Biomechanics, 4040 Lewis and Clark Drive, Charlottesville, VA 22911, USA
[b] University of Alabama at Birmingham, University Transportation Center, 933 19th Street South, Birmingham, AL 35205, USA

ARTICLE INFO

Article history:
Received 25 March 2011
Received in revised form 2 June 2011
Accepted 6 June 2011

Keywords:
Computational
Occupant
Injury-risk
Restraints
Multibody

ABSTRACT

Advanced Automatic Crash Notification (AACN) systems, capable of predicting post-crash injury severity and subsequent automatic transfer of injury assessment data to emergency medical services, may significantly improve the timeliness, appropriateness, and efficacy of care provided. The estimation of injury severity based on statistical field data, as incorporated in current AACN systems, lack specificity and accuracy to identify the risk of life-threatening conditions. To enhance the existing AACN framework, the goal of the current study was to develop a computational methodology to predict risk of injury in specific body regions based on specific characteristics of the crash, occupant and vehicle. The computational technique involved multibody models of the vehicle and the occupant to simulate the case-specific occupant dynamics and subsequently predict the injury risk using established physical metrics. To demonstrate the computational-based injury prediction methodology, three frontal crash cases involving adult drivers in passenger cars were extracted from the US National Automotive Sampling System Crashworthiness Data System. The representative vehicle model, anthropometrically scaled model of the occupant and kinematic information related to the crash cases, selected at different severities, were used for the blinded verification of injury risk estimations in five different body regions. When compared to existing statistical algorithms, the current computational methodology is a significant improvement toward post-crash injury prediction specifically tailored to individual attributes of the crash. Variations in the initial posture of the driver, analyzed as a pre-crash variable, were shown to have a significant effect on the injury risk.

© 2011 Elsevier Ltd. All rights reserved.

1. Introduction

Traffic data indicated that approximately 835,000 motor vehicle occupants sustain moderate to severe injuries and another 30,000 succumb to fatal injuries each year in the United States (NHTSA, 2008). A significant portion of the fatal victims (56% in year 2002) did not receive medical treatment. Additionally, as Champion et al. (2004) described in an earlier work, there is certainty that a substantial portion of the injured victims received less than optimal care in terms of timeliness, appropriateness, or effectiveness of treatment. Towards solving that problem, researchers expect that improvements in emergency care including technological advances in automatic crash notification and injury assessment will save up to an additional thousand lives every year (Clark and Cushing, 2002; Evanco, 1999). In contrast, about 7 million people in the

* Corresponding author. Tel.: +1 434 296 7288x114; fax: +1 434 296 3453.
E-mail addresses: dbose@virginia.edu (D. Bose), jrc2h@virginia.edu (J.R. Crandall), Gerald.McGwin@ccc.uab.edu (G. McGwin), jgoldman@uab.edu (J. Goldman), Jeffrey.Foster@ccc.uab.edu (J. Foster), rfine@uab.edu (P.R. Fine).

0968-090X/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.trc.2011.06.001

Author's personal copy

US suffer minor or no injuries in motor vehicle crashes each year, of which an unknown portion are over-triaged to inappropriate hospitals and trauma centers resulting in an unnecessary burden on emergency medical resources, and health care costs (Champion et al., 2005). Thus, a more timely and accurate assessment of the injury severity and condition of the occupant involved in a motor vehicle crash could significantly improve the allocation of the emergency medical resources.

Efforts towards the assessment of injury severity sustained by motor vehicle crash victims have been helped by technologies such as Advanced Automatic Crash Notification (AACN) systems. While a standard crash notification system is capable of determining the geographic location of the crash and the severity of damage to the vehicle, an AACN can also be configured to estimate the extent of injuries sustained by the occupant, thus facilitating the appropriate Emergency Medical Services (EMS). For instance, the BMW Assist™ technology estimates the injuries sustained by passengers and transmits that information to emergency and medical care personnel (Belson, 2009). Such technologies require accurate assessment of parameters which are crash-specific, for example crash direction, severity, restraint usage, airbag deployment and vehicle properties. These data along with occupant specific information can be used to evaluate injury risk as a function of the crash using traditional statistical regression models. The most widely used algorithm is the Urgency Algorithm developed through a collaboration of researchers at the University of Miami School of Medicine, George Washington University, and the National Highway Traffic Safety Administration (NHTSA) (Malliaris et al., 1997). While the Urgency Algorithm may accurately predict the overall occurrence of severe occupant injuries (i.e., Abbreviated Injury Score(AIS) 3+ injury, AAAM, 1990), the applicability of this algorithm for the EMS and medical personnel is rather limited due to its lack of specificity regarding the injured body region(s) and it's inability to detect life-threatening occult injuries (Champion et al., 2005; Augenstein et al., 2003).

Improvements in statistical algorithms to predict the region-specific risk of injury have been conceptualized (c.f. Segui-Gomez et al., 2009). However, the limitations of regression models based on field observations must be realized. For instance, Nordhoff (2005) has discussed the potential bias and inaccuracies associated with recording injury data in the National Automotive Sampling System Crashworthiness Data System (NASS CDS) which is currently used in most injury severity assessment algorithms. Moreover, regression models described in the literature are typically linear models which fail to capture the non-linear effects or interactions between the variables in the crash environment (e.g., effectiveness of wearing a seat belt on injury outcome is dependent on the direction of the crash). This is particularly true when certain variables (like crash direction) being controlled in the model dominate the injury response. Finally, current statistical models lack details on crash information necessary for accurate and specific injury risk prediction. Future revisions to injury prediction algorithms may incorporate details such as seating positions of occupants, seat track location (proximity to the air bag), crash pulse time history, timing of air bag deployment, pattern of airbag loading, deployment of seat belt tensioning retractors, failure of the seat back, steering column integrity, and additional injury risk predictors in the occupant compartment.

Based on the known limitations of current injury predicting algorithms, an alternate computational methodology for predicting body region-specific injury risk adjusted to the specific crash scenario is presented in this study. The proposed computational framework is based on a *deterministic* approach involving reconstruction of the crash event using validated simulation models. It is envisioned that the next generation of sensor technology used for active crash protection will be able to measure or store information describing occupant anthropometry, pre-crash positioning, restraint usage, and accurate estimation of the crash pulse. The information collected during the pre-crash phase may be processed in real-time using either onboard computing facilities or by transmitting the information elsewhere. Processing of information will involve simulating the specific crash and loading scenario and using existing injury risk functions to calculate full body injury risk assessment. Additional strategies such as a pre-computed database of simulation results coupled with interpolation methods may further reduce the time required for injury risk estimation. It is anticipated that access to real-time information specific to the crash will reduce errors and inaccuracies associated with field observational studies. Also of interest is the stochastic estimation of the injury risk using parametric sensitivity analysis which would account for the errors in the sensor estimates involving the crash and occupant parameters. The output estimated by the computational methodology may be represented by probability density functions of the injury severity risk in individual body regions.

Towards the development of a conceptual computational methodology for injury risk prediction, the objectives of the study may be summarized as follows:

- To develop a computational methodology to predict body region-specific injury risk in a crash using occupant, vehicle and collision property data.
- To validate the computational methodology using real world crash data and to compare the predicted injury outcomes with results obtained using the NHTSA Urgency Algorithm and the body-region regression model developed by Segui-Gomez et al. (2009).

2. Methodology

The computational injury prediction methodology described in this study is based on a multibody simulation platform, MADYMO™ v6.3.2 (TNO MADYMO BV., Netherlands) designed to evaluate occupant dynamics in a crash loading environment. The computational methodology is developed and validated as a proof of concept focusing on representative injuries sustained by a motor vehicle driver in frontal crashes. To validate the methodology, three cases of frontal crashes of varying severities involving a unique compact-class vehicle model were obtained from the NHTSA's Crash Injury Research and

Author's personal copy

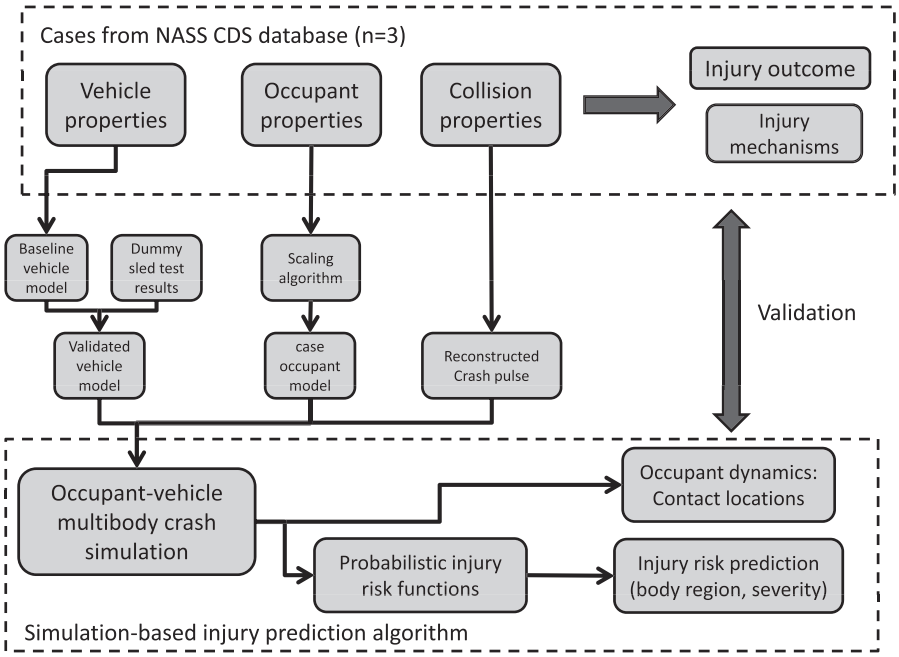


Fig. 1. Overview of the simulation-based injury prediction methodology.

Engineering Network (CIREN) database. The case information included details on the crash kinematics, occupant characteristics, usage of safety restraint systems, vehicle properties and detailed injury reports consisting of standardized injury classification, radiographic images and physician notes.

For the simulation framework, a compact-class vehicle multibody model was modified and validated to match the selected case vehicle using dummy sled test data available from the US New Car Assessment Program (USNCAP) reports. An occupant scaling algorithm was used to develop case-specific occupant models with matched anthropometric properties. To determine the crash kinematics, an equivalent barrier impact speed was determined for each of the frontal crashes using the information obtained from the vehicle Event Data Recorder (EDR). Using the validated vehicle model, scaled occupant model, standard restraint models and crash kinematics information, the crash-event was simulated in order to estimate five injury metrics-head injury criteria, neck injury criteria, chest deflection, femur force, and tibial force-for each of the crash cases. The body-region specific, probabilistic risk of injury was then calculated based on the injury metrics in conjunction with the NHTSA injury risk functions (Eppinger et al., 1999).

The whole body and region-specific injury risk estimated by the computational methodology, blinded to the true injury outcome, was then compared to the CIREN medical reports. In addition, the injury mechanism as hypothesized in the CIREN biomechanical analysis was cross-validated with the gross occupant kinematics as observed from the simulated animation. The sensitivity of estimated injury risk to variability in occupant posture and crash speeds was investigated using parametric simulations. As a comparison with existing injury predicting algorithms, the computationally predicted injury risk was compared with the results from the NHTSA Urgency Algorithm and the body-region regression model. An overall summary of the study methodology is shown in Fig. 1. Details about the CIREN cases, multibody model development and validation as well as the methodology for injury prediction is presented in the following subsections.

2.1. CIREN case description

The sampled cases in the CIREN include motor vehicle occupants seriously injured in a crash and admitted to one of six CIREN Level-1 trauma centers in the United States (NHTSA, 2002). Inclusion criteria for the CIREN database include restrictions on vehicle model year (newer than six years), serious injury (i.e., AIS 3+ or certain combinations of two AIS 2 injuries). Details available in the database regarding reconstructed crash kinematics, occupant characteristics, vehicle damage profiling, evidence-based occupant contacts, and detailed injury causation analysis determined through peer-reviewed interdisciplinary research, provides the necessary information for validating the injury predicting algorithms. For the purposes of this study, occupants involved in representative frontal crashes were selected from the CIREN database using the following criteria:

1. Case occupant must be in a single-event frontal crash (principal direction of force between 11 o'clock and 1 o'clock) involving a maximum of two vehicles.
2. Case vehicle must be equipped with the EDR system.
3. Case vehicle type to include only passenger cars, sport utility vehicles, light trucks and mini vans.

Author's personal copy

Table 1
Description of selected CIREN cases.

	Case 1	Case 2	Case 3
Crash type	Frontal	Frontal	Frontal
PDOF (deg)	340	350	350
Delta-V (km/h)	35	68	18
Opposing impactor	Vehicle	Vehicle	Concrete barrier
Airbag status	Deployed	Deployed	Deployed
Vehicle class	Compact car	Compact car	Compact car
Vehicle model year	1999	2002	2001
Vehicle curb weight (kg)	1315	1214	1188
Occupant role	Driver	Driver	Driver
Occupant sex	Female	Female	Female
Occupant age (years)	43	75	75
Occupant height (m)	1.61	1.75	1.68
Occupant weight (kg)	158	87	48
Seatbelt usage	Used	Used	Used
Whole body MAIS	3	4	3

PDOF and MAIS are abbreviations for Principal Direction of Force in the crash and the Maximum Abbreviated Injury Scale, respectively.

4. Case Occupant must be an adult (16 years or older) in the role of a driver during the crash.
5. Case occupant must be restrained by a 3-point safety belt during the crash and the airbag must have deployed as a result of the impact.

The search yielded 62 crash cases involving 29 different vehicle models (descriptive statistics listed in Appendix A). A compact-class vehicle model with highest frequency ($n = 11$) among the selected cases was chosen to represent the standard vehicle model. Further, three crash cases involving significantly different crash severities (range of barrier impact speed between 18–72 km/h) were chosen for the validation of injury prediction using the computational method. Details about the three selected CIREN cases are listed in Table 1.

2.2. Multibody crash simulation framework

2.2.1. Occupant model

A multibody representation of a 50th percentile adult male Hybrid-III dummy, available in the database of MADYMO™ (v6.3.2), was modified to represent the case occupants involved the CIREN crashes (TNO, 2006a). The multibody occupant model used in this study comprises of 37 ellipsoidal rigid bodies connected through non-linear joints. The non-linear joint properties, contact characteristics, and physiological range of motion have been derived through various component level validation tests (TNO, 2006b). The MADYMO™ model has been validated for multi-directional loading environment (frontal and lateral impacts) using biofidelic requirements for rating numerical models and mechanical test surrogates (de Lange et al., 2005).

A case specific occupant model was developed by scaling the anthropometric measures of the 50th percentile adult occupant model based on the principles of geometric scaling(Langhaar, 1951). The reference values for scaling the occupant stature (Occ_s) and mass (Occ_m), correspond to the stature and mass of a 50th percentile adult male and were obtained from an US-based, human anthropometric database (Gordon et al., 1988). Using mean (standard deviation) values of 1.757 m ($\sigma = 0.071$ m) and 77.99 kg ($\sigma = 11.04$ kg) for the normal distribution of population stature and mass, respectively, values of Occ_s and Occ_m for each occupant model were evaluated as a function of their percentile rank in the population. For geometric scaling of the occupant models to represent different percentile ranks of stature and mass, the length scaling factors in three directions and mass scaling factor were determined based on equivalent length scaling in the two non-axial directions (x and y directions in the model) and mass density were invariant across the population (Eq. (1)). Using the software MADYSCALE™, occupant models with different values of Occ_s and Occ_m were developed using the length and mass scaling factors estimated from the anthropometry database, and assuming that the length and mass scaling factors are uniformly applicable to all body regions of the adult human model. The adopted methodology for developing numerical human models based on the dimensional scaling principle has been previously reported by Rodarius et al. (2007).

$$\lambda_{lz} = \frac{Occ_s}{Occ_{sref}}; \quad \lambda_m = \frac{Occ_m}{Occ_{mref}}; \quad \lambda_{lx} = \lambda_{ly} = \sqrt{\frac{\lambda_{lx}}{\lambda_{lx}}} \tag{1}$$

2.2.2. Vehicle model

A simplified multibody model representing a compact passenger car developed by NHTSA was used as the baseline vehicle model in this study (Fig. 2). The front end of the vehicle model included a simplified rigid body representation of the front

Author's personal copy

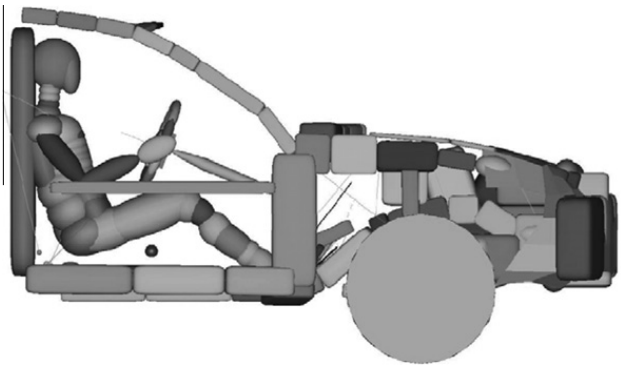


Fig. 2. Multibody model of the occupant–vehicle system.

bumper, front wheel and axle system, hood and the critical components of the engine compartment. The driver compartment consisted of the windshield, A-pillar, B-pillar, steering column and wheel, instrumentation panel, firewall, toe-pan, knee bolster, and seat structure. The occupant safety system was modeled using a finite element (FE) model of the driver-side frontal airbag and a force-limited retractor and a 3-point FE belt system. The properties of the restraint system were obtained from standard values as provided in the MADYMO™ database and further optimized during vehicle model validation. The modeling of the vehicle is designed to provide reasonable crash kinematics to the occupant compartment in moderate to severe frontal crashes.

To reconstruct each of the crash cases, the baseline vehicle model was modified to represent the unique compact-class vehicle model. The modification included matching the geometrical dimensions of the driver compartment in the baseline model to an exemplar vehicle model. The geometrical dimensions adjusted in the vehicle model included the A-pillar curvature, windshield angle, steering column angle, and steering wheel geometry. The geometrical dimensions were obtained from a US NCAP report describing frontal barrier crash tests involving the specific compact-class vehicle model.

Besides geometrical dimensions certain parameters of the vehicle model were critical for the accuracy of the simulated crash dynamics but were unknown for the model used in this study. The injury predictability of the unknown explanatory variables was determined based on stepwise regression of the multivariate model. The predictor variables with significant effect on the injury outcome ($p < 0.05$) included airbag trigger time and friction, belt friction and stiffness, seat friction, belt load-limiting value, knee bolster stiffness and friction and shoe friction. The results of the US NCAP dynamic tests were used to optimize the values of the parameters in the vehicle model. To accomplish this, a parametric simulation was set up using the vehicle model and the 50th percentile Hybrid-III male dummy model to simulate a 56km/h frontal barrier impact test.

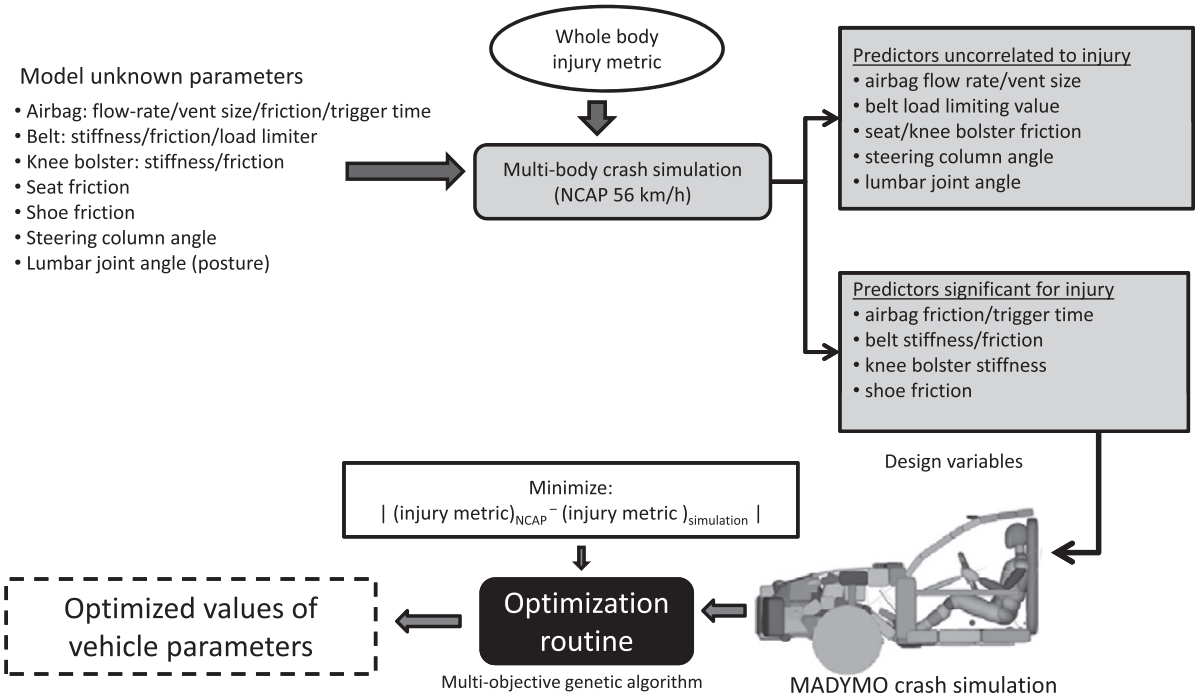


Fig. 3. Methodology to optimize unknown parameters of the vehicle model.

Author's personal copy

The unknown variables to be determined through the optimization routine included the vehicle parameters described previously. The objective defined for the optimization routine was to minimize the difference between the aggregated injury metrics measured during the US NCAP test and the same values predicted in the simulation. The aggregated injury metrics was the sum of measured head injury criteria, neck injury criteria, chest deflection and femur force. A multi-objective genetic algorithm was used in the optimization routine which included a initial randomized set of 20 designs mutated over 30 generations (a total of 600 simulations). The overview of the optimization routine is shown in Fig. 3.

2.3. Injury prediction

Using the validated multibody vehicle model, case-specific occupant model, and the barrier impact speed as reported in the CIREN database, a frontal crash simulation was performed in MADYMO™ for each of the three CIREN cases. In the standard run, the posture of the occupant model was oriented in a standard posture as described in the US NCAP procedures. Using post-simulation results the injury metrics in the five body regions-head, neck, chest, thigh and leg-were estimated and converted to injury risk using functions described in Appendix B. The injury risk estimation was blinded to the actual injuries observed in the CIREN cases. In addition to the standard, two additional simulation runs were done with varying impact speeds and two others with varying initial posture of the occupant. The variation in the impact speed included two additional barrier impact speeds, 10% of the originally estimated speed. For postural orientation, two additional postures-one leaning forward and second reclined back-were used to simulate each of the cases. The simulations were performed on a standard personal computer (Intel Core 2 Duo™ 3Ghz processor).

3. Results

3.1. Injury risk prediction

Simulation results for each crash case provided reasonable estimates for overall occupant kinematics and interaction with the restraint systems (Fig. 4). The evidence-based occupant contact data, available in the CIREN data, were matched to corroborate the simulation kinematics. Region-specific injury risks predicted by the computation methodology and comparisons with actual values of maximum AIS recorded in that body region are shown in Fig. 5. In CIREN case 1, three AIS 2+ injuries were noted on the right lower extremity with probable causation attributable to toe-pan intrusion (injury details listed in Appendix C). Although not accounting for realistic toe-pan intrusion, the simulation results indicated loading of the leg/foot complex by the floor structure. Consistent with the clinical findings, the simulation results indicated a 100% probability of AIS 2+ injury to the leg/foot region. Low severity injuries to the head, neck and chest region were suggested by a lower than 30% probability for the risk of AIS 2+ and AIS 3+ injuries in these regions.

Case 2 was a high crash severity case (Δv 68 km/h). The most severely injured body region for this case was the thorax which sustained two AIS 4 injuries: rib fractures as well as several AIS 3 injuries to the extremities. Case documents lead to the conclusion that occupant contact with the steering wheel rim, seat belt webbing/buckle, knee bolster/instrumentation panel and portions of the floor was responsible for most of the significant injuries. By comparison simulation results predicted a high risk for head, chest and lower extremity injuries, which is in agreement with the observed injuries.

Case 3 was a low velocity crash case (Δv 18 km/h) in which occupant sustained severe upper extremity, fibula fracture and the lumbar spine injuries. Unfortunately, none of the five injury metrics targeted the upper extremity or the lumbar spine region and therefore, the risk or probability of injury predicted by the computational methodology was relatively low (less than 30% for either region).

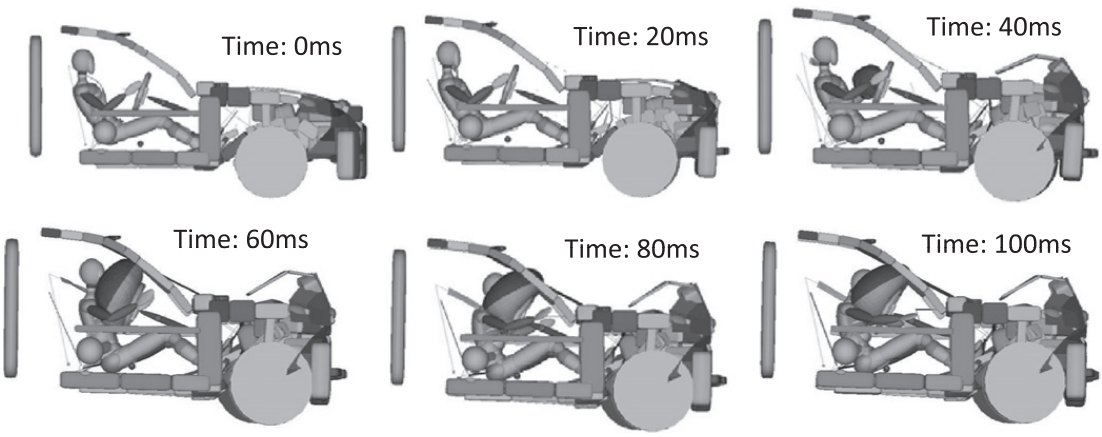


Fig. 4. Simulation snap-shots at 20 ms interval.

Author's personal copy

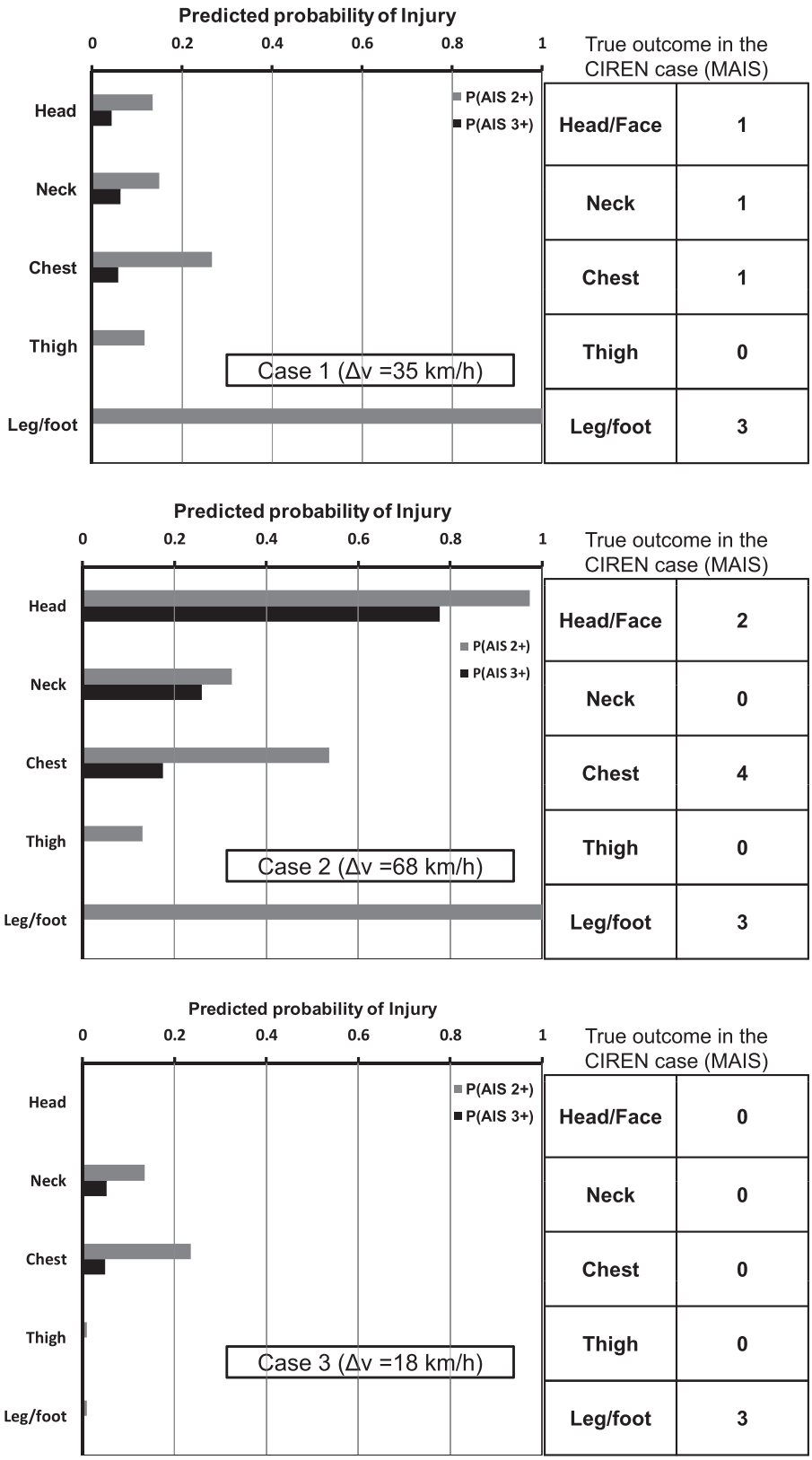


Fig. 5. Injury risks for the CIREN cases predicted by the computational methodology.

3.2. Sensitivity to posture and impact speed

The effect of impact speed and initial driving posture on the region specific injury risk is shown in Fig. 6. For impact at 35 km/h, the risk of injury to all body regions except the chest was greater for occupants who were reclining or leaning

Author's personal copy

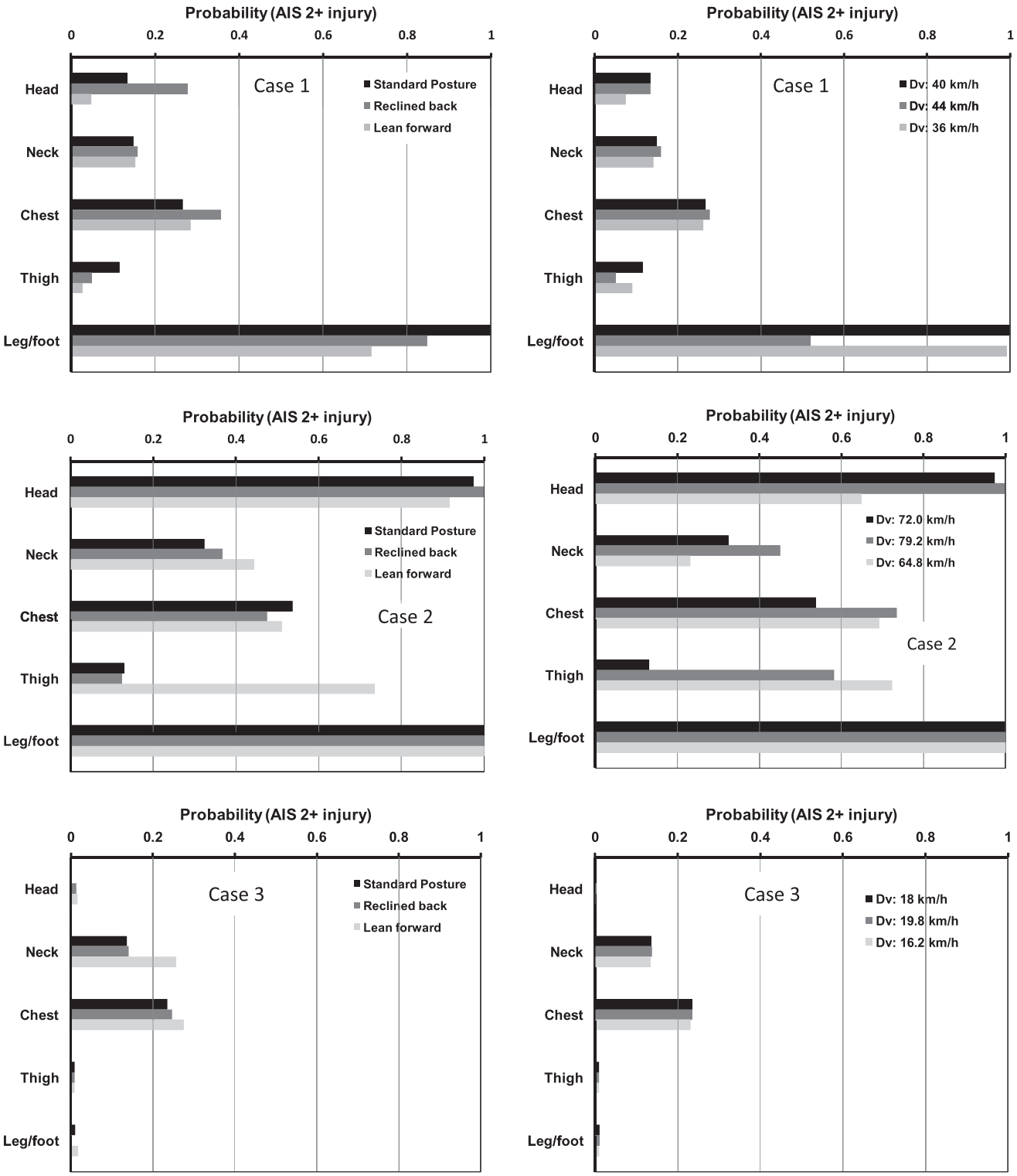


Fig. 6. Sensitivity of injury risks to initial posture and impact speed.

forward. This finding tends to confirm an overall impression that seat belt-airbag systems perform optimally when the occupant is in the standard driving posture. In general the reclined posture posed a higher threat for the head/neck region while occupants leaning forward at the moment of the impact were at increased risk for lower extremity injuries. A ten percent variation in impact speed was associated with a marginal effect on the risk of upper body injuries. For example, in Case 2 (high impact speed) postural variation yielded results similar to a crash of moderate severity, although the probability of lower extremity injuries increased to 100%. In low impact speed conditions (Case 3) the variation in injury risk was minimal when initial posture or impact speed was varied by 10%. The exception was a marginally higher risk of chest and neck injuries if the occupant was leaning forward when compared to an occupant in a standard or reclining posture.

Author's personal copy

Table 2
Comparison of injury risk outcomes as predicted by NHTSA Urgency algorithm, body-region regression algorithm, computation methodology, and the true injury outcome recorded in CIREN database.

Body region	CIREN injury	Urgency	Body-region regression	Computation method	
	MAIS	P(MAIS 3+)	P(MAIS 3+)	P(MAIS 2+)	P(MAIS 3+)
Case 1					
Whole body	3	0.22	0.10	–	–
Head/face	1	–	0.01	0.13	0.04
Neck	1	–	–	0.15	0.06
Chest	1	–	0.00	0.27	0.06
Thigh	0	–	0.05	0.12	–
Leg/foot	3	–	0.05	1.00	–
Case 2					
Whole body	4	0.96	0.87	–	–
Head/face	2	–	0.86	1.00	1.00
Neck	0	–	–	0.37	0.32
Chest	4	–	0.01	0.48	0.14
Thigh	0	–	0.03	0.13	–
Leg/foot	3	–	0.03	1.00	–
Case 3					
Whole body	3	0.16	0.16	–	–
Head/face	0	–	0.88	0.01	0.01
Neck	0	–	–	0.14	0.06
Chest	0	–	0.00	0.25	0.05
Thigh	0	–	0.00	0.01	–
Leg/foot	3	–	0.00	0.00	–

The injury risk is expressed in terms of probabilities denoted by P( ).

3.3. Comparison with regression model results

A comparison of estimated injury risk based on statistical models with injury risk based on computational methodology is presented in Table 2. The NHTSA Urgency Algorithm as evaluated in this study has shown better predictive accuracy for high impact speed crashes then for low speed crashes. While the body-region regression model showed consistent results for *whole body risk estimates*, it provided comparatively poor estimates for region-specific injury risk. Compared to the two statistical approaches, the estimates obtained from the multibody model appear more consistent with the actual injury data.

4. Discussion

While advances in AACN technology provide opportunities for improving both the quality of emergency medical care as well as clinical outcomes of motor vehicle crash victims, there is also enormous potential for improving the existing framework of immediate injury assessment and identification of life threatening conditions. Towards that goal, this study focuses on the development and validation of a computational methodology for post-crash injury risk assessment Compared to existing statistical regression techniques, the computational algorithm for stochastic injury prediction provided greater specificity regarding pre-crash conditions (e.g., occupant posture) as well as better information about the vehicle kinematics evolving during the crash. Validation results involving three real-world frontal crashes indicated better injury prediction by the computational methodology when compared to existing algorithms, such as the Urgency Algorithm.

For example, in the frontal crash loading environment, the study compared occupant interaction with vehicle components between the simulation results and physical contact evidence reflected in the CIREN data. It must be noted that the intrusion of the vehicle interior components was not simulated accurately due to lack of sufficient modeling details. Additional modeling efforts are needed to accurately represent vehicle intrusions which may contribute to increase the injury-risk being analyzed. However, the data confirmed that physical contact evidence as well as the gross kinematics of the driver were simulated appropriately with the methodology. Subsequently, the computational methodology based algorithm was able to identify the risk of injuries in regions of the head, chest and the lower extremities that were frequently contacted.

The modeling approach as evaluated in this study provides a stochastic estimate of the injury outcome taking into account the variability in the estimates of the crash properties. The conceptual framework for an AACN system assumes that specific vehicle properties and restraint usage are known apriori to the crash; however, crash kinematics and occupant characteristics may only be determined with lesser degree of certainty as probabilistic estimates. It is hypothesized that with real-time monitoring of sensor data during the progression of the crash, the error in the final estimates of the crash and occupant properties may be reduced but their variance is important for the injury risk prediction. A stochastic estimation approach allows to incorporate the variance in the input parameters and determine the sensitivity of the injury outcome to such parameters. To demonstrate this, the sensitivity of injury risk to initial posture and impact speeds was evaluated using parametric simulations. Results indicated that both parameters, initial posture and crash speed, had a substantial effect on the region-specific risk of injury for the given crash test conditions.

Author's personal copy

The computational methodology developed in the study has been demonstrated as a *proof of concept* using a limited number of crash cases. However, one of the major short comings was the inability of the simplified modeling approach to accurately estimate the risk of injury in certain real-world conditions. The injury metrics and the injury risk functions used in the methodology are based on metrics applicable in dummy tests. Additionally, the injury metrics in the present form covers only five body regions and are representative of injury mechanisms typically associated with frontal crash loading. Further, the occupant model used in the methodology has been specifically validated for high-speed (around 56 km/h) frontal impact test conditions and is unable to represent a broader spectrum of injuries due to biofidelic limitations. Thus, the occupant model and the injury risk estimation technique is not applicable for all crash conditions, representing only a small portion of overall real world crash scenarios. For example, to evaluate injury risk in a rollover crash at a similar level of accuracy will require: (1) significant changes to the occupant model that incorporate substantially increased focus on the vertebral column; along with (2) a precise definition of injury metrics and injury risk functions specific to spinal injuries. Other limitations of the computational methodology include its current inability to incorporate important occupant characteristics properties such as age, sex, pre-crash driving behavior including but not limited to muscle bracing. Additionally, because of the simplifications incorporated in the vehicle model, kinematics of the crash evaluated in a 2-D plane, and other forms of variability related to real world crash conditions have not been captured by this simulation approach.

Overall, an AACN framework with the capacity to identify life threatening injuries occurring in different body regions as well as occult, soft tissue injuries requires precise understanding of crash loading and its interaction with the occupant in all body regions. Clearly, both statistical regression and computational methodology have their relative merits as well as their inherent limitations. From the results derived in this study, it is speculated that a computational methodology may have a greater potential for developing injury risk estimation algorithms most suitable for AACN applications. Anticipated advances in sensor technology involving occupant-adaptive restraints and stability control devices leads credence to the belief that the accuracy of information required for injury prediction will be significantly improved in the near future. For example, an optical scanning technique to estimate pre-crash occupant head position for optimal restraint and minimized injury is already under research. Data provided by such sensors will greater improve the accuracy of simulation predictions for head contact and associated injury risk.

5. Conclusion

A computational methodology for predicting the risk of crash-related injuries was developed and validated. A significant improvement in predicting the risk of real-world frontal crash injuries compared to existing algorithms was demonstrated in the study. Admittedly, the scope of the validated computational methodology is presently limited to specific crash orientations and severity; however, advanced biofidelity of human models coupled with real-time computational strategies may soon realize the potential of AACN-based applications in real-world motor vehicle crashes.

Acknowledgements

This research was supported by Grant No. DTRT06-G-0048 from the US Department of Transportation's Research and Innovative Technology Administration to the University of Alabama at Birmingham University Transportation Center. The authors would like to acknowledge the help provided by Rafael Heredero Ordoyo at the European Center for Injury Prevention for providing details on the Multibody regression model.

Table A.1
Description summary of 62 CIREN crash cases filtered through the selection criteria defined in Section 2.1.

Variables	Units	Count	Mean/median[1]	Stdev.
Occupant age	Year	–	43	14
Occupant sex	(Male)	31	–	–
Occupant stature	m	–	1.68	0.19
Occupant mass	kg	–	85.3	35.6
Seating position	(Driver)	43	–	–
	(Front pass.)	16	–	–
Vehicle model year*	Year	–	2001	–
Vehicle type	(Car)	42	–	–
	(SUV)	8	–	–
	(Pick-up truck)	7	–	–
	(Mini van)	4	–	–
Vehicle curb mass	kg	–	1522	313
Crash delta-v	km/h	–	48.1	17.5
MAIS	(3)	45	–	–
MAIS	(4)	14	–	–
MAIS	(5)	3	–	–

Standard Deviation, front passenger, Sports Utility Vehicle, Maximum Abbreviated Injury Score, are abbreviated as Stdev., Front pass., SUV, MAIS, respectively.

[1] For binary variables, *Count* gives the sample size corresponding to the value noted in parenthesis under *Units*.

Author's personal copy

Appendix A. Descriptive statistics for CIREN cases

See Table A.1.

Appendix B. Injury risk prediction

To provide probabilistic estimates of region-specific injury risk as a function of their severities, NHTSA has published injury criteria based on statistical regression models (Eppinger et al., 1999). The statistical regression models define the relationship between variables measured by the injury metrics (e.g., force, acceleration, deflection) during an experimental test and the severity of concomitant post-test injuries, frequently classified for severity according to the Abbreviated Injury Scale (AIS) nomenclature (AAAM, 1990). The analytical closed form expression for the injury risk functions applicable to the five standard injury metrics are summarized below. To obtain the probability of sustaining an injury for a specific AIS level, the probabilities of sustaining injuries for two successive levels of injury and higher were subtracted.

- Head injury risk function as a function of HIC NHTSA (1997)

$$P(AIS \geqslant 1)_{head} = \frac{1}{1 + e^{(1.54+\frac{200}{HIC})-0.0065HIC}} \tag{B.1}$$

$$P(AIS \geqslant 2)_{head} = \frac{1}{1 + e^{(2.49+\frac{200}{HIC})-0.0048HIC}} \tag{B.2}$$

$$P(AIS \geqslant 3)_{head} = \frac{1}{1 + e^{(3.39+\frac{200}{HIC})-0.0037HIC}} \tag{B.3}$$

$$P(AIS \geqslant 4)_{head} = \frac{1}{1 + e^{(4.90+\frac{200}{HIC})-0.0035HIC}} \tag{B.4}$$

$$P(AIS \geqslant 5)_{head} = \frac{1}{1 + e^{(7.82+\frac{200}{HIC})-0.0043HIC}} \tag{B.5}$$

$$P(AIS \geqslant 6)_{head} = \frac{1}{1 + e^{(12.24+\frac{200}{HIC})-0.0057HIC}} \tag{B.6}$$

- Neck injury risk function as a function of Nij Eppinger et al. (1999)

$$P(AIS \geqslant 2)_{neck} = \frac{1}{1 + e^{(2.054-1.195Nij)}} \tag{B.7}$$

$$P(AIS \geqslant 3)_{neck} = \frac{1}{1 + e^{(3.227-1.969Nij)}} \tag{B.8}$$

$$P(AIS \geqslant 4)_{neck} = \frac{1}{1 + e^{(2.693-1.195Nij)}} \tag{B.9}$$

$$P(AIS \geqslant 5)_{neck} = \frac{1}{1 + e^{(3.817-1.195Nij)}} \tag{B.10}$$

- Thorax injury risk function as a function of chest displacement Eppinger et al. (1999)

$$P(AIS \geqslant 2)_{thorax} = \frac{1}{1 + e^{(1.87-0.044cdisp)}} \tag{B.11}$$

$$P(AIS \geqslant 3)_{thorax} = \frac{1}{1 + e^{(3.71-0.047cdisp)}} \tag{B.12}$$

$$P(AIS \geqslant 4)_{thorax} = \frac{1}{1 + e^{(5.09-0.047cdisp)}} \tag{B.13}$$

$$P(AIS \geqslant 5)_{thorax} = \frac{1}{1 + e^{(8.83-0.046cdisp)}} \tag{B.14}$$

- Upper leg injury risk function (Eppinger et al., 1999)

$$P(AIS \geqslant 2)_{upperleg} = \frac{1}{1 + e^{(5.79-0.519femurforce)}} \tag{B.15}$$

- Lower leg/ankle injury risk function (Funk et al., 2002)

$$P(AIS \geqslant 2)_{lowerleg} = e^{-e^{4.99ln(tibiaforce)-45.412}} \tag{B.16}$$

Appendix C. Injury Details for Selected CIREN cases

See Table C.1.

Author's personal copy

Table C.1
Description of injuries sustained by the case occupant in the three CIREN cases.

	Case 1	Case 2	Case 3
Head	None	Scalp cont.(1)	None
Face	Skin abrsn.(1)	Orbit fx.(2) Orbit fx.(2)	None
Neck	Skin abrsn.(1)	None	None
Thorax	Skin abrsnn.(1)	Bilat. lung cont.(4) Rib fx.(4) Diaphragm lac.(3) Sternum fx.(2)	None
Abdomen	Skin abrsn.(1)	Spleen lac.(2) Skin cont.(1)	None
Spine	None	Lumbar spine fx.(2)	Lumbar spine fx.(3)
Upper extremity	Skin cont.(1)	Radius fx.(3) Ulna fx.(3)	Radius fx.(3) Metacarpus fx.(3)
Lower extremity	Tibia fx.(3) Fibula fx.(2) Ankle disloc.(2) Skin cont.(1)	Pubic symphysis sep.(3) Sacroilium fx.(3) Tibia fx.(3) Pelvis fx.(2) Fibula fx.(2) Calcaneus fx.(2)	Fibula fx.(3)

The number in parenthesis indicates AIS level. Abrasion, contusion, dislocation, bilateral, laceration, seperation and fracture are abbreviated as abrsn., cont., disloc., bilat., lac., sep. and fx., respectively.

References

AAAM, 1990. The abbreviated injury scale – 1990 revision (ais 90). Published report, Association for the Advancement of Automotive Medicine.

Augenstein, J., Perdeck, E., Stratton, J., Digges, K., Bahouth, G., 2003. Characteristics of crashes that increase the risk of serious injuries. Annual Proceedings/Association for the Advancement of Automotive Medicine 47, 561–576.

Belson, K., January 2009. Injury report from the car. New York Times.

Champion, H.R., Augenstein, J., Blatt, A.J., Cushing, B., Digges, K.H., Siegel, J.H., Flanigan, M.C., 2004. Automatic crash notification and the urgency algorithm: its history and use. Topics in Emergency Medicine 26 (2), 143–156.

Champion, H.R., Augenstein, J.S., Blatt, A.J., Cushing, B., Digges, K.H., Flanigan, M.C., Hunt, R.C., Lombardo, L.V., Siegel, J.H., June 2005. New tools to reduce deaths and disabilities by improving emergency care: urgency software, occult injury warnings and air medical services database. In: The 19th International Technical Conference on the Enhanced Safety of Vehicles (ESV).

Clark, D.E., Cushing, B.M., 2002. Predicted effect of automatic crash notification on traffic mortality. Accident Analysis and Prevention 34, 507–513, iD: 558; ID: 2539; Injury – M/V – Others – Effectiveness; RP: IN FILE.

de Lange, R., van Rooij, L., Mooi, H., Wismans, J., 2005. Objective biofidelity rating of a numerical human occupant model in frontal to lateral impact. Stapp Car Crash Journal 49, 457–479.

Eppinger, R., Sun, E., Bandak, F., Haffner, M., Khaewpong, N., Maltese, M., Kuppa, S., Nguyen, T., Takhounts, E., Tannous, R., Zhang, A., Saul, R., 1999. Development of improved injury criteria for the assessment of advanced automotive restraint systems – ii. Technical report.

Evanco, W.M., 1999. The potential impact of rural mayday systems on vehicular crash fatalities. Accident; Analysis and Prevention 31 (5), 455–462, lR: 20041117; JID: 1254476; ppublish.

Funk, J.R., Crandall, J.R., Tourret, L.J., MacMohan, C.B., Bass, C.R., Patrie, J.T., Khaewpong, N., Eppinger, R., 2002. The axial injury tolerance of the human foot/ankle complex and the effect of achilles tension. Journal of Biomechanical Engineering 124 (1).

Gordon, C.C., Churchill, T., Clauser, C.E., Bradtmiller, B., McConville, J.T., Tebbetts, I., Walker, R.A., 1988. Anthropometric survey of US army personnel: methods and summary statistics. Technical report.

Langhaar, H.L., 1951. Dimensional Analysis and Theory of Models. John Wiley & Sons.

Malliaris, A.C., Digges, K.H., DeBlois, J.H., 1997. Relationship between crash causalities and crash attributes. In: SAE Technical Paper Series-International Congress and Exposition.

NHTSA, 1997. Final regulatory evaluation, actions to reduce the adverse effects of air bags, fmvss 208, depowering. Technical report.

NHTSA, 2002. Crash injury research and engineering network program report, 2002, dot hs 809 564. Program report.

NHTSA, 2008. Traffic safety facts 2007: a compilation of motor vehicle crash data from the fatality analysis reporting system and the general estimate system. Annual report DOT HS 811 002, National Highway Traffic Safety Administration, National Center for Statistics and Analysis, US Department of Transportation.

Nordhoff, L.S., 2005. Motor Vehicle Collision Injuries: Biomechanics, Diagnosis, and Management. Jones and Bartlett Publishers, Sudbury, Mass.

Rodarius, C., van Rooij, L., de Lange, R., 2007. Scalability of human models. In: The 20th ESV Conference Proceedings.

Segui-Gomez, M., Lopez-Valdes, F.J., Crandall, J.R., September 2009. Characterizing the distribution of injury and injury severity for belted front-seat occupants involved in frontal crashes. In: 2009 International IRCOBI Conference on the Biomechanics of Injury.

TNO, 2006a. Madymo human models manual. Version 6.3.2. Technical report.

TNO, 2006b. Madymo theory manual, release 6.3.2. Technical report.

Domain 2
Project 1

Capacity Building, Education, and Technology Transfer

Capacity Building, Education, and Technology Transfer

Final Report

UAB UTC Domain 2: Development of a Dynamic Traffic Assignment and Simulation Model for Incident and Emergency Management Applications in the Birmingham Region (Aim 1)

Prepared By:

Virginia Sisiopiku, PhD
Andrew Sullivan, MSCE, PE
Fouad H. Fouad, PhD, PE
Department of Civil, Construction, and Environmental Engineering
University of Alabama at Birmingham

Prepared for:

The UAB University Transportation Center
Birmingham, Alabama
DTRT06-G-0048

UAB UTC

December 2010

1. Report No. FHWA/CA/OR	**2. Government Accession No.**	**3. Recipient Catalog No.**
4 Title and Subtitle Capacity Building, Education, and Technology Transfer UAB UTC Domain 2: Development of a Dynamic Traffic Assignment and Simulation Model for Incident and Emergency Management Applications in the Birmingham Region, Aim 1.		**5 Report Date** December 2010 **6 Performing Organization Code**
7. Author(s) Virginia P. Sisiopiku, Andrew J. Sullivan, Fouad H. Fouad		**8 Performing Organization Report No.**
9 Performing Organization Name and Address University of Alabama at Birmingham 1075 13th Street South Birmingham, AL 35294-4554		**10 Work Unit No. (TRAIS)** **11 Contract or Grant No.**
12 Sponsoring Agency Name and Address UAB University Transportation Center 1530 3rd Avenue South Birmingham, AL 35294-2041		**13 Type of Report and Period Covered** **14 Sponsoring Agency Code**
15 Supplementary Notes		

16 Abstract

A number of initiatives were undertaken to support education, training, and technology transfer objectives related to UAB UTC Domain 2 Project: Development of a Dynamic Traffic Assignment and Simulation Model for Incident and Emergency Management Applications in the Birmingham Region. Examples include planning and delivery of technical workshops, short courses, seminars and scientific papers as well as development of training manuals and informational materials. These initiatives aimed at advancing the knowledge and practice in incident and emergency management.

This report highlights education and technology transfer initiatives and provides samples of products developed under this contract. The transfer of research results into practice performed in this study provides a wide range of opportunities for training students as well as the scientific community and authorities responsible for emergency planning, response and recovery, and operation of transportation facilities emergency management personnel.

17 Key Words Technology Transfer, Education		**18 Distribution Statement** No restrictions.	
19 **Security Classification (of this report)** Unclassified	20 **Security Classification (of this page)** Unclassified	**21 No. of pages**	**22 Price**

Table of Contents

ABSTRACT 5
1. INTRODUCTION 6
2. PROGRAM DEVELOPMENT AND ACCOMPLISHMENTS 7
2.1. Training Materials 7
2.2. Short Courses 7
2.3. Research Briefs 8
2.4. Seminars and Presentations 8
2.5. Certificate Program 9
2.6. Study Abroad Opportunity for UAB/UA Students 10
2.7. Annual Student Awards Luncheon 10
2.8. UAB UTC Student of the Year 11
2.9. Student Training and Mentoring 12
2.10. Technical Publications 13
2.11. Other 13
3. CONCLUSIONS 14
APPENDIX A 15
VISTA SOFTWARE CHARACTERISTICS AND MODULES 15
APPENDIX B 108
SHORT COURSE: VISTA SCENARIO MANUAL 108
APPENDIX C 118
STUDY ABROAD PROMOTIONAL MATERIALS 118
APPENDIX D 124
5th ANNUAL STUDENT AWARDS LUNCHEON PROGRAM 124

Table of Figures

FIGURE 1 Alabama-in-Greece, June 2010 10

FIGURE 2 Student Awardees and their advisors Drs. Sisiopiku (UAB), Turner (UA), and Anderson (UAH) at the 4th Annual Student Awards Luncheon at UAB (11/20/2009) 11

FIGURE 3 Ms Cavusoglu with Dr. Sisiopiku at the UTC Outstanding Student of the Year Ceremony in Washington D.C. 12

ABSTRACT

A number of initiatives were undertaken to support education, training, and technology transfer objectives related to UAB UTC Domain 2 Project: Development of a Dynamic Traffic Assignment and Simulation Model for Incident and Emergency Management Applications in the Birmingham Region. Examples include planning and delivery of technical workshops, short courses, seminars and scientific papers as well as development of training manuals and informational materials. These initiatives aimed at advancing the knowledge and practice in incident and emergency management.

This report highlights education and technology transfer initiatives and provides samples of products developed under this contract. The transfer of research results into practice performed in this study provides a wide range of opportunities for training students as well as the scientific community and authorities responsible for emergency planning, response and recovery, and operation of transportation facilities emergency management personnel.

Keywords: Technology Transfer, Education

1. INTRODUCTION

Technology Transfer has been a strategic goal of the University of Alabama at Birmingham University Transportation Center (UAB UTC) since its inception. This report documents the accomplishments of the UAB UTC Domain 2 research team in support of its educational and technology transfer objectives.

Examples of initiatives undertaken during the course of the project include planning and delivery of technical workshops, short courses, seminars and scientific papers as well as development of training manuals and informational materials. Moreover, a number of ancillary activities took place where the work related to UAB UTC Domain 2 was positively represented.

The following sections highlight education and technology transfer initiatives and provide examples of products developed under this contract. As a result of these initiatives, UAB UTC was active in technology transfer and provided a wide range of opportunities for training students as well as the scientific community and authorities responsible for emergency planning, response and recovery, and operation of transportation facilities emergency management personnel.

2. PROGRAM DEVELOPMENT AND ACCOMPLISHMENTS

A number of outreach and development activities have been contacted since the start of the project in the summer of 2008. Each of these is descried briefly in the sections below.

2.1. Training Materials

The VISTA platform used in the Domain 2 research is a complex, recently developed simulation and optimization model. As such many practitioners, academics, and transportation agency employees are not familiar with the concepts, structure, requirements, and use of the model. The need to develop training materials was recognized early on in order to guide potential users on the features and requirements of the model. Thus, on the onset of the project, members of the research team put together a document to serve as a guide for using the VISTA software. The document contains instructions on:

- Logging into and out of VISTA
- Viewing and editing data inputs
- Running the Dynamic Traffic Assignment (DTA) module
- Running reporting modules, and
- Running the simulation animation

This software walk-through provided detailed instructions and illustrations on how to use the VISTA software from both the GIS Java GIS Interface and the web interface, and is available in **Appendix A.**

2.2. Short Courses

A short training course on VISTA was developed and delivered in 2008 as a webinar series. The short course provided training on:

- VISTA's features and capabilities
- Steps involved in preparing and running a base case network in VISTA
- Details on how to prepare reports and visualize outputs
- Demonstrations on how to introduce changes in the base case in order to evaluate different scenarios

The training was offered by the CCNY and VTG Inc. and facilitated by UAB. The course was made available to students, ALDOT, state, and MPO and other interested agencies and attracted seventeen (17) participants. The participants were able to get step-by-step instructions as well as become involved in hands on use of the VISTA model.

The course had three parts that were delivered on October 29th, November 5th, and November 12th, 2008 respectively. The first session provided details on the VISTA model capabilities and focused on model introduction and base case preparation. Session 2 demonstrated the steps to be taken in order to modify the network, run the VISTA simulator and DTA, and obtain results using the add lanes scenario as a case study. Session 3 covered an incident case study and showcased how to add a temporary closure to the traffic network and analyze the effects of the closure on traffic. **Appendix B** provides details about the scenarios developed for the 3-session short course on VISTA.

In order to allow access to the short course to other interested parties in the future, the webinars were archived with the assistance of UAB UTC personnel and are available at the following links:

Session 1: http://uab.wimba.com/launcher.cgi?room=_uab_s_368952178011_344623_2008_1027_1103_38

Session 2: http://uab.wimba.com/launcher.cgi?room=_uab_s_368952178011_344623_2008_1105_1047_41

Session 3: http://uab.wimba.com/launcher.cgi?room=_uab_s_368952178011_344623_2008_1112_1040_26

2.3. Research Briefs

The research-oriented newsletters, *The UAB University Transportation Center Update*, featured articles on the project that highlighted the project scope and objectives, project progress, and accomplishments, and preliminary findings. Related information can be found at the following issues:

- Summer 2010 edition of *UPDATE* (To view please click here)
- Winter 2010 edition of *UPDATE* (To view please click here)
- Spring 2009 edition of *UPDATE* (To view please click here)
- Winter 2009 edition of *UPDATE* (To view please click here)
- Summer 2008 edition of *UPDATE* (To view please click here)

Moreover, articles on the Domain 2 project were included in the:

- UAB UTC Annual Report 2007-2008[1] (pages 15, 16)
- UAB UTC Annual Report 2008-2009[2] (pages 22, 23)
- UAB UTC Annual Report 2009-2010[3] (page 28)

2.4. Seminars and Presentations

A number of technical seminars and presentations directly resulting from to the UAB UTC Domain 2 Project were delivered at regional, national and international scientific meetings during the course of the project. Examples include the following:

1. "Modeling Incidents and Emergencies in the Birmingham Area Using VISTA", Transportation Research Board 90th Annual Meeting, ANB10 (4) – TRB Subcommittee on Emergency Evacuation, Washington, D.C. 2011, Presenter: V. Sisiopiku, forthcoming.
2. "Emergency Response and Traffic Congestion: The Dispatchers Perspective", Conference on Disaster Management and Human Health: Reducing Risk, Improving Outcomes, Orlando, FL, 2011, Presenter: V. Sisiopiku, forthcoming.
3. Emergency Response: Models, Formulations, and Insights. Decision Sciences Institute Annual Conference, San Diego, CA, November 20-23, 2010, Presenter: S. Melouk.
4. "Incident Management Study in the Birmingham Region", 5th Annual Student Awards Luncheon', Birmingham, AL, 2010, Presenter: Ozge Cavusoglu.

[1] Available at http://www.uab.edu/utc/PDF%20Files/2007-2008%20UTC%20Annual%20Report.pdf
[2] Available at http://www.uab.edu/utc/PDF%20Files/UTC%20Annual%20Report%202008-2009.pdf
[3] Available at http://www.uab.edu/utc/PDF%20Files/UTC_AnnualReport_2010_Final%20v8.pdf

5. "Impacts of Traffic Incidents and Disasters on Traffic Network Operations and Emergency Response", 2010 Huntsville Simulation Conference, Huntsville, AL, 2010, Presenter: Ozge Cavusoglu.
6. "Transportation-Oriented Communications with Vulnerable Populations During Major Emergencies: Current Challenges and Best Practices", 89th Transportation Research Board Annual Meeting, Washington, D.C., 2010, Presenter: D. Turner.
7. "Mitigating Traffic Congestion Using Simulation and Optimization", INFORMS 2010 Southern Regional Conference, Huntsville, AL, 2010, Presenters: C. Armbrester and S. H. Melouk.
8. "A Holistic Approach to Incident Management", INFORMS 2010 Southern Regional Conference, Huntsville, AL, 2010, Presenter: V. Sisiopiku.
9. "Emergency Response and Traffic Congestion: Dispatchers' Perspectives", National Evacuation Conference, New Orleans, LA, 2010, Presenter: V. Sisiopiku.
10. "Contra Flow Operations for Hurricane evacuation: Lessons learned from an Alabama case study. National Evacuation Conference, New Orleans, LA, 2010, Presenter: V. Sisiopiku.
11. "Modeling Traffic Incidents in VISTA". Traffic Simulation Workshop, Graz, Austria, 2008 Presenter: V. Sisiopiku.
12. "Traffic Management Strategies for Hurricane Evacuations in the Southeastern United States", 2008 TSITE/ALSITE Joint Fall Meeting, Chattanooga, TN, 2008, Presenter: V. Sisiopiku.

Moreover, faculty and students associated with the project delivered relevant presentations at the UAB University Transportation Center's *"Research in Progress Seminar Series"*, including the following:

- July 2010, Speaker: Cheng Zhong, PhD Candidate, V.P. Sisiopiku, Advisor, Civil, Construction, and Environmental Engineering, UAB, Crash Prediction on Rural Roads
- February 2010, Speaker: Ozge Cavusoglu, PhD Candidate, V.P. Sisiopiku, Advisor, Civil, Construction, and Environmental Engineering, UAB, Transit Practices for Evacuation Preparedness and Response for Vulnerable Populations
- October 2008, Speaker: Virginia Sisiopiku, PhD, Civil, Construction, and Environmental Engineering, UAB, Traffic Management Strategies for Hurricane Evacuations in the Southeastern United States.

Project briefings and progress report updates were also given at the UAB UTC Annual Advisory Board Meetings held on May 20th, 2010; and December 9th, 2008. In addition to UTC Advisory Board members and representatives from the Research and Innovative Technology Administration (RITA) and the academia, numerous transportation professionals attended these events and took advantage of the opportunity to network as well as learn more about incident and emergency management and the effects of traffic congestion on the effectiveness of EMS response.

2.5. Certificate Program

The Department of Civil, Construction, and Environmental Engineering (CCEE) offers four Category A Certificates, including one in the area of Transportation Engineering. During the course of the project UAB UTC and CCEE leadership met and discuss the establishment and promotion of a new **Certificate in Transportation Safety and Injury Control Engineering.** The intent of this Certificate is to allow UAB students and professionals to obtain formal specialization in topics related to transportation safety, public health, and injury control engineering. The first such certificate was awarded to a UAB student on Dec. 12, 2009.

2.6. Study Abroad Opportunity for UAB/UA Students

Study abroad programs provide exceptional educational experiences for students and expand their academic and cultural experiences. During the academic year 2009-2010 the project PI, Dr. Sisiopiku, led an initiative to establish a new faculty led study abroad program to Greece. The UAB Alabama-in-Greece Study Away program was established in collaboration with the University of Alabama (UA). Promotional materials were developed in support of the program, including a recruitment brochure, and a detailed informational document. These documents are displayed in Appendix C and are also available on-line at http://www.uab.edu/engineering/departments-research/civil/people/273-virginia-p-sisiopiku-

FIGURE 1 Alabama-in-Greece, June 2010

The **"Alabama-in-Greece Study Away"** program was very successful and drew a total of twenty eight (28) students between the UAB and UA campuses who traveled to Greece for three weeks in the summer of 2010 (6/2/10 to 6/23/10). Participants enrolled in and attended two 3-credit courses while in Greece. Dr. Tsakiropoulou-Summers (Dept. of Classics- UA) served as the program director and Dr. Sisiopiku (CCEE Dept- UAB) was the program facilitator.

Due to the popularity and success of the program the PI is considering potential additional offerings of the UAB Alabama-in-Greece Study Away program in the future. Moreover, she plans to explore the opportunity for incorporation of a course on transportation planning and urban development as part of future curriculum offerings.

2.7. Annual Student Awards Luncheon

During the course of the project, the UAB Institute of Transportation Engineers under the leadership of faculty advisor and project PI, Dr. Sisiopiku organized and hosted at UAB the Annual Student Awards luncheon three years in a row. The events were co-sponsored by the University Transportation Center for Alabama (UTCA) and the Department of Civil, Construction, and Environmental Engineering. Each event drew 25-30 participants representing a mix from academia, transportation professionals/consultants, and local and regional transportation agencies.

The events took place on December 5th, 2008; November 20th, 2009; and November 19, 2010. The technical program for each event included technical presentations from students at UAB, UA, and UAH universities showcasing their research activities (see **Appendix D** for a sample). During the event, awards were presented to 3-4 selected transportation students from each university to cover travel expenses to the Annual Meeting of the Transportation Research Board.

FIGURE 2 Student Awardees and their advisors Drs. Sisiopiku (UAB), Turner (UA), and Anderson (UAH) at the 4th Annual Student Awards Luncheon at UAB (11/20/2009)

2.8. UAB UTC Student of the Year

Each year the UAB University Transportation Center has the opportunity to select one UTC-affiliated student participating in transportation-related research as Student of the Year. The UAB project team nominated students in response to the call for Outstanding Student of the Year Nominations. Ms. Cavusoglu was selected as the 2009-2010 **UAB University Transportation Center's Student of the Year**.

Ms. Cavusoglu is a PhD Candidate in Transportation Engineering at the department of CCEE at UAB and a valuable member of the research team for the UAB UTC Domain 2 Project. Her PhD dissertation is titled: "Modeling incident and emergency management from a regional perspective".

The U.S. Department of Transportation (USDOT) honors one outstanding student from each UTC at a special ceremony held during the TRB Annual Meeting. Ms. Cavusoglu was recognized at the 19th Annual Outstanding Student of the Year Awards ceremony that took place as part of the Council of University Transportation Centers (CUTC) annual banquet on Saturday, January 9, 2010. Ms. Cavusoglu was accompanied by Dr. Russ Fine, Director of UAB UTC and Dr. Virginia Sisiopiku, Faculty Advisor.

FIGURE 3 Ms Cavusoglu with Dr. Sisiopiku at the UTC Outstanding Student of the Year Ceremony in Washington D.C.

2.9. Student Training and Mentoring

Six graduate students and one undergraduate student were funded through UAB UTC recourses during the course of the UAB UTC Domain 2 study. These include:

1. Ozge Cavusoglu (Ph.D., expected graduation: Summer 2011- CCEE UAB).
2. Abdul Muqueet Abro (Ph.D., expected graduation: Spring 2012- CCEE UAB).
3. Cheng Zhong (Ph.D., expected graduation: Fall 2013- CCEE UAB).
4. Sara Alnazer (M.S., expected graduation: Fall 2011- CCEE UAB).
5. Sujit Rathi, (M.S., graduated: Fall 2009- CCEE UAB).
6. Germin Fadel (M.S., graduated: Summer 2009- CCEE UAB).
7. Chris Armbrester (B.S., Information Systems, Statistics & Management Science-UA)

The students became actively involved in literature review, data collection, data processing, simulation modeling, and technical writing as a result of the grant. A number of other graduate transportation students also received indirect benefits from the grant's education and technology transfer activities. These include the following:

8. **Imran Md. S.** (M.S., expected graduation: Spring 2012- CCEE UAB).
9. **Islam Md. Saidul** (M.S., expected graduation: Spring 2012- CCEE UAB).
10. **Santosh Chitikesi** (M.S., graduated: Spring 2010- CCEE UAB).
11. **Sujit Rathi**, (M.S., graduated: Fall 2009- CCEE UAB).
12. **Michael Shinouda**, (M.S., graduated: Summer 2009- CCEE UAB).
13. **Germin Fadel,** (M.S., graduated: Summer 2009- CCEE UAB).
14. **Shrikanth Mamidipalli,** (M.S., graduated: Spring 2009- CCEE UAB).
15. **Jugnu Chemmannur**, (M.S., graduated: Fall 2008- CCEE UAB).
16. **Suman R. Surabhi**, (M.S., graduated: Fall 2008- CCEE UAB).

2.10. Technical Publications

Technical papers were developed by the research team to disseminate widely the information on project methods and study results. This task is still on-going and will be completed following the publication of the final project report and project completion. Examples of related publications to date include the following:

1. **Sisiopiku, V. P.**, Sullivan, A.J., Fine P.R. and Foster P.J. (2011). "Emergency Response and Traffic Congestion: The Dispatchers Perspective". Proceedings of the 2nd International Conference on Disaster Management and Human Health: Reducing Risk, Improving Outcomes, under review.
2. Turner D., Wolshon B., Dixit V., Evans W., **Sisiopiku V.P.**, Islam S., Anderson M., Teklewold M. (2011). "Transportation-Oriented Communications with Vulnerable Populations during Major Emergencies: Current Challenges and Best Practices", Accepted for publication in the *Journal of the Transportation Research Board, Transportation Research Record (TRR), forthcoming.*
3. Melouk, S., Keskin, B. and Capar, I. (2010). "Emergency Response: Models, Formulations, and Insights". Decision Sciences Institute Annual Conference, San Diego, CA. November 20-23.
4. **Sisiopiku, V.P.,** Acharya, A., Anderson M., and Turner D. (2009). "Evaluation of Traffic Signal Performance under Oversaturated Conditions Using VISTA". Proceedings of the 2009 Transportation Simulation Symposium (TSS 09), Spring Simulation Multiconference 2009, San Diego, CA.
5. **Sisiopiku, V.P.,** Mouskos K., Barrett C., Abro A.M., and Parker N. (2008) "Evaluation of Transit Operations Using a Regional Dynamic Traffic Assignment and Simulation Approach", Proceedings of the 10th International Conference on Application of Advanced Technologies in Transportation (AATT), Athens, GR.

2.11. Other

Throughout the course of the study, project team members became engaged in a number of other activities that provided significant service to the profession on the national and local levels. Efforts include serving on Technical Advisory Committees, organizing conferences and workshops, serving on several national professional committees and societies, chairing technical sessions at conferences, performing manuscript reviews for national journals in the field, and contributions to local professional groups. Such initiatives showcase the commitment of the research team to outreach and service and help enhance UAB UTC's local and national visibility.

Moreover, faculty members involved in the study mentored undergraduate, graduate, and post-doctoral students, supervised theses and dissertations, and supported numerous student professional development activities including field trips to conferences and meetings; poster and paper presentations; guest speaker lectures; student competitions etc. It is believed that these activities further strengthened the quality of education offered at UAB and provided unique opportunities to students affiliated with the UAB UTC to engage in valuable professional and life-long learning experiences.

3. CONCLUSIONS

A variety of educational, outreach and technology transfer activities were undertaken as part of the UAB UTC Domain 2 project.

The development of training materials and the delivery of the VISTA short course offering were very successful. Main beneficiaries include students, faculty, and transportation professionals interested in using VISTA for simulation and optimization of transportation networks. The short course was an excellent opportunity for UAB UTC to provide a direct training to the transportation community in Alabama.

Technical paper publications and presentations at local, regional, national, and international transportation conferences were utilized effectively to disseminate the study findings to interested parties, including the scientific community, authorities responsible for emergency planning, response and recovery, and operation of transportation facilities, emergency management personnel, and students. Furthermore, research briefs and work-in-progress seminars and publications gave many project investigators a chance to showcase their work and receive feedback from their colleagues and peers.

Other accomplishments include the development and promotion of a new Certificate Program and a new UAB Study Abroad program. Such initiatives expand training and experiential learning opportunities at UAB and support educational objectives of the UAB UTC, in general and the Domain 2 Project in particular.

Overall, the project team engaged in numerous technology transfer activities which helped enhance the visibility of the UAB UTC at the local, regional, and national scales and support the technology transfer goals of the UAB UTC as described in its strategic plan.

APPENDIX A

VISTA SOFTWARE CHARACTERISTICS AND MODULES

Curtis Barrett VISTA Transport Group Inc. Evanston, IL, USA

Thanasis Ziliaskopoulos, PhD VISTA Transport Group Inc. Evanston, IL, USA

Kyriacos C. Mouskos, PhD Associate Director, UTMSC CCNY

Neville Parker, PhD, PE Director, UTMSC CCNY VISTA Transport Group Inc. Universal Transportation Model Simulation Center (UTMSC) at CCNY

July 10, 2008

1.0 INTRODUCTION

The Visual Interactive System for Transport Algorithms (VISTA) software can be used to view and edit data inputs, and to run modules, reports and simulation animation. These functions can be accessed through either a web interface or a JAVA Geographic Information System (GIS) Java GIS Interface, which is also called the VISTA editor. The web interface displays data and reports in detailed table format, and allows the status of analysis and reporting tasks to be observed. The GIS Java GIS Interface shows the data in graphic format, and includes windows for editing of input values. DTA and reporting modules can be run in both the web and Java GIS Interfaces. Simulation animation is only available in the Java GIS Interface, since it is inherently a graphic function. This document is a guide to using these functions in the VISTA software, beginning with instructions on logging into and out of VISTA. Appendix A provides an example of the implementation of the VISTA software in the City of Nicosia as part of the European Union Eureka program - EUNEA1204-08. In appendix A we provide the MOEs that can be produced by the VISTA General Report for the City of Nicosia. In addition, we provide a sample run of the OD report in Appendix B also for the City of Nicosia. Further, we provide an example (Appendix C) of the implementation of the VISTA Incident/Construction Management (VISTA-IM) and the VISTA-IM Variable Message Sign (VISTA-IM-VMS) modules that were developed for the European Union project called Monitor Integrated Safety System (MISS – www.missproject.net).

2.0 LOGGING INTO AND OUT OF VISTA

The VISTA software runs over a network, and can be accessed anytime from any machine; however, access is password-protected, so users must log into and out of the software. This section explains how to log into VISTA, open a network and log out of VISTA in both the web and Java GIS Interfaces.

3.1 Logging into and out of the Web Interface

Launch the server at the CCNY-CUNY of the Universal Transport Model Simulation Center (UTMSC) http://134.74.90.26/vista/ in Internet Explorer or Mozilla Firefox (see Figure 1), and login by entering your username and password in the Web Interface login box. The link in blue ―launch the GIS Interface‖ can be accessed by activating the link and then inputting the corresponding Username and password in the window that will pop-up (it usually takes from a few seconds to a few minutes). We note here that the CTL has come to an agreement with the CCNY-UTMSC to utilize their VISTA server, an SGI Altix 4700 which is a mini supercomputer and offers substantial computational speed in running the VISTA model that requires substantial computational power and computer memory.

The next screen is the Home screen that allows the user to select a network from the list under "Networks" (see Figure 2).

When a network has been selected (Figure 3), the Modules, Tasks, Reports and Database tabs along the top of the page can be selected. The Modules page allows modules such as DTA and cell generation to be run on the selected network. The Tasks page shows the completion status of the modules and reports that have been run on the network. The Reports page allows the user to run and view reports for the selected network. The Database page allows the user to view and query data

tables associated with the selected network. These pages will be described in more detail in later sections.

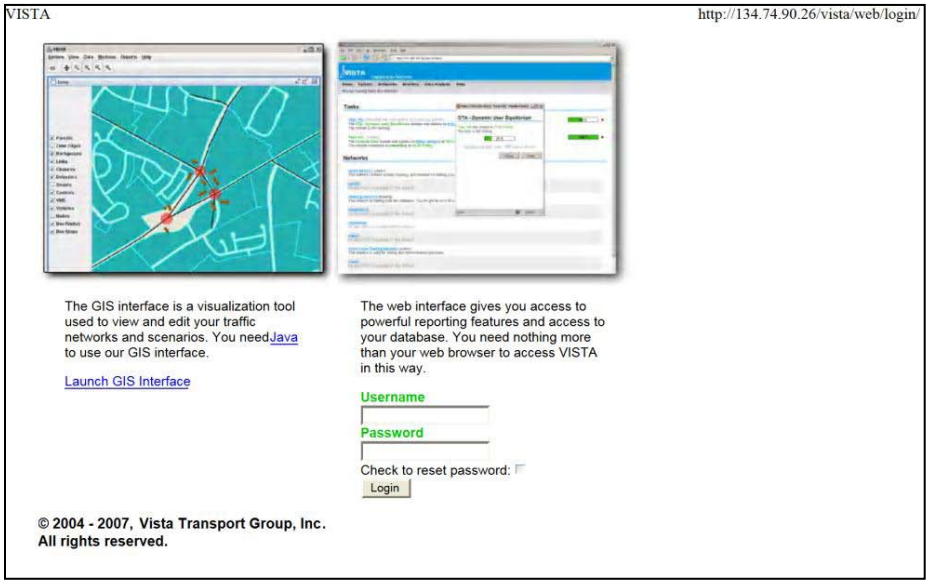


Figure 1: VISTA Web interface Login screen

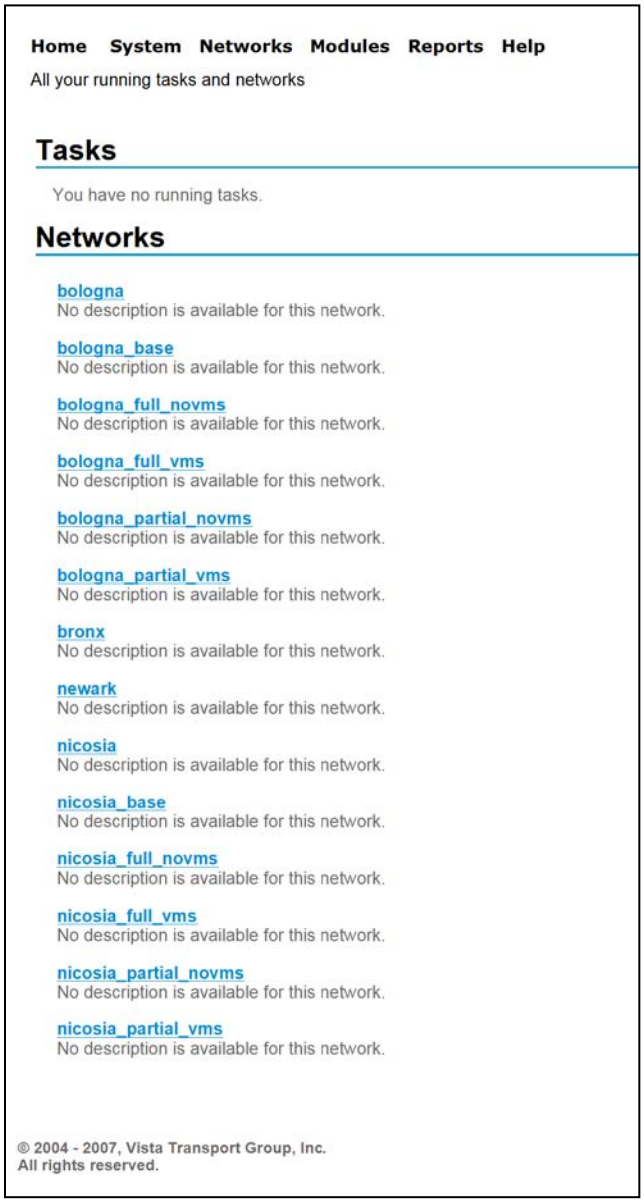


Figure 2: Web interface Overview screen

Figure 3: Selected Specific Network Screen (e.g. Nicosia-Base)

When you are finished working in the web interface, you can logout by clicking on the “logout” link in the top right-hand corner of the window. This link appears in all screens of the web interface, regardless of which network or function page (Overview, Modules, Tasks, Reports or Database) is open.

2.2 Logging into and out of the Java GIS Interface

Launch http://134.74.77.13/vista/ in Internet Explorer and click on “Launch the GIS Interface” (see Figure 2-3). The GIS Interface requires the Java Runtime Environment and Java Web Start to be installed on the client terminal – this now is loaded automatically in all newer computers. If these are not already installed on the client terminal, they can be downloaded from the Java web site.

When the login window will appears (see Figure 4), enter your personal username and password. The server name is http://134.74.77.13/vista/web/login/. The GIS Interface window will appear as shown in Figure 5. To open a network, click on the corresponding network name. The selected network will then be loaded for viewing (depending on the size of the network, this may take several minutes).

When you are finished working in the Java GIS Interface, you can logout by selecting System|Exit (see Figure 6). The VISTA client window will then close.

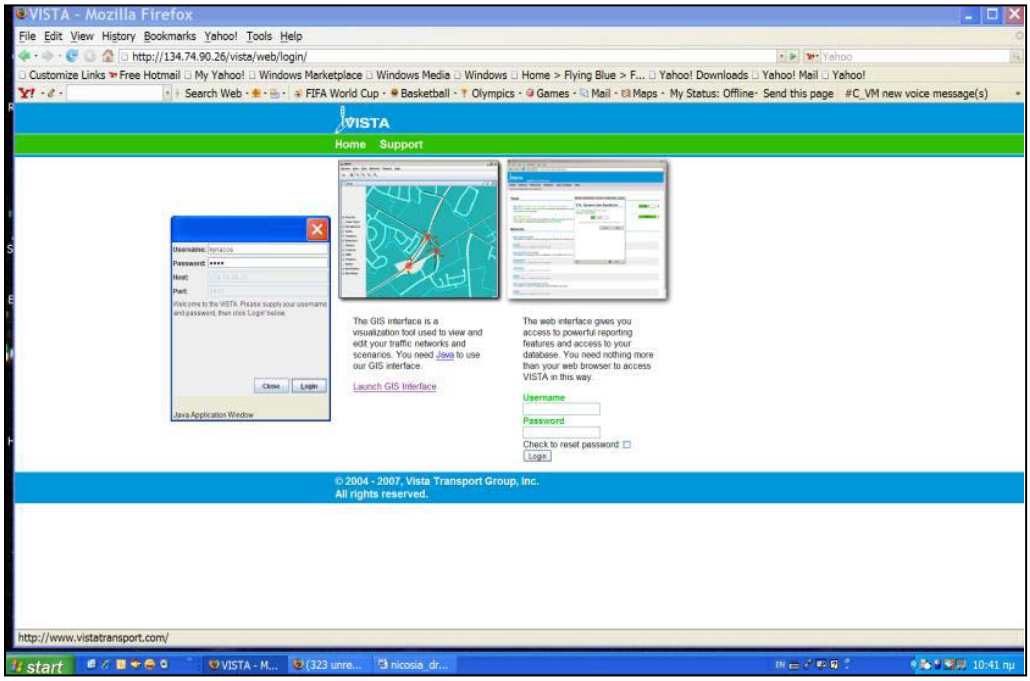


Figure 4: Access the VISTA GIS Interface (small window)

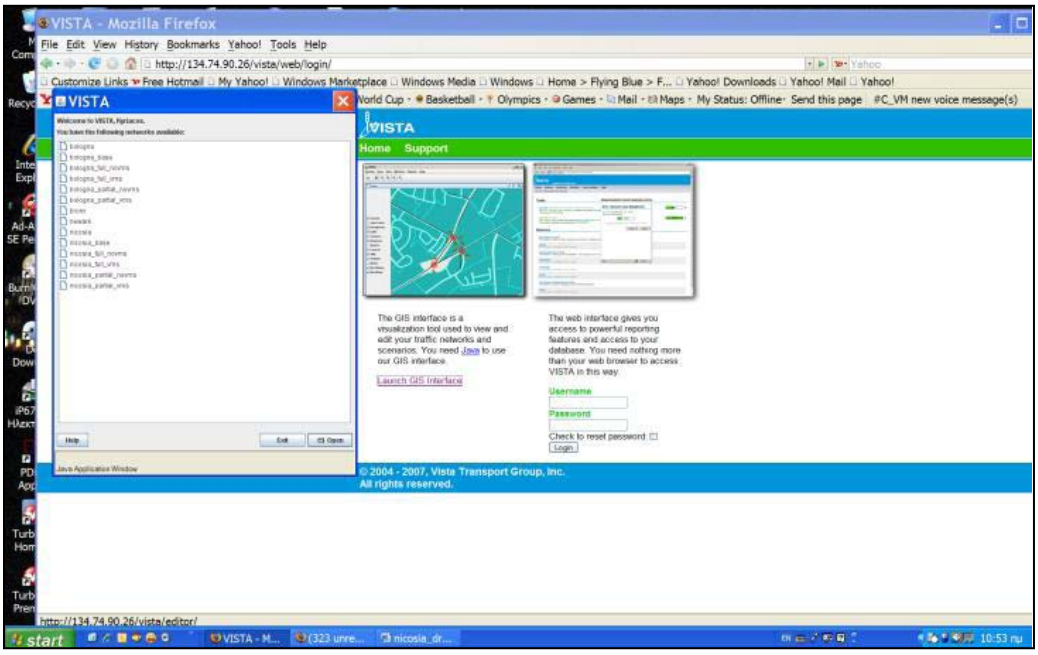


Figure 5: VISTA Open Network window (small VISTA window)

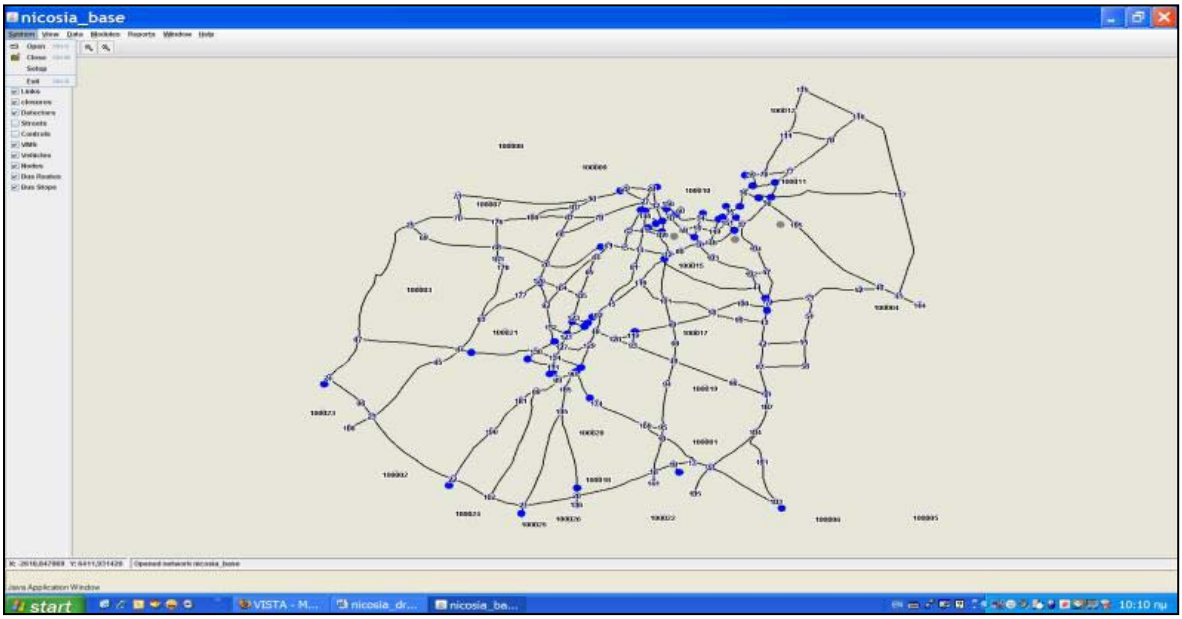


Figure 6: VISTA System|Exit menu option (Nicosia-Base network)

3.0 VIEWING AND EDITING DATA INPUTS

The web interface allows for convenient and detailed querying and editing of data tables. The Java GIS Interface allows for GIS-based viewing of the input data, as well as editing, adding and deleting of network elements.

3.1 Viewing and Editing Data in the Web Interface

The Tables page (see Figure 7) allows the user to view table fields and records associated with the selected network. The network name is shown at the top of the page where the network in the figure is “nicosia_base”. A list of database tables appears in scroll menu on the left, and a database table can be selected by clicking to highlight that table name. The fields contained in that table appear to the right, and the records in the table can be viewed by clicking on the corresponding table name (e.g. linkdetails) – the table records are shown below the table headings if there are any entries.

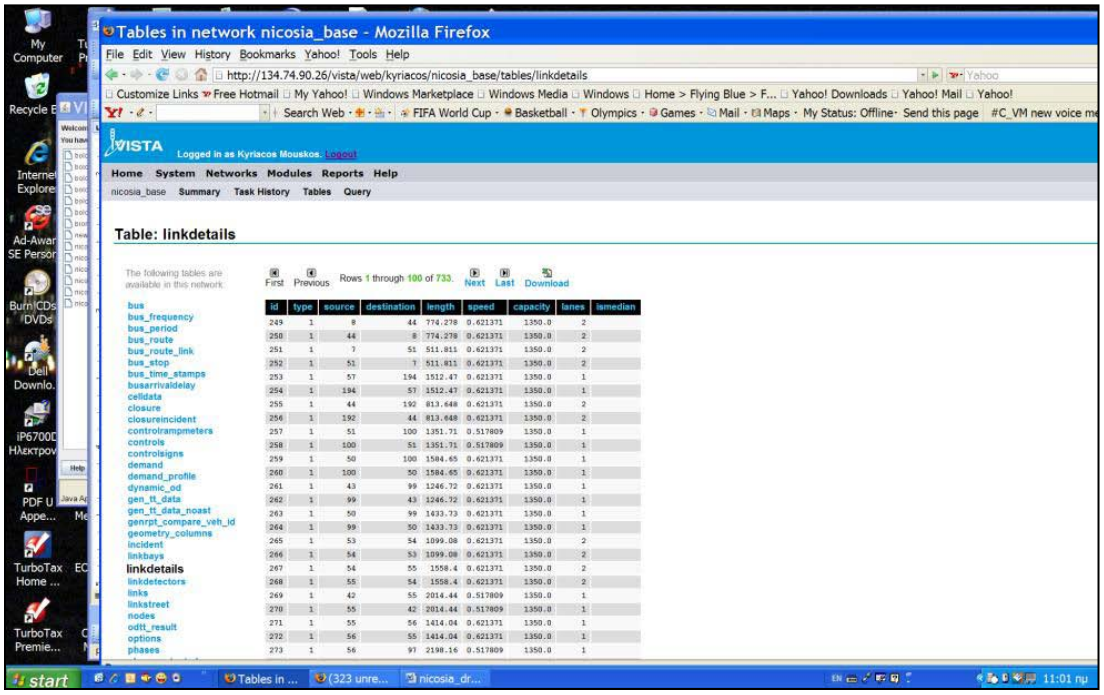


Figure 7: Web interface Tables Page (linkdetails example)

The database tables can also be queried by entering a PSQL "select" statement in the SQL query box – by clicking at the Queries link - and the resulting table will appear in the same window, below the PSQL query box. An example PSQL query is shown in Figure 8. The results can also be saved to a CSV (comma-separated text) file by clicking on "Download MS Excel" link, which is on top of the table.

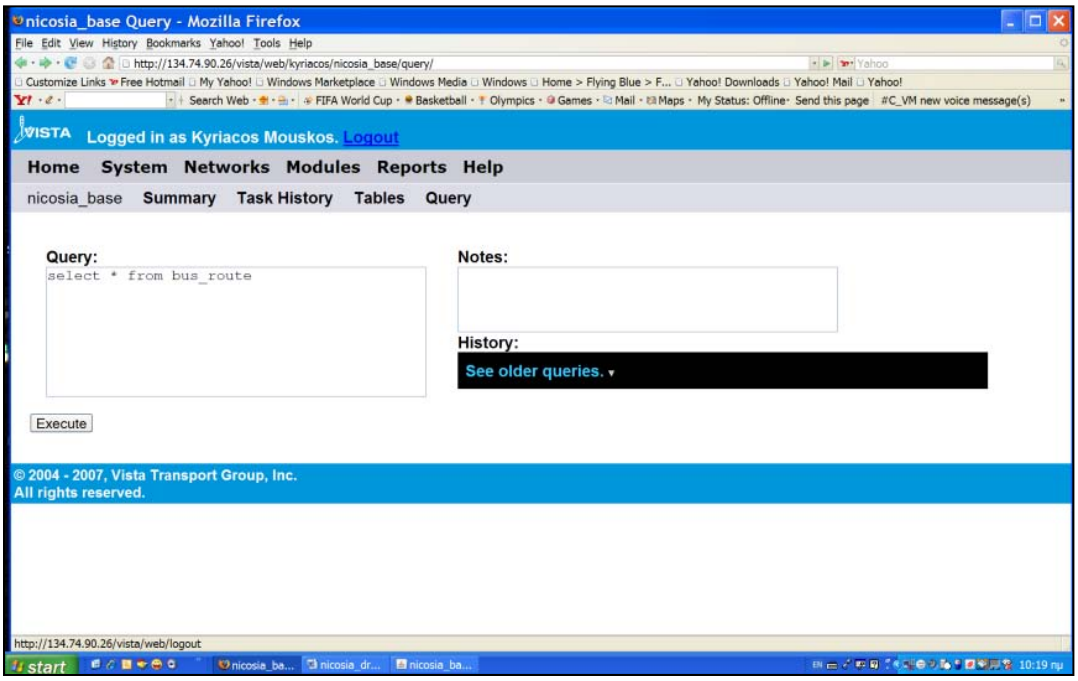


Figure 8: Sample SQL query in the VISTA web interface

Any PSQL query statement can be entered in the SQL box; for example, the statement

SELECT * FROM bus;

will return all fields (represented by *) of all records in the bus table. To narrow the search conditional expressions may also be specified in the target list; for example,

SELECT * FROM bus WHERE route=100;

will return all fields (represented by *) in the bus table, but only for buses on route 100. Boolean operators (and, or, not) are also allowed in the qualification of a query; for example,

SELECT * FROM bus WHERE route=100 AND starttime<600;

will return all fields (represented by *) in the bus table, but only for buses on route 100 that depart before 600 seconds of the simulation have elapsed.
As a final note, you can specify that the results of a select can be returned in a sorted order or with duplicate instances removed; for example,

SELECT DISTINCT route FROM bus ORDER BY preemption;

The SQL box can also be used to insert, update or delete table entries; for example, the command,

INSERT INTO bus (id,type,route,starttime,preemption) VALUES (100,1,32,5,1);

will add a record in the bus table, corresponding to a bus of type 1 on route 32 with vehicle id 100. The bus departs at time 5 and triggers preemption strategy 1. To edit records that already exist in the database, the update command can be used; for example, the command

UPDATE bus SET preemption=1 WHERE route=50;

will set all buses on route 50 to trigger preemption strategy 1. In addition, records can also be deleted from the database; for example, the command

DELETE FROM bus WHERE route=50;

will delete all bus on route 50 from the bus table.

More detailed guides to PSQL commands are widely available on the internet. Two such tutorial pages are found at

http://www.us.postgresql.org/users-lounge/docs/6.5/tutorial/query.htm
http://www.eskimo.com/~ericj/comp/sql1b.htm

3.2 Viewing and Editing Data in the Java GIS Interface

The Java GIS Interface allows the user to view and edit the data in GIS-based format, but also provides access to the Data Warehouse where data can be viewed and queried in detailed table format. This section begins with a discussion of basic tools for viewing networks, such as zooming and panning, as well as tools for adjusting the appearance and colors of network elements. Next, methods of editing data in the client are explained, and then methods of editing data through the client's data warehouse are explained.

3.2.1 GIS-based Viewing of Data

After logging into the client, a network can be opened to be viewed in GIS format (see Section 2.2). An example network, rtatest3, is shown in Figure 9.

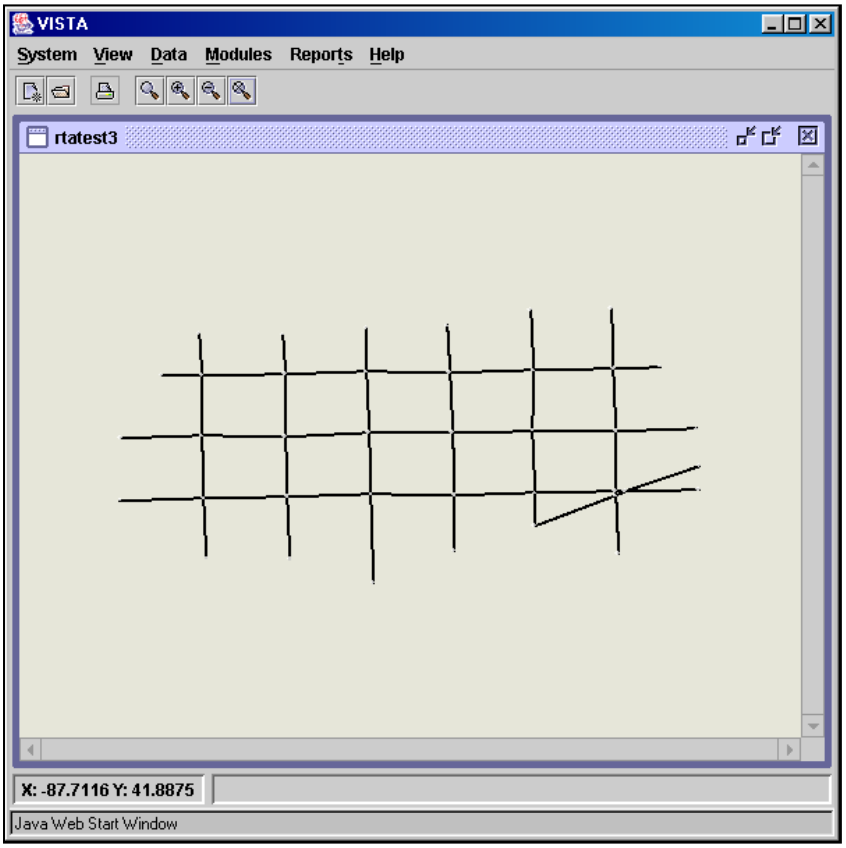


Figure 9: Sample network, rtatest3, in the Java GIS Interface

The VISTA GIS Interface window includes many options for adjusting the appearance of the network. For example, the client window can be maximized by clicking on the maximization button in the top right corner of the window (see Figure 10).

Figure 10: Client window maximization button

To zoom into a particular area of the network, click on , then select the area you want to zoom into using the red box (see Figure 11).

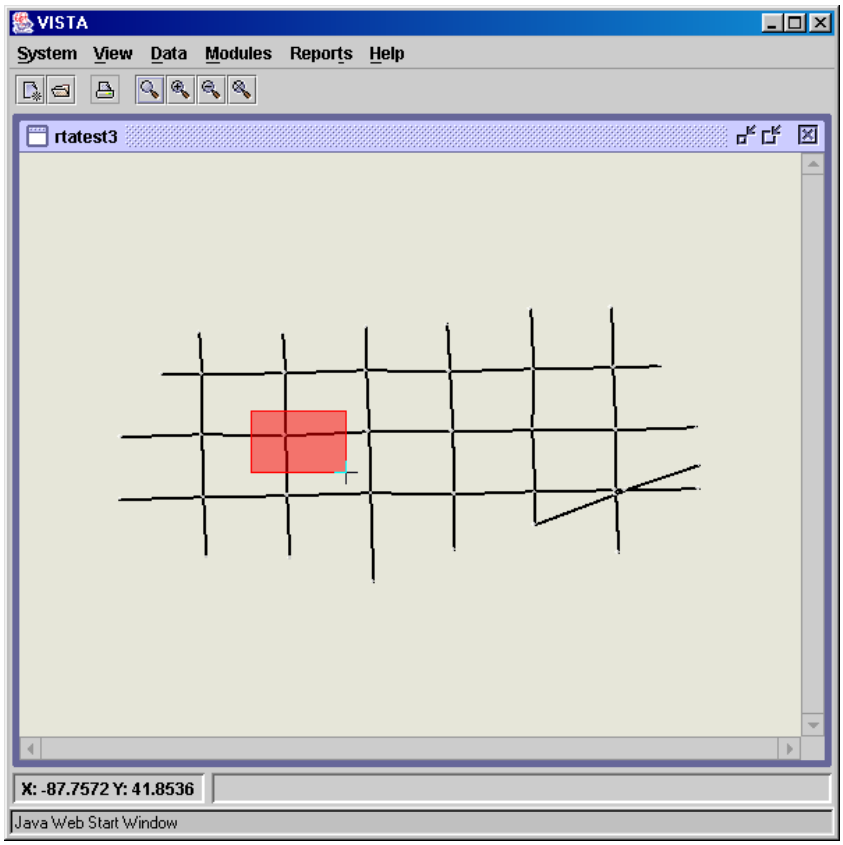


Figure 11: Java GIS Interface zoom function

To zoom into the center of the screen by a predetermined amount, click on . To zoom out of the center of the screen by a predetermined amount, click on . To zoom out to the full network, click on .

In addition, a drag button , has recently been added to the button bar. The drag button is used to reposition the section of the network shown in the GIS client window. To reposition the network first click on the button, then click on a spot in the network and hold the mouse button as you drag the network to a new position. Let go of the mouse button to drop the network in its new position.

The color and appearance of the network nodes, links and other elements can be adjusted by right-clicking on any part of the network window to bring up the menu shown in Figure 12. The options most relevant to the transit signal priority project include adjustments to the appearance of nodes, links, controls, bus stops and bus routes.

Figure 12: Java GIS Interface element appearance editing menu

Nodes - If the "Nodes" is selected from the menu, a node appearance editing window appears (see Figure 13). Nodes and node labels, which indicate node id numbers, can be made visible or hidden. Further, the color of nodes and node labels can be adjusted by clicking on the color boxes. A Color Picker window then appears (see Figure 14), and any color in the spectrum can be selected by adjusting the amount of red, green and blue. The alpha value adjusts the contrast of the checker pattern. Further, the label font can be adjusted by clicking on the label font box. A Font Picker window then appears such that the font and font size can be adjusted (see Figure 15).

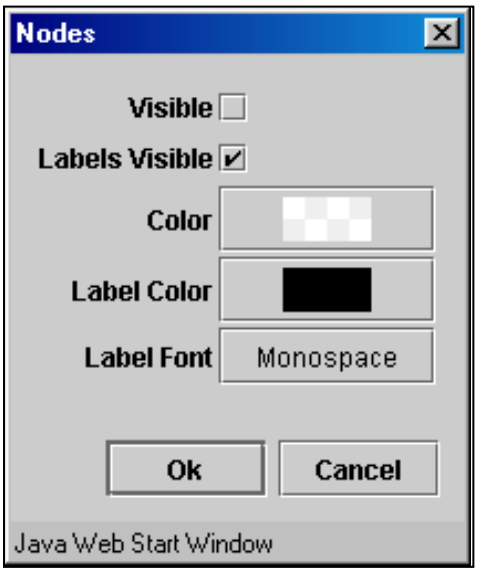


Figure 13: Java GIS Interface node appearance editor

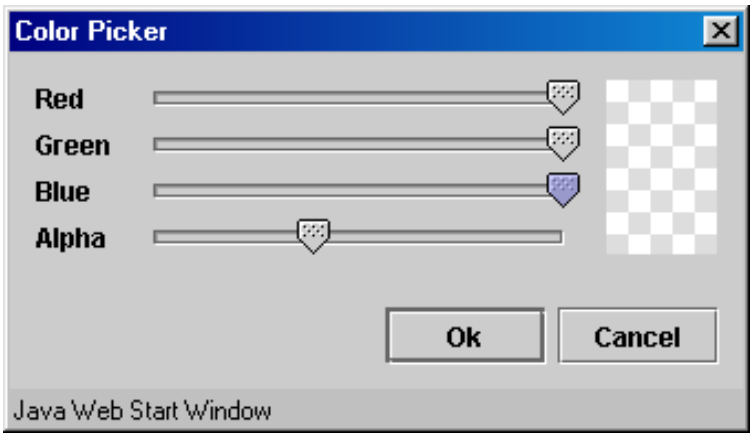


Figure 14: Java GIS Interface color picker

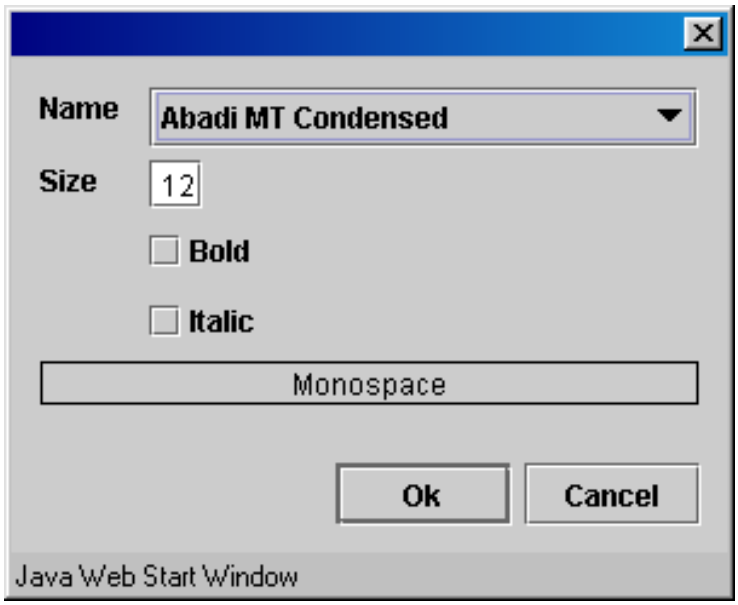


Figure 15: Java GIS Interface font picker

Links - Link appearance characteristics can also be adjusted by selecting “Links” from the element appearance editing menu (Figure 12). The link appearance editing window then appears (see Figure 16). This window allows links and link labels can also be set to be visible or hidden. Further, the colors and fonts can also be adjusted by clicking on the color and font boxes, to make Color Picker and Font Picker windows appear. Further, arrows can be made visible, so that the link directions are apparent, and lanes and centroids can also be made visible.

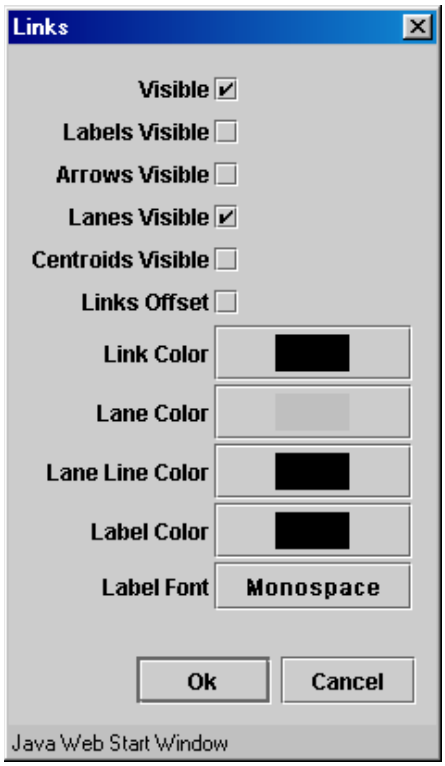


Figure 16: Java GIS Interface link appearance editor

When "Controls" are selected from the element appearance editing menu (Figure 12), a controls appearance editing window appears (see Figure 17). Controls can be made visible or hidden, and colors can be selected as they are with nodes and links. The colors selected appear only during animation, otherwise, only the "stop" color is shown as in Figure 18.

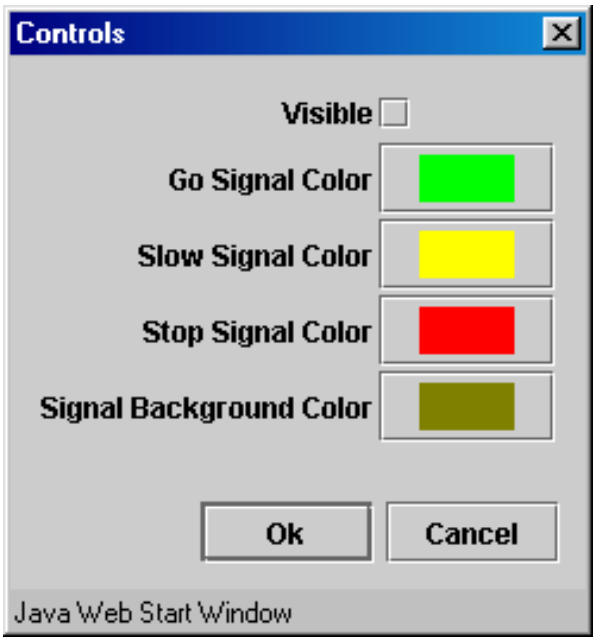


Figure 17: Java GIS Interface controls appearance editor

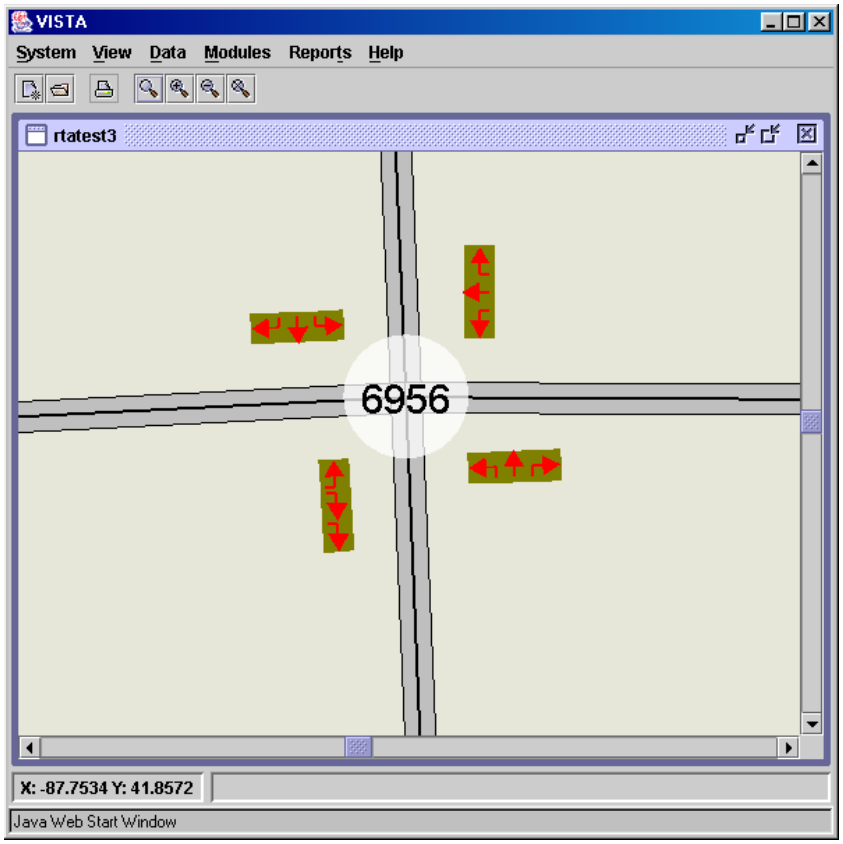


Figure 18: Representation of controls in the Java GIS Interface

When "Bus stops" are selected from the element appearance editing menu (Figure 12), a bus stop appearance editing window appears (see Figure 19). Similarly, when "Bus routes" are selected from the element appearance editing menu (Figure 12), a bus route appearance editing window appears (see Figure 20). Bus stops and bus routes can be made visible or hidden, and colors can be selected as with other network elements. Routes and stops appear slightly offset from the links, as shown in Figure 21.

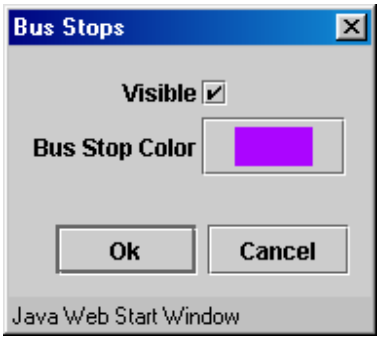


Figure 19: Java GIS Interface bus stop appearance editor

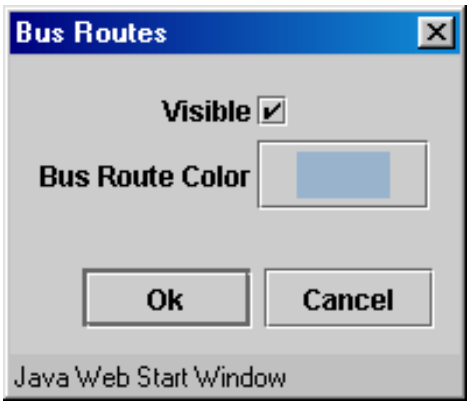


Figure 20: Java GIS Interface bus route appearance editor

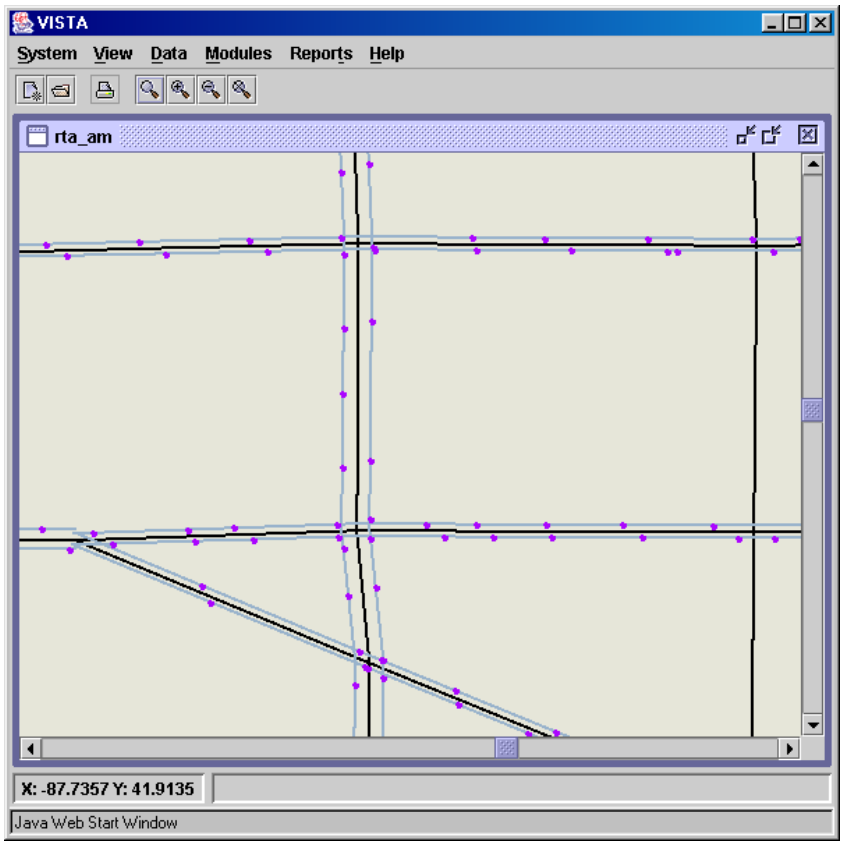


Figure 21: Java GIS Interface representation of bus routes and bus stops

3.2.2 GIS-based Editing of Data

Java GIS Interface - The *VISTA Editor or Java GIS Interface* allows network elements to be added, edited or deleted. The network data that can be altered are listed under the Data menu. The options most relevant to the transit signal priority project include adjustments to nodes, links, zones, controls and buses.

Data-Nodes - When "Nodes" is selected from the Data menu, the options of adding, removing, editing and finding a node appear (see Figure 22). When "Add Node" is selected, a node can be

added to the network by clicking in the desired location. When “Remove Node” is selected, an existing node can be removed by clicking on that node. When “Edit Node” is selected, an existing node can be selected by clicking on that node, and a window will appear in which the x and y coordinates of that node can be adjusted (see Figure 23). When “Find Node” is selected a “Find Node” window will appear, in which the desired node id can be entered (see Figure 24). That node will then be highlighted in the network window.

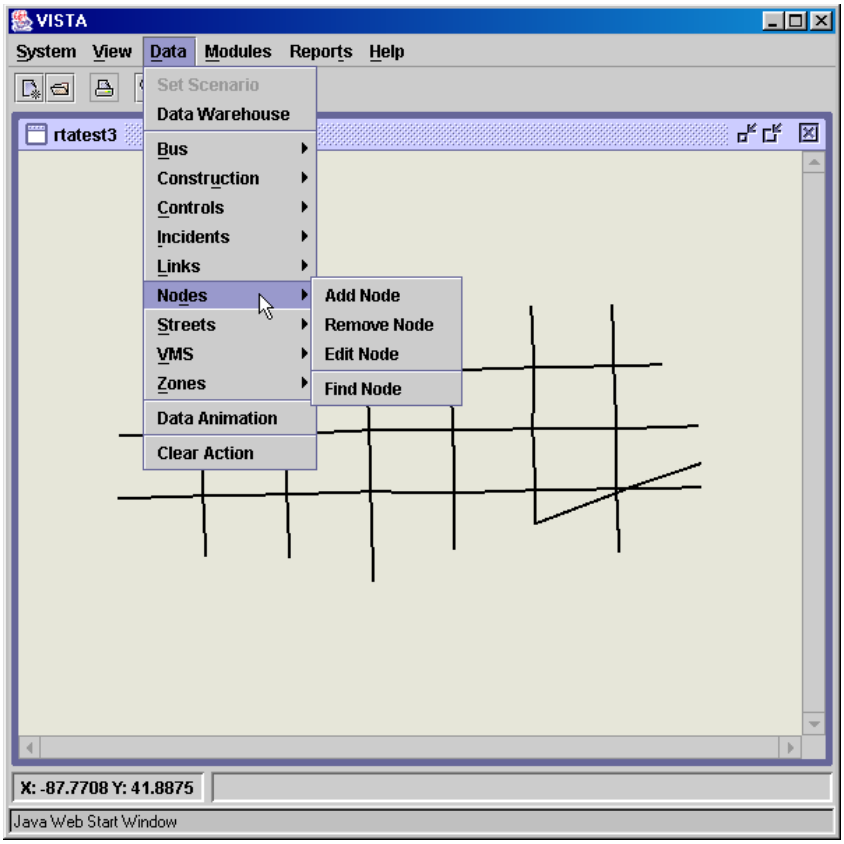


Figure 22: Java GIS Interface Data|Nodes menu option

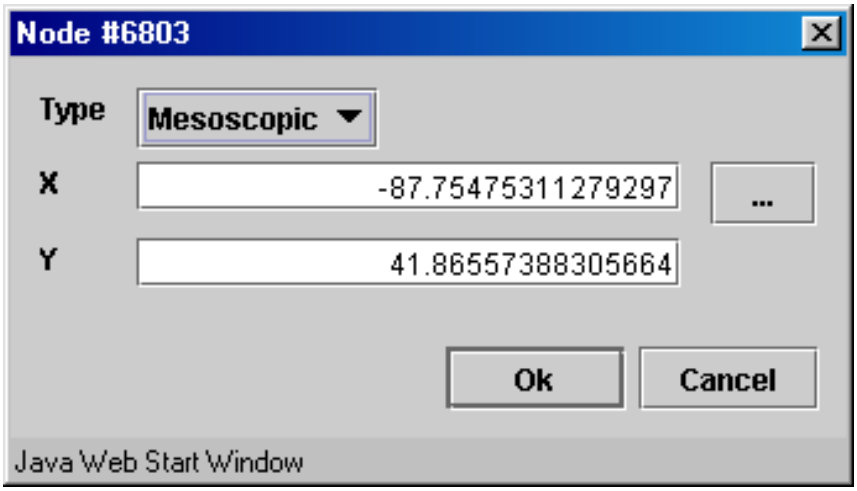


Figure 23: Java GIS Interface node editing window

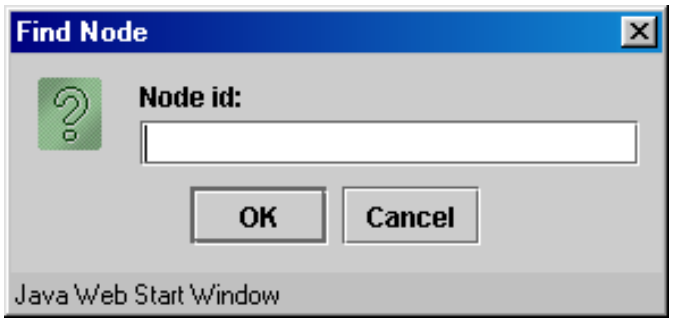


Figure 24: Java GIS Interface - Find Node window

Data-Links - When "Links" is selected from the Data menu, the options of adding, removing, editing and finding a link appear (see Figure 25). When "Add Link" is selected, a link can be added to the network by clicking to join two nodes. When "Remove Link" is selected, an existing link can be removed by clicking on that link. When "Edit Link" is selected, an existing link can be selected by clicking on that link, and a Link Editor window with tabs to Attributes, Geometry, Bays and Detectors will appear. In the Attributes section (see Figure 26), link attributes, such as origin node, destination node, length, speed, number of lanes and capacity can be edited (capacity is optional if the number of lanes is entered). In the Geometry section (see Figure 27), the polyline coordinates can be edited to adjust the appearance of the link in the GIS. In the Bays section (see Figure 28), merge lanes and turning bays can be defined. In the Detectors section (see Figure 29), link detectors can be defined for use with the OD calibration module.

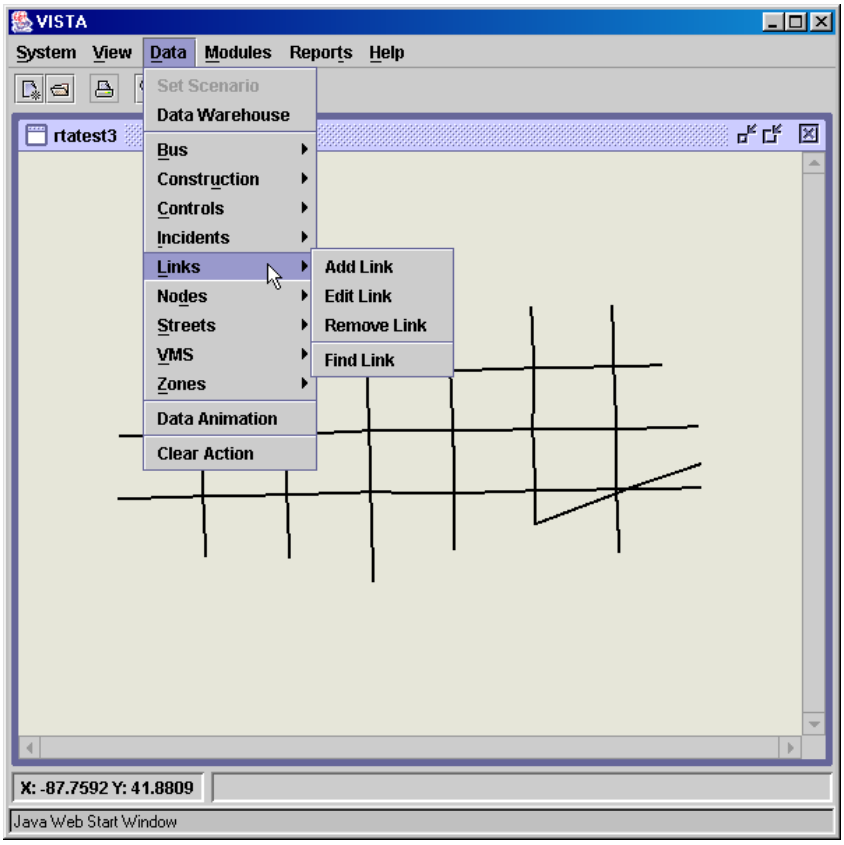


Figure 25: Java GIS Interface Data|Links menu option

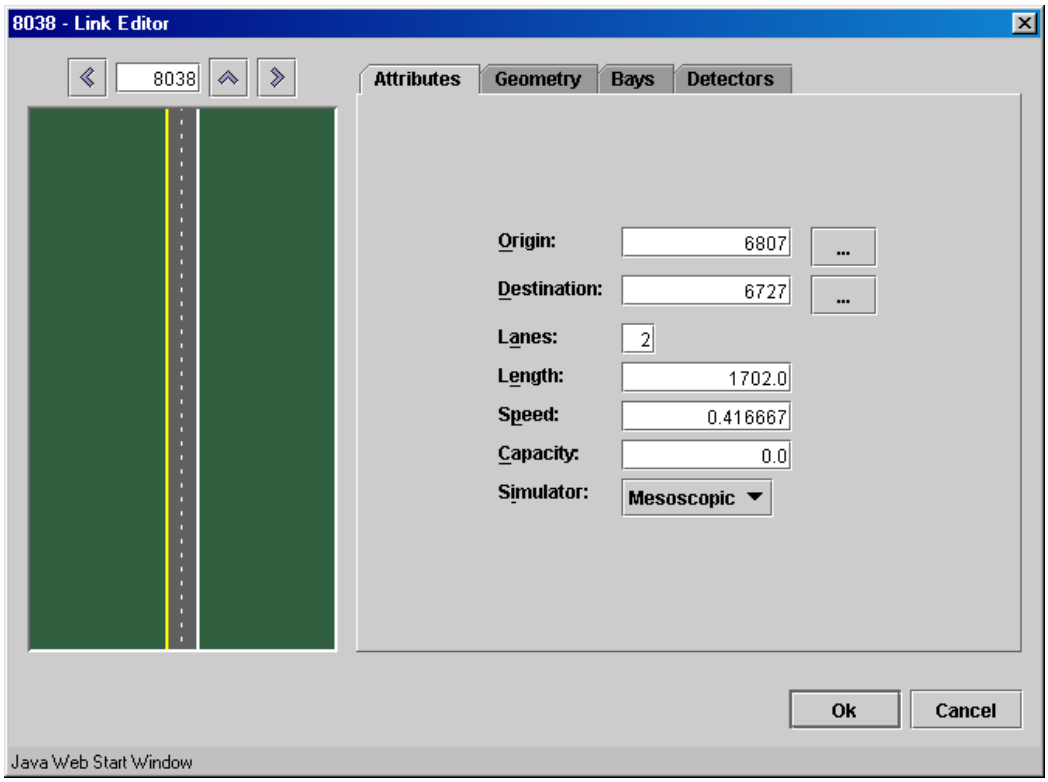


Figure 26: Java GIS Interface Link Attribute editor

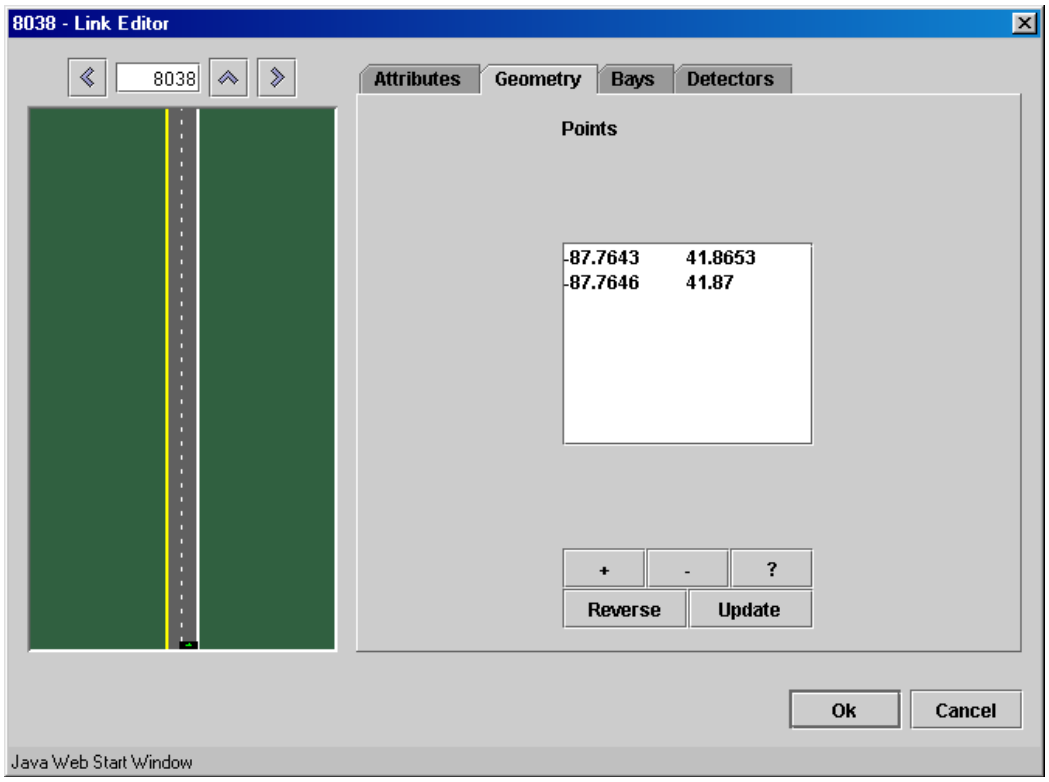


Figure 27: Java GIS Interface Link Geometry editor

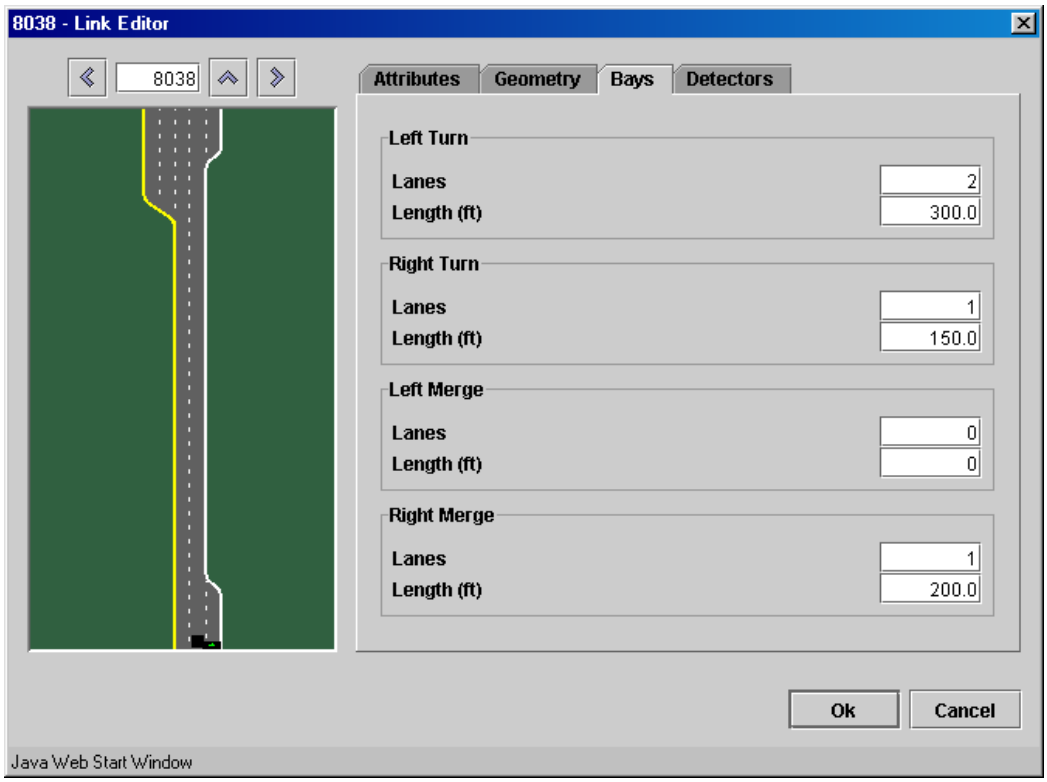


Figure 28: Java GIS Interface Link Bay editor

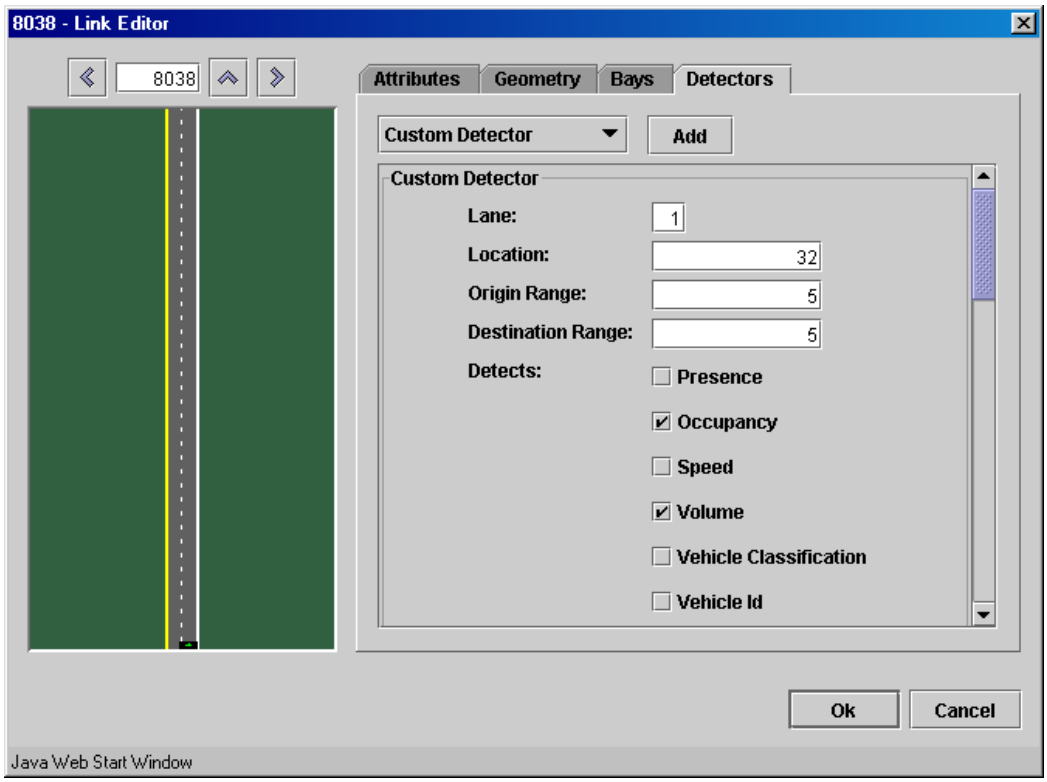


Figure 29: Java GIS Interface Link Detector editor

Find Link - When “Find Link” is selected a “Find Link” window (see Figure 30) will appear, in which the desired link id can be entered. That link will then be highlighted in the network window.

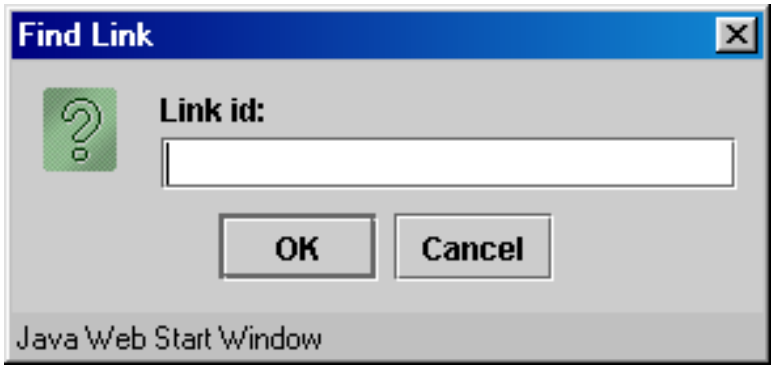


Figure 30: Java GIS Interface Find Link window

Data-Zones - When ―Zones‖ is selected from the Data menu, the options of adding, removing, editing and finding a zone appear (see Figure 31). When “Add Zone” is selected, a Create New Zone window will appear in which the nodes to be included in that zone can be specified (see Figure 32). When “Edit Link” or “Remove Link” is selected, an existing zone can be edited of removed by clicking on that zone. When “Find Zone” is selected a “Find Zone” window (see Figure 33) will appear, in which the desired zone id can be entered. That zone will then be highlighted in the network window.

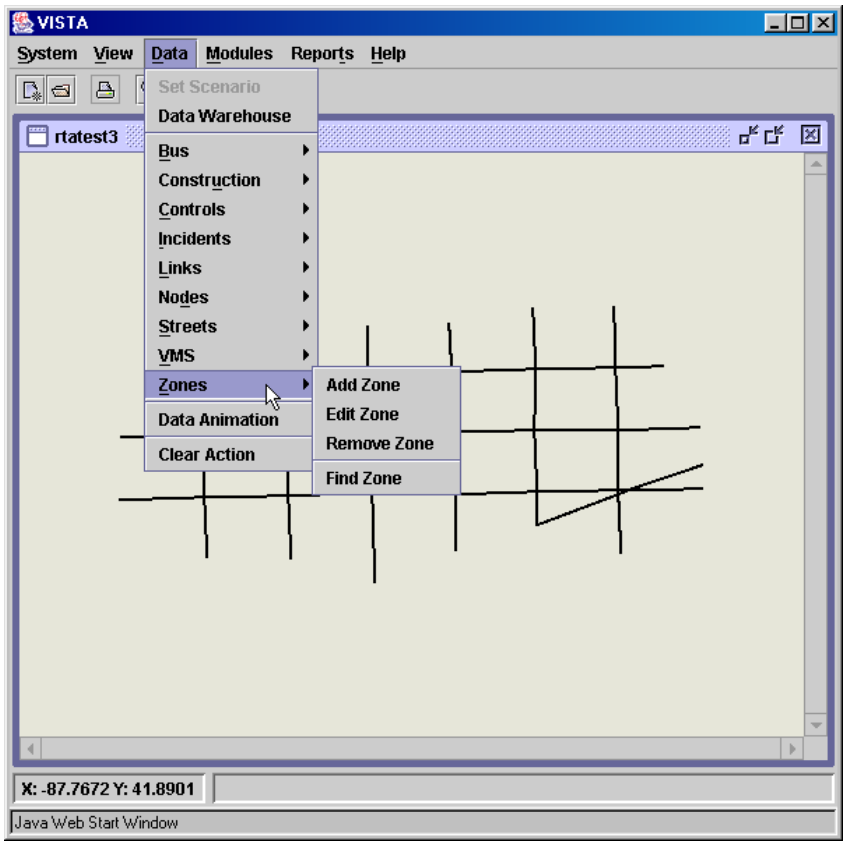


Figure 31: Java GIS Interface Data|Zones menu option

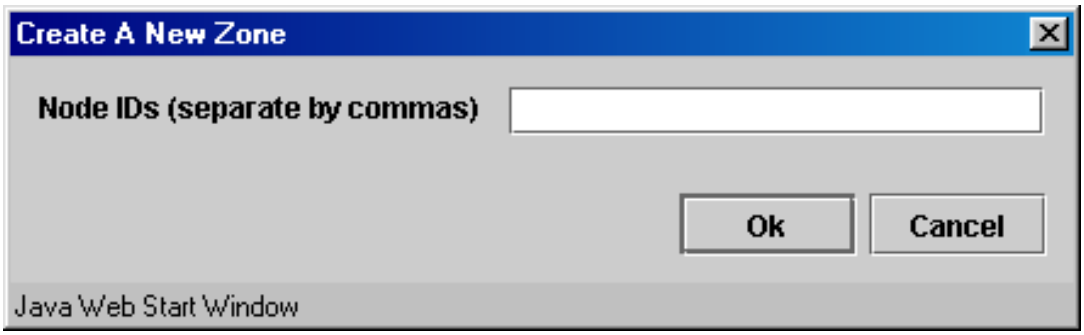


Figure 32: Java GIS Interface Create a New Zone window

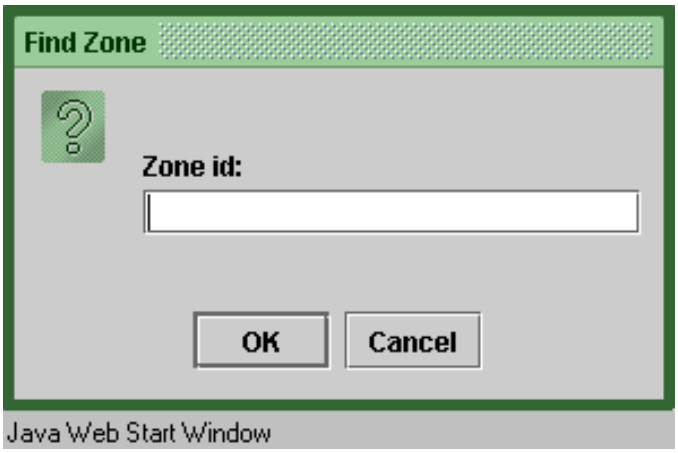


Figure 33: Java GIS Interface Find Zone window

Data-Controls - When "Controls" is selected from the Data menu, the options of adding, editing and removing controls and signal preemption appear (see Figure 34).

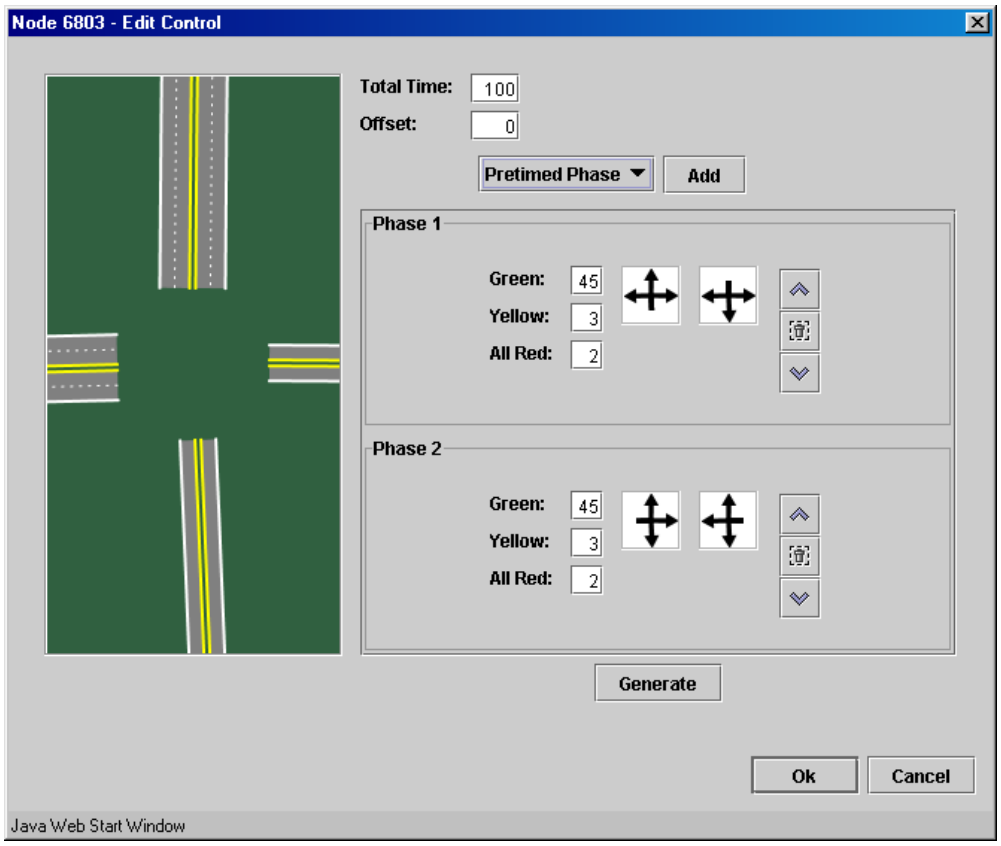


Figure 36: Java GIS Interface Edit Control window

Data-Edit Signal Preemption - If "Edit Signal Preemption" is selected from the Data menu, the "Choose Signal Preemption" window appears (see Figure 37). When the user selects a signal preemption plan from the drop down menu, a signal preemption editing window will appear (see Figure 38), which allows the user to choose the signals to be included in the preemption plan and to adjust the preemption parameters associated with that plan. If "Add Signal Preemption" is selected from the Data menu, the signal preemption editing window appears, so that the user can create a new plan from scratch. If "Remove Signal Preemption" is selected from the Data menu, the Choose Signal Preemption window appears, so that the user can select the preemption plan to be removed from the drop down list.

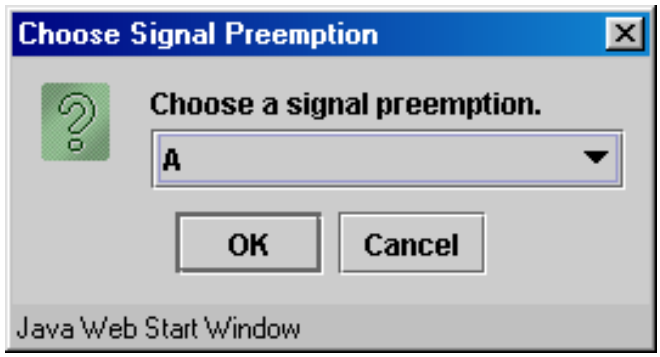


Figure 37: Java GIS Interface Choose Signal Preemption window

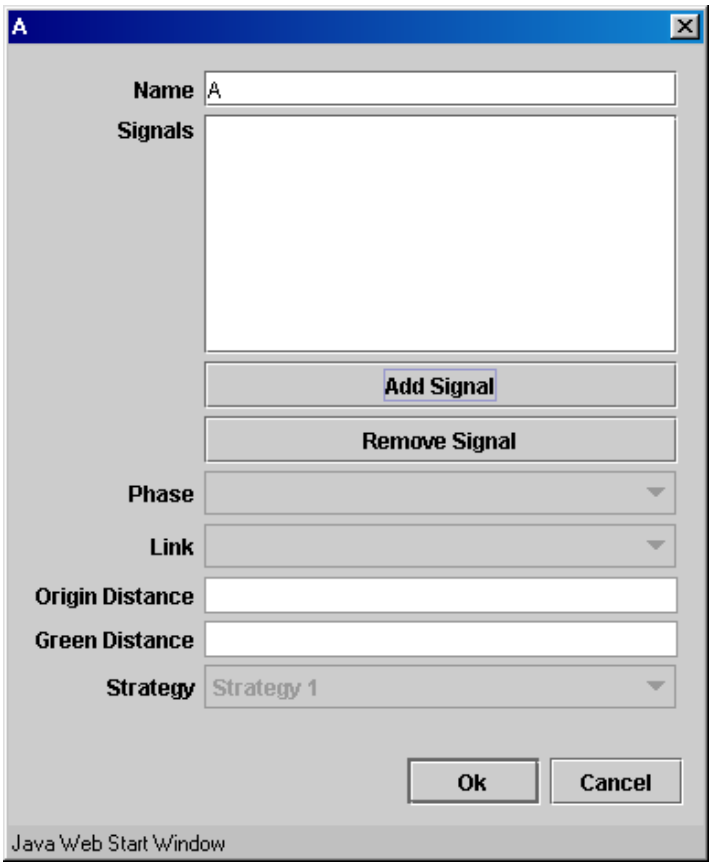


Figure 38: Java GIS Interface Signal Preemption editing window

Data-Bus Option - The Data|Bus option allows the user to add, edit and remove bus stops, bus periods and bus routes (see Figure 39). If the user chooses to add or edit bus stops a bus stop editing window appears (see Figure 40) in which the user can define the link on which the bus stop is to be located, the name of the bus stop, the location along that link (distance in feet from the destination end of the link), and length of the bus bay if one exists. If ―Remove Bus Stop‖ is selected, the user can click on a bus stop to delete it from the network.

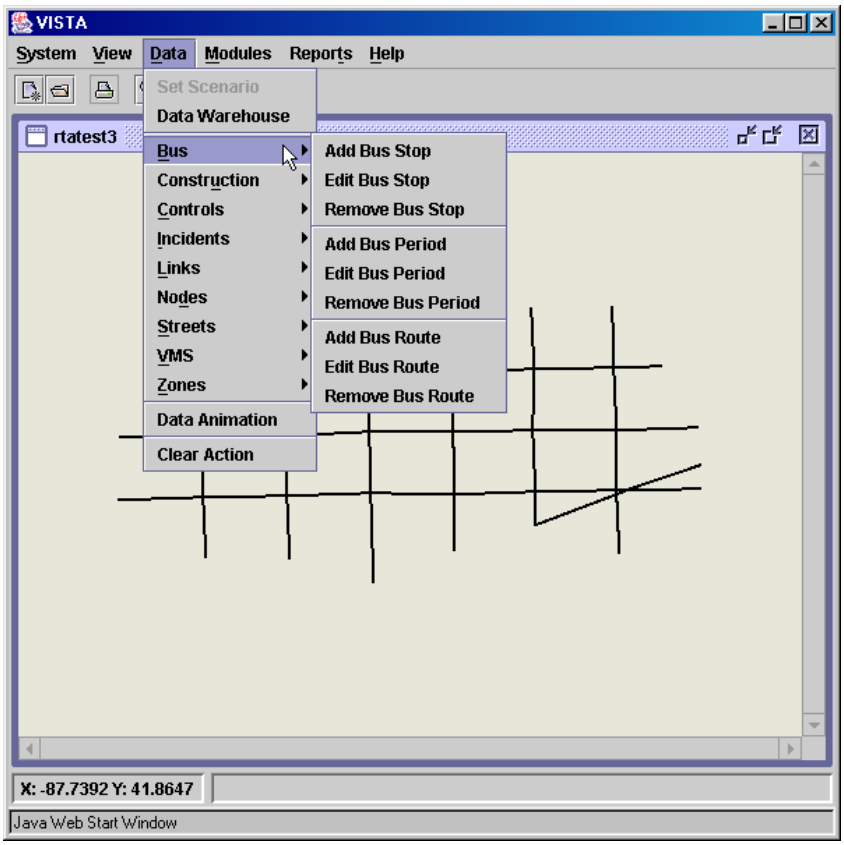


Figure 39: Java GIS Interface Data|Bus menu option

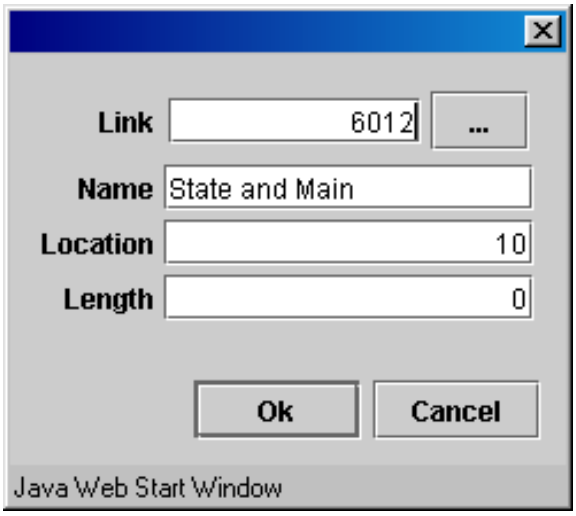


Figure 40: Java GIS Interface Add/Edit bus stop window

Choose a bus period - If the user chooses to edit bus periods a bus period selection window appears (see Figure 41) in which the user can select from the drop down menu the bus period to be edited. A bus period editing window then appears (see Figure 42) in which the user can adjust the start and end times of the selected bus period. If ―Add Bus Period‖ is selected, a window similar t o the bus period editing window (Figure 41) appears in which a new bus period can be defined. If ―Remove

Bus Period|| is selected, the bus period selection window appears (Figure 41) from which the user can select the bus period to delete it from the network.

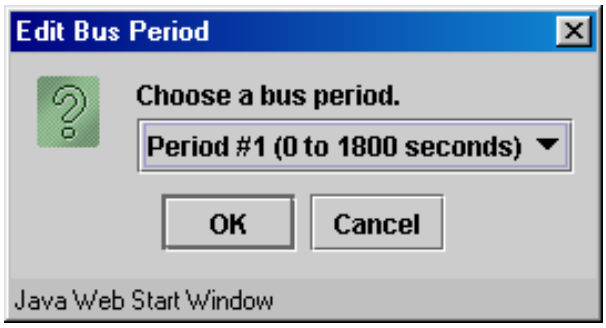


Figure 41: Java GIS Interface Edit Bus Period selection window

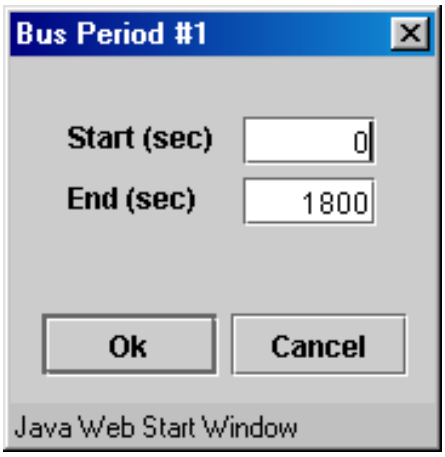


Figure 42: Java GIS Interface Edit Bus Period window

Choose Bus Route - If the user chooses to edit bus route, the Choose Bus Route window appears (see Figure 43) in which select from the drop down menu the bus route to be edited. A bus route editing window then appears in which the user can adjust the route link definition (see Figure 44) and the schedule (see Figure 45) of the selected bus route (there are tabs for each at the top of the window). If "Add Bus Route" is selected, a window similar to the bus route editing window appears in which a new bus route and schedule can be defined. If "Remove Bus Period" is selected, the bus route selection window appears (Figure 46) from which the user can select the bus route to delete it from the network.

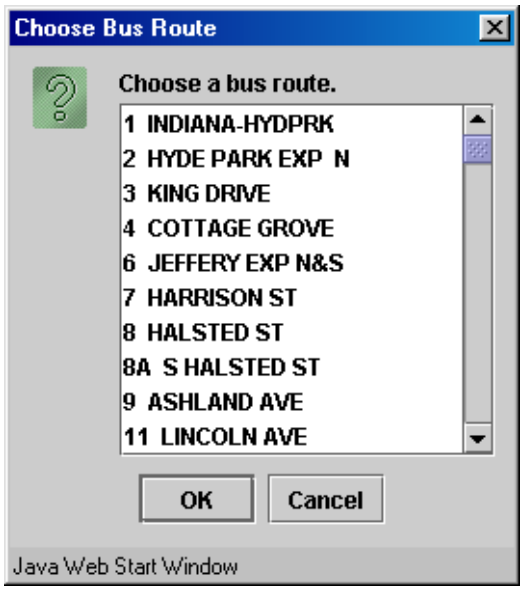


Figure 43: Java GIS Interface Choose Bus Route window

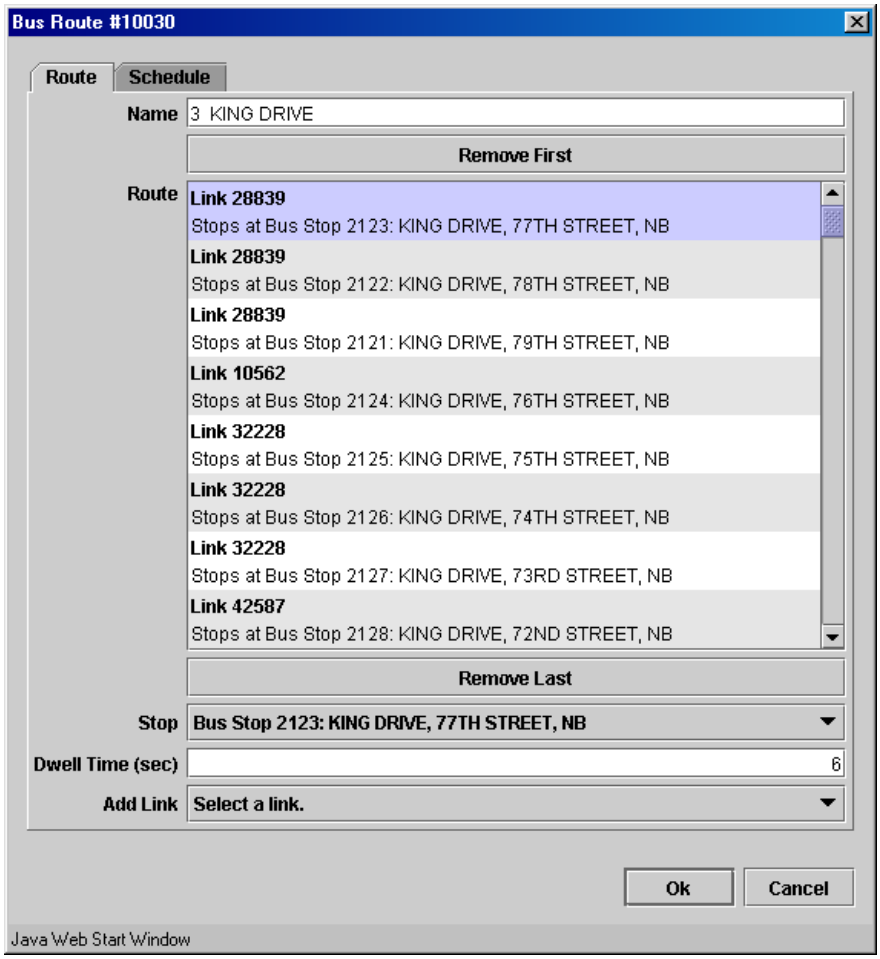


Figure 44: Java GIS Interface Bus Route editing window (route links)

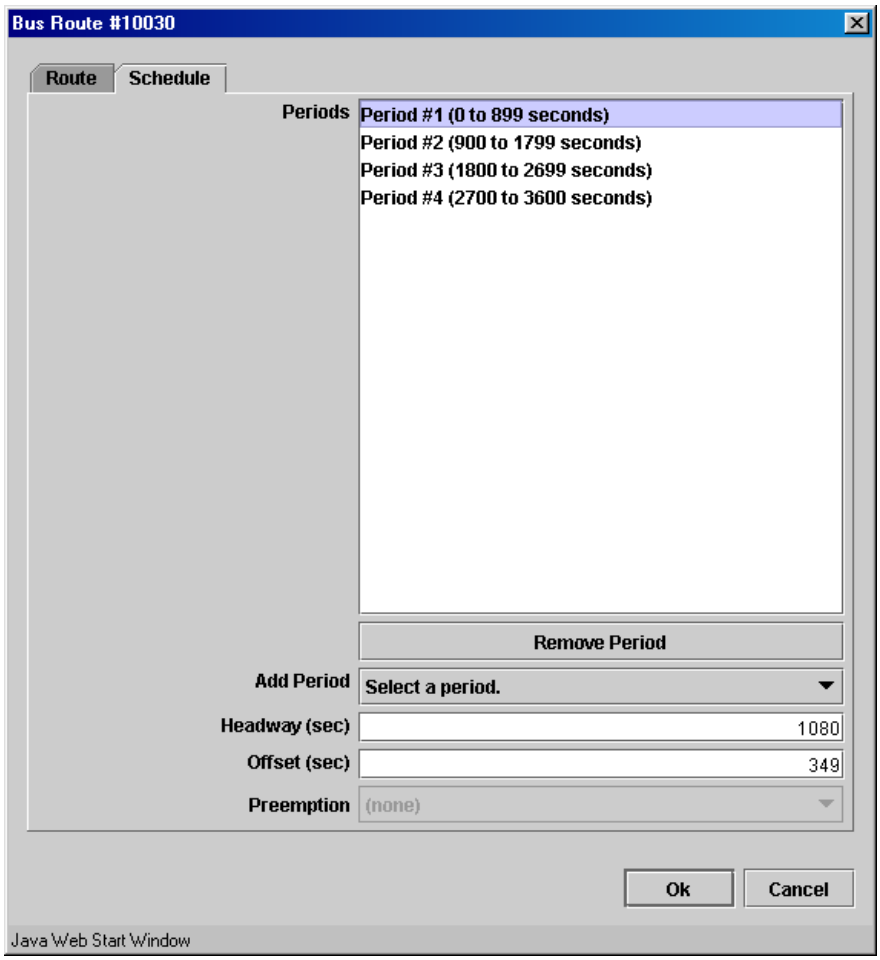


Figure 45: Java GIS Interface Bus Route editing window (schedule)

3.2.3 Viewing and Editing Data in the Data Warehouse

The detailed data tables and queries available in the VISTA web interface can also be accessed through the Java GIS Interface using the Data Warehouse option (available only to authorized users based on their account and password) in the Data menu (see Figure 46).

Data-Data Warehouse - When the Data Warehouse option is selected, the Data Warehouse window appears as shown in Figure 47. In this window, the File|Open option can be selected in order to open a specific table. The Choose Table window will then appear with a list of tables available in the database (see Figure 48). The user can then select one or several tables which will appear in the Data Warehouse window.

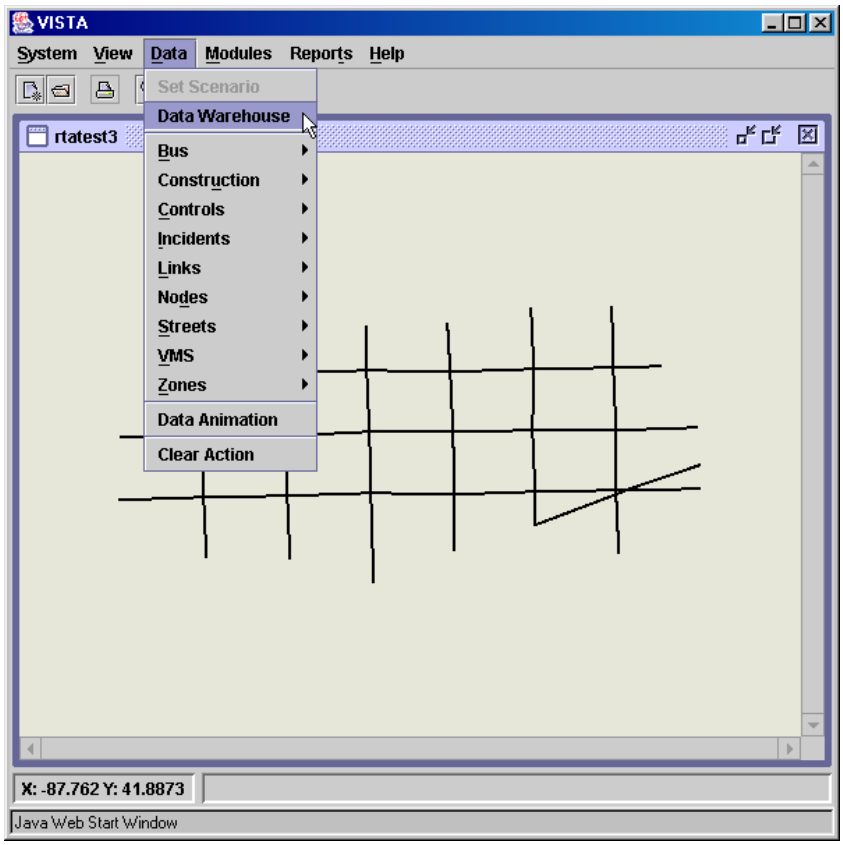


Figure 46: Java GIS Interface Data|Data Warehouse menu option

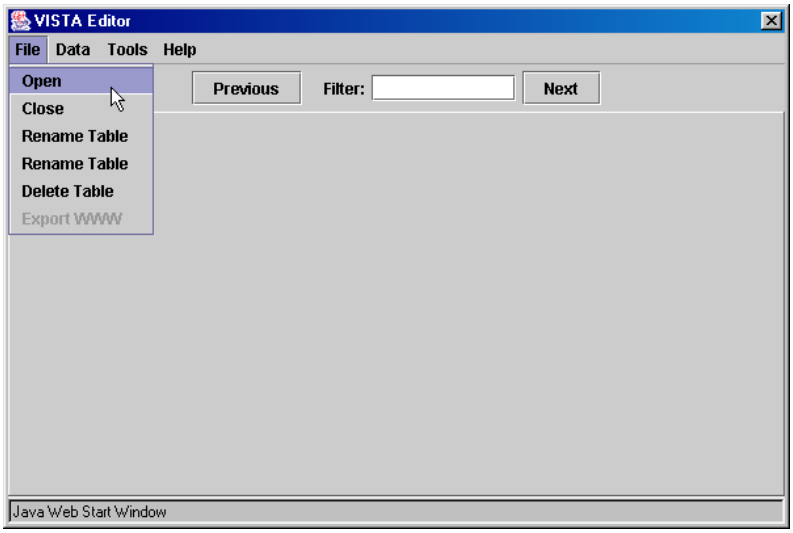


Figure 47: Data warehouse File|Open menu option

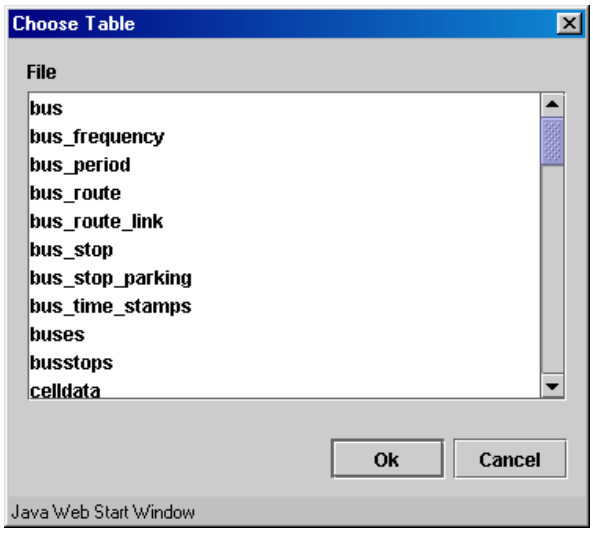
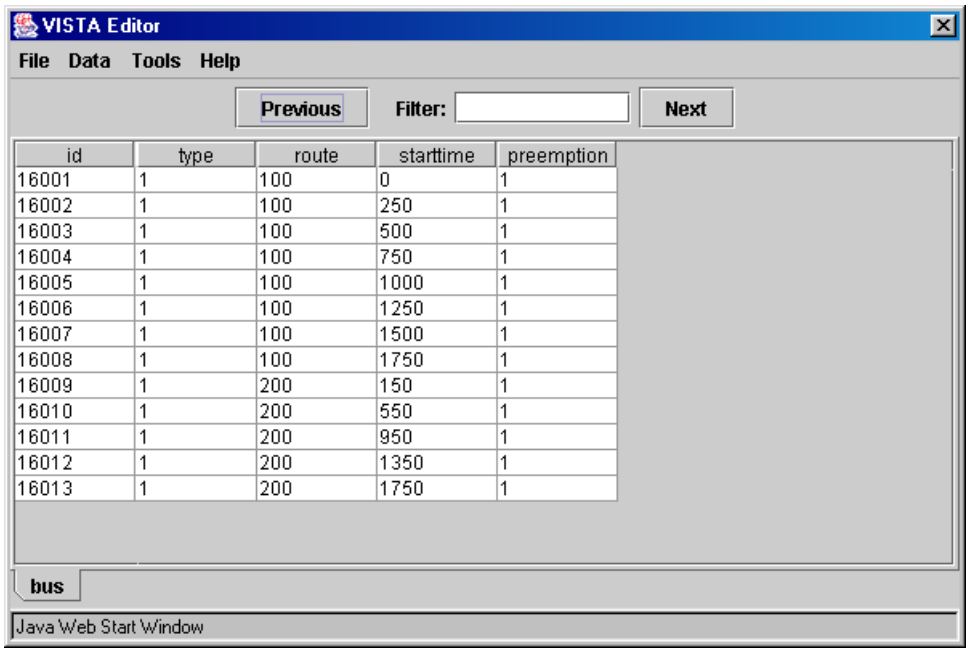


Figure 48: Data warehouse Choose Table window

Bus Table Example - Figure 49 shows the bus table for the example network. The tab at the bottom of the window shows that name of the table (bus), and multiple tabs will appear if several tables are open. If the table has more records than can be shown in one screen, the Previous and Next buttons at the top of the window can be used to see other records. Further, the table can be queried by entering an expression in the Filter box and clicking on Data|Reload Data (see Figure 50).



id	type	route	starttime	preemption
16001	1	100	0	1
16002	1	100	250	1
16003	1	100	500	1
16004	1	100	750	1
16005	1	100	1000	1
16006	1	100	1250	1
16007	1	100	1500	1
16008	1	100	1750	1
16009	1	200	150	1
16010	1	200	550	1
16011	1	200	950	1
16012	1	200	1350	1
16013	1	200	1750	1

Figure 49: Data warehouse example data table (bus table)

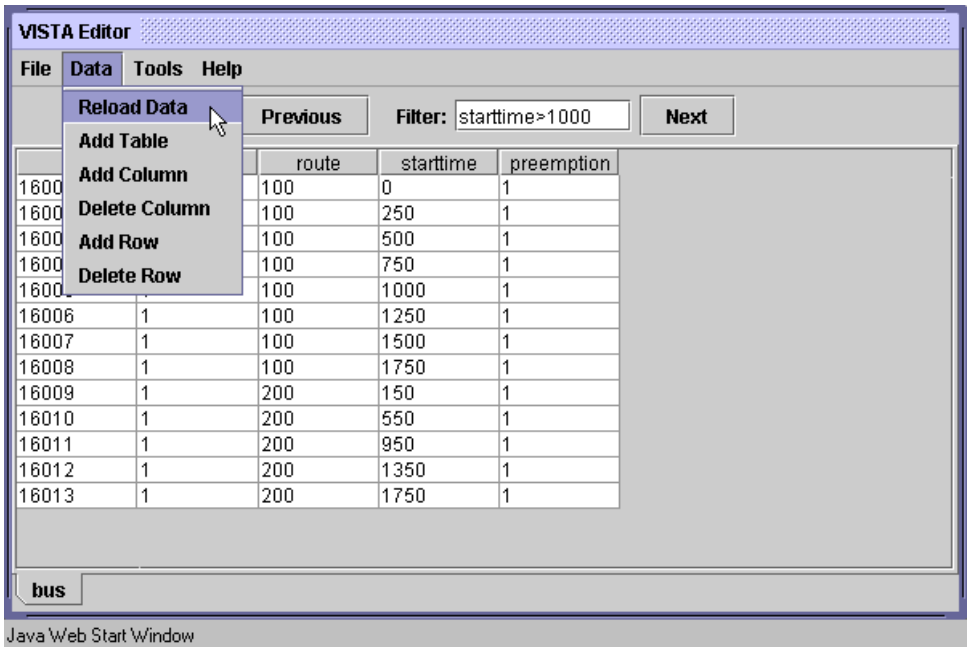


Figure 50: Data warehouse example data table with a query (bus table)

4.0 Running the Dynamic Traffic Assignment Module

The DTA and DTA-related modules used in the TSP project are listed in Table 1, along with lists of the parameters that must be defined and the functions performed by each module. The Cell Generation, Demand Profiler, Bus Assignment, Intersection Signal Optimization and Intersection Signal Coordination modules are run before DTA to ensure that network, demand, bus and signal data are in the format required by the DTA module. DTA is then run and RouteSim is called from within DTA. When DTA is complete, the vehicle path and travel time results are imported to the database, so that they can be used in reporting modules. Access to the modules through the web and Java GIS Interfaces are also described in this section.

Table 1: DTA and DTA related Modules

Module	Parameters	Module Function
Generate Cell File	Time Step Weather—clear, light rain, moderate rain, heavy rain	Creates a cell network based on the node and link network, with the length of each cell equal to the distance traveled in one time step at free flow speed. If rainy weather is selected, lower free flow speeds will be assumed, resulting in shorter cells.
Demand Profiler	Weightings Simulation Length (seconds) Use Zone IDs Use Dynamic Table Max O-D Pairs	Assigns exact departure times to each vehicle. The weightings entered determine the proportion of vehicles to depart in each interval within the selected simulation length. The "Use Zone IDs" box should be selected if the origins and destinations in the static_od table are zone ids rather than node ids. The "Use Dynamic Table" box can be selected if the demand to be profiled is already in time-dependent rather than static format. A maximum number of OD pairs can be entered to limit the number of vehicle trips created in the demand table.
Bus Assignment	None	Assigns exact departure times to buses based on the data in the bus period and frequency tables.
Intersection Signal Optimization	Node ID Minimum Cycle Length Minimum Phase Green Time Force Generation	Creates and optimizes signal at node selected, subject to the timing constraints entered. If "Force Generation" is selected, a signal will be created even if flows do not warrant it according to the MUTCD rules.
Intersection Signal Coordination	Nodes	Coordinates the signals at the nodes selected.
DTA with TDSP	Iterations Ending Time (seconds) Time Step (seconds) Assignment Length (steps) Warm Up/Cool Down	Performs DTA with calculation of time dependent shortest paths (TDSP) at each iteration. The number of iterations, simulation length ("Ending Time"), time step and number of time steps ("Assignment Length") can be specified. If "Warm Up/Cool Down" is selected, the simulation will begin 15 minutes early to pre-load the network, and end 15 minutes late to allow vehicles to complete their trips.
DTA with Updates Only	Same parameters as DTA with TDSP	Performs DTA with updates of previously calculated paths at each iteration, instead of calculating the time dependent shortest paths (TDSP). This saves significant computational time, but can only be done if DTA has been previously performed, and a library of routes has already been created.
RouteSim	Simulation Length (seconds) Time Step (seconds)	RouteSim is automatically called from within DTA, but can also be run on its own.
Import Simulation Results to Database	None	After DTA has been run, this module is run to create vehicle path and travel time database tables based on the text file output created by the DTA module. The database tables will then be used to run reporting modules.

4.1 Running DTA Modules from the Web interface

The Modules page allows the user to run DTA and other utilities on the selected network. A scroll menu of modules appears on the left side of the page, and the right side lists any parameters that must be entered for the selected module (see Figure 51). The status of a module can be tracked by checking the "Tasks" page (see Figure 52). This page lists all the tasks that are in process and complete and also provides links to log files for each task.

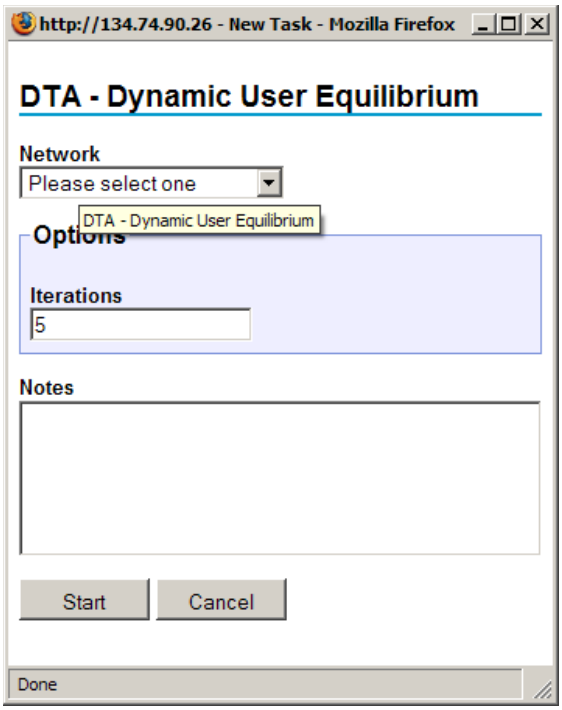


Figure 51: Web interface Modules page

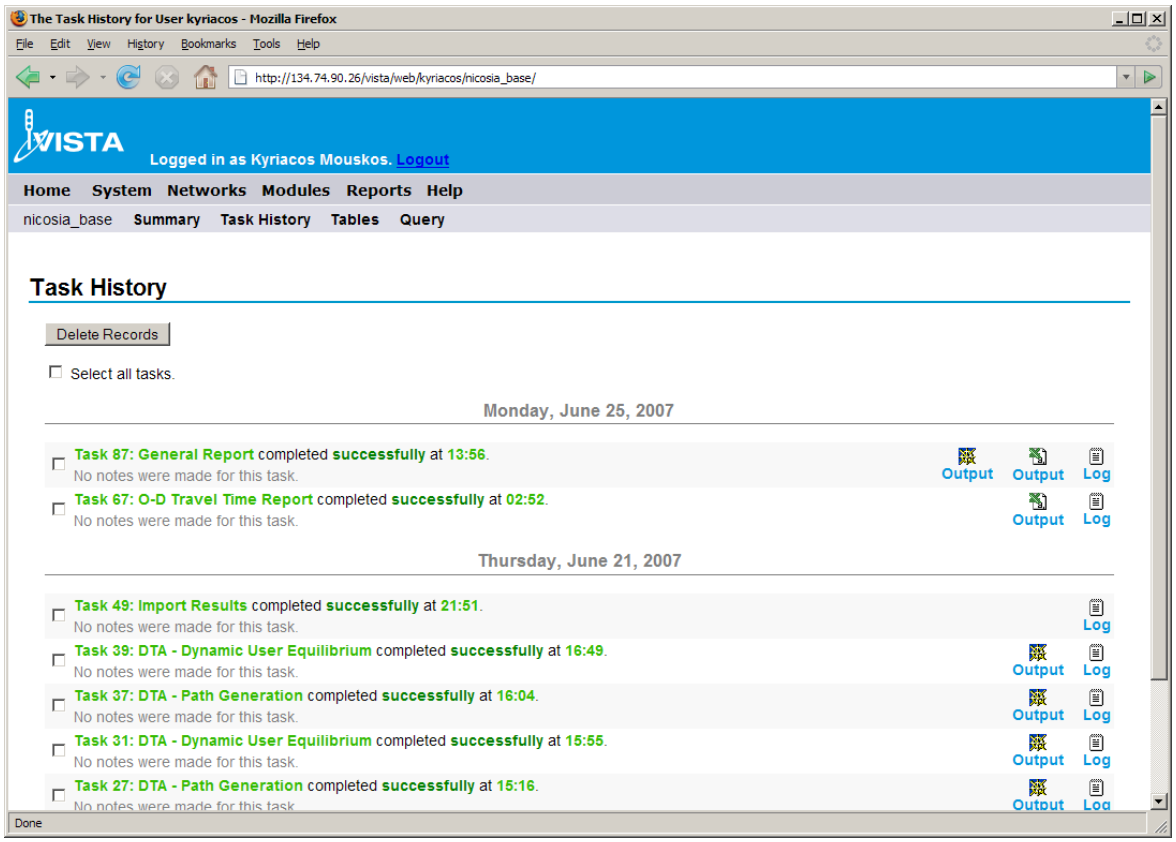


Figure 52: Web interface Tasks page

4.2 Running DTA Modules from the JAVA GIS Interface

The Modules menu allows the user to run DTA and other utilities on the selected network (see Figure 53).

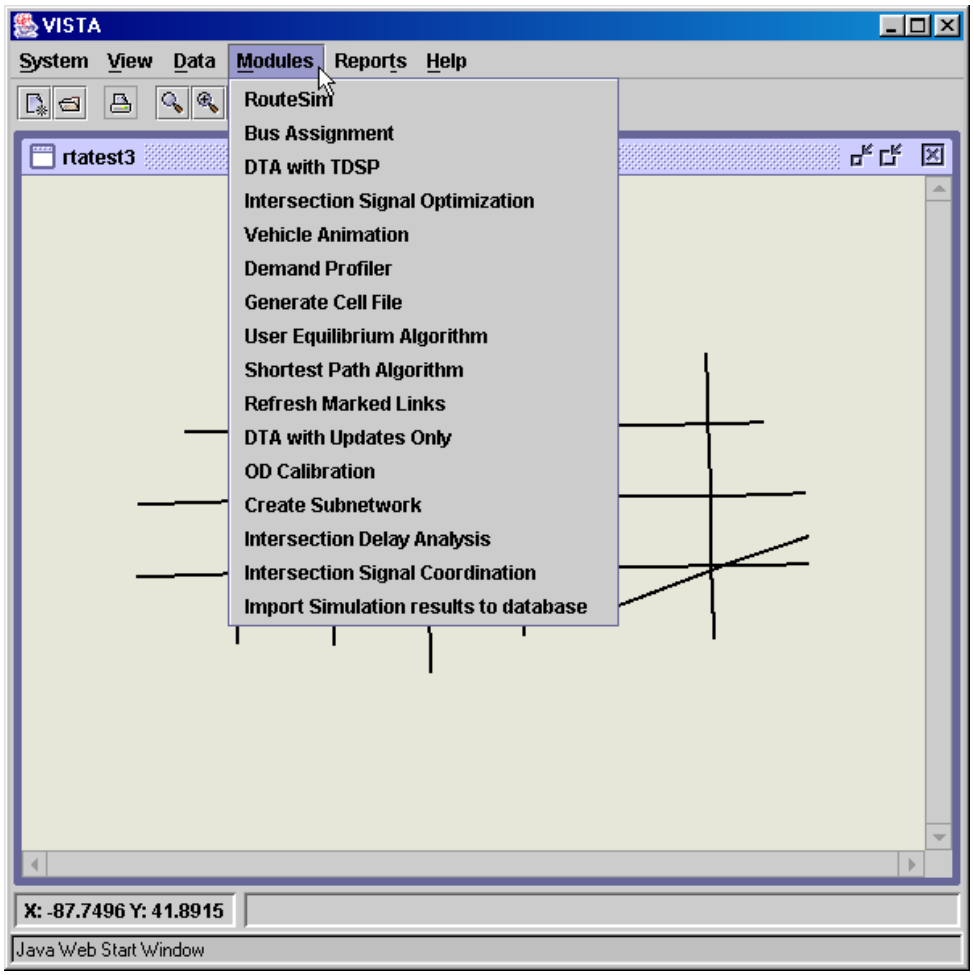


Figure 53: Java GIS Interface Modules menu

5.0 RUNNING REPORTING MODULES

The reporting modules used in the TSP project are listed in Table 2, along with lists of the parameters that must be defined and the functions performed by each module. In each case, "Table Name" indicates the name of the database table to which the report results should be written. Access to the reporting modules through the web and Java GIS Interfaces are also described in this section.

Table 2: Reporting Modules

Module	Parameters	Report Output
General Report	Time Intervals	Aggregate system-wide travel time report
Path Time Space Diagram	Link IDs Table Name	Plot of the average travel time through the corridor.
Origin Destination Travel Time Report	none Table Name	Listing of average travel time, travel time variance and number of vehicles for each OD pair.
Path Information Analysis	Table Name Origin Node Destination Node Use Zone	Table listing all paths used between the origin and destination selected. If ―Use Zone‖ is selected, the ―Origin Node‖ and ―Destination Node‖ values will be taken as zone ids instead of node ids.
Link Traffic Composition Analysis	Link ID Table Name	For the selected link, the origins and destinations of all vehicles that travel on that link will be reported.
Bus Travel Time Report	Bus Route Table Name	For the selected bus route, the travel time for each run completed during the simulation will be reported, along with the travel time average and variance for that route.
Bus Path Time Space Report	Link IDs Table Name	For the selected links, the bus travel time average and variance are reported.
Schedule Adherence Report	Bus Route Table Name	For the selected bus route, the schedule adherence of each run at each time point will be reported.
Signal Report	Node Table Name	For a selected intersection, the total green time and proportion of green time over the whole simulation period will be reported. Also, maximum, minimum, average and variance of green times per cycle will be listed.
Intersection Vehicle Counts	Table Name Node Time Interval	For the selected intersection, the number of vehicles making each movement is listed for each time interval of the specified length.
Cumulative Flows	Link ID	For the selected link, a plot showing cumulative in-flow and out-flow is produced.
VMS Report	Time Interval VMS ID	For the selected VMS, the vehicle counts and travel times on the all route alternatives are shown for each time interval.
Detector Report	Time Interval Detector ID	For the selected detector, the average and standard deviation of the vehicle occupancy, flow and travel time for each time interval are shown in both table and plot format.
TRANSMIT Detector Report	Time Interval TRANSMIT Detector ID	A table listing the number of vehicles detected by the selected detector for each time interval is shown. A second table lists all other TRANSMIT detectors that detected vehicles that had passed through the selected detector, and shows the number of vehicles that passed through those detectors.
DTA Aggregator	none	The DTA Aggregator reports link travel times averaged over each minute of simulation.
Link Plots	Link ID	Travel time, density flow in or flow out curves are reported for the selected link.

5.1 Running Reports from the Web interface

In the web interface, all of the reports can be run from the “Reports” page (see Figure 54), except for the Intersection Movement Counts and the Link Traffic Composition Analysis, which are found on the “Modules” page. A list of previously run reports appears in the “Reports History” section of the “Reports” page. Further, the progress and completion of a report can be tracked through the web interface “Tasks” page (see Figure 52). Examples of the report results are shown below.

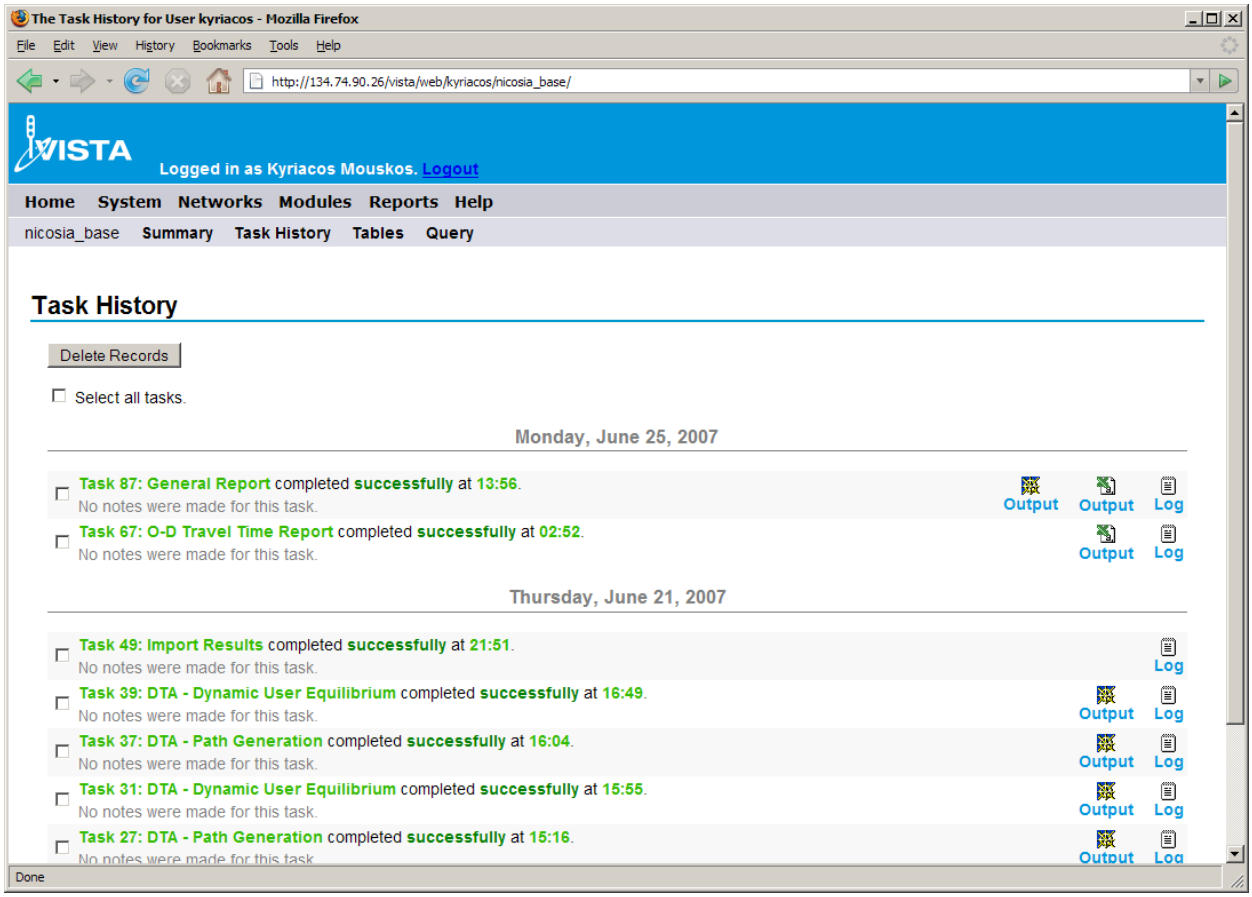


Figure 54: Web interface Tasks page with Reports

5.1.1 General Report

The General Report gives general network statistics, such as number of nodes, links, controls and OD pairs. It also gives aggregate travel statistics; including total system travel time and average, maximum and minimum OD travel times. Further, the distributions of OD travel times and vehicles departure times are shown. The level of detail of the distributions can be increased by setting a smaller “Time Interval” value at the top of the General Report page and clicking on “Update”. An example of a General Report is shown in Figure 55.

General Report - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://134.74.90.26/vista/web/kyriacos/nicosia_base/87/87.html

General Report

Prepared by Kyriacos Mouskos at 13:58 Mon, Jun 25, 2007 for network(s) nicosia_base.

Table of Contents

1. Basic Network Information
2. Travel Time information (Entered Vehicles)
3. Travel Time information (Through Vehicles)
4. Travel Time information (Loaded Vehicles)
5. Delay Information (Entered Vehicles)
6. Delay Information (Through Vehicles)
7. Delay Information (Loaded Vehicles)
8. Distribution Graph
9. Terminology

1. Basic Network Information

Table 1. Network Overview

Item	Counts in network nicosia_base
Nodes	235
Links	733
Signalized Intersection	0
VMS panels	0
Detectors	0
TRANSMIT Detectors	0

Done

General Report - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://134.74.90.26/vista/web/kyriacos/nicosia_base/87/87.html

Detectors	0
TRANSMIT Detectors	0
Zones	0
O-D pairs	622
Demand Total	517514
Demand Passenger Vehicles	517514
Demand Commercial Vehicles	0
Buses	0
Bus Routes	0
Assignment Length (s)	86400
Assignment Inverval(S)	900

Table 2. Vehicles Overview

	Loaded	Non-entered	Non-exited	Through	Entered Total TT(H)	AVG (M)	STD (M)	Entered Veh. VMT (Miles)	Through
All Type Vehicles	517514	0	0	517514	26289.0	3.05	2.18	937890.54	
Passenger Veh.	517514	0	0	517514	26289.0	3.05	2.18	937890.54	
Commercial Veh.	0	0	0	0					

2. Travel Time information (Entered Vehicles)

Table 3. All Type Vehicles Travel Time

Assignment	Start	End	No. Veh.	Total TT (H)	AVG (M)	STD (M)	VMT (Mile)

Done

Figure 55: Sample General Report from nicosia_base

5.1.2 Origin Destination Travel Time Report

The Origin Destination Travel Time Report lists the average travel time and travel time variance for each OD pair in the network, as well as the number of vehicles that traveled between each OD pair. An example of an Origin Destination Travel Time Report is shown in Figure 56. (The origins and destinations are listed as centroid node IDs.) This report will allow for convenient comparison of OD travel times for different TSP scenarios.

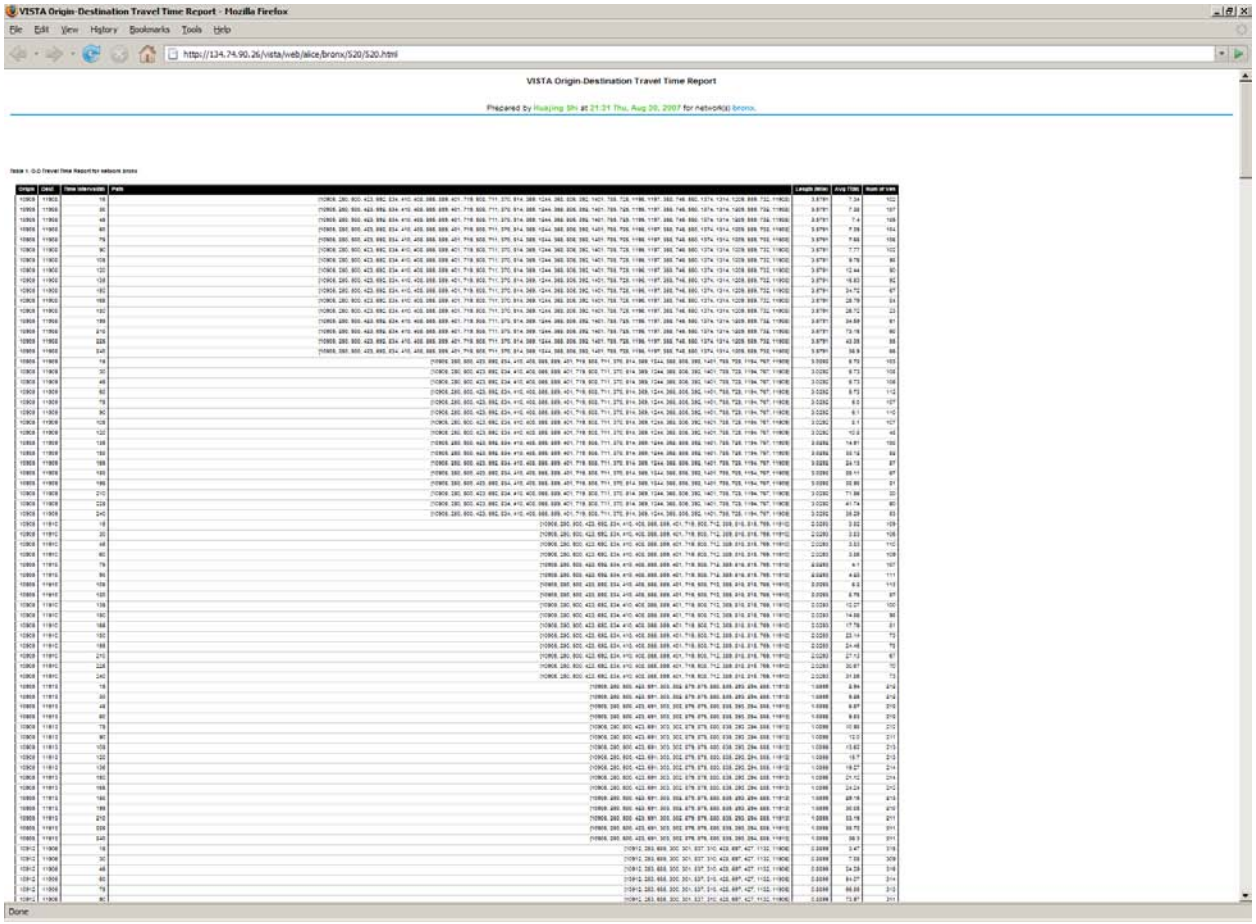
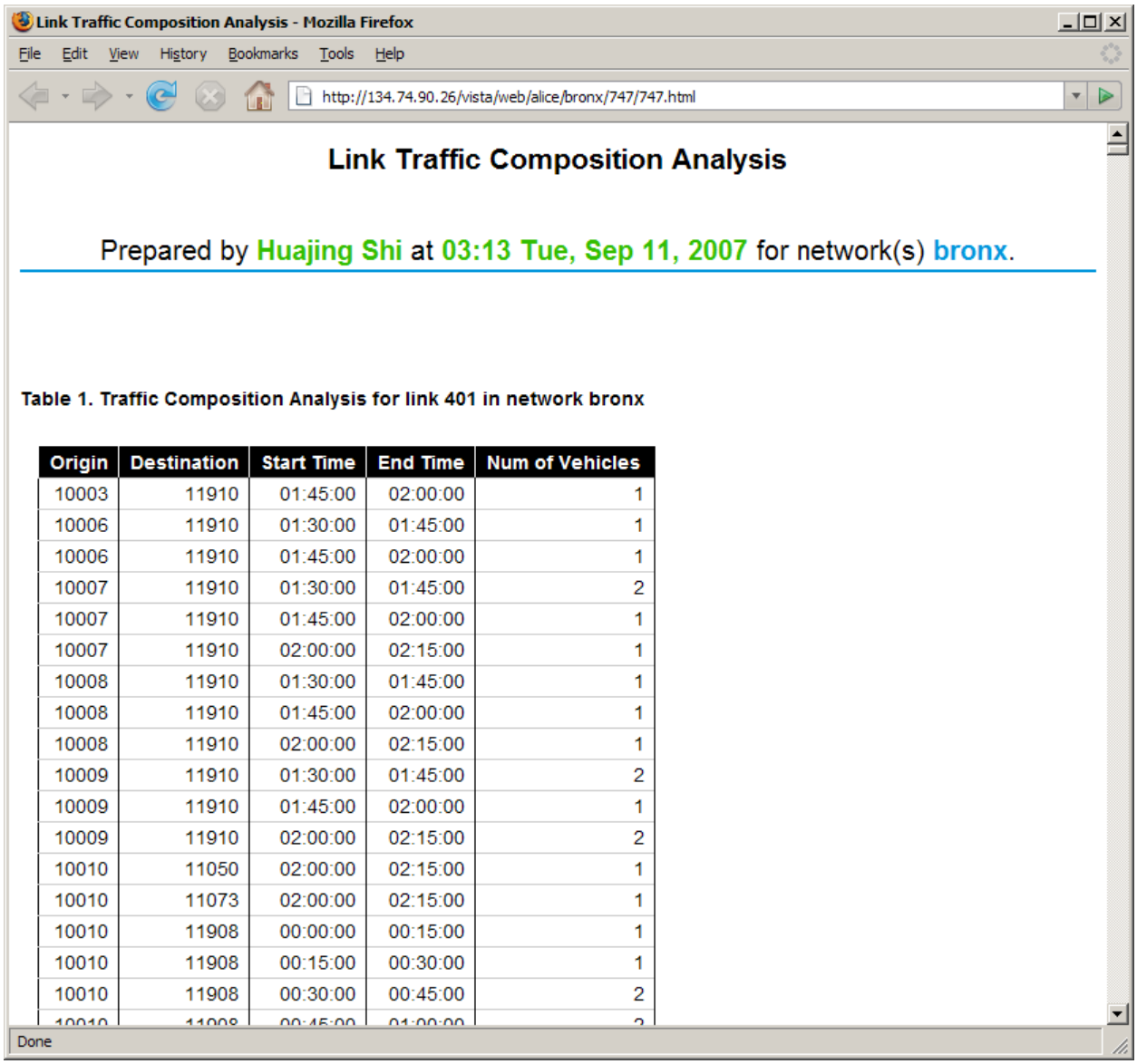


Figure 56: The Origin Destination Travel Time Report

5.1.3 Link Traffic Composition Analysis

For a selected link, the Link Traffic Composition Analysis report lists the OD pairs of the vehicles that traveled along that link. The results are stored in a database table, and can be accessed through the Database web page. An example of a Link Traffic Composition Analysis result table is shown in Figure 57. The first column, “id”, shows the ids of each entry. The “source” column shows the origin zone, and the “destination” column shows the destination zone. The “interval” column indicates a time interval within the simulation period, and the vehno column shows the number of vehicles that traveled on the selected link to travel between the given OD pair during the given time interval. The first row, with id=0, does not correspond to a link traffic composition entry, but instead shows origin node (in the “source” column), destination node (in the “destination” column) and link id (in the “interval” column) of the link.



Link Traffic Composition Analysis - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://134.74.90.26/vista/web/alice/bronx/747/747.html

Link Traffic Composition Analysis

Prepared by Huajing Shi at 03:13 Tue, Sep 11, 2007 for network(s) bronx.

Table 1. Traffic Composition Analysis for link 401 in network bronx

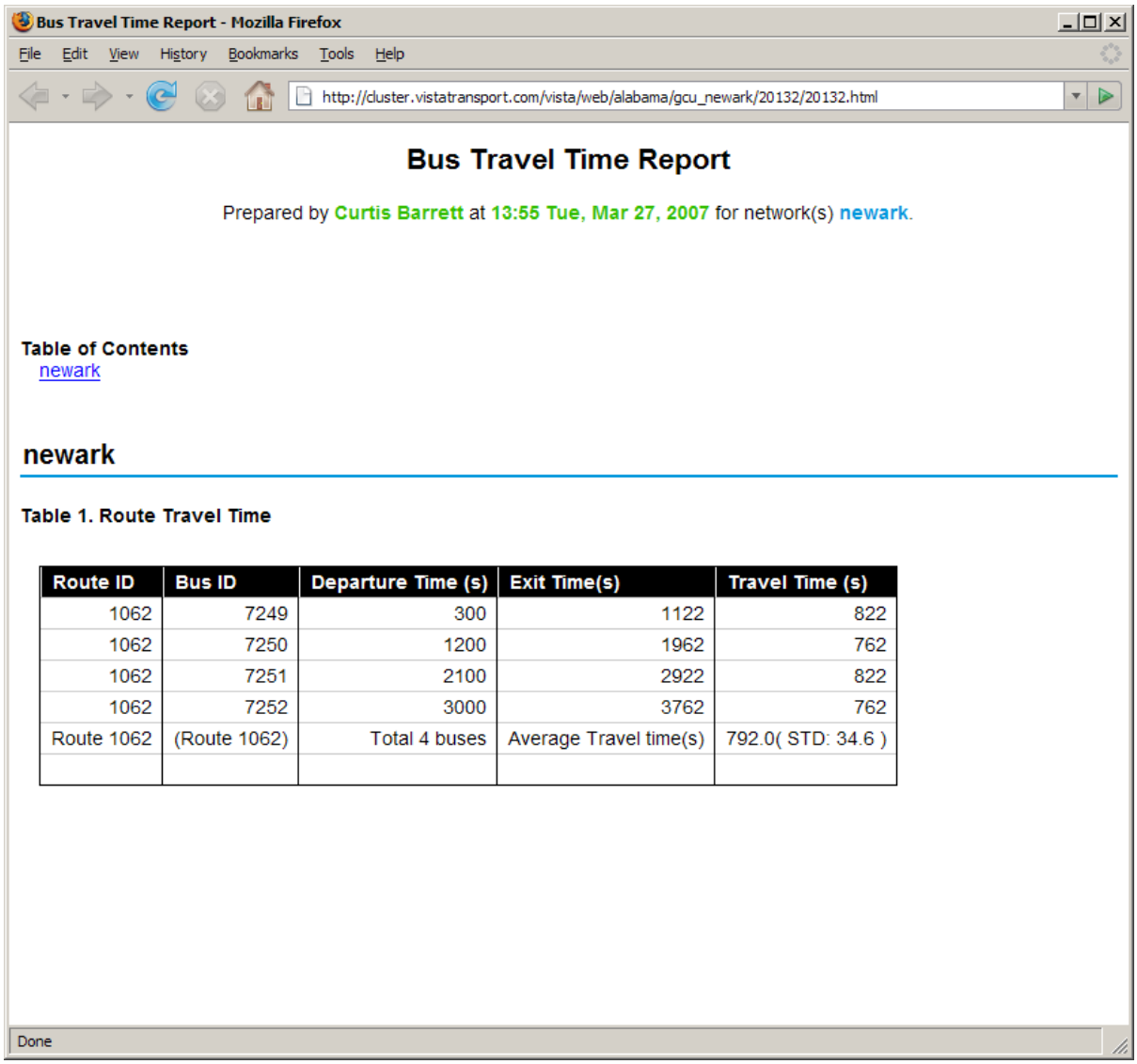
Origin	Destination	Start Time	End Time	Num of Vehicles
10003	11910	01:45:00	02:00:00	1
10006	11910	01:30:00	01:45:00	1
10006	11910	01:45:00	02:00:00	1
10007	11910	01:30:00	01:45:00	2
10007	11910	01:45:00	02:00:00	1
10007	11910	02:00:00	02:15:00	1
10008	11910	01:30:00	01:45:00	1
10008	11910	01:45:00	02:00:00	1
10008	11910	02:00:00	02:15:00	1
10009	11910	01:30:00	01:45:00	2
10009	11910	01:45:00	02:00:00	1
10009	11910	02:00:00	02:15:00	2
10010	11050	02:00:00	02:15:00	1
10010	11073	02:00:00	02:15:00	1
10010	11908	00:00:00	00:15:00	1
10010	11908	00:15:00	00:30:00	1
10010	11908	00:30:00	00:45:00	2

Done

Figure 57: The Link Traffic Composition Analysis Table

5.1.4 Bus Travel Time Report

The Bus Travel Time Report lists the departure time and total travel time of each run made for a selected route (only runs completed before the end of the simulation period are included). The average travel time and standard deviation and variance of the travel time for the bus route are then shown. An example of a Bus Travel Time Report is shown in Figure 58.



Bus Travel Time Report - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://cluster.vistatransport.com/vista/web/alabama/gcu_newark/20132/20132.html

Bus Travel Time Report

Prepared by Curtis Barrett at 13:55 Tue, Mar 27, 2007 for network(s) newark.

Table of Contents

newark

newark

Table 1. Route Travel Time

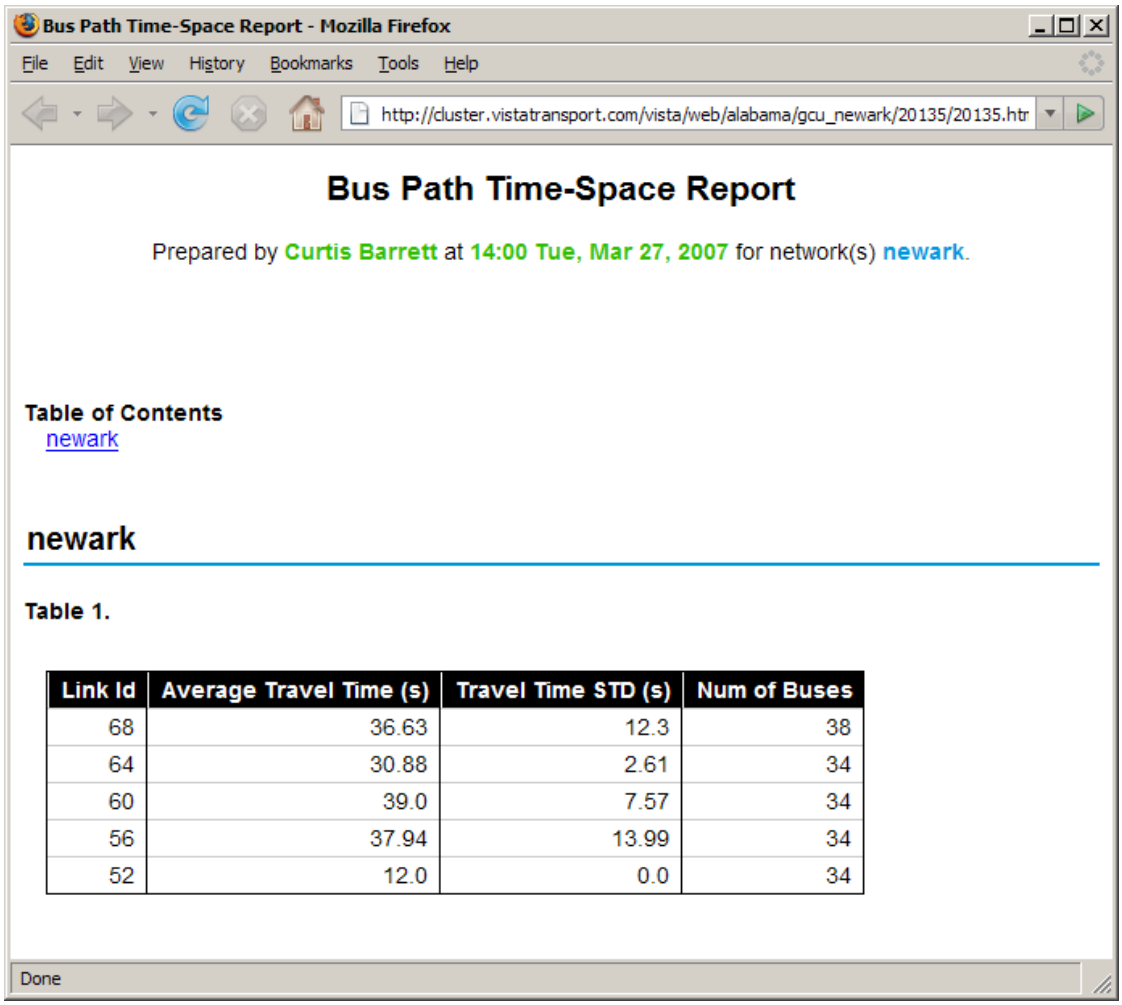
Route ID	Bus ID	Departure Time (s)	Exit Time(s)	Travel Time (s)
1062	7249	300	1122	822
1062	7250	1200	1962	762
1062	7251	2100	2922	822
1062	7252	3000	3762	762
Route 1062	(Route 1062)	Total 4 buses	Average Travel time(s)	792.0(STD: 34.6)

Done

Figure 58: The Bus Travel Time Report

5.1.5 Bus Path Time Space Report

For a selected set of links representing a corridor, the Bus Path Time Space Report shows the average travel time and travel time variance for each link. The number of buses included in the calculations is also listed for each link. An example of a Bus Path Time Space Report is shown in Figure 59.

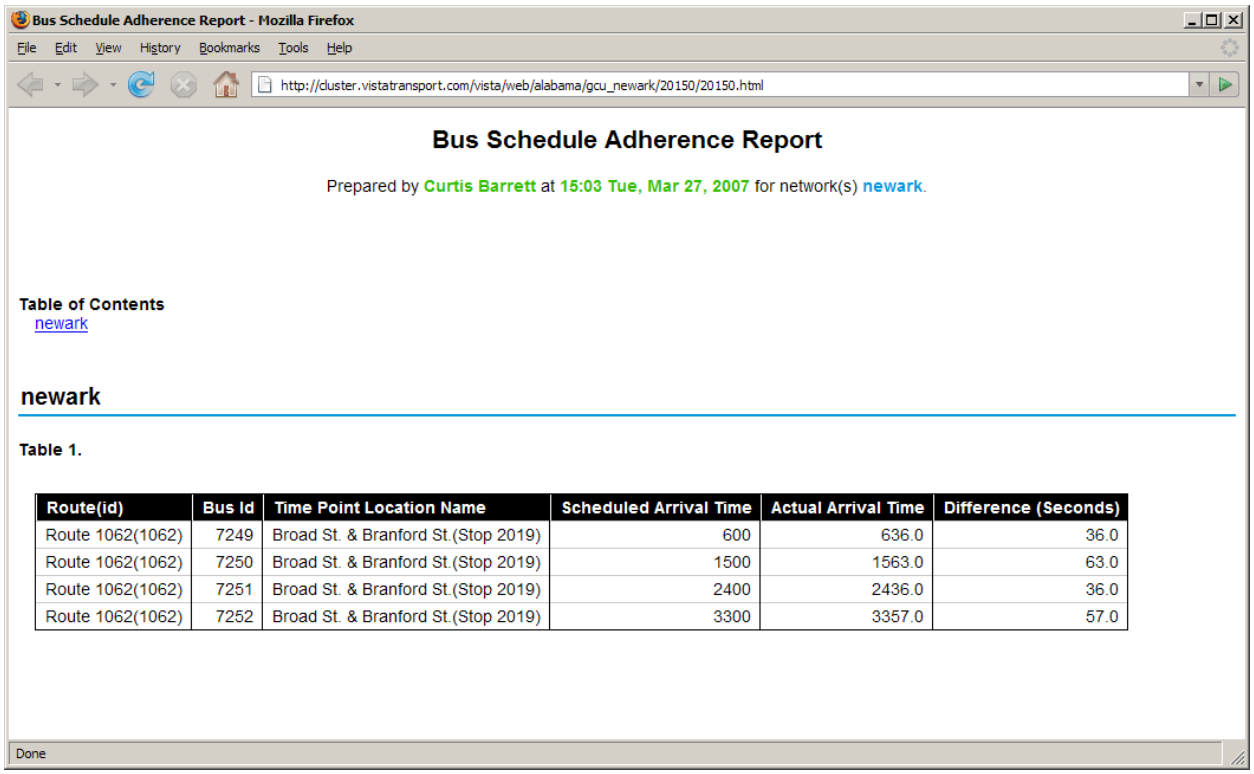


Link Id	Average Travel Time (s)	Travel Time STD (s)	Num of Buses
68	36.63	12.3	38
64	30.88	2.61	34
60	39.0	7.57	34
56	37.94	13.99	34
52	12.0	0.0	34

Figure 59: The Bus Path Time Space Report

5.1.6 Schedule Adherence Report

For a selected bus route, the Schedule Adherence Report shows the scheduled arrival time, actual arrival time and the difference between the two for each bus run and time point on that route. The scheduled arrival time is derived from data in the bus_time_stamps table and the actual arrival time is determined from the simulation output. An example of a Schedule Adherence Report is shown in Figure 60.



Bus Schedule Adherence Report - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://cluster.vistatransport.com/vista/web/alabama/gcu_newark/20150/20150.html

Bus Schedule Adherence Report

Prepared by Curtis Barrett at 15:03 Tue, Mar 27, 2007 for network(s) newark.

Table of Contents

newark

newark

Table 1.

Route(id)	Bus Id	Time Point Location Name	Scheduled Arrival Time	Actual Arrival Time	Difference (Seconds)
Route 1062(1062)	7249	Broad St. & Branford St.(Stop 2019)	600	636.0	36.0
Route 1062(1062)	7250	Broad St. & Branford St.(Stop 2019)	1500	1563.0	63.0
Route 1062(1062)	7251	Broad St. & Branford St.(Stop 2019)	2400	2436.0	36.0
Route 1062(1062)	7252	Broad St. & Branford St.(Stop 2019)	3300	3357.0	57.0

Done

Figure 60: The Schedule Adherence Report

5.1.7 VMS Report

The Variable Message Sign (VMS) report shows the vehicle count and average travel times for each of the route alternatives associated with a VMS. An example of a VMS report is shown in Figure 61. First, the report describes the location of the VMS and then shows the link ids of the links associated with each route alternative. Next, the report shows a table listing the average travel time and number of vehicles for each time interval on the first route alternative is shown along with a plot of the average travel time on the route. (The time interval is selected by the report user). A similar table and plot are then shown for the second route alternative.

VMS Report

Time Interval (minute): 5 VMS ID 2 Update

VMS 2 Location: **50** feet downstream on link **9** in lane **0**
Total Number of Vehicles Passed This VMS: 2810
Compliance Rate: 0.5
Strategy: 2

2 Routes attached:
Freeway -- Link id: 3 12 22 23 24 25
Number of vehicles went through this route: 2412
State Route -- Link id: 13 42 10 43 38 34 33
Number of vehicles went through this route: 51

Route 5 Freeway

Start	Average Travel Time (seconds)	Vehicle Count
0	73	**200**
300	75	**284**
600	79	**281**
900	81	**278**
1200	87	**286**
1500	88	**298**
1800	91	**284**
2100	95	**276**
2400	93	**278**
2700	92	**274**
3000	77	**281**
3300	101	**220**

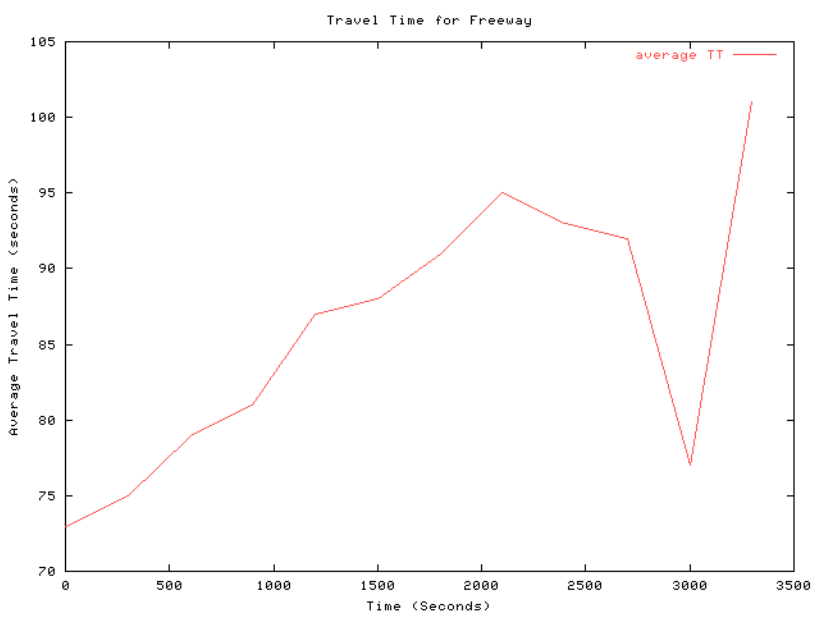


Figure 61: VMS Report

Route 6 State Route

Start	Average Travel Time (seconds)	Vehicle Count
2100	47	11
2400	153	27
2700	162	35
3000	281	26
3300	210	23

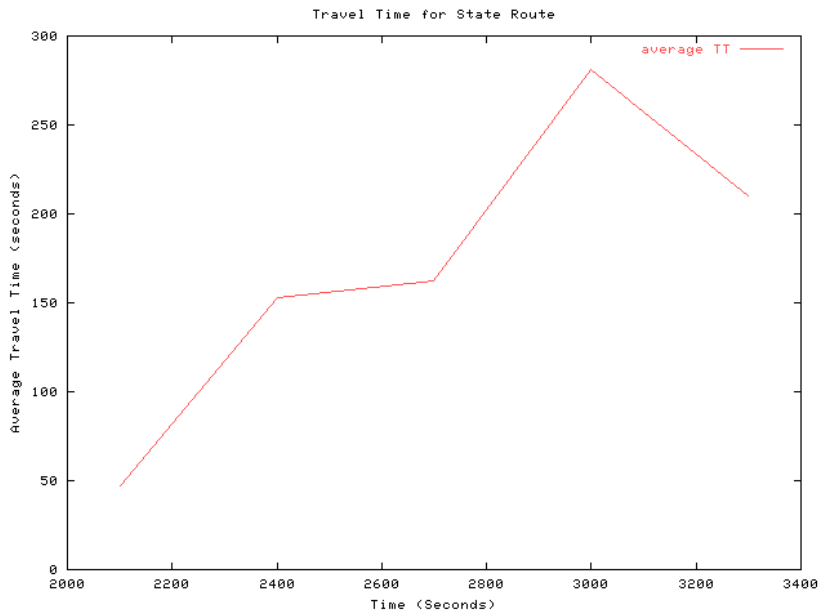


Figure 61 (continued): VMS Report

5.1.8 Detector Report

The detector report shows the flow, occupancy and speed detected by a selected detector in the simulator. An example of a Detector Report is shown in Figure 62. First, report describes the location of the detector. Next, the report shows a table listing the average and standard deviation of vehicle flow detected for each time interval, along with a plot of flow detected throughout the simulation period. (The time interval is selected by the report user.) A similar table and plot are then shown for the speed detected by the detector. The detector used in the example was set to detect only flow and speed, and not occupancy; therefore, the report shows a message stating that no occupancy data was found for the occupancy report.

Detector Report for detector 155

Time Interval (minute): 5 | Detector ID 148 | Update

Detector 155 Location: **1583** feet downstream on link **4465** in lane **3**

No data found for Occupancy Report

Flow Report

Period		Flow (vehicles/hour)	
Start	End	Average	Standard Deviation
0	300	**0.00**	**0**
300	600	**10.62**	**9**
600	900	**24.18**	**3**
900	1200	**57.26**	**14**
1200	1500	**118.60**	**11**
1500	1800	**144.26**	**10**
1800	2100	**164.52**	**3**
2100	2400	**160.90**	**3**
2400	2700	**176.82**	**10**
2700	3000	**202.86**	**5**
3000	3300	**203.32**	**2**
3300	0	**201.41**	**1**

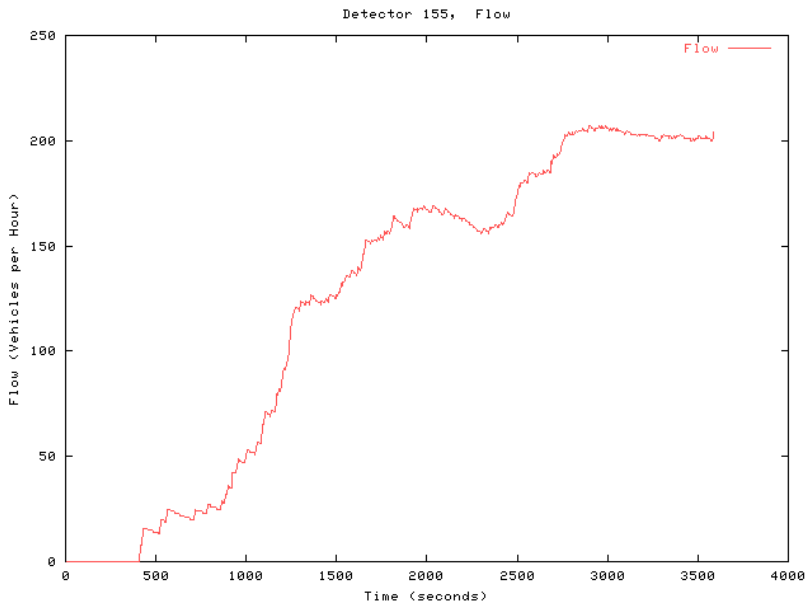


Figure 62: Detector Report

Speed Report

Period		Speed (mph)	
Start	End	Average	Standard Deviation
0	300	7.00	0
300	600	7.00	0
600	900	7.00	0
900	1200	7.00	0
1200	1500	7.00	0
1500	1800	7.00	0
1800	2100	7.00	0
2100	2400	7.00	0
2400	2700	7.00	0
2700	3000	7.00	0
3000	3300	7.00	0
3300	0	7.00	0

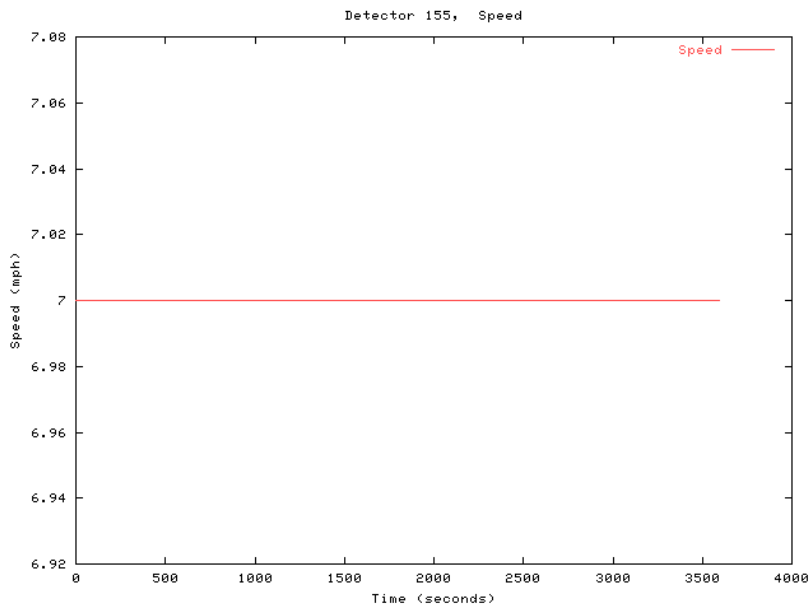


Figure 62 (continued): Detector Report

5.1.9 TRANSMIT Detector Report

The TRANSMIT detector report shows the number of vehicles detected by a selected TRANSMIT detector in the simulator. An example of a TRANSMIT Detector Report is shown in Figure 63, where the detector of interest is number 6147022, as shown in the title bar of the window. First, the report describes the location of the detector. Next, the report shows a table listing the number of vehicles detected for each time interval. (The time interval is selected by the report user.) The total, average, standard deviation and variance of the number of vehicles detected are listed at the end of the table. A second table lists all other TRANSMIT detectors that detected vehicles that had passed through the detector 6147022, and shows the number of vehicles that passed through those detectors.

TRANSMIT Detector Reports for detector 6147022

Time Interval (minute): 5 | Detector ID 6147016 | Update

Detector 6147022 Location: 2000 feet downstream on link 21402130 in lane 1

Period Start	Period End	Vehicles
00:00:00	00:05:00	23
00:05:00	00:10:00	43
00:10:00	00:15:00	61
00:15:00	00:20:00	64
00:20:00	00:25:00	77
00:25:00	00:30:00	54
Total		322
Average		54
Standard Deviation		19
Variance		352

Detector	Vehicles
6147032	315
6147042	1
Total	315
Exclusive	7

Figure 63: TRANSMIT Detector Report

5.2 Running Reports from the Java GIS Interface

The Reports menu allows the user to run reports on the selected network (see Figure 64). Most of the reports output their results to tables, which can be viewed in the Data Warehouse or the web interface. Results that are not outputted to tables can be viewed in the web interface. The DTA Aggregator and link plots are described in this section. See Section 5.1 on Running Reports from the Web interface for detailed explanations and examples of the Path Information Analysis, Link Traffic Composition Analysis, Path Time Space Diagram, Cumulative Flows, General Report and Intersection Vehicle Count Reports.

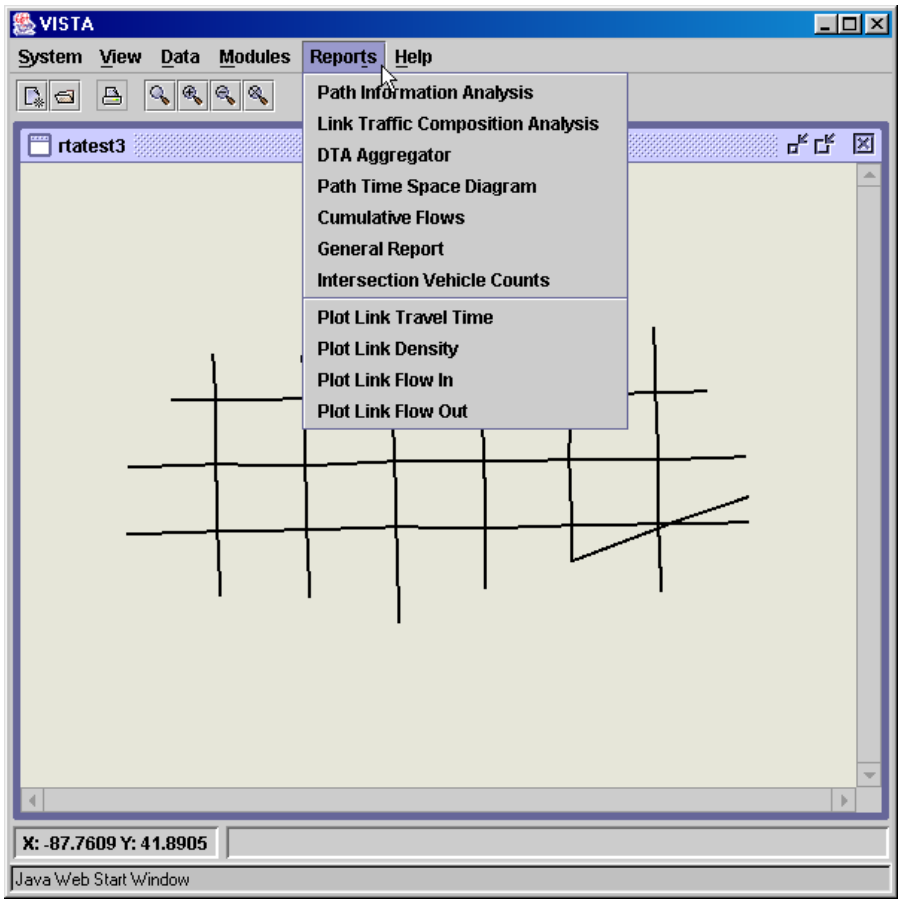


Figure 64: Java GIS Interface Reports menu

5.2.1 Link Plots

Travel time, density flow in and flow out curves can also be reported for user-selected links. The reports show the respective measures plotted over the simulation period. For example, Figure 65 shows the density plot of link 19868. A Data tab is available in the top left of the window, and allows the density data to be viewed in table format, as shown in Figure 66. The Preferences tab provides display options for the plot, as shown in Figure 67.

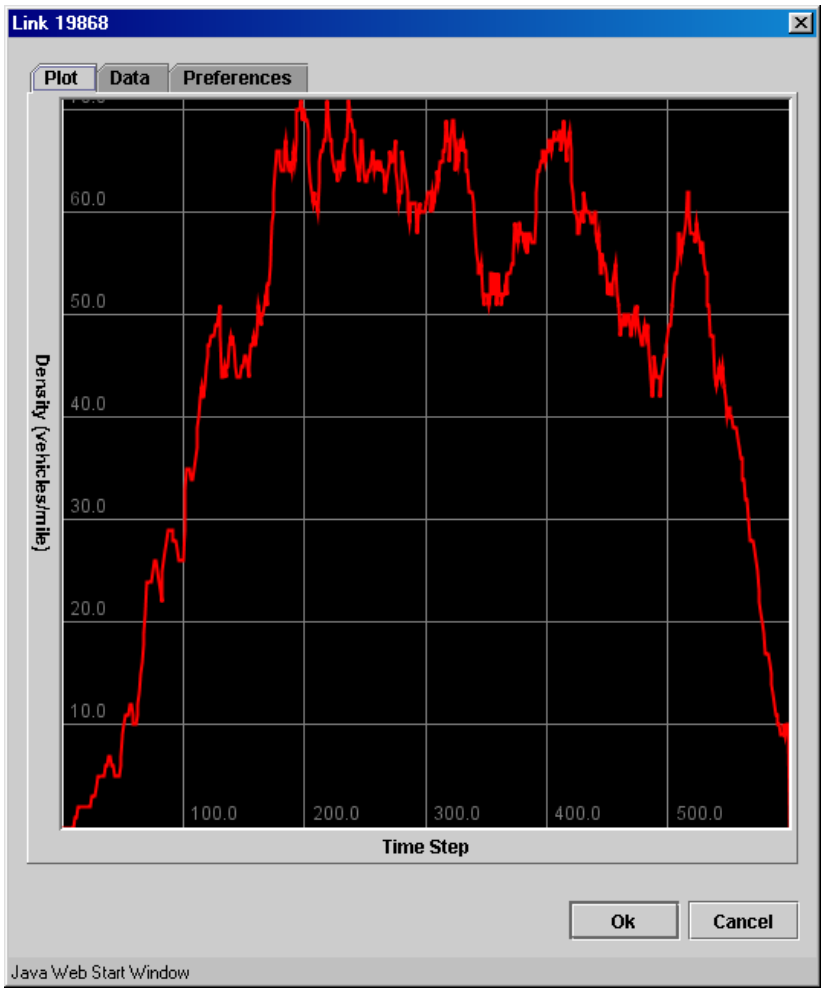
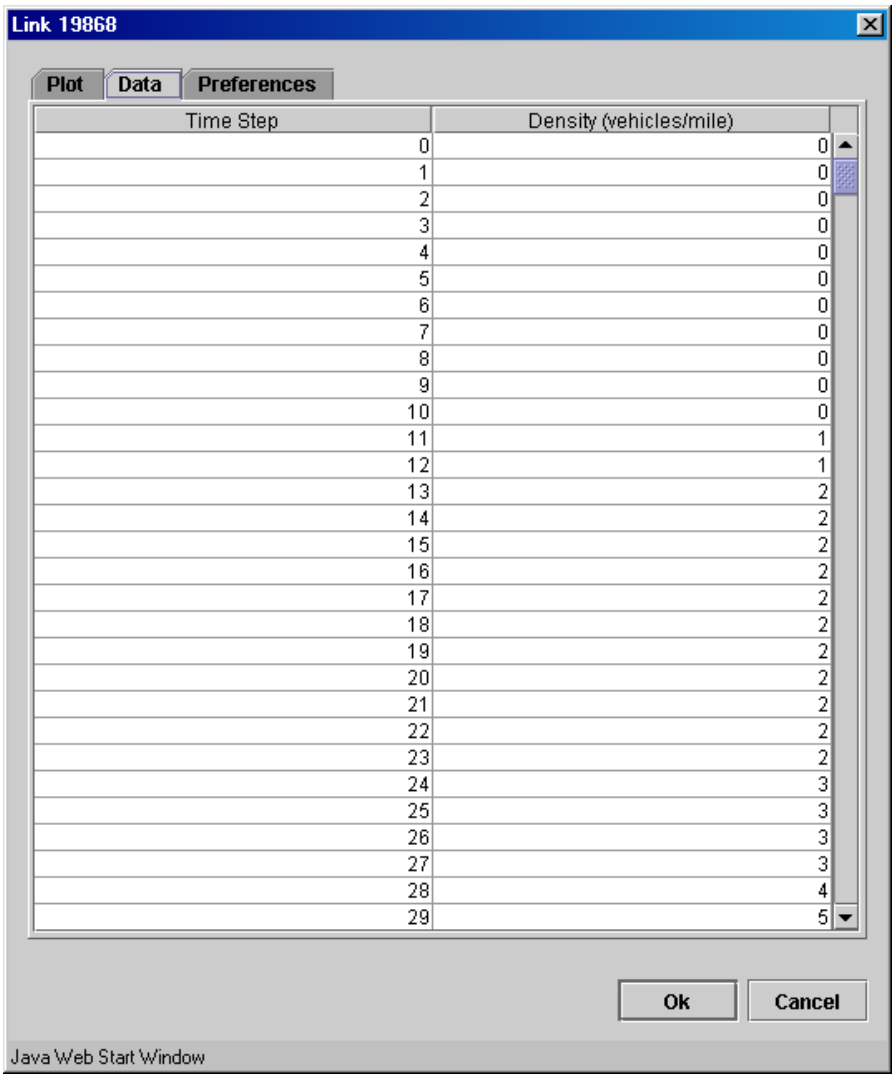


Figure 65: Link Density Plot



Time Step	Density (vehicles/mile)
0	0
1	0
2	0
3	0
4	0
5	0
6	0
7	0
8	0
9	0
10	0
11	1
12	1
13	2
14	2
15	2
16	2
17	2
18	2
19	2
20	2
21	2
22	2
23	2
24	3
25	3
26	3
27	3
28	4
29	5

Figure 66: Link Density Plot – Data

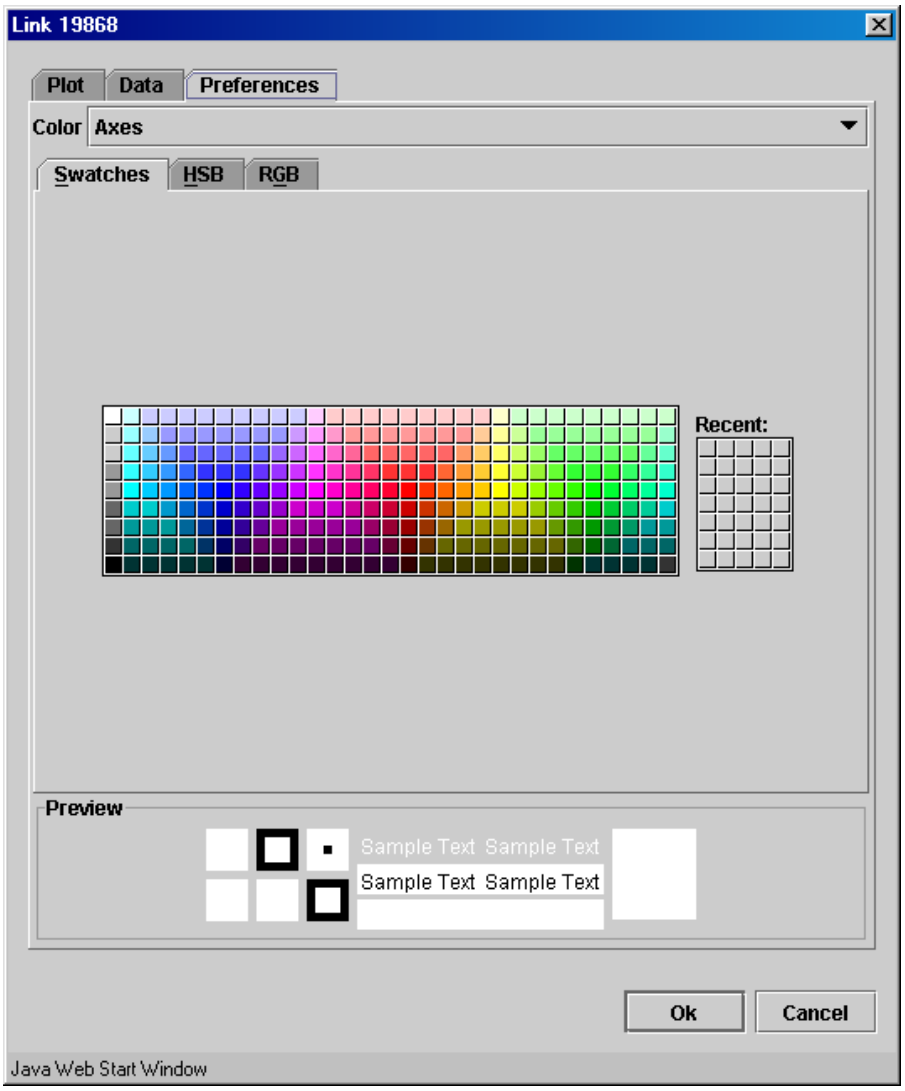


Figure 67: Link Density Plot – Preferences

6.0 Running Simulation Animation

Animation is a convenient method of performing an initial verification of whether or not the results of a simulation are reasonable. Since animation is inherently graphic, it cannot be viewed in the web interface, and instead must be viewed in the GIS Java GIS Interface.

After DTA has been run on a network, the simulation animation can be viewed by selecting Data Animation from the Data menu (see Figure 68). The Configure Animation window then appears to prompt the user to select the data that is to be animated (see Figure 69). Specifically, the user can select to have links color-coded by density, travel time, inflow or outflow (see Figure 70). During animation, a color-code legend will appear to show the values associated with each color. If the animation is by density, the colors indicate the proportion of jam density associated on each link (the legend is shown in Figure 71). If the animation is by travel time, the colors indicate the link travel time as a multiple of free flow travel time on each link (the legend is shown in Figure 72). If animation is by inflow or outflow, the colors indicate the number of vehicles entering or leaving the

link during each time step (the legend is shown in Figure 73). Figure 74 shows an example of what a network looks like during animation.

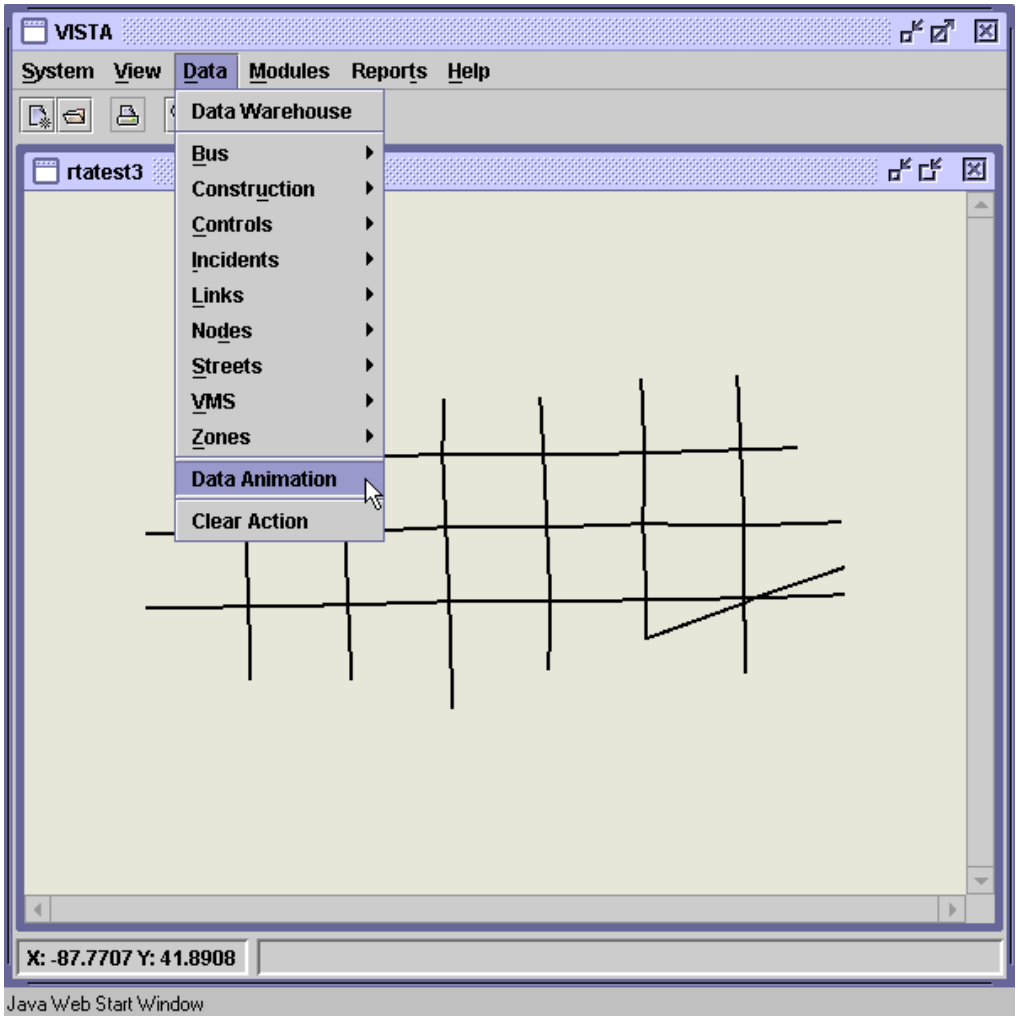


Figure 68: Java GIS Interface Data|Data Animation menu option

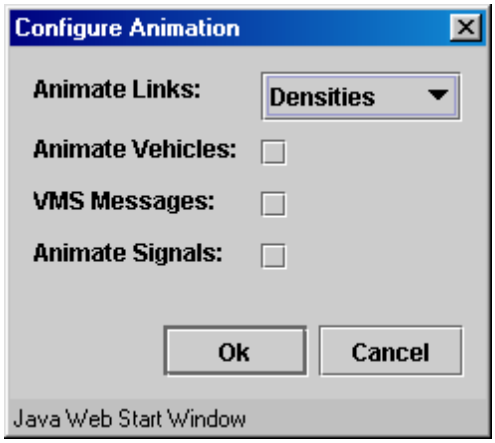


Figure 69: Configure Animation window

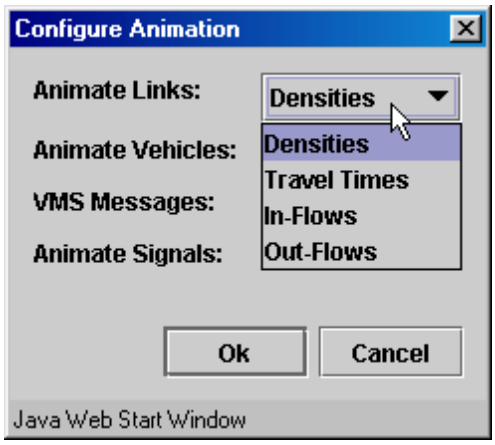


Figure 70: Animation options

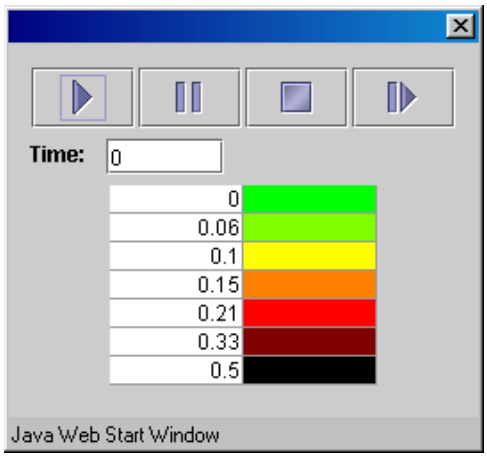


Figure 71: Color codes for animation by density

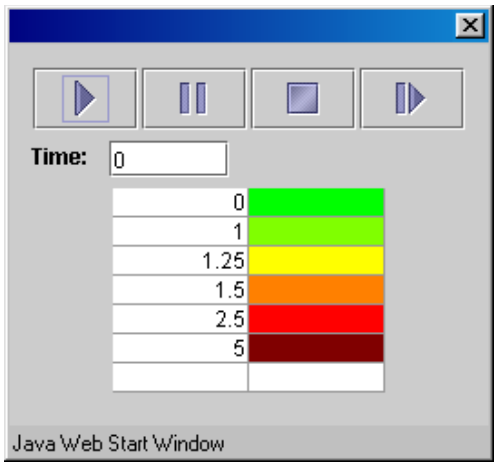


Figure 72: Color codes for animation by travel time

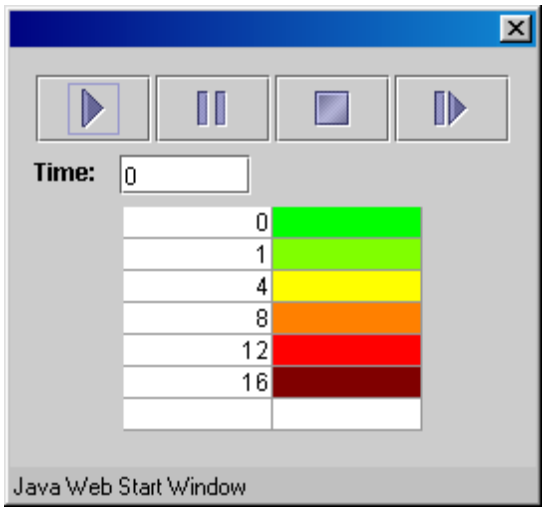


Figure 73: Color codes for animation by inflow or outflow

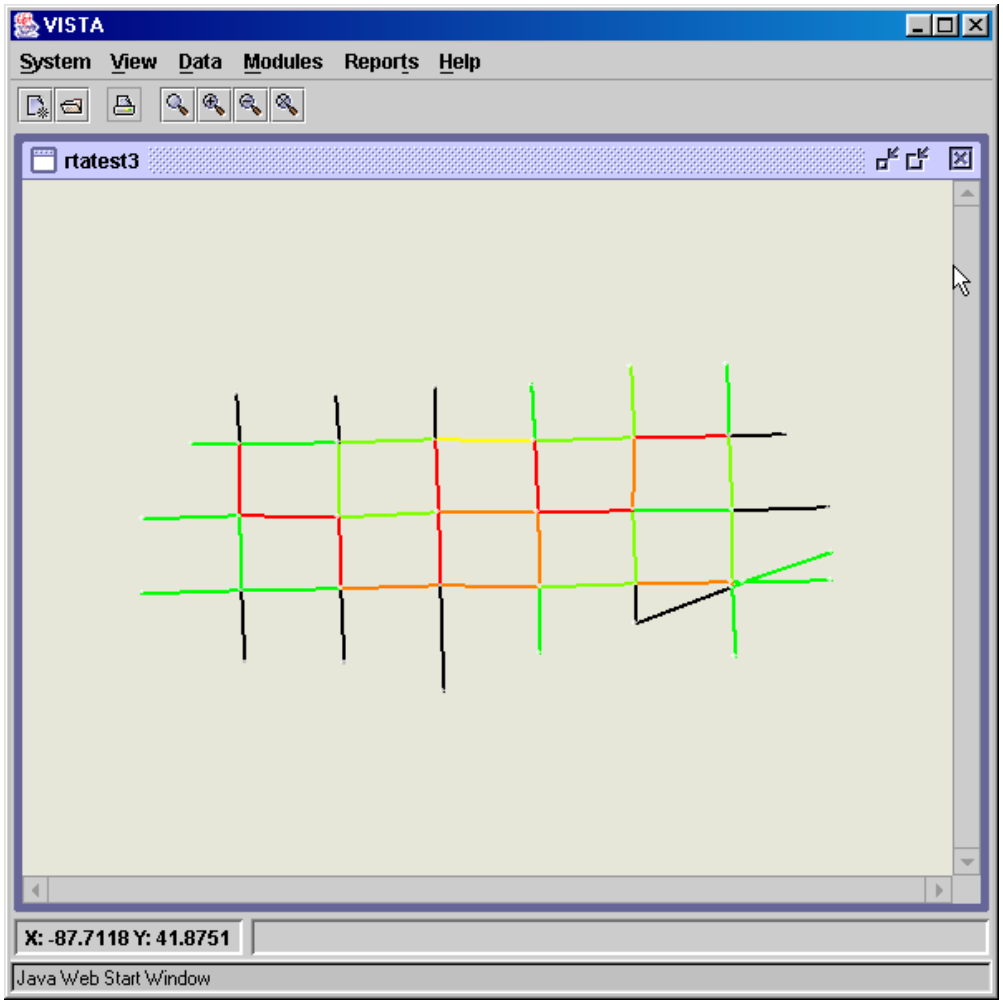


Figure 74: Example of network animation

For more detail, individual vehicles and signals can also be animated. Before running the Data Animation, the Vehicle Animation module must be run from the Modules menu. This module will prompt the user for the percentage of vehicles to animate (see Figure 75). When the Vehicle Animation module has finished, Data Animation can be selected from the Data menu, then in the Configure Data Animation window, Animate Vehicles and Animate Signals can be selected. (There are no VMS's in the Chicago network, so this option is irrelevant.) The data animation will then appear as shown in Figure 76. The small dark circles represent cars, and the large circles represent buses. The small light colored circles represent bus stops.

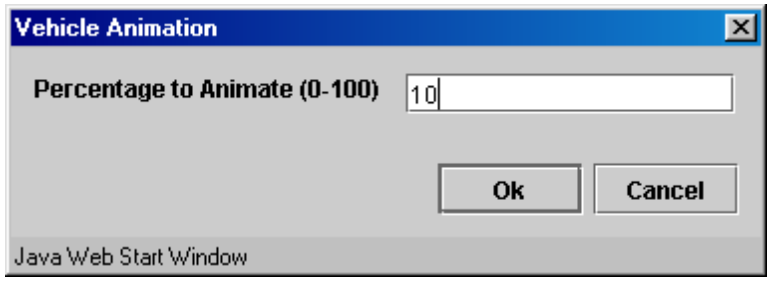


Figure 75: Vehicle Animation window

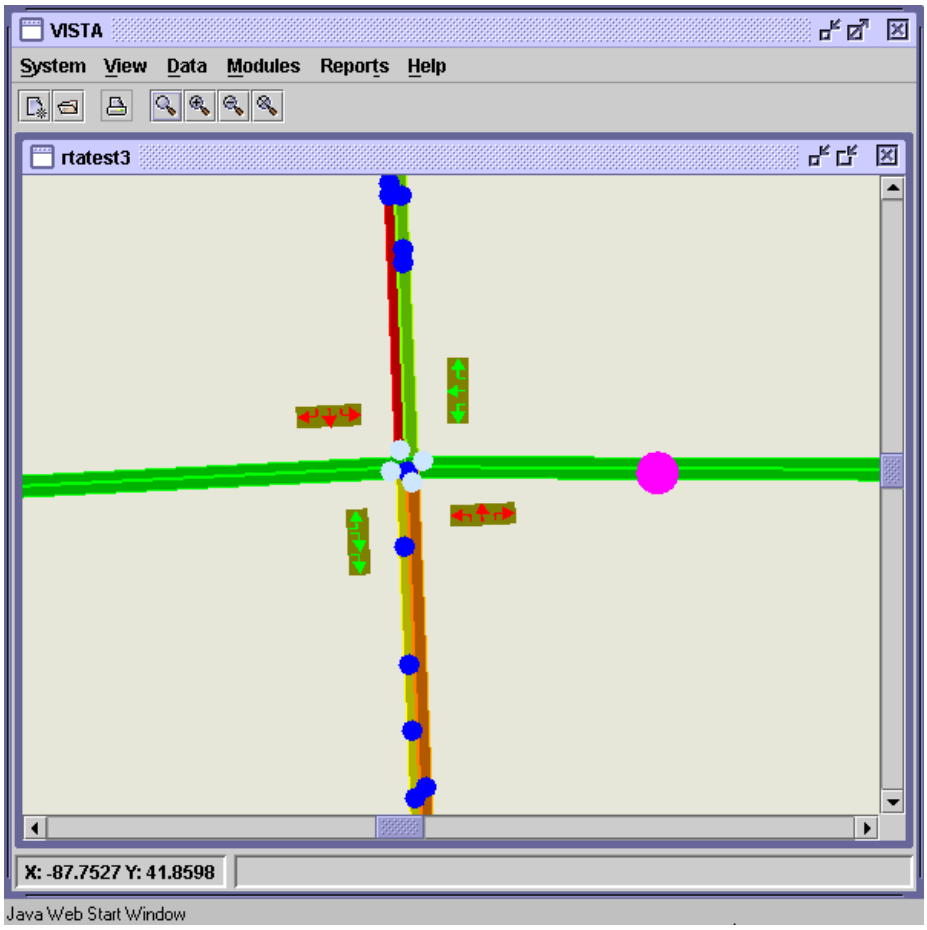


Figure 76: Example of vehicle and signal animation

7.0 SUMMARY

This software walk-through provided detailed instructions and illustrations on how to use the VISTA software from both the GIS Java GIS Interface and the web interface. The following topics were covered for each interface:

- logging into and out of VISTA
- viewing and editing data inputs
- running the dynamic traffic assignment module
- running reporting modules
- running simulation (GIS client only).

General Report

Prepared by Kyriacos Mouskos at 13:58 Mon, Jun 25, 2007 for network(s) nicosia_base.

Table of Contents

1. Basic Network Information
2. Travel Time information (Entered Vehicles)
3. Travel Time information (Through Vehicles)
4. Travel Time information (Loaded Vehicles)
5. Delay Information (Entered Vehicles)
6. Delay Information (Through Vehicles)
7. Delay Information (Loaded Vehicles)
8. Distribution Graph
9. Terminology

1. Basic Network Information

Table 1. Network Overview

Item	Counts in network nicosia_base
Nodes	235
Links	733
Signalized Intersection	0
VMS panels	0
Detectors	0
TRANSMIT Detectors	0
Zones	0
O-D pairs	622
Demand Total	517514
Demand Passenger Vehicles	517514
Demand Commercial Vehicles	0
Buses	0
Bus Routes	0
Assignment Length (s)	86400
Assignment Inverval(S)	900

Table 2. Vehicles Overview

	Loaded	Non-entered	Non-exited	Through	Entered Total TT(H)	AVG (M)	STD (M)	Entered Veh. VMT (Miles)	Through Veh. VMT (Miles)
All Type Vehicles	517514	0	0	517514	26289.0	3.05	2.18	937890.54	937890.54
Passenger Veh.	517514	0	0	517514	26289.0	3.05	2.18	937890.54	937890.54
Commercial Veh.	0	0	0	0					

2. Travel Time information (Entered Vehicles)

Table 3. All Type Vehicles Travel Time

Assignment	Start	End	No. Veh.	Total TT (H)	AVG (M)	STD (M)	VMT (Mile)
0	00:00:00	00:15:00	5391	272.0	3.04	2.18	9732.85
1	00:15:00	00:30:00	5391	275.0	3.07	2.18	9747.14
2	00:30:00	00:45:00	5391	272.0	3.04	2.15	9803.24
3	00:45:00	01:00:00	5391	273.0	3.05	2.19	9760.61
4	01:00:00	01:15:00	5391	276.0	3.07	2.2	9745.39
5	01:15:00	01:30:00	5391	272.0	3.03	2.16	9758.38
6	01:30:00	01:45:00	5391	271.0	3.02	2.16	9783.07
7	01:45:00	02:00:00	5391	272.0	3.04	2.17	9773.65
8	02:00:00	02:15:00	5391	274.0	3.06	2.2	9746.94
9	02:15:00	02:30:00	5391	275.0	3.07	2.18	9782.2
10	02:30:00	02:45:00	5391	274.0	3.05	2.19	9750.63
11	02:45:00	03:00:00	5391	274.0	3.05	2.18	9777.47
12	03:00:00	03:15:00	5391	274.0	3.05	2.19	9758.89
13	03:15:00	03:30:00	5391	275.0	3.06	2.19	9750.04
14	03:30:00	03:45:00	5391	274.0	3.06	2.19	9772.13
15	03:45:00	04:00:00	5391	275.0	3.06	2.22	9763.92
16	04:00:00	04:15:00	5391	273.0	3.04	2.17	9790.88
17	04:15:00	04:30:00	5391	274.0	3.06	2.19	9765.15
18	04:30:00	04:45:00	5391	273.0	3.05	2.17	9783.15
19	04:45:00	05:00:00	5391	275.0	3.06	2.19	9788.66
20	05:00:00	05:15:00	5391	273.0	3.05	2.17	9771.58
21	05:15:00	05:30:00	5391	273.0	3.04	2.16	9787.43
22	05:30:00	05:45:00	5391	274.0	3.06	2.18	9770.24
23	05:45:00	06:00:00	5391	275.0	3.06	2.18	9790.8
24	06:00:00	06:15:00	5391	274.0	3.05	2.18	9774.97
25	06:15:00	06:30:00	5391	274.0	3.05	2.19	9761.05
26	06:30:00	06:45:00	5391	272.0	3.04	2.17	9780.78
27	06:45:00	07:00:00	5391	275.0	3.07	2.2	9769.05
28	07:00:00	07:15:00	5391	273.0	3.04	2.17	9758.03
29	07:15:00	07:30:00	5391	273.0	3.04	2.15	9789.71
30	07:30:00	07:45:00	5391	273.0	3.05	2.18	9774.0
31	07:45:00	08:00:00	5391	273.0	3.05	2.18	9787.51
32	08:00:00	08:15:00	5391	274.0	3.05	2.18	9786.54
33	08:15:00	08:30:00	5391	272.0	3.03	2.16	9768.79
34	08:30:00	08:45:00	5391	272.0	3.03	2.17	9755.18
35	08:45:00	09:00:00	5391	274.0	3.05	2.18	9780.77
36	09:00:00	09:15:00	5391	273.0	3.04	2.18	9759.03
37	09:15:00	09:30:00	5391	274.0	3.06	2.19	9760.09
38	09:30:00	09:45:00	5391	275.0	3.06	2.19	9775.36

Assignment	Start	End	No. Veh.	Total TT (H)	AVG (M)	STD (M)	VMT (Mile)
39	09:45:00	10:00:00	5391	273.0	3.05	2.18	9765.53
40	10:00:00	10:15:00	5391	273.0	3.05	2.19	9762.93
41	10:15:00	10:30:00	5391	272.0	3.04	2.17	9765.0
42	10:30:00	10:45:00	5391	274.0	3.05	2.19	9750.29
43	10:45:00	11:00:00	5391	273.0	3.05	2.18	9780.75
44	11:00:00	11:15:00	5391	273.0	3.04	2.18	9767.24
45	11:15:00	11:30:00	5391	273.0	3.05	2.18	9783.08
46	11:30:00	11:45:00	5391	272.0	3.03	2.16	9776.59
47	11:45:00	12:00:00	5391	273.0	3.04	2.16	9776.46
48	12:00:00	12:15:00	5391	274.0	3.06	2.18	9789.04
49	12:15:00	12:30:00	5391	273.0	3.04	2.16	9776.78
50	12:30:00	12:45:00	5391	273.0	3.05	2.17	9771.23
51	12:45:00	13:00:00	5391	274.0	3.06	2.19	9773.12
52	13:00:00	13:15:00	5391	273.0	3.05	2.18	9783.86
53	13:15:00	13:30:00	5391	274.0	3.05	2.17	9763.98
54	13:30:00	13:45:00	5391	273.0	3.04	2.17	9761.95
55	13:45:00	14:00:00	5391	274.0	3.05	2.19	9757.15
56	14:00:00	14:15:00	5391	274.0	3.06	2.19	9762.01
57	14:15:00	14:30:00	5391	273.0	3.04	2.17	9777.7
58	14:30:00	14:45:00	5391	272.0	3.04	2.17	9766.83
59	14:45:00	15:00:00	5391	273.0	3.04	2.16	9769.37
60	15:00:00	15:15:00	5391	272.0	3.04	2.16	9770.27
61	15:15:00	15:30:00	5391	273.0	3.04	2.17	9746.22
62	15:30:00	15:45:00	5391	275.0	3.07	2.19	9756.9
63	15:45:00	16:00:00	5391	272.0	3.03	2.16	9783.92
64	16:00:00	16:15:00	5391	273.0	3.04	2.17	9765.87
65	16:15:00	16:30:00	5391	274.0	3.05	2.18	9753.97
66	16:30:00	16:45:00	5391	273.0	3.04	2.17	9784.59
67	16:45:00	17:00:00	5391	273.0	3.04	2.17	9759.0
68	17:00:00	17:15:00	5391	275.0	3.06	2.21	9753.15
69	17:15:00	17:30:00	5391	274.0	3.06	2.18	9768.12
70	17:30:00	17:45:00	5391	275.0	3.07	2.2	9753.22
71	17:45:00	18:00:00	5391	274.0	3.05	2.18	9763.82
72	18:00:00	18:15:00	5391	273.0	3.04	2.18	9740.54
73	18:15:00	18:30:00	5391	273.0	3.04	2.18	9762.51
74	18:30:00	18:45:00	5390	272.0	3.03	2.17	9773.69
75	18:45:00	19:00:00	5390	273.0	3.05	2.18	9782.38
76	19:00:00	19:15:00	5390	273.0	3.05	2.17	9789.08
77	19:15:00	19:30:00	5390	271.0	3.02	2.16	9772.8
78	19:30:00	19:45:00	5390	272.0	3.03	2.16	9770.33
79	19:45:00	20:00:00	5390	273.0	3.05	2.18	9793.39
80	20:00:00	20:15:00	5390	273.0	3.05	2.16	9786.0
81	20:15:00	20:30:00	5390	275.0	3.07	2.18	9782.26
82	20:30:00	20:45:00	5390	274.0	3.06	2.18	9774.29
83	20:45:00	21:00:00	5390	274.0	3.06	2.18	9790.51
84	21:00:00	21:15:00	5390	272.0	3.04	2.18	9782.42
85	21:15:00	21:30:00	5390	274.0	3.05	2.17	9776.66
86	21:30:00	21:45:00	5390	273.0	3.05	2.17	9765.33
87	21:45:00	22:00:00	5390	272.0	3.03	2.16	9763.94
88	22:00:00	22:15:00	5390	274.0	3.05	2.18	9759.12
89	22:15:00	22:30:00	5390	272.0	3.03	2.16	9764.24
90	22:30:00	22:45:00	5390	272.0	3.03	2.16	9774.56
91	22:45:00	23:00:00	5390	274.0	3.06	2.19	9735.45
92	23:00:00	23:15:00	5390	273.0	3.05	2.15	9770.97
93	23:15:00	23:30:00	5390	275.0	3.07	2.19	9773.8
94	23:30:00	23:45:00	5390	272.0	3.04	2.16	9776.25
95	23:45:00	24:00:00	5390	273.0	3.04	2.15	9774.77
Total	00:00:00	24:00:00	517514	26289.0	3.05	2.18	937890.54

Table 4. Passenger Vehicle Travel Time

Assignment	Start	End	No. Veh.	Total TT (H)	AVG (M)	STD (M)	VMT (Mile)
0	00:00:00	00:15:00	5391	272.0	3.04	2.18	9732.85
1	00:15:00	00:30:00	5391	275.0	3.07	2.18	9747.14
2	00:30:00	00:45:00	5391	272.0	3.04	2.15	9803.24
3	00:45:00	01:00:00	5391	273.0	3.05	2.19	9760.61
4	01:00:00	01:15:00	5391	276.0	3.07	2.2	9745.39
5	01:15:00	01:30:00	5391	272.0	3.03	2.16	9758.38
6	01:30:00	01:45:00	5391	271.0	3.02	2.16	9783.07
7	01:45:00	02:00:00	5391	272.0	3.04	2.17	9773.65
8	02:00:00	02:15:00	5391	274.0	3.06	2.2	9746.94
9	02:15:00	02:30:00	5391	275.0	3.07	2.18	9782.2
10	02:30:00	02:45:00	5391	274.0	3.05	2.19	9750.63
11	02:45:00	03:00:00	5391	274.0	3.05	2.18	9777.47
12	03:00:00	03:15:00	5391	274.0	3.05	2.19	9758.89
13	03:15:00	03:30:00	5391	275.0	3.06	2.19	9750.04
14	03:30:00	03:45:00	5391	274.0	3.06	2.19	9772.13
15	03:45:00	04:00:00	5391	275.0	3.06	2.22	9763.92
16	04:00:00	04:15:00	5391	273.0	3.04	2.17	9790.88
17	04:15:00	04:30:00	5391	274.0	3.06	2.19	9765.15
18	04:30:00	04:45:00	5391	273.0	3.05	2.17	9783.15
19	04:45:00	05:00:00	5391	275.0	3.06	2.19	9788.66
20	05:00:00	05:15:00	5391	273.0	3.05	2.17	9771.58
21	05:15:00	05:30:00	5391	273.0	3.04	2.16	9787.43
22	05:30:00	05:45:00	5391	274.0	3.06	2.18	9770.24
23	05:45:00	06:00:00	5391	275.0	3.06	2.18	9790.8
24	06:00:00	06:15:00	5391	274.0	3.05	2.18	9774.97
25	06:15:00	06:30:00	5391	274.0	3.05	2.19	9761.05
26	06:30:00	06:45:00	5391	272.0	3.04	2.17	9780.78
27	06:45:00	07:00:00	5391	275.0	3.07	2.2	9769.05
28	07:00:00	07:15:00	5391	273.0	3.04	2.17	9758.03

Assignment	Start	End	No. Veh.	Total TT (H)	AVG (M)	STD (M)	VMT (Mile)
29	07:15:00	07:30:00	5391	273.0	3.04	2.15	9789.71
30	07:30:00	07:45:00	5391	273.0	3.05	2.18	9774.0
31	07:45:00	08:00:00	5391	273.0	3.05	2.18	9767.51
32	08:00:00	08:15:00	5391	274.0	3.05	2.18	9786.54
33	08:15:00	08:30:00	5391	272.0	3.03	2.16	9768.79
34	08:30:00	08:45:00	5391	272.0	3.03	2.17	9755.18
35	08:45:00	09:00:00	5391	274.0	3.05	2.18	9780.77
36	09:00:00	09:15:00	5391	273.0	3.04	2.18	9759.03
37	09:15:00	09:30:00	5391	274.0	3.06	2.19	9760.09
38	09:30:00	09:45:00	5391	275.0	3.06	2.19	9775.36
39	09:45:00	10:00:00	5391	273.0	3.05	2.18	9765.53
40	10:00:00	10:15:00	5391	273.0	3.05	2.19	9762.93
41	10:15:00	10:30:00	5391	272.0	3.04	2.17	9765.0
42	10:30:00	10:45:00	5391	274.0	3.05	2.19	9750.29
43	10:45:00	11:00:00	5391	273.0	3.05	2.18	9780.75
44	11:00:00	11:15:00	5391	273.0	3.04	2.18	9767.24
45	11:15:00	11:30:00	5391	273.0	3.05	2.18	9783.08
46	11:30:00	11:45:00	5391	272.0	3.03	2.16	9776.59
47	11:45:00	12:00:00	5391	273.0	3.04	2.16	9776.46
48	12:00:00	12:15:00	5391	274.0	3.06	2.18	9789.04
49	12:15:00	12:30:00	5391	273.0	3.04	2.16	9776.78
50	12:30:00	12:45:00	5391	273.0	3.05	2.17	9771.23
51	12:45:00	13:00:00	5391	274.0	3.06	2.19	9773.12
52	13:00:00	13:15:00	5391	273.0	3.05	2.18	9783.86
53	13:15:00	13:30:00	5391	274.0	3.05	2.17	9763.98
54	13:30:00	13:45:00	5391	273.0	3.04	2.17	9761.95
55	13:45:00	14:00:00	5391	274.0	3.05	2.19	9757.15
56	14:00:00	14:15:00	5391	274.0	3.06	2.19	9762.01
57	14:15:00	14:30:00	5391	273.0	3.04	2.17	9777.7
58	14:30:00	14:45:00	5391	272.0	3.04	2.17	9766.83
59	14:45:00	15:00:00	5391	273.0	3.04	2.16	9769.37
60	15:00:00	15:15:00	5391	272.0	3.04	2.16	9770.27
61	15:15:00	15:30:00	5391	273.0	3.04	2.17	9746.22
62	15:30:00	15:45:00	5391	275.0	3.07	2.19	9756.9
63	15:45:00	16:00:00	5391	272.0	3.03	2.16	9783.92
64	16:00:00	16:15:00	5391	273.0	3.04	2.17	9765.87
65	16:15:00	16:30:00	5391	274.0	3.05	2.18	9753.97
66	16:30:00	16:45:00	5391	273.0	3.04	2.17	9784.59
67	16:45:00	17:00:00	5391	273.0	3.04	2.17	9759.0
68	17:00:00	17:15:00	5391	275.0	3.06	2.21	9753.15
69	17:15:00	17:30:00	5391	274.0	3.06	2.18	9768.12
70	17:30:00	17:45:00	5391	275.0	3.07	2.2	9753.22
71	17:45:00	18:00:00	5391	274.0	3.05	2.18	9763.82
72	18:00:00	18:15:00	5391	273.0	3.04	2.18	9740.54
73	18:15:00	18:30:00	5391	273.0	3.04	2.18	9762.51
74	18:30:00	18:45:00	5390	272.0	3.03	2.17	9773.69
75	18:45:00	19:00:00	5390	273.0	3.05	2.18	9782.38
76	19:00:00	19:15:00	5390	273.0	3.05	2.17	9789.08
77	19:15:00	19:30:00	5390	271.0	3.02	2.16	9772.8
78	19:30:00	19:45:00	5390	272.0	3.03	2.16	9770.33
79	19:45:00	20:00:00	5390	273.0	3.05	2.18	9793.39
80	20:00:00	20:15:00	5390	273.0	3.05	2.16	9786.0
81	20:15:00	20:30:00	5390	275.0	3.07	2.18	9782.26
82	20:30:00	20:45:00	5390	274.0	3.06	2.18	9774.29
83	20:45:00	21:00:00	5390	274.0	3.06	2.18	9790.51
84	21:00:00	21:15:00	5390	272.0	3.04	2.18	9782.42
85	21:15:00	21:30:00	5390	274.0	3.05	2.17	9776.66
86	21:30:00	21:45:00	5390	273.0	3.05	2.17	9765.33
87	21:45:00	22:00:00	5390	272.0	3.03	2.16	9763.94
88	22:00:00	22:15:00	5390	274.0	3.05	2.18	9759.12
89	22:15:00	22:30:00	5390	272.0	3.03	2.16	9764.24
90	22:30:00	22:45:00	5390	272.0	3.03	2.16	9774.56
91	22:45:00	23:00:00	5390	274.0	3.06	2.19	9735.45
92	23:00:00	23:15:00	5390	273.0	3.05	2.15	9770.97
93	23:15:00	23:30:00	5390	275.0	3.07	2.19	9773.8
94	23:30:00	23:45:00	5390	272.0	3.04	2.16	9776.25
95	23:45:00	24:00:00	5390	273.0	3.04	2.15	9774.77
Total	00:00:00	24:00:00	517514	26289.0	3.05	2.18	937890.54

3. Travel Time information (Through Vehicles)

Table 5. All Type Vehicles Travel Time

Assignment	Start	End	No. Veh.	Total TT (H)	AVG (M)	STD (M)	VMT (Mile)
0	00:00:00	00:15:00	5391	272.0	3.04	2.18	9732.85
1	00:15:00	00:30:00	5391	275.0	3.07	2.18	9747.14
2	00:30:00	00:45:00	5391	272.0	3.04	2.15	9803.24
3	00:45:00	01:00:00	5391	273.0	3.05	2.19	9760.61
4	01:00:00	01:15:00	5391	276.0	3.07	2.2	9745.39
5	01:15:00	01:30:00	5391	272.0	3.03	2.16	9758.38
6	01:30:00	01:45:00	5391	271.0	3.02	2.16	9783.07
7	01:45:00	02:00:00	5391	272.0	3.04	2.17	9773.65
8	02:00:00	02:15:00	5391	274.0	3.06	2.2	9746.94
9	02:15:00	02:30:00	5391	275.0	3.07	2.18	9782.2
10	02:30:00	02:45:00	5391	274.0	3.05	2.19	9750.63
11	02:45:00	03:00:00	5391	274.0	3.05	2.18	9777.47
12	03:00:00	03:15:00	5391	274.0	3.05	2.19	9758.89
13	03:15:00	03:30:00	5391	275.0	3.06	2.19	9750.04

Assignment	Start	End	No. Veh.	Total TT (H)	AVG (M)	STD (M)	VMT (Mile)
14	03:30:00	03:45:00	5391	274.0	3.06	2.19	9772.13
15	03:45:00	04:00:00	5391	275.0	3.06	2.22	9763.92
16	04:00:00	04:15:00	5391	273.0	3.04	2.17	9790.88
17	04:15:00	04:30:00	5391	274.0	3.06	2.19	9765.15
18	04:30:00	04:45:00	5391	273.0	3.05	2.17	9783.15
19	04:45:00	05:00:00	5391	275.0	3.06	2.19	9788.66
20	05:00:00	05:15:00	5391	273.0	3.05	2.17	9771.58
21	05:15:00	05:30:00	5391	273.0	3.04	2.16	9787.43
22	05:30:00	05:45:00	5391	274.0	3.06	2.18	9770.24
23	05:45:00	06:00:00	5391	275.0	3.06	2.18	9790.8
24	06:00:00	06:15:00	5391	274.0	3.05	2.18	9774.97
25	06:15:00	06:30:00	5391	274.0	3.05	2.19	9761.05
26	06:30:00	06:45:00	5391	272.0	3.04	2.17	9780.78
27	06:45:00	07:00:00	5391	275.0	3.07	2.2	9769.05
28	07:00:00	07:15:00	5391	273.0	3.04	2.17	9758.03
29	07:15:00	07:30:00	5391	273.0	3.04	2.15	9789.71
30	07:30:00	07:45:00	5391	273.0	3.05	2.18	9774.0
31	07:45:00	08:00:00	5391	273.0	3.05	2.18	9767.51
32	08:00:00	08:15:00	5391	274.0	3.05	2.18	9786.54
33	08:15:00	08:30:00	5391	272.0	3.03	2.16	9768.79
34	08:30:00	08:45:00	5391	272.0	3.03	2.17	9755.18
35	08:45:00	09:00:00	5391	274.0	3.05	2.18	9780.77
36	09:00:00	09:15:00	5391	273.0	3.04	2.18	9759.03
37	09:15:00	09:30:00	5391	274.0	3.06	2.19	9760.09
38	09:30:00	09:45:00	5391	275.0	3.06	2.19	9775.36
39	09:45:00	10:00:00	5391	273.0	3.05	2.18	9765.53
40	10:00:00	10:15:00	5391	273.0	3.05	2.19	9762.93
41	10:15:00	10:30:00	5391	272.0	3.04	2.17	9765.0
42	10:30:00	10:45:00	5391	274.0	3.05	2.19	9750.29
43	10:45:00	11:00:00	5391	273.0	3.05	2.18	9780.75
44	11:00:00	11:15:00	5391	273.0	3.04	2.18	9767.24
45	11:15:00	11:30:00	5391	273.0	3.05	2.18	9783.08
46	11:30:00	11:45:00	5391	272.0	3.03	2.16	9776.59
47	11:45:00	12:00:00	5391	273.0	3.04	2.16	9776.46
48	12:00:00	12:15:00	5391	274.0	3.06	2.18	9789.04
49	12:15:00	12:30:00	5391	273.0	3.04	2.16	9776.78
50	12:30:00	12:45:00	5391	273.0	3.05	2.17	9771.23
51	12:45:00	13:00:00	5391	274.0	3.06	2.19	9773.12
52	13:00:00	13:15:00	5391	273.0	3.05	2.18	9783.86
53	13:15:00	13:30:00	5391	274.0	3.05	2.17	9763.98
54	13:30:00	13:45:00	5391	273.0	3.04	2.17	9761.95
55	13:45:00	14:00:00	5391	274.0	3.05	2.19	9757.15
56	14:00:00	14:15:00	5391	274.0	3.06	2.19	9762.01
57	14:15:00	14:30:00	5391	273.0	3.04	2.17	9777.7
58	14:30:00	14:45:00	5391	272.0	3.04	2.17	9766.83
59	14:45:00	15:00:00	5391	273.0	3.04	2.16	9769.37
60	15:00:00	15:15:00	5391	272.0	3.04	2.16	9770.27
61	15:15:00	15:30:00	5391	273.0	3.04	2.17	9746.22
62	15:30:00	15:45:00	5391	275.0	3.07	2.19	9756.9
63	15:45:00	16:00:00	5391	272.0	3.03	2.16	9783.92
64	16:00:00	16:15:00	5391	273.0	3.04	2.17	9765.87
65	16:15:00	16:30:00	5391	274.0	3.05	2.18	9753.97
66	16:30:00	16:45:00	5391	273.0	3.04	2.17	9784.59
67	16:45:00	17:00:00	5391	273.0	3.04	2.17	9759.0
68	17:00:00	17:15:00	5391	275.0	3.06	2.21	9753.15
69	17:15:00	17:30:00	5391	274.0	3.06	2.18	9768.12
70	17:30:00	17:45:00	5391	275.0	3.07	2.2	9753.22
71	17:45:00	18:00:00	5391	274.0	3.05	2.18	9763.82
72	18:00:00	18:15:00	5391	273.0	3.04	2.18	9740.54
73	18:15:00	18:30:00	5391	273.0	3.04	2.18	9762.51
74	18:30:00	18:45:00	5390	272.0	3.03	2.17	9773.69
75	18:45:00	19:00:00	5390	273.0	3.05	2.18	9782.38
76	19:00:00	19:15:00	5390	273.0	3.05	2.17	9789.08
77	19:15:00	19:30:00	5390	271.0	3.02	2.16	9772.8
78	19:30:00	19:45:00	5390	272.0	3.03	2.16	9770.33
79	19:45:00	20:00:00	5390	273.0	3.05	2.18	9793.39
80	20:00:00	20:15:00	5390	273.0	3.05	2.16	9786.0
81	20:15:00	20:30:00	5390	275.0	3.07	2.18	9782.26
82	20:30:00	20:45:00	5390	274.0	3.06	2.18	9774.29
83	20:45:00	21:00:00	5390	274.0	3.06	2.18	9790.51
84	21:00:00	21:15:00	5390	272.0	3.04	2.18	9782.42
85	21:15:00	21:30:00	5390	274.0	3.05	2.17	9776.66
86	21:30:00	21:45:00	5390	273.0	3.05	2.17	9765.33
87	21:45:00	22:00:00	5390	272.0	3.03	2.16	9763.94
88	22:00:00	22:15:00	5390	274.0	3.05	2.18	9759.12
89	22:15:00	22:30:00	5390	272.0	3.03	2.16	9764.24
90	22:30:00	22:45:00	5390	272.0	3.03	2.16	9774.56
91	22:45:00	23:00:00	5390	274.0	3.06	2.19	9735.45
92	23:00:00	23:15:00	5390	273.0	3.05	2.15	9770.97
93	23:15:00	23:30:00	5390	275.0	3.07	2.19	9773.8
94	23:30:00	23:45:00	5390	272.0	3.04	2.16	9776.25
95	23:45:00	24:00:00	5390	273.0	3.04	2.15	9774.77
Total	00:00:00	24:00:00	517514	26289.0	3.05	2.18	937890.54

Table 6. Passenger Vehicle Travel Time

Assignment	Start	End	No. Veh.	Total TT (H)	AVG (M)	STD (M)	VMT (Mile)
0	00:00:00	00:15:00	5391	272.0	3.04	2.18	9732.85
1	00:15:00	00:30:00	5391	275.0	3.07	2.18	9747.14
2	00:30:00	00:45:00	5391	272.0	3.04	2.15	9803.24
3	00:45:00	01:00:00	5391	273.0	3.05	2.19	9760.61

Assignment	Start	End	No. Veh.	Total TT (H)	AVG (M)	STD (M)	VMT (Mile)
4	01:00:00	01:15:00	5391	276.0	3.07	2.2	9745.39
5	01:15:00	01:30:00	5391	272.0	3.03	2.16	9758.38
6	01:30:00	01:45:00	5391	271.0	3.02	2.16	9783.07
7	01:45:00	02:00:00	5391	272.0	3.04	2.17	9773.65
8	02:00:00	02:15:00	5391	274.0	3.06	2.2	9746.94
9	02:15:00	02:30:00	5391	275.0	3.07	2.18	9782.2
10	02:30:00	02:45:00	5391	274.0	3.05	2.19	9750.63
11	02:45:00	03:00:00	5391	274.0	3.05	2.18	9777.47
12	03:00:00	03:15:00	5391	274.0	3.05	2.19	9758.89
13	03:15:00	03:30:00	5391	275.0	3.06	2.19	9750.04
14	03:30:00	03:45:00	5391	274.0	3.06	2.19	9772.13
15	03:45:00	04:00:00	5391	275.0	3.06	2.22	9763.92
16	04:00:00	04:15:00	5391	273.0	3.04	2.17	9790.88
17	04:15:00	04:30:00	5391	274.0	3.06	2.19	9765.15
18	04:30:00	04:45:00	5391	273.0	3.05	2.17	9783.15
19	04:45:00	05:00:00	5391	275.0	3.06	2.19	9788.66
20	05:00:00	05:15:00	5391	273.0	3.05	2.17	9771.58
21	05:15:00	05:30:00	5391	273.0	3.04	2.16	9787.43
22	05:30:00	05:45:00	5391	274.0	3.06	2.18	9770.24
23	05:45:00	06:00:00	5391	275.0	3.06	2.18	9790.8
24	06:00:00	06:15:00	5391	274.0	3.05	2.18	9774.97
25	06:15:00	06:30:00	5391	274.0	3.05	2.19	9761.05
26	06:30:00	06:45:00	5391	272.0	3.04	2.17	9780.78
27	06:45:00	07:00:00	5391	275.0	3.07	2.2	9769.05
28	07:00:00	07:15:00	5391	273.0	3.04	2.17	9758.03
29	07:15:00	07:30:00	5391	273.0	3.04	2.15	9789.71
30	07:30:00	07:45:00	5391	273.0	3.05	2.18	9774.0
31	07:45:00	08:00:00	5391	273.0	3.05	2.18	9767.51
32	08:00:00	08:15:00	5391	274.0	3.05	2.18	9786.54
33	08:15:00	08:30:00	5391	272.0	3.03	2.16	9768.79
34	08:30:00	08:45:00	5391	272.0	3.03	2.17	9755.18
35	08:45:00	09:00:00	5391	274.0	3.05	2.18	9780.77
36	09:00:00	09:15:00	5391	273.0	3.04	2.18	9759.03
37	09:15:00	09:30:00	5391	274.0	3.06	2.19	9760.09
38	09:30:00	09:45:00	5391	275.0	3.06	2.19	9775.36
39	09:45:00	10:00:00	5391	273.0	3.05	2.18	9765.53
40	10:00:00	10:15:00	5391	273.0	3.05	2.19	9762.93
41	10:15:00	10:30:00	5391	272.0	3.04	2.17	9765.0
42	10:30:00	10:45:00	5391	274.0	3.05	2.19	9750.29
43	10:45:00	11:00:00	5391	273.0	3.05	2.18	9780.75
44	11:00:00	11:15:00	5391	273.0	3.04	2.18	9767.24
45	11:15:00	11:30:00	5391	273.0	3.05	2.18	9783.08
46	11:30:00	11:45:00	5391	272.0	3.03	2.16	9776.59
47	11:45:00	12:00:00	5391	273.0	3.04	2.16	9776.46
48	12:00:00	12:15:00	5391	274.0	3.06	2.18	9789.04
49	12:15:00	12:30:00	5391	273.0	3.04	2.16	9776.78
50	12:30:00	12:45:00	5391	273.0	3.05	2.17	9771.23
51	12:45:00	13:00:00	5391	274.0	3.06	2.19	9773.12
52	13:00:00	13:15:00	5391	273.0	3.05	2.18	9783.86
53	13:15:00	13:30:00	5391	274.0	3.05	2.17	9763.98
54	13:30:00	13:45:00	5391	273.0	3.04	2.17	9761.95
55	13:45:00	14:00:00	5391	274.0	3.05	2.19	9757.15
56	14:00:00	14:15:00	5391	274.0	3.06	2.19	9762.01
57	14:15:00	14:30:00	5391	273.0	3.04	2.17	9777.7
58	14:30:00	14:45:00	5391	272.0	3.04	2.17	9766.83
59	14:45:00	15:00:00	5391	273.0	3.04	2.16	9769.37
60	15:00:00	15:15:00	5391	272.0	3.04	2.16	9770.27
61	15:15:00	15:30:00	5391	273.0	3.04	2.17	9746.22
62	15:30:00	15:45:00	5391	275.0	3.07	2.19	9756.9
63	15:45:00	16:00:00	5391	272.0	3.03	2.16	9783.92
64	16:00:00	16:15:00	5391	273.0	3.04	2.17	9765.87
65	16:15:00	16:30:00	5391	274.0	3.05	2.18	9753.97
66	16:30:00	16:45:00	5391	273.0	3.04	2.17	9784.59
67	16:45:00	17:00:00	5391	273.0	3.04	2.17	9759.0
68	17:00:00	17:15:00	5391	275.0	3.06	2.21	9753.15
69	17:15:00	17:30:00	5391	274.0	3.06	2.18	9768.12
70	17:30:00	17:45:00	5391	275.0	3.07	2.2	9753.22
71	17:45:00	18:00:00	5391	274.0	3.05	2.18	9763.82
72	18:00:00	18:15:00	5391	273.0	3.04	2.18	9740.54
73	18:15:00	18:30:00	5391	273.0	3.04	2.18	9762.51
74	18:30:00	18:45:00	5390	272.0	3.03	2.17	9773.69
75	18:45:00	19:00:00	5390	273.0	3.05	2.18	9782.38
76	19:00:00	19:15:00	5390	273.0	3.05	2.17	9789.08
77	19:15:00	19:30:00	5390	271.0	3.02	2.16	9772.8
78	19:30:00	19:45:00	5390	272.0	3.03	2.16	9770.33
79	19:45:00	20:00:00	5390	273.0	3.05	2.18	9793.39
80	20:00:00	20:15:00	5390	273.0	3.05	2.16	9786.0
81	20:15:00	20:30:00	5390	275.0	3.07	2.18	9782.26
82	20:30:00	20:45:00	5390	274.0	3.06	2.18	9774.29
83	20:45:00	21:00:00	5390	274.0	3.06	2.18	9790.51
84	21:00:00	21:15:00	5390	272.0	3.04	2.18	9782.42
85	21:15:00	21:30:00	5390	274.0	3.05	2.17	9776.66
86	21:30:00	21:45:00	5390	273.0	3.05	2.17	9765.33
87	21:45:00	22:00:00	5390	272.0	3.03	2.16	9763.94
88	22:00:00	22:15:00	5390	274.0	3.05	2.18	9759.12
89	22:15:00	22:30:00	5390	272.0	3.03	2.16	9764.24
90	22:30:00	22:45:00	5390	272.0	3.03	2.16	9774.56
91	22:45:00	23:00:00	5390	274.0	3.06	2.19	9735.45
92	23:00:00	23:15:00	5390	273.0	3.05	2.15	9770.97
93	23:15:00	23:30:00	5390	275.0	3.07	2.19	9773.8
94	23:30:00	23:45:00	5390	272.0	3.04	2.16	9776.25

Assignment	Start	End	No. Veh.	Total TT (H)	AVG (M)	STD (M)	VMT (Mile)
95	23:45:00	24:00:00	5390	273.0	3.04	2.15	9774.77
Total	00:00:00	24:00:00	517514	26289.0	3.05	2.18	937890.54

4. Travel Time information (Loaded Vehicles)

Table 7. All Type Vehicles Travel Time

Assignment	Start	End	No. Veh.	Total TT (H)	AVG (M)	STD (M)
0	00:00:00	00:15:00	5391	272.0	3.04	2.18
1	00:15:00	00:30:00	5391	275.0	3.07	2.18
2	00:30:00	00:45:00	5391	272.0	3.04	2.15
3	00:45:00	01:00:00	5391	273.0	3.05	2.19
4	01:00:00	01:15:00	5391	276.0	3.07	2.2
5	01:15:00	01:30:00	5391	272.0	3.03	2.16
6	01:30:00	01:45:00	5391	271.0	3.02	2.16
7	01:45:00	02:00:00	5391	272.0	3.04	2.17
8	02:00:00	02:15:00	5391	274.0	3.06	2.2
9	02:15:00	02:30:00	5391	275.0	3.07	2.18
10	02:30:00	02:45:00	5391	274.0	3.05	2.19
11	02:45:00	03:00:00	5391	274.0	3.05	2.18
12	03:00:00	03:15:00	5391	274.0	3.05	2.19
13	03:15:00	03:30:00	5391	275.0	3.06	2.19
14	03:30:00	03:45:00	5391	274.0	3.06	2.19
15	03:45:00	04:00:00	5391	275.0	3.06	2.22
16	04:00:00	04:15:00	5391	273.0	3.04	2.17
17	04:15:00	04:30:00	5391	274.0	3.06	2.19
18	04:30:00	04:45:00	5391	273.0	3.05	2.17
19	04:45:00	05:00:00	5391	275.0	3.06	2.19
20	05:00:00	05:15:00	5391	273.0	3.05	2.17
21	05:15:00	05:30:00	5391	273.0	3.04	2.16
22	05:30:00	05:45:00	5391	274.0	3.06	2.18
23	05:45:00	06:00:00	5391	275.0	3.06	2.18
24	06:00:00	06:15:00	5391	274.0	3.05	2.18
25	06:15:00	06:30:00	5391	274.0	3.05	2.19
26	06:30:00	06:45:00	5391	272.0	3.04	2.17
27	06:45:00	07:00:00	5391	275.0	3.07	2.2
28	07:00:00	07:15:00	5391	273.0	3.04	2.17
29	07:15:00	07:30:00	5391	273.0	3.04	2.15
30	07:30:00	07:45:00	5391	273.0	3.05	2.18
31	07:45:00	08:00:00	5391	273.0	3.05	2.18
32	08:00:00	08:15:00	5391	274.0	3.05	2.18
33	08:15:00	08:30:00	5391	272.0	3.03	2.16
34	08:30:00	08:45:00	5391	272.0	3.03	2.17
35	08:45:00	09:00:00	5391	274.0	3.05	2.18
36	09:00:00	09:15:00	5391	273.0	3.04	2.18
37	09:15:00	09:30:00	5391	274.0	3.06	2.19
38	09:30:00	09:45:00	5391	275.0	3.06	2.19
39	09:45:00	10:00:00	5391	273.0	3.05	2.18
40	10:00:00	10:15:00	5391	273.0	3.05	2.19
41	10:15:00	10:30:00	5391	272.0	3.04	2.17
42	10:30:00	10:45:00	5391	274.0	3.05	2.19
43	10:45:00	11:00:00	5391	273.0	3.05	2.18
44	11:00:00	11:15:00	5391	273.0	3.04	2.18
45	11:15:00	11:30:00	5391	273.0	3.05	2.18
46	11:30:00	11:45:00	5391	272.0	3.03	2.16
47	11:45:00	12:00:00	5391	273.0	3.04	2.16
48	12:00:00	12:15:00	5391	274.0	3.06	2.18
49	12:15:00	12:30:00	5391	273.0	3.04	2.16
50	12:30:00	12:45:00	5391	273.0	3.05	2.17
51	12:45:00	13:00:00	5391	274.0	3.06	2.19
52	13:00:00	13:15:00	5391	273.0	3.05	2.18
53	13:15:00	13:30:00	5391	274.0	3.05	2.17
54	13:30:00	13:45:00	5391	273.0	3.04	2.17
55	13:45:00	14:00:00	5391	274.0	3.05	2.19
56	14:00:00	14:15:00	5391	274.0	3.06	2.19
57	14:15:00	14:30:00	5391	273.0	3.04	2.17
58	14:30:00	14:45:00	5391	272.0	3.04	2.17
59	14:45:00	15:00:00	5391	273.0	3.04	2.16
60	15:00:00	15:15:00	5391	272.0	3.04	2.16
61	15:15:00	15:30:00	5391	273.0	3.04	2.17
62	15:30:00	15:45:00	5391	275.0	3.07	2.19
63	15:45:00	16:00:00	5391	272.0	3.03	2.16
64	16:00:00	16:15:00	5391	273.0	3.04	2.17
65	16:15:00	16:30:00	5391	274.0	3.05	2.18
66	16:30:00	16:45:00	5391	273.0	3.04	2.17
67	16:45:00	17:00:00	5391	273.0	3.04	2.17
68	17:00:00	17:15:00	5391	275.0	3.06	2.21
69	17:15:00	17:30:00	5391	274.0	3.06	2.18
70	17:30:00	17:45:00	5391	275.0	3.07	2.2
71	17:45:00	18:00:00	5391	274.0	3.05	2.18
72	18:00:00	18:15:00	5391	273.0	3.04	2.18
73	18:15:00	18:30:00	5391	273.0	3.04	2.18
74	18:30:00	18:45:00	5390	272.0	3.03	2.17
75	18:45:00	19:00:00	5390	273.0	3.05	2.18
76	19:00:00	19:15:00	5390	273.0	3.05	2.17
77	19:15:00	19:30:00	5390	271.0	3.02	2.16
78	19:30:00	19:45:00	5390	272.0	3.03	2.16
79	19:45:00	20:00:00	5390	273.0	3.05	2.18

Assignment	Start	End	No. Veh.	Total TT (H)	AVG (M)	STD (M)
80	20:00:00	20:15:00	5390	273.0	3.05	2.16
81	20:15:00	20:30:00	5390	275.0	3.07	2.18
82	20:30:00	20:45:00	5390	274.0	3.06	2.18
83	20:45:00	21:00:00	5390	274.0	3.06	2.18
84	21:00:00	21:15:00	5390	272.0	3.04	2.18
85	21:15:00	21:30:00	5390	274.0	3.05	2.17
86	21:30:00	21:45:00	5390	273.0	3.05	2.17
87	21:45:00	22:00:00	5390	272.0	3.03	2.16
88	22:00:00	22:15:00	5390	274.0	3.05	2.18
89	22:15:00	22:30:00	5390	272.0	3.03	2.16
90	22:30:00	22:45:00	5390	272.0	3.03	2.16
91	22:45:00	23:00:00	5390	274.0	3.06	2.19
92	23:00:00	23:15:00	5390	273.0	3.05	2.15
93	23:15:00	23:30:00	5390	275.0	3.07	2.19
94	23:30:00	23:45:00	5390	272.0	3.04	2.16
95	23:45:00	24:00:00	5390	273.0	3.04	2.15
Total	00:00:00	24:00:00	517514	26289.0	3.05	2.18

Table 8. Passenger Vehicle Travel Time

Assignment	Start	End	No. Veh.	Total TT (H)	AVG (M)	STD (M)
0	00:00:00	00:15:00	5391	272.0	3.04	2.18
1	00:15:00	00:30:00	5391	275.0	3.07	2.18
2	00:30:00	00:45:00	5391	272.0	3.04	2.15
3	00:45:00	01:00:00	5391	273.0	3.05	2.19
4	01:00:00	01:15:00	5391	276.0	3.07	2.2
5	01:15:00	01:30:00	5391	272.0	3.03	2.16
6	01:30:00	01:45:00	5391	271.0	3.02	2.16
7	01:45:00	02:00:00	5391	272.0	3.04	2.17
8	02:00:00	02:15:00	5391	274.0	3.06	2.2
9	02:15:00	02:30:00	5391	275.0	3.07	2.18
10	02:30:00	02:45:00	5391	274.0	3.05	2.19
11	02:45:00	03:00:00	5391	274.0	3.05	2.18
12	03:00:00	03:15:00	5391	274.0	3.05	2.19
13	03:15:00	03:30:00	5391	275.0	3.06	2.19
14	03:30:00	03:45:00	5391	274.0	3.06	2.19
15	03:45:00	04:00:00	5391	275.0	3.06	2.22
16	04:00:00	04:15:00	5391	273.0	3.04	2.17
17	04:15:00	04:30:00	5391	274.0	3.06	2.19
18	04:30:00	04:45:00	5391	273.0	3.05	2.17
19	04:45:00	05:00:00	5391	275.0	3.06	2.19
20	05:00:00	05:15:00	5391	273.0	3.05	2.17
21	05:15:00	05:30:00	5391	273.0	3.04	2.16
22	05:30:00	05:45:00	5391	274.0	3.06	2.18
23	05:45:00	06:00:00	5391	275.0	3.06	2.18
24	06:00:00	06:15:00	5391	274.0	3.05	2.18
25	06:15:00	06:30:00	5391	274.0	3.05	2.19
26	06:30:00	06:45:00	5391	272.0	3.04	2.17
27	06:45:00	07:00:00	5391	275.0	3.07	2.2
28	07:00:00	07:15:00	5391	273.0	3.04	2.17
29	07:15:00	07:30:00	5391	273.0	3.04	2.15
30	07:30:00	07:45:00	5391	273.0	3.05	2.18
31	07:45:00	08:00:00	5391	273.0	3.05	2.18
32	08:00:00	08:15:00	5391	274.0	3.05	2.18
33	08:15:00	08:30:00	5391	272.0	3.03	2.16
34	08:30:00	08:45:00	5391	272.0	3.03	2.17
35	08:45:00	09:00:00	5391	274.0	3.05	2.18
36	09:00:00	09:15:00	5391	273.0	3.04	2.18
37	09:15:00	09:30:00	5391	274.0	3.06	2.19
38	09:30:00	09:45:00	5391	275.0	3.06	2.19
39	09:45:00	10:00:00	5391	273.0	3.05	2.18
40	10:00:00	10:15:00	5391	273.0	3.05	2.19
41	10:15:00	10:30:00	5391	272.0	3.04	2.17
42	10:30:00	10:45:00	5391	274.0	3.05	2.19
43	10:45:00	11:00:00	5391	273.0	3.05	2.18
44	11:00:00	11:15:00	5391	273.0	3.04	2.18
45	11:15:00	11:30:00	5391	273.0	3.05	2.18
46	11:30:00	11:45:00	5391	272.0	3.03	2.16
47	11:45:00	12:00:00	5391	273.0	3.04	2.16
48	12:00:00	12:15:00	5391	274.0	3.06	2.18
49	12:15:00	12:30:00	5391	273.0	3.04	2.16
50	12:30:00	12:45:00	5391	273.0	3.05	2.17
51	12:45:00	13:00:00	5391	274.0	3.06	2.19
52	13:00:00	13:15:00	5391	273.0	3.05	2.18
53	13:15:00	13:30:00	5391	274.0	3.05	2.17
54	13:30:00	13:45:00	5391	273.0	3.04	2.17
55	13:45:00	14:00:00	5391	274.0	3.05	2.19
56	14:00:00	14:15:00	5391	274.0	3.06	2.19
57	14:15:00	14:30:00	5391	273.0	3.04	2.17
58	14:30:00	14:45:00	5391	272.0	3.04	2.17
59	14:45:00	15:00:00	5391	273.0	3.04	2.16
60	15:00:00	15:15:00	5391	272.0	3.04	2.16
61	15:15:00	15:30:00	5391	273.0	3.04	2.17
62	15:30:00	15:45:00	5391	275.0	3.07	2.19
63	15:45:00	16:00:00	5391	272.0	3.03	2.16
64	16:00:00	16:15:00	5391	273.0	3.04	2.17
65	16:15:00	16:30:00	5391	274.0	3.05	2.18
66	16:30:00	16:45:00	5391	273.0	3.04	2.17
67	16:45:00	17:00:00	5391	273.0	3.04	2.17
68	17:00:00	17:15:00	5391	275.0	3.06	2.21
69	17:15:00	17:30:00	5391	274.0	3.06	2.18

Assignment	Start	End	No. Veh.	Total TT (H)	AVG (M)	STD (M)
70	17:30:00	17:45:00	5391	275.0	3.07	2.2
71	17:45:00	18:00:00	5391	274.0	3.05	2.18
72	18:00:00	18:15:00	5391	273.0	3.04	2.18
73	18:15:00	18:30:00	5391	273.0	3.04	2.18
74	18:30:00	18:45:00	5390	272.0	3.03	2.17
75	18:45:00	19:00:00	5390	273.0	3.05	2.18
76	19:00:00	19:15:00	5390	273.0	3.05	2.17
77	19:15:00	19:30:00	5390	271.0	3.02	2.16
78	19:30:00	19:45:00	5390	272.0	3.03	2.16
79	19:45:00	20:00:00	5390	273.0	3.05	2.18
80	20:00:00	20:15:00	5390	273.0	3.05	2.16
81	20:15:00	20:30:00	5390	275.0	3.07	2.18
82	20:30:00	20:45:00	5390	274.0	3.06	2.18
83	20:45:00	21:00:00	5390	274.0	3.06	2.18
84	21:00:00	21:15:00	5390	272.0	3.04	2.18
85	21:15:00	21:30:00	5390	274.0	3.05	2.17
86	21:30:00	21:45:00	5390	273.0	3.05	2.17
87	21:45:00	22:00:00	5390	272.0	3.03	2.16
88	22:00:00	22:15:00	5390	274.0	3.05	2.18
89	22:15:00	22:30:00	5390	272.0	3.03	2.16
90	22:30:00	22:45:00	5390	272.0	3.03	2.16
91	22:45:00	23:00:00	5390	274.0	3.06	2.19
92	23:00:00	23:15:00	5390	273.0	3.05	2.15
93	23:15:00	23:30:00	5390	275.0	3.07	2.19
94	23:30:00	23:45:00	5390	272.0	3.04	2.16
95	23:45:00	24:00:00	5390	273.0	3.04	2.15
Total	00:00:00	24:00:00	517514	26289.0	3.05	2.18

5. Delay Information (Entered Vehicles)

Table 9. All Type Vehicles Delay

Assignment	Starting Time	Ending Time	Vehicle Count	AVG Delay (M/Veh)	Delay STD (M)
0	00:00:00	00:15:00	5391	0.11	0.18
1	00:15:00	00:30:00	5391	0.14	0.25
2	00:30:00	00:45:00	5391	0.09	0.14
3	00:45:00	01:00:00	5391	0.12	0.2
4	01:00:00	01:15:00	5391	0.15	0.26
5	01:15:00	01:30:00	5391	0.11	0.15
6	01:30:00	01:45:00	5391	0.09	0.12
7	01:45:00	02:00:00	5391	0.1	0.14
8	02:00:00	02:15:00	5391	0.13	0.23
9	02:15:00	02:30:00	5391	0.13	0.22
10	02:30:00	02:45:00	5391	0.13	0.21
11	02:45:00	03:00:00	5391	0.11	0.18
12	03:00:00	03:15:00	5391	0.12	0.2
13	03:15:00	03:30:00	5391	0.13	0.21
14	03:30:00	03:45:00	5391	0.13	0.2
15	03:45:00	04:00:00	5391	0.13	0.27
16	04:00:00	04:15:00	5391	0.11	0.17
17	04:15:00	04:30:00	5391	0.13	0.23
18	04:30:00	04:45:00	5391	0.11	0.19
19	04:45:00	05:00:00	5391	0.13	0.2
20	05:00:00	05:15:00	5391	0.12	0.17
21	05:15:00	05:30:00	5391	0.1	0.15
22	05:30:00	05:45:00	5391	0.13	0.23
23	05:45:00	06:00:00	5391	0.13	0.21
24	06:00:00	06:15:00	5391	0.12	0.17
25	06:15:00	06:30:00	5391	0.13	0.21
26	06:30:00	06:45:00	5391	0.1	0.15
27	06:45:00	07:00:00	5391	0.14	0.26
28	07:00:00	07:15:00	5391	0.11	0.16
29	07:15:00	07:30:00	5391	0.1	0.17
30	07:30:00	07:45:00	5391	0.11	0.17
31	07:45:00	08:00:00	5391	0.12	0.18
32	08:00:00	08:15:00	5391	0.12	0.2
33	08:15:00	08:30:00	5391	0.1	0.16
34	08:30:00	08:45:00	5391	0.11	0.16
35	08:45:00	09:00:00	5391	0.12	0.2
36	09:00:00	09:15:00	5391	0.11	0.17
37	09:15:00	09:30:00	5391	0.13	0.2
38	09:30:00	09:45:00	5391	0.13	0.2
39	09:45:00	10:00:00	5391	0.12	0.18
40	10:00:00	10:15:00	5391	0.12	0.2
41	10:15:00	10:30:00	5391	0.11	0.16
42	10:30:00	10:45:00	5391	0.12	0.2
43	10:45:00	11:00:00	5391	0.12	0.18
44	11:00:00	11:15:00	5391	0.11	0.17
45	11:15:00	11:30:00	5391	0.11	0.17
46	11:30:00	11:45:00	5391	0.1	0.13
47	11:45:00	12:00:00	5391	0.11	0.16
48	12:00:00	12:15:00	5391	0.12	0.19
49	12:15:00	12:30:00	5391	0.11	0.16
50	12:30:00	12:45:00	5391	0.11	0.17
51	12:45:00	13:00:00	5391	0.13	0.2
52	13:00:00	13:15:00	5391	0.11	0.17
53	13:15:00	13:30:00	5391	0.12	0.19
54	13:30:00	13:45:00	5391	0.11	0.15

Assignment	Starting Time	Ending Time	Vehicle Count	AVG Delay (M/Veh)	Delay STD (M)
55	13:45:00	14:00:00	5391	0.12	0.2
56	14:00:00	14:15:00	5391	0.13	0.2
57	14:15:00	14:30:00	5391	0.11	0.16
58	14:30:00	14:45:00	5391	0.11	0.15
59	14:45:00	15:00:00	5391	0.11	0.17
60	15:00:00	15:15:00	5391	0.1	0.15
61	15:15:00	15:30:00	5391	0.12	0.18
62	15:30:00	15:45:00	5391	0.14	0.23
63	15:45:00	16:00:00	5391	0.1	0.14
64	16:00:00	16:15:00	5391	0.11	0.16
65	16:15:00	16:30:00	5391	0.13	0.2
66	16:30:00	16:45:00	5391	0.1	0.15
67	16:45:00	17:00:00	5391	0.12	0.17
68	17:00:00	17:15:00	5391	0.14	0.25
69	17:15:00	17:30:00	5391	0.13	0.21
70	17:30:00	17:45:00	5391	0.15	0.24
71	17:45:00	18:00:00	5391	0.12	0.19
72	18:00:00	18:15:00	5391	0.12	0.18
73	18:15:00	18:30:00	5391	0.12	0.19
74	18:30:00	18:45:00	5390	0.1	0.16
75	18:45:00	19:00:00	5390	0.12	0.18
76	19:00:00	19:15:00	5390	0.11	0.16
77	19:15:00	19:30:00	5390	0.09	0.11
78	19:30:00	19:45:00	5390	0.1	0.13
79	19:45:00	20:00:00	5390	0.11	0.18
80	20:00:00	20:15:00	5390	0.11	0.18
81	20:15:00	20:30:00	5390	0.13	0.22
82	20:30:00	20:45:00	5390	0.13	0.2
83	20:45:00	21:00:00	5390	0.12	0.19
84	21:00:00	21:15:00	5390	0.11	0.16
85	21:15:00	21:30:00	5390	0.12	0.17
86	21:30:00	21:45:00	5390	0.12	0.18
87	21:45:00	22:00:00	5390	0.1	0.13
88	22:00:00	22:15:00	5390	0.12	0.19
89	22:15:00	22:30:00	5390	0.1	0.15
90	22:30:00	22:45:00	5390	0.1	0.14
91	22:45:00	23:00:00	5390	0.13	0.23
92	23:00:00	23:15:00	5390	0.12	0.19
93	23:15:00	23:30:00	5390	0.13	0.22
94	23:30:00	23:45:00	5390	0.1	0.15
95	23:45:00	24:00:00	5390	0.11	0.17
Total	00:00:00	24:00:00	517514	0.12	0.19

Table 10. Passenger Vehicle Delay

Assignment	Starting Time	Ending Time	Vehicle Count	AVG Delay (M/Veh)	Delay STD (M)
0	00:00:00	00:15:00	5391	0.11	0.18
1	00:15:00	00:30:00	5391	0.14	0.25
2	00:30:00	00:45:00	5391	0.09	0.14
3	00:45:00	01:00:00	5391	0.12	0.2
4	01:00:00	01:15:00	5391	0.15	0.26
5	01:15:00	01:30:00	5391	0.11	0.15
6	01:30:00	01:45:00	5391	0.09	0.12
7	01:45:00	02:00:00	5391	0.1	0.14
8	02:00:00	02:15:00	5391	0.13	0.23
9	02:15:00	02:30:00	5391	0.13	0.22
10	02:30:00	02:45:00	5391	0.13	0.21
11	02:45:00	03:00:00	5391	0.11	0.18
12	03:00:00	03:15:00	5391	0.12	0.2
13	03:15:00	03:30:00	5391	0.13	0.21
14	03:30:00	03:45:00	5391	0.13	0.2
15	03:45:00	04:00:00	5391	0.13	0.27
16	04:00:00	04:15:00	5391	0.11	0.17
17	04:15:00	04:30:00	5391	0.13	0.23
18	04:30:00	04:45:00	5391	0.11	0.19
19	04:45:00	05:00:00	5391	0.13	0.2
20	05:00:00	05:15:00	5391	0.12	0.17
21	05:15:00	05:30:00	5391	0.1	0.15
22	05:30:00	05:45:00	5391	0.13	0.23
23	05:45:00	06:00:00	5391	0.13	0.21
24	06:00:00	06:15:00	5391	0.12	0.17
25	06:15:00	06:30:00	5391	0.13	0.21
26	06:30:00	06:45:00	5391	0.1	0.15
27	06:45:00	07:00:00	5391	0.14	0.26
28	07:00:00	07:15:00	5391	0.11	0.16
29	07:15:00	07:30:00	5391	0.1	0.17
30	07:30:00	07:45:00	5391	0.11	0.17
31	07:45:00	08:00:00	5391	0.12	0.18
32	08:00:00	08:15:00	5391	0.12	0.2
33	08:15:00	08:30:00	5391	0.1	0.16
34	08:30:00	08:45:00	5391	0.11	0.16
35	08:45:00	09:00:00	5391	0.12	0.2
36	09:00:00	09:15:00	5391	0.11	0.17
37	09:15:00	09:30:00	5391	0.13	0.2
38	09:30:00	09:45:00	5391	0.13	0.2
39	09:45:00	10:00:00	5391	0.12	0.18
40	10:00:00	10:15:00	5391	0.12	0.2
41	10:15:00	10:30:00	5391	0.11	0.16
42	10:30:00	10:45:00	5391	0.12	0.2
43	10:45:00	11:00:00	5391	0.12	0.18
44	11:00:00	11:15:00	5391	0.11	0.17

Assignment	Starting Time	Ending Time	Vehicle Count	AVG Delay (M/Veh)	Delay STD (M)
45	11:15:00	11:30:00	5391	0.11	0.17
46	11:30:00	11:45:00	5391	0.1	0.13
47	11:45:00	12:00:00	5391	0.11	0.16
48	12:00:00	12:15:00	5391	0.12	0.19
49	12:15:00	12:30:00	5391	0.11	0.16
50	12:30:00	12:45:00	5391	0.11	0.17
51	12:45:00	13:00:00	5391	0.13	0.2
52	13:00:00	13:15:00	5391	0.11	0.17
53	13:15:00	13:30:00	5391	0.12	0.19
54	13:30:00	13:45:00	5391	0.11	0.15
55	13:45:00	14:00:00	5391	0.12	0.2
56	14:00:00	14:15:00	5391	0.13	0.2
57	14:15:00	14:30:00	5391	0.11	0.16
58	14:30:00	14:45:00	5391	0.11	0.15
59	14:45:00	15:00:00	5391	0.11	0.17
60	15:00:00	15:15:00	5391	0.1	0.15
61	15:15:00	15:30:00	5391	0.12	0.18
62	15:30:00	15:45:00	5391	0.14	0.23
63	15:45:00	16:00:00	5391	0.1	0.14
64	16:00:00	16:15:00	5391	0.11	0.16
65	16:15:00	16:30:00	5391	0.13	0.2
66	16:30:00	16:45:00	5391	0.1	0.15
67	16:45:00	17:00:00	5391	0.12	0.17
68	17:00:00	17:15:00	5391	0.14	0.25
69	17:15:00	17:30:00	5391	0.13	0.21
70	17:30:00	17:45:00	5391	0.15	0.24
71	17:45:00	18:00:00	5391	0.12	0.19
72	18:00:00	18:15:00	5391	0.12	0.18
73	18:15:00	18:30:00	5391	0.12	0.19
74	18:30:00	18:45:00	5390	0.1	0.16
75	18:45:00	19:00:00	5390	0.12	0.18
76	19:00:00	19:15:00	5390	0.11	0.16
77	19:15:00	19:30:00	5390	0.09	0.11
78	19:30:00	19:45:00	5390	0.1	0.13
79	19:45:00	20:00:00	5390	0.11	0.18
80	20:00:00	20:15:00	5390	0.11	0.18
81	20:15:00	20:30:00	5390	0.13	0.22
82	20:30:00	20:45:00	5390	0.13	0.2
83	20:45:00	21:00:00	5390	0.12	0.19
84	21:00:00	21:15:00	5390	0.11	0.16
85	21:15:00	21:30:00	5390	0.12	0.17
86	21:30:00	21:45:00	5390	0.12	0.18
87	21:45:00	22:00:00	5390	0.1	0.13
88	22:00:00	22:15:00	5390	0.12	0.19
89	22:15:00	22:30:00	5390	0.1	0.15
90	22:30:00	22:45:00	5390	0.1	0.14
91	22:45:00	23:00:00	5390	0.13	0.23
92	23:00:00	23:15:00	5390	0.12	0.19
93	23:15:00	23:30:00	5390	0.13	0.22
94	23:30:00	23:45:00	5390	0.1	0.15
95	23:45:00	24:00:00	5390	0.11	0.17
Total	00:00:00	24:00:00	517514	0.12	0.19

6. Delay Information (Through Vehicles)

Table 11. All Type Vehicles Delay

Assignment	Starting Time	Ending Time	Vehicle Count	AVG Delay (M/Veh)	Delay STD (M)
0	00:00:00	00:15:00	5391	0.11	0.18
1	00:15:00	00:30:00	5391	0.14	0.25
2	00:30:00	00:45:00	5391	0.09	0.14
3	00:45:00	01:00:00	5391	0.12	0.2
4	01:00:00	01:15:00	5391	0.15	0.26
5	01:15:00	01:30:00	5391	0.11	0.15
6	01:30:00	01:45:00	5391	0.09	0.12
7	01:45:00	02:00:00	5391	0.1	0.14
8	02:00:00	02:15:00	5391	0.13	0.23
9	02:15:00	02:30:00	5391	0.13	0.22
10	02:30:00	02:45:00	5391	0.13	0.21
11	02:45:00	03:00:00	5391	0.11	0.18
12	03:00:00	03:15:00	5391	0.12	0.2
13	03:15:00	03:30:00	5391	0.13	0.21
14	03:30:00	03:45:00	5391	0.13	0.2
15	03:45:00	04:00:00	5391	0.13	0.27
16	04:00:00	04:15:00	5391	0.11	0.17
17	04:15:00	04:30:00	5391	0.13	0.23
18	04:30:00	04:45:00	5391	0.11	0.19
19	04:45:00	05:00:00	5391	0.13	0.2
20	05:00:00	05:15:00	5391	0.12	0.17
21	05:15:00	05:30:00	5391	0.1	0.15
22	05:30:00	05:45:00	5391	0.13	0.23
23	05:45:00	06:00:00	5391	0.13	0.21
24	06:00:00	06:15:00	5391	0.12	0.17
25	06:15:00	06:30:00	5391	0.13	0.21
26	06:30:00	06:45:00	5391	0.1	0.15
27	06:45:00	07:00:00	5391	0.14	0.26
28	07:00:00	07:15:00	5391	0.11	0.16
29	07:15:00	07:30:00	5391	0.1	0.17

Assignment	Starting Time	Ending Time	Vehicle Count	AVG Delay (M/Veh)	Delay STD (M)
30	07:30:00	07:45:00	5391	0.11	0.17
31	07:45:00	08:00:00	5391	0.12	0.18
32	08:00:00	08:15:00	5391	0.12	0.2
33	08:15:00	08:30:00	5391	0.1	0.16
34	08:30:00	08:45:00	5391	0.11	0.16
35	08:45:00	09:00:00	5391	0.12	0.2
36	09:00:00	09:15:00	5391	0.11	0.17
37	09:15:00	09:30:00	5391	0.13	0.2
38	09:30:00	09:45:00	5391	0.13	0.2
39	09:45:00	10:00:00	5391	0.12	0.18
40	10:00:00	10:15:00	5391	0.12	0.2
41	10:15:00	10:30:00	5391	0.11	0.16
42	10:30:00	10:45:00	5391	0.12	0.2
43	10:45:00	11:00:00	5391	0.12	0.18
44	11:00:00	11:15:00	5391	0.11	0.17
45	11:15:00	11:30:00	5391	0.11	0.17
46	11:30:00	11:45:00	5391	0.1	0.13
47	11:45:00	12:00:00	5391	0.11	0.16
48	12:00:00	12:15:00	5391	0.12	0.19
49	12:15:00	12:30:00	5391	0.11	0.16
50	12:30:00	12:45:00	5391	0.11	0.17
51	12:45:00	13:00:00	5391	0.13	0.2
52	13:00:00	13:15:00	5391	0.11	0.17
53	13:15:00	13:30:00	5391	0.12	0.19
54	13:30:00	13:45:00	5391	0.11	0.15
55	13:45:00	14:00:00	5391	0.12	0.2
56	14:00:00	14:15:00	5391	0.13	0.2
57	14:15:00	14:30:00	5391	0.11	0.16
58	14:30:00	14:45:00	5391	0.11	0.15
59	14:45:00	15:00:00	5391	0.11	0.17
60	15:00:00	15:15:00	5391	0.1	0.15
61	15:15:00	15:30:00	5391	0.12	0.18
62	15:30:00	15:45:00	5391	0.14	0.23
63	15:45:00	16:00:00	5391	0.1	0.14
64	16:00:00	16:15:00	5391	0.11	0.16
65	16:15:00	16:30:00	5391	0.13	0.2
66	16:30:00	16:45:00	5391	0.1	0.15
67	16:45:00	17:00:00	5391	0.12	0.17
68	17:00:00	17:15:00	5391	0.14	0.25
69	17:15:00	17:30:00	5391	0.13	0.21
70	17:30:00	17:45:00	5391	0.15	0.24
71	17:45:00	18:00:00	5391	0.12	0.19
72	18:00:00	18:15:00	5391	0.12	0.18
73	18:15:00	18:30:00	5391	0.12	0.19
74	18:30:00	18:45:00	5390	0.1	0.16
75	18:45:00	19:00:00	5390	0.12	0.18
76	19:00:00	19:15:00	5390	0.11	0.16
77	19:15:00	19:30:00	5390	0.09	0.11
78	19:30:00	19:45:00	5390	0.1	0.13
79	19:45:00	20:00:00	5390	0.11	0.18
80	20:00:00	20:15:00	5390	0.11	0.18
81	20:15:00	20:30:00	5390	0.13	0.22
82	20:30:00	20:45:00	5390	0.13	0.2
83	20:45:00	21:00:00	5390	0.12	0.19
84	21:00:00	21:15:00	5390	0.11	0.16
85	21:15:00	21:30:00	5390	0.12	0.17
86	21:30:00	21:45:00	5390	0.12	0.18
87	21:45:00	22:00:00	5390	0.1	0.13
88	22:00:00	22:15:00	5390	0.12	0.19
89	22:15:00	22:30:00	5390	0.1	0.15
90	22:30:00	22:45:00	5390	0.1	0.14
91	22:45:00	23:00:00	5390	0.13	0.23
92	23:00:00	23:15:00	5390	0.12	0.19
93	23:15:00	23:30:00	5390	0.13	0.22
94	23:30:00	23:45:00	5390	0.1	0.15
95	23:45:00	24:00:00	5390	0.11	0.17
Total	00:00:00	24:00:00	517514	0.12	0.19

Table 12. Passenger Vehicle Delay

Assignment	Starting Time	Ending Time	Vehicle Count	AVG Delay (M/Veh)	Delay STD (M)
0	00:00:00	00:15:00	5391	0.11	0.18
1	00:15:00	00:30:00	5391	0.14	0.25
2	00:30:00	00:45:00	5391	0.09	0.14
3	00:45:00	01:00:00	5391	0.12	0.2
4	01:00:00	01:15:00	5391	0.15	0.26
5	01:15:00	01:30:00	5391	0.11	0.15
6	01:30:00	01:45:00	5391	0.09	0.12
7	01:45:00	02:00:00	5391	0.1	0.14
8	02:00:00	02:15:00	5391	0.13	0.23
9	02:15:00	02:30:00	5391	0.13	0.22
10	02:30:00	02:45:00	5391	0.13	0.21
11	02:45:00	03:00:00	5391	0.11	0.18
12	03:00:00	03:15:00	5391	0.12	0.2
13	03:15:00	03:30:00	5391	0.13	0.21
14	03:30:00	03:45:00	5391	0.13	0.2
15	03:45:00	04:00:00	5391	0.13	0.27
16	04:00:00	04:15:00	5391	0.11	0.17
17	04:15:00	04:30:00	5391	0.13	0.23
18	04:30:00	04:45:00	5391	0.11	0.19
19	04:45:00	05:00:00	5391	0.13	0.2

Assignment	Starting Time	Ending Time	Vehicle Count	AVG Delay (M/Veh)	Delay STD (M)
20	05:00:00	05:15:00	5391	0.12	0.17
21	05:15:00	05:30:00	5391	0.1	0.15
22	05:30:00	05:45:00	5391	0.13	0.23
23	05:45:00	06:00:00	5391	0.13	0.21
24	06:00:00	06:15:00	5391	0.12	0.17
25	06:15:00	06:30:00	5391	0.13	0.21
26	06:30:00	06:45:00	5391	0.1	0.15
27	06:45:00	07:00:00	5391	0.14	0.26
28	07:00:00	07:15:00	5391	0.11	0.16
29	07:15:00	07:30:00	5391	0.1	0.17
30	07:30:00	07:45:00	5391	0.11	0.17
31	07:45:00	08:00:00	5391	0.12	0.18
32	08:00:00	08:15:00	5391	0.12	0.2
33	08:15:00	08:30:00	5391	0.1	0.16
34	08:30:00	08:45:00	5391	0.11	0.16
35	08:45:00	09:00:00	5391	0.12	0.2
36	09:00:00	09:15:00	5391	0.11	0.17
37	09:15:00	09:30:00	5391	0.13	0.2
38	09:30:00	09:45:00	5391	0.13	0.2
39	09:45:00	10:00:00	5391	0.12	0.18
40	10:00:00	10:15:00	5391	0.12	0.2
41	10:15:00	10:30:00	5391	0.11	0.16
42	10:30:00	10:45:00	5391	0.12	0.2
43	10:45:00	11:00:00	5391	0.12	0.18
44	11:00:00	11:15:00	5391	0.11	0.17
45	11:15:00	11:30:00	5391	0.11	0.17
46	11:30:00	11:45:00	5391	0.1	0.13
47	11:45:00	12:00:00	5391	0.11	0.16
48	12:00:00	12:15:00	5391	0.12	0.19
49	12:15:00	12:30:00	5391	0.11	0.16
50	12:30:00	12:45:00	5391	0.11	0.17
51	12:45:00	13:00:00	5391	0.13	0.2
52	13:00:00	13:15:00	5391	0.11	0.17
53	13:15:00	13:30:00	5391	0.12	0.19
54	13:30:00	13:45:00	5391	0.11	0.15
55	13:45:00	14:00:00	5391	0.12	0.2
56	14:00:00	14:15:00	5391	0.13	0.2
57	14:15:00	14:30:00	5391	0.11	0.16
58	14:30:00	14:45:00	5391	0.11	0.15
59	14:45:00	15:00:00	5391	0.11	0.17
60	15:00:00	15:15:00	5391	0.1	0.15
61	15:15:00	15:30:00	5391	0.12	0.18
62	15:30:00	15:45:00	5391	0.14	0.23
63	15:45:00	16:00:00	5391	0.1	0.14
64	16:00:00	16:15:00	5391	0.11	0.16
65	16:15:00	16:30:00	5391	0.13	0.2
66	16:30:00	16:45:00	5391	0.1	0.15
67	16:45:00	17:00:00	5391	0.12	0.17
68	17:00:00	17:15:00	5391	0.14	0.25
69	17:15:00	17:30:00	5391	0.13	0.21
70	17:30:00	17:45:00	5391	0.15	0.24
71	17:45:00	18:00:00	5391	0.12	0.19
72	18:00:00	18:15:00	5391	0.12	0.18
73	18:15:00	18:30:00	5391	0.12	0.19
74	18:30:00	18:45:00	5390	0.1	0.16
75	18:45:00	19:00:00	5390	0.12	0.18
76	19:00:00	19:15:00	5390	0.11	0.16
77	19:15:00	19:30:00	5390	0.09	0.11
78	19:30:00	19:45:00	5390	0.1	0.13
79	19:45:00	20:00:00	5390	0.11	0.18
80	20:00:00	20:15:00	5390	0.11	0.18
81	20:15:00	20:30:00	5390	0.13	0.22
82	20:30:00	20:45:00	5390	0.13	0.2
83	20:45:00	21:00:00	5390	0.12	0.19
84	21:00:00	21:15:00	5390	0.11	0.16
85	21:15:00	21:30:00	5390	0.12	0.17
86	21:30:00	21:45:00	5390	0.12	0.18
87	21:45:00	22:00:00	5390	0.1	0.13
88	22:00:00	22:15:00	5390	0.12	0.19
89	22:15:00	22:30:00	5390	0.1	0.15
90	22:30:00	22:45:00	5390	0.1	0.14
91	22:45:00	23:00:00	5390	0.13	0.23
92	23:00:00	23:15:00	5390	0.12	0.19
93	23:15:00	23:30:00	5390	0.13	0.22
94	23:30:00	23:45:00	5390	0.1	0.15
95	23:45:00	24:00:00	5390	0.11	0.17
Total	00:00:00	24:00:00	517514	0.12	0.19

7. Delay Information (Loaded Vehicles)

Table 13. All Type Vehicles Delay

Assignment	Starting Time	Ending Time	Vehicle Count	AVG Delay (M/Veh)	Delay STD (M)
0	00:00:00	00:15:00	5391	0.11	0.18
1	00:15:00	00:30:00	5391	0.14	0.25
2	00:30:00	00:45:00	5391	0.09	0.14
3	00:45:00	01:00:00	5391	0.12	0.2
4	01:00:00	01:15:00	5391	0.15	0.26

Assignment	Starting Time	Ending Time	Vehicle Count	AVG Delay (M/Veh)	Delay STD (M)
5	01:15:00	01:30:00	5391	0.11	0.15
6	01:30:00	01:45:00	5391	0.09	0.12
7	01:45:00	02:00:00	5391	0.1	0.14
8	02:00:00	02:15:00	5391	0.13	0.23
9	02:15:00	02:30:00	5391	0.13	0.22
10	02:30:00	02:45:00	5391	0.13	0.21
11	02:45:00	03:00:00	5391	0.11	0.18
12	03:00:00	03:15:00	5391	0.12	0.2
13	03:15:00	03:30:00	5391	0.13	0.21
14	03:30:00	03:45:00	5391	0.13	0.2
15	03:45:00	04:00:00	5391	0.13	0.27
16	04:00:00	04:15:00	5391	0.11	0.17
17	04:15:00	04:30:00	5391	0.13	0.23
18	04:30:00	04:45:00	5391	0.11	0.19
19	04:45:00	05:00:00	5391	0.13	0.2
20	05:00:00	05:15:00	5391	0.12	0.17
21	05:15:00	05:30:00	5391	0.1	0.15
22	05:30:00	05:45:00	5391	0.13	0.23
23	05:45:00	06:00:00	5391	0.13	0.21
24	06:00:00	06:15:00	5391	0.12	0.17
25	06:15:00	06:30:00	5391	0.13	0.21
26	06:30:00	06:45:00	5391	0.1	0.15
27	06:45:00	07:00:00	5391	0.14	0.26
28	07:00:00	07:15:00	5391	0.11	0.16
29	07:15:00	07:30:00	5391	0.1	0.17
30	07:30:00	07:45:00	5391	0.11	0.17
31	07:45:00	08:00:00	5391	0.12	0.18
32	08:00:00	08:15:00	5391	0.12	0.2
33	08:15:00	08:30:00	5391	0.1	0.16
34	08:30:00	08:45:00	5391	0.11	0.16
35	08:45:00	09:00:00	5391	0.12	0.2
36	09:00:00	09:15:00	5391	0.11	0.17
37	09:15:00	09:30:00	5391	0.13	0.2
38	09:30:00	09:45:00	5391	0.13	0.2
39	09:45:00	10:00:00	5391	0.12	0.18
40	10:00:00	10:15:00	5391	0.12	0.2
41	10:15:00	10:30:00	5391	0.11	0.16
42	10:30:00	10:45:00	5391	0.12	0.2
43	10:45:00	11:00:00	5391	0.12	0.18
44	11:00:00	11:15:00	5391	0.11	0.17
45	11:15:00	11:30:00	5391	0.11	0.17
46	11:30:00	11:45:00	5391	0.1	0.13
47	11:45:00	12:00:00	5391	0.11	0.16
48	12:00:00	12:15:00	5391	0.12	0.19
49	12:15:00	12:30:00	5391	0.11	0.16
50	12:30:00	12:45:00	5391	0.11	0.17
51	12:45:00	13:00:00	5391	0.13	0.2
52	13:00:00	13:15:00	5391	0.11	0.17
53	13:15:00	13:30:00	5391	0.12	0.19
54	13:30:00	13:45:00	5391	0.11	0.15
55	13:45:00	14:00:00	5391	0.12	0.2
56	14:00:00	14:15:00	5391	0.13	0.2
57	14:15:00	14:30:00	5391	0.11	0.16
58	14:30:00	14:45:00	5391	0.11	0.15
59	14:45:00	15:00:00	5391	0.11	0.17
60	15:00:00	15:15:00	5391	0.1	0.15
61	15:15:00	15:30:00	5391	0.12	0.18
62	15:30:00	15:45:00	5391	0.14	0.23
63	15:45:00	16:00:00	5391	0.1	0.14
64	16:00:00	16:15:00	5391	0.11	0.16
65	16:15:00	16:30:00	5391	0.13	0.2
66	16:30:00	16:45:00	5391	0.1	0.15
67	16:45:00	17:00:00	5391	0.12	0.17
68	17:00:00	17:15:00	5391	0.14	0.25
69	17:15:00	17:30:00	5391	0.13	0.21
70	17:30:00	17:45:00	5391	0.15	0.24
71	17:45:00	18:00:00	5391	0.12	0.19
72	18:00:00	18:15:00	5391	0.12	0.18
73	18:15:00	18:30:00	5391	0.12	0.19
74	18:30:00	18:45:00	5390	0.1	0.16
75	18:45:00	19:00:00	5390	0.12	0.18
76	19:00:00	19:15:00	5390	0.11	0.16
77	19:15:00	19:30:00	5390	0.09	0.11
78	19:30:00	19:45:00	5390	0.1	0.13
79	19:45:00	20:00:00	5390	0.11	0.18
80	20:00:00	20:15:00	5390	0.11	0.18
81	20:15:00	20:30:00	5390	0.13	0.22
82	20:30:00	20:45:00	5390	0.13	0.2
83	20:45:00	21:00:00	5390	0.12	0.19
84	21:00:00	21:15:00	5390	0.11	0.16
85	21:15:00	21:30:00	5390	0.12	0.17
86	21:30:00	21:45:00	5390	0.12	0.18
87	21:45:00	22:00:00	5390	0.1	0.13
88	22:00:00	22:15:00	5390	0.12	0.19
89	22:15:00	22:30:00	5390	0.1	0.15
90	22:30:00	22:45:00	5390	0.1	0.14
91	22:45:00	23:00:00	5390	0.13	0.23
92	23:00:00	23:15:00	5390	0.12	0.19
93	23:15:00	23:30:00	5390	0.13	0.22
94	23:30:00	23:45:00	5390	0.1	0.15
95	23:45:00	24:00:00	5390	0.11	0.17

Assignment	Starting Time	Ending Time	Vehicle Count	AVG Delay (M/Veh)	Delay STD (M)
Total	00:00:00	24:00:00	517514	0.12	0.19

Table 14. Passenger Vehicle Delay

Assignment	Starting Time	Ending Time	Vehicle Count	AVG Delay (M/Veh)	Delay STD (M)
0	00:00:00	00:15:00	5391	0.11	0.18
1	00:15:00	00:30:00	5391	0.14	0.25
2	00:30:00	00:45:00	5391	0.09	0.14
3	00:45:00	01:00:00	5391	0.12	0.2
4	01:00:00	01:15:00	5391	0.15	0.26
5	01:15:00	01:30:00	5391	0.11	0.15
6	01:30:00	01:45:00	5391	0.09	0.12
7	01:45:00	02:00:00	5391	0.1	0.14
8	02:00:00	02:15:00	5391	0.13	0.23
9	02:15:00	02:30:00	5391	0.13	0.22
10	02:30:00	02:45:00	5391	0.13	0.21
11	02:45:00	03:00:00	5391	0.11	0.18
12	03:00:00	03:15:00	5391	0.12	0.2
13	03:15:00	03:30:00	5391	0.13	0.21
14	03:30:00	03:45:00	5391	0.13	0.2
15	03:45:00	04:00:00	5391	0.13	0.27
16	04:00:00	04:15:00	5391	0.11	0.17
17	04:15:00	04:30:00	5391	0.13	0.23
18	04:30:00	04:45:00	5391	0.11	0.19
19	04:45:00	05:00:00	5391	0.13	0.2
20	05:00:00	05:15:00	5391	0.12	0.17
21	05:15:00	05:30:00	5391	0.1	0.15
22	05:30:00	05:45:00	5391	0.13	0.23
23	05:45:00	06:00:00	5391	0.13	0.21
24	06:00:00	06:15:00	5391	0.12	0.17
25	06:15:00	06:30:00	5391	0.13	0.21
26	06:30:00	06:45:00	5391	0.1	0.15
27	06:45:00	07:00:00	5391	0.14	0.26
28	07:00:00	07:15:00	5391	0.11	0.16
29	07:15:00	07:30:00	5391	0.1	0.17
30	07:30:00	07:45:00	5391	0.11	0.17
31	07:45:00	08:00:00	5391	0.12	0.18
32	08:00:00	08:15:00	5391	0.12	0.2
33	08:15:00	08:30:00	5391	0.1	0.16
34	08:30:00	08:45:00	5391	0.11	0.16
35	08:45:00	09:00:00	5391	0.12	0.2
36	09:00:00	09:15:00	5391	0.11	0.17
37	09:15:00	09:30:00	5391	0.13	0.2
38	09:30:00	09:45:00	5391	0.13	0.2
39	09:45:00	10:00:00	5391	0.12	0.18
40	10:00:00	10:15:00	5391	0.12	0.2
41	10:15:00	10:30:00	5391	0.11	0.16
42	10:30:00	10:45:00	5391	0.12	0.2
43	10:45:00	11:00:00	5391	0.12	0.18
44	11:00:00	11:15:00	5391	0.11	0.17
45	11:15:00	11:30:00	5391	0.11	0.17
46	11:30:00	11:45:00	5391	0.1	0.13
47	11:45:00	12:00:00	5391	0.11	0.16
48	12:00:00	12:15:00	5391	0.12	0.19
49	12:15:00	12:30:00	5391	0.11	0.16
50	12:30:00	12:45:00	5391	0.11	0.17
51	12:45:00	13:00:00	5391	0.13	0.2
52	13:00:00	13:15:00	5391	0.11	0.17
53	13:15:00	13:30:00	5391	0.12	0.19
54	13:30:00	13:45:00	5391	0.11	0.15
55	13:45:00	14:00:00	5391	0.12	0.2
56	14:00:00	14:15:00	5391	0.13	0.2
57	14:15:00	14:30:00	5391	0.11	0.16
58	14:30:00	14:45:00	5391	0.11	0.15
59	14:45:00	15:00:00	5391	0.11	0.17
60	15:00:00	15:15:00	5391	0.1	0.15
61	15:15:00	15:30:00	5391	0.12	0.18
62	15:30:00	15:45:00	5391	0.14	0.23
63	15:45:00	16:00:00	5391	0.1	0.14
64	16:00:00	16:15:00	5391	0.11	0.16
65	16:15:00	16:30:00	5391	0.13	0.2
66	16:30:00	16:45:00	5391	0.1	0.15
67	16:45:00	17:00:00	5391	0.12	0.17
68	17:00:00	17:15:00	5391	0.14	0.25
69	17:15:00	17:30:00	5391	0.13	0.21
70	17:30:00	17:45:00	5391	0.15	0.24
71	17:45:00	18:00:00	5391	0.12	0.19
72	18:00:00	18:15:00	5391	0.12	0.18
73	18:15:00	18:30:00	5391	0.12	0.19
74	18:30:00	18:45:00	5390	0.1	0.16
75	18:45:00	19:00:00	5390	0.12	0.18
76	19:00:00	19:15:00	5390	0.11	0.16
77	19:15:00	19:30:00	5390	0.09	0.11
78	19:30:00	19:45:00	5390	0.1	0.13
79	19:45:00	20:00:00	5390	0.11	0.18
80	20:00:00	20:15:00	5390	0.11	0.18
81	20:15:00	20:30:00	5390	0.13	0.22
82	20:30:00	20:45:00	5390	0.13	0.2
83	20:45:00	21:00:00	5390	0.12	0.19
84	21:00:00	21:15:00	5390	0.11	0.16
85	21:15:00	21:30:00	5390	0.12	0.17

Assignment	Starting Time	Ending Time	Vehicle Count	AVG Delay (M/Veh)	Delay STD (M)
86	21:30:00	21:45:00	5390	0.12	0.18
87	21:45:00	22:00:00	5390	0.1	0.13
88	22:00:00	22:15:00	5390	0.12	0.19
89	22:15:00	22:30:00	5390	0.1	0.15
90	22:30:00	22:45:00	5390	0.1	0.14
91	22:45:00	23:00:00	5390	0.13	0.23
92	23:00:00	23:15:00	5390	0.12	0.19
93	23:15:00	23:30:00	5390	0.13	0.22
94	23:30:00	23:45:00	5390	0.1	0.15
95	23:45:00	24:00:00	5390	0.11	0.17
Total	00:00:00	24:00:00	517514	0.12	0.19

8. Distribution Graph

Figure 1. Passenger Vehicle Travel Time Categories in network nicosia_base

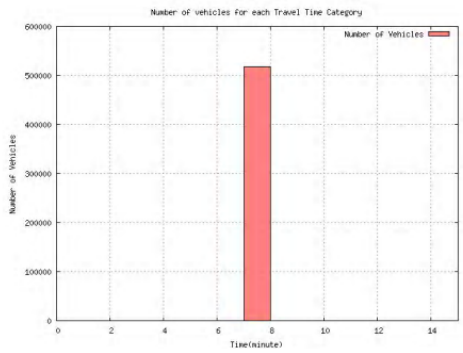


Table 15.

Time (Minute)	0 ~ 15
No. Vehicles	517514

Figure 2. Passenger Vehicle Departure Time Distribution in network nicosia_base

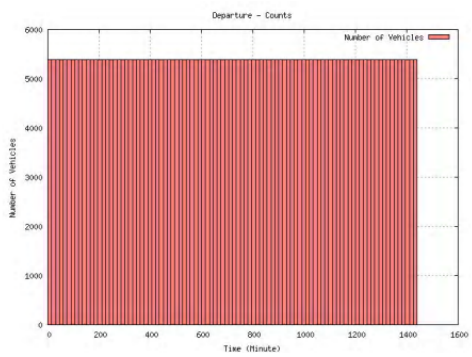


Table 16.

Start (M)	0	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	300	315	330	345	360	375	390	405	420	435
End (M)	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	300	315	330	345	360	375	390	405	420	435	450
No. Vehicles	5391	5391	5391	5391	5391	5391	5391	5391	5391	5391	5391	5391	5391	5391	5391	5391	5391	5391	5391	5391	5391	5391	5391	5391	5391	5391	5391	5391	5391	5391

Figure 3. Passenger Vehicle Departure Time Cumulative Distribution in network nicosia_base

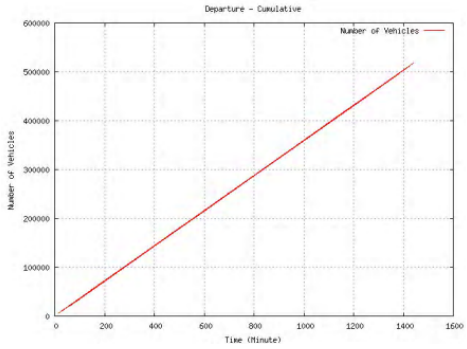


Table 17. Passenger Vehicle Departure Time Cumulative Distribution in network nicosia_base

Time (Minute)	255	510	765	1020	1275	240	495	750	1005	1260	225	480	735	990	1245	210	465	720	975	1230	195	450	705
No. Vehicles	91647	183294	274941	366588	458224	86256	177903	269550	361197	452834	80865	172512	264159	355806	447444	75474	167121	258768	350415	442054	70083	161730	253377

9. Terminology

Loaded Vehicles

The total number of arranged vehicles..

Entered Vehicles

Vehicles that entered (but not necessarily exited) the network..

Non-entered Vehicles

Vehicles that are loaded but never left their origin zone..

Through Vehicles

Vehicles exited the network.

Non-exited Vehicles

Vehicles that entered but not exited.

Loaded = Entered + Non-entered.

Entered = Through + Non-exited.

Delay

Delay = Travel Time - Free Flow Travel Time.

APPENDIX B. VISTA OD Report

The VISTA OD Report is designed to produce specific statistics for each OD pair that the analyst desires. The main tables that are produced by the OD report are provided below as an example from the preliminary VISTA prototype of Nicosia.

Table B1 is generated automatically by specifying the Origin, the Destination, the time interval of analysis. It produces the OD pair, the DUE paths for each OD pair, the length of the path, the average travel time for the OD pair and the number of vehicles that were assigned to each OD path. For example, the OD pair (10003-200004) produces three DUE paths for the time interval from zero to 15 minutes and the same one for the time interval from 15 to 30 minutes. It is noted that different paths may be generated for various time intervals of the day due to the variations in demand.

Table B1. This report provides the summary statistics for a specific OD pair (10003-200004)

Origin	**Destination**	**Time Interval (M)**	**Path**	**Length (Mile)**	**Avg TT(M)**	**Number of Vehs**
100003	200004	15.0	{549,440,74,467,112,114,116,154,155,278,250, 246,243,265,676}	36.965	6.53	15
100003	200004	15.0	{549,440,74,467,112,114,116,154,155,285,284, 263,262,20,269,677}	40.029	6.82	26
100003	200004	15.0	{549,440,74,467,112,114,116,154,157,160,529, 528,256,250,246,243,265,676}	37.338	6.45	218
100003	200004	30.0	{549,440,74,467,112,114,116,154,155,278,250, 246,243,265,676}	36.965	6.75	44
100003	200004	30.0	{549,440,74,467,112,114,116,154,155,285,284, 263,262,20,269,677}	40.029	6.84	26
100003	200004	30.0	{549,440,74,467,112,114,116,154,157,160,529, 528,256,250,246,243,265,676}	37.338	6.68	189
100003	200004	45.0	{549,440,74,467,112,114,116,154,155,278,250, 246,243,265,676}	36.965	6.58	61
100003	200004	45.0	{549,440,74,467,112,114,116,154,155,285,284, 263,262,20,269,677}	40.029	6.83	26
100003	200004	45.0	{549,440,74,467,112,114,116,154,157,160,529, 528,256,250,246,243,265,676}	37.338	6.5	144
100003	200004	45.0	{549,440,74,467,112,114,116,154,157,160,529, 528,256,250,246,251,276,20,269,677}	39.842	6.86	28
100003	200004	60.0	{549,440,74,467,112,114,116,154,155,278,250, 246,243,265,676}	36.965	6.61	35
100003	200004	60.0	{549,440,74,467,112,114,116,154,155,285,284, 263,262,20,269,677}	40.029	6.83	18
100003	200004	60.0	{549,440,74,467,112,114,116,154,157,160,529, 528,256,250,246,243,265,676}	37.338	6.54	206
100003	200004	75.0	{549,440,74,467,112,114,116,154,155,278,250, 246,243,265,676}	36.965	7.12	28
100003	200004	75.0	{549,440,74,467,112,114,116,154,155,285,284, 263,262,20,269,677}	40.029	6.83	29
100003	200004	75.0	{549,440,74,467,112,114,116,154,157,160,529, 528,256,250,246,243,265,676}	37.338	7.05	202
100003	200004	90.0	{549,440,74,467,112,114,116,154,155,278,250, 246,243,265,676}	36.965	6.71	48
100003	200004	90.0	{549,440,74,467,112,114,116,154,155,285,284, 263,262,20,269,677}	40.029	6.83	32
100003	200004	90.0	{549,440,74,467,112,114,116,154,157,160,529, 528,256,250,246,243,265,676}	37.338	6.63	179
100003	200004	105.0	{549,440,74,467,112,114,116,154,155,278,250, 246,243,265,676}	36.965	6.45	43
100003	200004	105.0	{549,440,74,467,112,114,116,154,155,285,284, 263,262,20,269,677}	40.029	6.85	14

100003	200004	105.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.38	162
100003	200004	105.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,251,276,20,269,677}	39.842	6.88	40
100003	200004	120.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.46	26
100003	200004	120.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.84	41
100003	200004	120.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.4	192
100003	200004	135.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.78	27
100003	200004	135.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.82	12
100003	200004	135.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.71	220
100003	200004	150.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	7.06	51
100003	200004	150.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.84	15
100003	200004	150.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	7.0	178
100003	200004	150.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,251,276,20,269,677}	39.842	6.91	15
100003	200004	165.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.58	26
100003	200004	165.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.85	6
100003	200004	165.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.51	227
100003	200004	180.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	10
100003	200004	180.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	7.01	86
100003	200004	180.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.84	17
100003	200004	180.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.92	123
100003	200004	180.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,251,276,20,269,677}	39.842	6.97	23
100003	200004	195.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	6
100003	200004	195.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.57	32
100003	200004	195.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.83	11
100003	200004	195.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.5	210
100003	200004	210.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.13	8
100003	200004	210.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.97	60
100003	200004	210.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.83	15
100003	200004	210.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.89	176
100003	200004	225.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	9
100003	200004	225.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.84	36

100003	200004	225.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.83	28
100003	200004	225.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.78	177
100003	200004	225.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,251,276,20,269,677}	39.842	6.9	9
100003	200004	240.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	5
100003	200004	240.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.57	49
100003	200004	240.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.52	205
100003	200004	255.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.11	18
100003	200004	255.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	7.01	63
100003	200004	255.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.83	33
100003	200004	255.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.93	145
100003	200004	270.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	5
100003	200004	270.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.47	36
100003	200004	270.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.4	218
100003	200004	285.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	10
100003	200004	285.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.91	53
100003	200004	285.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.85	14
100003	200004	285.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.83	182
100003	200004	300.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	8
100003	200004	300.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.6	34
100003	200004	300.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.82	32
100003	200004	300.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.52	185
100003	200004	315.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	6
100003	200004	315.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.66	36
100003	200004	315.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.58	217
100003	200004	330.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.13	9
100003	200004	330.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.65	38
100003	200004	330.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.82	19
100003	200004	330.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.58	193
100003	200004	345.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.11	8
100003	200004	345.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.54	32

100003	200004	345.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.83	30
100003	200004	345.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.47	189
100003	200004	360.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	8
100003	200004	360.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.85	77
100003	200004	360.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.82	15
100003	200004	360.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.77	159
100003	200004	375.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	9
100003	200004	375.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.79	49
100003	200004	375.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.82	25
100003	200004	375.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.72	176
100003	200004	390.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	7
100003	200004	390.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.7	34
100003	200004	390.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.63	218
100003	200004	405.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	16
100003	200004	405.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.83	64
100003	200004	405.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.85	28
100003	200004	405.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.75	136
100003	200004	405.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,251,276,20,269,677}	39.842	6.88	15
100003	200004	420.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.11	10
100003	200004	420.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.58	43
100003	200004	420.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.85	19
100003	200004	420.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.51	187
100003	200004	435.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	8
100003	200004	435.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.86	32
100003	200004	435.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.84	39
100003	200004	435.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.78	179
100003	200004	450.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	8
100003	200004	450.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.37	81
100003	200004	450.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.83	14
100003	200004	450.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.29	155

100003	200004	465.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	9
100003	200004	465.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.55	57
100003	200004	465.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.84	19
100003	200004	465.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.47	173
100003	200004	480.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	6
100003	200004	480.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.83	48
100003	200004	480.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.77	192
100003	200004	480.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,251,276,20,269,677}	39.842	6.86	12
100003	200004	495.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	11
100003	200004	495.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.73	60
100003	200004	495.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.84	19
100003	200004	495.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.65	149
100003	200004	495.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,251,276,20,269,677}	39.842	6.91	19
100003	200004	510.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	8
100003	200004	510.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.41	45
100003	200004	510.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.83	40
100003	200004	510.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.34	165
100003	200004	525.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	6
100003	200004	525.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.37	46
100003	200004	525.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.29	206
100003	200004	540.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	10
100003	200004	540.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.91	79
100003	200004	540.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.85	16
100003	200004	540.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.83	153
100003	200004	555.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	8
100003	200004	555.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.46	53
100003	200004	555.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.82	20
100003	200004	555.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.38	177
100003	200004	570.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	8
100003	200004	570.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.95	57

100003	200004	570.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.82	20
100003	200004	570.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.87	173
100003	200004	585.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	10
100003	200004	585.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.78	55
100003	200004	585.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.81	18
100003	200004	585.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.71	175
100003	200004	600.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	13
100003	200004	600.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.84	72
100003	200004	600.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.82	24
100003	200004	600.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.75	149
100003	200004	615.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.13	5
100003	200004	615.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.56	45
100003	200004	615.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.5	208
100003	200004	630.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	10
100003	200004	630.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.9	80
100003	200004	630.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.85	16
100003	200004	630.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.82	152
100003	200004	645.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	7
100003	200004	645.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.67	36
100003	200004	645.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.59	215
100003	200004	660.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	10
100003	200004	660.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.84	48
100003	200004	660.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.83	26
100003	200004	660.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.76	174
100003	200004	675.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.11	7
100003	200004	675.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.61	43
100003	200004	675.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.81	14
100003	200004	675.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.54	194
100003	200004	690.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	10
100003	200004	690.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.84	76

100003	200004	690.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.82	15
100003	200004	690.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.77	141
100003	200004	690.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,251,276,20,269,677}	39.842	6.88	16
100003	200004	705.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	10
100003	200004	705.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.56	72
100003	200004	705.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.82	15
100003	200004	705.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.47	161
100003	200004	720.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	9
100003	200004	720.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.52	70
100003	200004	720.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.83	15
100003	200004	720.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.45	164
100003	200004	735.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	11
100003	200004	735.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.67	57
100003	200004	735.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.82	20
100003	200004	735.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.6	170
100003	200004	750.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	10
100003	200004	750.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.61	79
100003	200004	750.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.83	19
100003	200004	750.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.53	127
100003	200004	750.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,251,276,20,269,677}	39.842	6.85	23
100003	200004	765.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	11
100003	200004	765.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.5	59
100003	200004	765.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.81	21
100003	200004	765.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.42	167
100003	200004	780.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	7
100003	200004	780.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.68	33
100003	200004	780.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.61	218
100003	200004	795.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	12
100003	200004	795.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.77	46
100003	200004	795.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.82	20

100003	200004	795.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.69	180
100003	200004	810.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	10
100003	200004	810.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.67	42
100003	200004	810.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.85	19
100003	200004	810.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.6	187
100003	200004	825.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.11	10
100003	200004	825.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.63	81
100003	200004	825.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.83	14
100003	200004	825.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.56	153
100003	200004	840.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.13	9
100003	200004	840.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.77	46
100003	200004	840.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.82	29
100003	200004	840.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.7	174
100003	200004	855.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	13
100003	200004	855.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.51	62
100003	200004	855.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.82	32
100003	200004	855.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.44	151
100003	200004	870.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	9
100003	200004	870.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.66	77
100003	200004	870.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.81	14
100003	200004	870.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.58	158
100003	200004	885.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.11	6
100003	200004	885.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.71	45
100003	200004	885.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.84	37
100003	200004	885.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.64	170
100003	200004	900.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	10
100003	200004	900.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.43	40
100003	200004	900.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.83	31
100003	200004	900.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.35	177
100003	200004	915.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	13

100003	200004	915.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.36	81
100003	200004	915.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.84	32
100003	200004	915.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.28	132
100003	200004	930.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.13	10
100003	200004	930.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.49	41
100003	200004	930.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.85	26
100003	200004	930.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.41	181
100003	200004	945.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	6
100003	200004	945.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.62	37
100003	200004	945.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.54	215
100003	200004	960.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.13	10
100003	200004	960.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.79	77
100003	200004	960.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.82	14
100003	200004	960.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.71	157
100003	200004	975.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	10
100003	200004	975.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.54	63
100003	200004	975.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.85	19
100003	200004	975.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.46	166
100003	200004	990.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	5
100003	200004	990.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.62	47
100003	200004	990.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.55	206
100003	200004	1005.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	10
100003	200004	1005.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.82	77
100003	200004	1005.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.83	17
100003	200004	1005.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.74	138
100003	200004	1005.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,251,276,20,269,677}	39.842	6.88	16
100003	200004	1020.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.13	8
100003	200004	1020.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.64	39
100003	200004	1020.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.86	33
100003	200004	1020.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.57	169

100003	200004	1020.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,251,276,20,269,677}	39.842	6.92	9
100003	200004	1035.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	5
100003	200004	1035.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.57	47
100003	200004	1035.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.51	206
100003	200004	1050.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	10
100003	200004	1050.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	7.03	60
100003	200004	1050.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.83	14
100003	200004	1050.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.96	174
100003	200004	1065.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	5
100003	200004	1065.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.75	45
100003	200004	1065.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.69	208
100003	200004	1080.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.11	11
100003	200004	1080.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.92	80
100003	200004	1080.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.83	15
100003	200004	1080.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.85	132
100003	200004	1080.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,251,276,20,269,677}	39.842	6.88	20
100003	200004	1095.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	6
100003	200004	1095.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.46	46
100003	200004	1095.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.4	206
100003	200004	1110.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.11	9
100003	200004	1110.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.88	57
100003	200004	1110.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.82	17
100003	200004	1110.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.81	175
100003	200004	1125.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.11	10
100003	200004	1125.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.56	82
100003	200004	1125.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.82	17
100003	200004	1125.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.48	150
100003	200004	1140.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	14
100003	200004	1140.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.61	45
100003	200004	1140.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.82	33

100003	200004	1140.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.53	167
100003	200004	1155.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	13
100003	200004	1155.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.57	49
100003	200004	1155.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.84	54
100003	200004	1155.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.5	143
100003	200004	1170.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.13	13
100003	200004	1170.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.4	35
100003	200004	1170.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.83	33
100003	200004	1170.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.32	178
100003	200004	1185.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	6
100003	200004	1185.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.39	44
100003	200004	1185.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.33	209
100003	200004	1200.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	6
100003	200004	1200.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.8	38
100003	200004	1200.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.74	215
100003	200004	1215.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.11	13
100003	200004	1215.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.45	63
100003	200004	1215.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.84	19
100003	200004	1215.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.37	145
100003	200004	1215.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,251,276,20,269,677}	39.842	6.85	19
100003	200004	1230.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.13	7
100003	200004	1230.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.55	46
100003	200004	1230.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.82	14
100003	200004	1230.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.48	192
100003	200004	1245.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.11	11
100003	200004	1245.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.86	57
100003	200004	1245.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.82	17
100003	200004	1245.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.8	174
100003	200004	1260.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	11
100003	200004	1260.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.7	57

100003	200004	1260.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.82	16
100003	200004	1260.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.62	175
100003	200004	1275.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.11	11
100003	200004	1275.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.67	61
100003	200004	1275.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.82	15
100003	200004	1275.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.58	172
100003	200004	1290.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.13	10
100003	200004	1290.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.7	57
100003	200004	1290.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.82	19
100003	200004	1290.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.63	173
100003	200004	1305.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	10
100003	200004	1305.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.54	43
100003	200004	1305.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.83	27
100003	200004	1305.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.46	179
100003	200004	1320.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	9
100003	200004	1320.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.44	68
100003	200004	1320.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.82	14
100003	200004	1320.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.36	168
100003	200004	1335.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	10
100003	200004	1335.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.77	86
100003	200004	1335.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.81	14
100003	200004	1335.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.69	149
100003	200004	1350.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	10
100003	200004	1350.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.58	35
100003	200004	1350.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.83	17
100003	200004	1350.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.5	197
100003	200004	1365.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.13	11
100003	200004	1365.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.51	64
100003	200004	1365.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.81	34
100003	200004	1365.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.44	150

100003	200004	1380.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	6
100003	200004	1380.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.45	37
100003	200004	1380.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.37	216
100003	200004	1395.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	5
100003	200004	1395.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.83	46
100003	200004	1395.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.75	208
100003	200004	1410.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	9
100003	200004	1410.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.59	63
100003	200004	1410.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.84	18
100003	200004	1410.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.53	169
100003	200004	1425.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	13
100003	200004	1425.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.75	64
100003	200004	1425.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.81	50
100003	200004	1425.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.67	132
100003	200004	1440.0	{546,505,520,355,364,339,310,301,14,22,23,12,513,502,523,680}	40.482	7.12	8
100003	200004	1440.0	{549,440,74,467,112,114,116,154,155,278,250,246,243,265,676}	36.965	6.36	45
100003	200004	1440.0	{549,440,74,467,112,114,116,154,155,285,284,263,262,20,269,677}	40.029	6.83	39
100003	200004	1440.0	{549,440,74,467,112,114,116,154,157,160,529,528,256,250,246,243,265,676}	37.338	6.28	167

Table B2 is automatically developed by specifying the following: Origin, Destination, the time interval of the desired statistics. The report produces, in addition to the input data the number of paths generated for the OD pair, the average path length, the Path Length Standard Deviation, the Maximum Path Length and the Minimum Path Length.

Table B2 Summary OD report per 15-minute time interval

Origin	**Destination**	**Time Interval (M)**	**Num of Paths**	**Avg Length (Mile)**	**Length STD (Mile)**	**Max Length (Mile)**	**Min Length (Mile)**
100003	200004	15.0	3	38.111	0.1671	40.029	36.965
100003	200004	30.0	3	38.111	0.1671	40.029	36.965
100003	200004	45.0	4	38.544	0.1616	40.029	36.965
100003	200004	60.0	3	38.111	0.1671	40.029	36.965
100003	200004	75.0	3	38.111	0.1671	40.029	36.965
100003	200004	90.0	3	38.111	0.1671	40.029	36.965
100003	200004	105.0	4	38.544	0.1616	40.029	36.965
100003	200004	120.0	3	38.111	0.1671	40.029	36.965
100003	200004	135.0	3	38.111	0.1671	40.029	36.965
100003	200004	150.0	4	38.544	0.1616	40.029	36.965

100003	200004	165.0	3	38.111	0.1671	40.029	36.965
100003	200004	180.0	5	38.931	0.1646	40.482	36.965
100003	200004	195.0	4	38.704	0.1808	40.482	36.965
100003	200004	210.0	4	38.704	0.1808	40.482	36.965
100003	200004	225.0	5	38.931	0.1646	40.482	36.965
100003	200004	240.0	3	38.262	0.1932	40.482	36.965
100003	200004	255.0	4	38.704	0.1808	40.482	36.965
100003	200004	270.0	3	38.262	0.1932	40.482	36.965
100003	200004	285.0	4	38.704	0.1808	40.482	36.965
100003	200004	300.0	4	38.704	0.1808	40.482	36.965
100003	200004	315.0	3	38.262	0.1932	40.482	36.965
100003	200004	330.0	4	38.704	0.1808	40.482	36.965
100003	200004	345.0	4	38.704	0.1808	40.482	36.965
100003	200004	360.0	4	38.704	0.1808	40.482	36.965
100003	200004	375.0	4	38.704	0.1808	40.482	36.965
100003	200004	390.0	3	38.262	0.1932	40.482	36.965
100003	200004	405.0	5	38.931	0.1646	40.482	36.965
100003	200004	420.0	4	38.704	0.1808	40.482	36.965
100003	200004	435.0	4	38.704	0.1808	40.482	36.965
100003	200004	450.0	4	38.704	0.1808	40.482	36.965
100003	200004	465.0	4	38.704	0.1808	40.482	36.965
100003	200004	480.0	4	38.657	0.1764	40.482	36.965
100003	200004	495.0	5	38.931	0.1646	40.482	36.965
100003	200004	510.0	4	38.704	0.1808	40.482	36.965
100003	200004	525.0	3	38.262	0.1932	40.482	36.965
100003	200004	540.0	4	38.704	0.1808	40.482	36.965
100003	200004	555.0	4	38.704	0.1808	40.482	36.965
100003	200004	570.0	4	38.704	0.1808	40.482	36.965
100003	200004	585.0	4	38.704	0.1808	40.482	36.965
100003	200004	600.0	4	38.704	0.1808	40.482	36.965
100003	200004	615.0	3	38.262	0.1932	40.482	36.965
100003	200004	630.0	4	38.704	0.1808	40.482	36.965
100003	200004	645.0	3	38.262	0.1932	40.482	36.965
100003	200004	660.0	4	38.704	0.1808	40.482	36.965
100003	200004	675.0	4	38.704	0.1808	40.482	36.965
100003	200004	690.0	5	38.931	0.1646	40.482	36.965
100003	200004	705.0	4	38.704	0.1808	40.482	36.965
100003	200004	720.0	4	38.704	0.1808	40.482	36.965
100003	200004	735.0	4	38.704	0.1808	40.482	36.965
100003	200004	750.0	5	38.931	0.1646	40.482	36.965
100003	200004	765.0	4	38.704	0.1808	40.482	36.965
100003	200004	780.0	3	38.262	0.1932	40.482	36.965
100003	200004	795.0	4	38.704	0.1808	40.482	36.965
100003	200004	810.0	4	38.704	0.1808	40.482	36.965
100003	200004	825.0	4	38.704	0.1808	40.482	36.965
100003	200004	840.0	4	38.704	0.1808	40.482	36.965
100003	200004	855.0	4	38.704	0.1808	40.482	36.965
100003	200004	870.0	4	38.704	0.1808	40.482	36.965
100003	200004	885.0	4	38.704	0.1808	40.482	36.965
100003	200004	900.0	4	38.704	0.1808	40.482	36.965
100003	200004	915.0	4	38.704	0.1808	40.482	36.965
100003	200004	930.0	4	38.704	0.1808	40.482	36.965
100003	200004	945.0	3	38.262	0.1932	40.482	36.965
100003	200004	960.0	4	38.704	0.1808	40.482	36.965
100003	200004	975.0	4	38.704	0.1808	40.482	36.965
100003	200004	990.0	3	38.262	0.1932	40.482	36.965
100003	200004	1005.0	5	38.931	0.1646	40.482	36.965
100003	200004	1020.0	5	38.931	0.1646	40.482	36.965
100003	200004	1035.0	3	38.262	0.1932	40.482	36.965

100003	200004	1050.0	4	38.704	0.1808	40.482	36.965
100003	200004	1065.0	3	38.262	0.1932	40.482	36.965
100003	200004	1080.0	5	38.931	0.1646	40.482	36.965
100003	200004	1095.0	3	38.262	0.1932	40.482	36.965
100003	200004	1110.0	4	38.704	0.1808	40.482	36.965
100003	200004	1125.0	4	38.704	0.1808	40.482	36.965
100003	200004	1140.0	4	38.704	0.1808	40.482	36.965
100003	200004	1155.0	4	38.704	0.1808	40.482	36.965
100003	200004	1170.0	4	38.704	0.1808	40.482	36.965
100003	200004	1185.0	3	38.262	0.1932	40.482	36.965
100003	200004	1200.0	3	38.262	0.1932	40.482	36.965
100003	200004	1215.0	5	38.931	0.1646	40.482	36.965
100003	200004	1230.0	4	38.704	0.1808	40.482	36.965
100003	200004	1245.0	4	38.704	0.1808	40.482	36.965
100003	200004	1260.0	4	38.704	0.1808	40.482	36.965
100003	200004	1275.0	4	38.704	0.1808	40.482	36.965
100003	200004	1290.0	4	38.704	0.1808	40.482	36.965
100003	200004	1305.0	4	38.704	0.1808	40.482	36.965
100003	200004	1320.0	4	38.704	0.1808	40.482	36.965
100003	200004	1335.0	4	38.704	0.1808	40.482	36.965
100003	200004	1350.0	4	38.704	0.1808	40.482	36.965
100003	200004	1365.0	4	38.704	0.1808	40.482	36.965
100003	200004	1380.0	3	38.262	0.1932	40.482	36.965
100003	200004	1395.0	3	38.262	0.1932	40.482	36.965
100003	200004	1410.0	4	38.704	0.1808	40.482	36.965
100003	200004	1425.0	4	38.704	0.1808	40.482	36.965
100003	200004	1440.0	4	38.704	0.1808	40.482	36.965

Table B3 produces a summary report for a specific OD pair for the entire time period of the analysis. It requires as input the Origin and the Destination. It produces the number of DUE paths, the average path length, the corresponding path length standard deviation, the maximum and the minimum path length.

Table B3. Sample Summary OD (100003 – 200004) Report

Origin	**Destination**	**Num of Paths**	**Avg Length (Mile)**	**Length STD (Mile)**	**Max Length (Mile)**	**Min Length (Mile)**
100003	200004	5	38.931	0.1646	40.482	36.965

APPENDIX C. VISTA-NICOSIA-IM-VMS Module Sample Case Study

We present here the VISTA-IM-VMS as implemented the Monitor Integrated Safety System (MISS) project. A set of incident and VMS –based case studies will be developed once the first complete Nicosia model will be developed.

The following models were developed and executed using the VISTA-IM module:

Base Case – the VISTA DTA is executed using the current demand for a 24 hour time period. The assignment interval is 15 minutes. The traffic simulator RouteSim is using a six second time step to emulate the traffic flow propagation. All results can be aggregated at the time interval of interest.

No VMS Case – An incident is emulated to have occurred that starts at the 120th minute of the simulation and lasts for 6 hours. The VISTA RouteSim is executed only based on the DTA paths that were generated in the Base case – assuming that the no travelers diverted to a new route.

VMS Case – The VMS sub-module within the IM module where a set of diversion routes are generated around the incident. The VMS module is used to emulate the behavior of travelers who will ―see‖ it once they are at the VMS location. The VMS is emulated to display the set of available routes and the corresponding travel time from the incident location to the destination. A percentage of travelers are assumed to follow these paths that are input by the analyst. Under this scenario, the VISTA RouteSim simulator is executed using the original Base case paths plus the designed route diversion paths.

It is noted that the Vehicle Delay is estimated based on a reference free flow travel time – hence a delay is reported also for the Base Case in the following tables.

Table 3. MISS-Nicosia VISTA-IM *Partial Closure*

6-hour closure starting at 2 hours into simulation. One lane of link 467 is closed during this time					
	Demand (vehs)	**Total TT (hours)**	**Average TT (min)**	**StdDev TT (min)**	**Total VKT (Veh-Km)**
Base	517.514	26.289 (0,00%)	3,05	2,18	1508127
No VMS	517.514	28.121 (6,96%)	3,26	2,75	1508127
VMS	517.514	26.593 (1,16%)	3,08	2,24	1511449

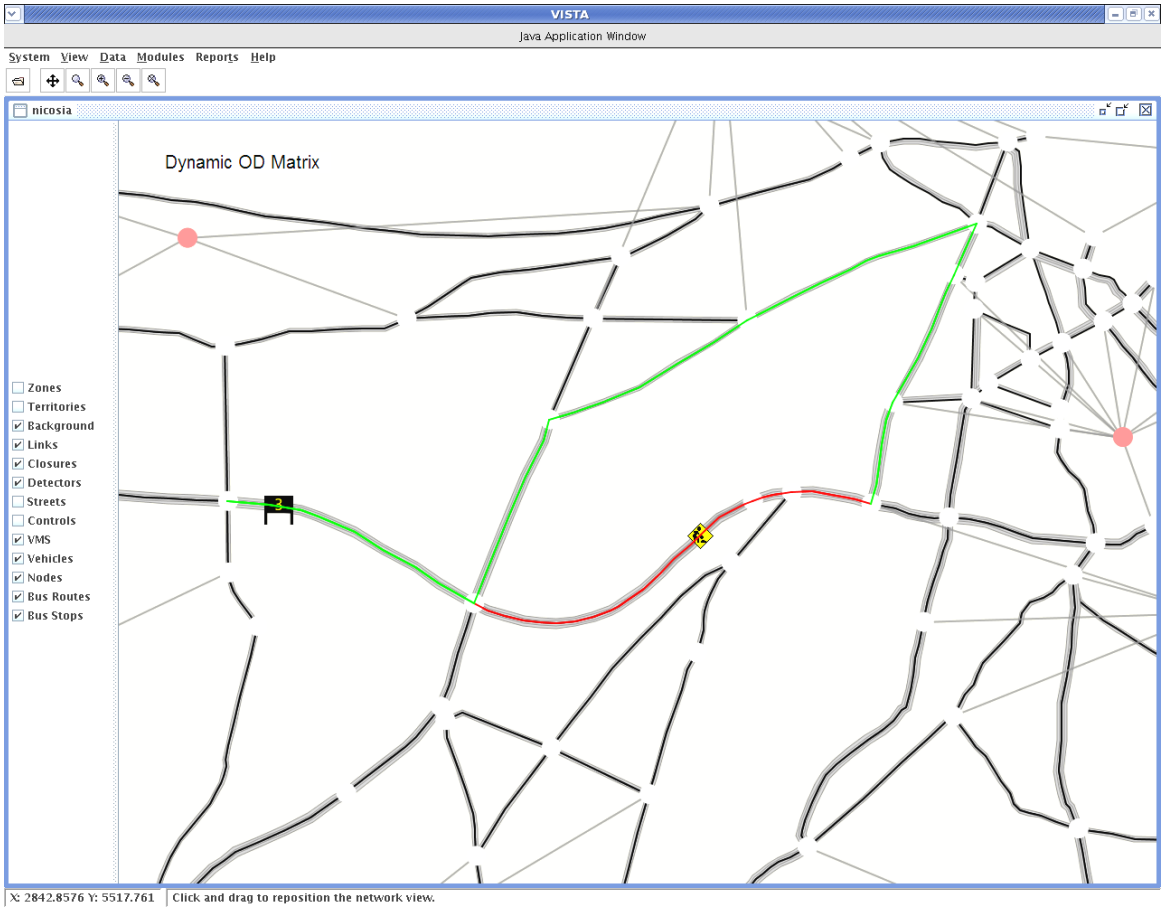


Figure 77. Nicosia Incident Characteristics with VMS as modeled in VISTA

The incident causes an increase in network travel time of 6,96% under the no traveler information option (No-VMS). Travelers are assumed to follow the same paths as without the incident – the Base case DTA paths found under normal conditions. Comparatively, the installation of the VMS (see Figure 2) upstream of the location of the incident in combination with the identification of a diversion route "displayed" on the VMS reduces the impact of the incident to 1,16% from the Base case.

Table 4. MISS-Nicosia VISTA-IM Partial Closure Travel Time Statistics for Affected Vehicles only

Affected Vehicle Travel Time					
Case	**Demand (Vehs)**	**Total (hours)**	**% Difference from Base Case**	**Average (minutes)**	**StdDev (minutes)**
Base	33.576	3.106	0,00	5,55	1,75
Inc-No VMS	33.576	14.236	358,38	25,44	18,59
Inc-VMS	33.576	4.824	55,32	8,62	60,41
Affected Vehicle Delay					
Base	33.576	207	0,00	0,37	0,36
Inc-No VMS	33.576	11.337	5.375,68	20,26	17,98
Inc-VMS	33.576	1.863	800,00	3,33	60,61
Affected Vehicle VKT (Veh-Km)					
Base	33.576	173.309	0,00	5,16168	1,57584
Inc-No VMS	33.576	173.309	0,00	5,16168	1,57584
Inc-VMS	33.576	176.548	1,87	5,25816	1,62408

Table 4 demonstrates that the impact of the VMS sign offers a dramatic improvement to the IM case study versus the Non-VMS – a drop of vehicle delay hours from 11.337 to 1.863, respectively. This further signifies that the implementation of a MISS UOC with an integrated traffic monitoring and traveler information system could have substantial impact on the efficiency of the transport system and the demand that is affected by the incident. The estimated VKT for affected vehicles show an increase under the VMS case versus the Base and the No-VMS, which correctly are the same. The increase in VKT is accompanied with a reduction of travel time as some vehicles are diverted to the diversion route (2.233) (see Table 5).

Table 5. MISS-Nicosia VISTA-IM – Partial Closure Rerouted Vehicle Travel Time Statistics

Rerouted Vehicle Travel Time					
	Demand	**Total (hours)**	**% Difference from Base**	**Average TT (min)**	**StdDev TT (min)**
Base	2.233	210	0,00	5,63	1,77
No VMS	2.233	1.368	552,66	36,77	16,33
VMS	2.233	220	4,73	5,90	1,97
Unrerouted Vehicle Travel Time					
Base	29.972	2.772	0,00	5,55	1,77
No VMS	29.972	12.638	355,86	25,30	18,53
VMS	29.972	4.238	52,85	8,48	2,13
Rerouted Vehicle Delay					
Base	2.233	14	0,00	0,38	0,35

No VMS	2.233	1.175	8250,97	31,57	16,22
VMS	2.233	122	767,89	3,28	1,11
Unrerouted Vehicle Delay					
Base	29.972	214	0,00	0,43	0,42
No VMS	29.972	10.049	4603,82	20,12	17,83
VMS	29.972	371	73,53	0,74	0,91
Rerouted Vehicle Kilometre Traveled (Veh-Km)					
Base	2.233	192	0,00	5,16	1,56
VMS	2.233	250	30,00	6,72	1,56

'Rerouted' vehicles in Table 5 refer to whether a vehicle chose a different route under the Incident VMS case. Under this case a total of 2.233 vehicles were rerouted and 29.972 vehicles stayed in their original routes. The Base case Rerouted vehicles reports the travel times, which were experienced by vehicles on their original route and were later rerouted under the Incident VMS case.

It can be observed that the rerouting information provided by the VMS resulted in a reduction to the incident vehicle delay for unrerouted and reroute vehicles from 10.049 to 371 and from 1.175 to 122 hours, respectively.

Table 6 provides a sample of OD trips travel times for the Base, Incident No VMS and Incident VMS cases. Similarly to the earlier conclusions, it can be observed that the VMS case reduces the corresponding travel time for each OD pair versus the No VMS case substantially.

Table 6. MISS-Nicosia VISTA-IM Partial Closure Scenario; Sample OD Pair Average Travel Time Incident and VMS Impact

Affected Vehicle Trip TT			**Average TT (minutes)**		
Origin Zone	**Destination Zone**	**Demand**	**Base**	**No VMS**	**VMS**
3	4	24041	6,57	31,35	7,13
3	11	9	5,08	11,07	5,08
3	12	42	6,48	7,38	6,48
3	13	273	3,78	13,54	4,32
3	14	121	4,38	11,75	4,79
3	15	7072	2,46	10,66	2,93
3	16	706	2,76	11,36	3,10

MISS-VISTA-IM Scenario 2 – Full Closure Case study

Link 467: six-hour full closure starting at 2 hours into simulation. Both lanes of link 467 are closed during this time. This is a more dramatic case as link 467 is closed completely in one direction. This impacts the network performance substantially as vehicles are forced to move under gridlock conditions.

Table 7. MISS-VISTA-IM case study 2 – Full Closure Case study

All Vehicles						
	Demand	**Total TT (hours)**	**% Difference from Base**	**Average TT (minutes)**	**StdDev TT (minutes)**	**Total VKT (Veh-Km)**
Base	517.514	26.289	0	3,05	2,18	1.508.127
No VMS	517.514	372.603	1.317,33	43,20	103,60	1.398.695
VMS	517.514	238.461	807,08	27,66	80,71	1.450.945

Table 7 reveals a more dramatic increase in travel times due to the full roadway closure versus the partial closure. Whereas under the partial closure the VMS case provided a dramatic improvement in travel time (6,96% to 1.16%) under the full closure the reduction is substantially less (from 1.317 to 807%). In addition, the average travel time increases substantially from 3,05 (base) to 43,2 (No VMS) and 27,8 (VMS) minutes for the overall network.

Table 8. MISS-VISTA-IM case study 2 – Full Closure Case study; Traffic Flow Characteristics

Affected Vehicle Travel Time					
	Demand	**Total (hours)**	**% Difference from Base**	**Average (minutes)**	**StdDev (minutes)**
Base	33.576	3.105	0	5,55	1,75
No VMS	33.576	149.732	4721	267,57	111,92
VMS	33.576	33.900	991	60,58	139,01
Affected Vehicle Delay					
Base	33.576	207	0,00	0,37	0,36
No VMS	33.576	147.208	71.00	263,06	111,12
VMS	33.576	30.688	14.72	54,84	139,37
Affected Vehicle VKT (Veh-Km)					
Base	33.576	173.309	0	5,16	1,58
No VMS	33.576	150.633	-13	4,49	2,19
VMS	33.576	191.665	11	5,71	1,80

The affected vehicles for the Full closure in Table 8 demonstrate similar results for the vehicles that were affected by the incident as the partial closure but in a much more profound way.

It is noted that the reduction of VKT reflects the fact that some vehicles under the incident No- VMS case did not manage to reach their destination during the allocated assignment time period. The No-VMS case reflects a rather rare traffic “gridlock” condition. In reality it is expected that a good percentage of travelers will be informed of the full closure at some point and choose other routes or other modes of transport or change their destinations. We emphasize that these scenarios are conducted for illustration purposes only. Under an operational DTA model, a travel behavior model should be integrated with the DTA to provide an estimate of the travelers that will follow different routes and other modes of transport.

Table 9. MISS-VISTA-IM Scenario 2 – Full Closure Case study; Reroute Vehicles Travel Time Statistics

Rerouted Vehicle Travel Time					
	Demand	**Total (hours)**	**% Difference from Base**	**Average (minutes)**	**StdDev (minutes)**
Base	12.333	1.158	0	5,63	1,77
No VMS	12.333	68.750	5.837,28	334,47	28,58
VMS	12.333	10.891	840,53	52,98	27,38
Unrerouted Vehicle Travel Time					
Base	19.644	1.812	0,00	5,53	1,75
No VMS	19.644	77.894	4.199,70	237,92	118,90
VMS	19.644	14.498	700,30	44,28	37,78
Rerouted Vehicle Delay					
Base	12.333	86	0,00	0,42	0,39

No VMS	12.333	67.677	79.020,01	329,25	27,65
VMS	12.333	9.818	11.378,51	47,77	26,85
Unrerouted Vehicle Delay					
Base	19.644	119	0	0,36	0,34
No VMS	19.644	76.197	63.918	232,73	118,75
VMS	19.644	12.801	10.655	39,10	37,13
Rerouted Vehicle Km Traveled (VKT) (Veh-Km)					
Base	12.333	1.061	0	5,16	0,16
VMS	12.333	1.381	30	6,72	1,56

Under the full closure 12.333 vehicles were rerouted (Table 9). The rerouted vehicles under the VMS show much more improvement in vehicle delay (9.818 hours) versus the No VMS case (67.577 hours). The improvement still does not remove the network from gridlock conditions.

Table 10. MISS-VISTA-IM Case study 2 – Scenario 2 Full Closure; Sample OD Pair Average Travel Time Incident with VMS Impact

Affected Vehicles Trip Travel Time					
Average TT (minutes)					
Origin Zone	**Destination Zone**	**Demand**	**Base**	**No VMS**	**VMS**
3	4	24041	6,57	284,48	56,07
3	11	9	5,08	314,98	44,92
3	12	42	6,48	284,53	32,50
3	13	273	3,78	265,18	36,08
3	14	121	4,38	244,37	31,30
3	15	7072	2,46	248,25	21,85
3	16	706	2,76	245,42	12,33

Table 10 shows a sample of OD pair travel times under the Base, No-VMS and VMS cases. The OD travel times under the incident are much higher than the corresponding OD travel times under the partial closure. Similarly, the VMS provided a substantial reduction in the OD trip travel time versus the No VMS case.

The above two case studies demonstrated the potential impact that a centralized system such as MISS could provide to improve traffic conditions when an incident occurs and reduces the capacity in one roadway for a substantially long time period – 6 hours in these two examples. These examples demonstrate the potential impact of the use of traveler information – in this case a VMS together with rerouting information – with substantial improvements in the overall network travel time as well as individual paths.

A more comprehensive analysis could be conducted where more than one diversion routes could be specified. In addition, a parametric analysis on the percentage of vehicles that will be diverted in each route could be conducted to find the best combination of routes and OD demand diversion. Further, an analysis of In-vehicle navigation and traveler information devices could be modeled in a similar manner as the VMS scenarios.

APPENDIX B

SHORT COURSE: VISTA SCENARIO MANUAL

Scenario Manual

August 7, 2008 VISTA Training

INTRODUCTION

The following scenarios are to be conducted using VISTA demonstration accounts provided by the City College of New York. Support of the training session will be provided, and follow up Q&A sessions will be held to answer any questions about the scenarios or material.

BASE CASE PREPARATION

There are a number of steps involved in preparing an equilibrium assignment on a base case network. These instructions assume the network and demand data have already been imported into VISTA and verified as correct.

Network Preparation

To prepare the network for simulation, the **`Cell Generator`** module should be run. The cell generator takes two options.

Set the **`Time Step`** for the mesoscopic simulator to a small value, ideally six. It's not recommended this value be changed.

Set the **`Minimum Density`** to the minimum cell density you want for mesoscopic cells. Again, it's not recommended this value be changed.

The default values for these parameters have been tested and work well for most networks.

Demand Preparation

Next, run the **`Prepare Demand`** module to turn the trip table into individual vehicles for assignment and simulation.

Specify a **`Demand Percentage`** to increase or decrease the total demand by the amount specified.

Checking **`Use Dynamic Trips`** will use the dynamic trip table instead of the static trip table. Your VISTA administrator, or whoever imported your trip tables for you, will inform you whether or not to use this option.

Dynamic Traffic Assignment

You're finally ready to run an assignment on the network.

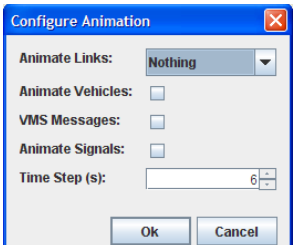
Start with the **`DTA – Path Generation`** module. You'll want to run this for at least 3 iterations to create a good set of paths for your early assignments.

When this completes, run **`DTA – Dynamic User Equilibrium`** for 5 to 10 iterations. This will take the paths already generated and attempt to find the best distribution of traffic among those paths.

You should now start another path generation run, followed by a DUE run, and so on. You'll have a good convergence when few new paths are being generated (check the log files) and the gap value from DUE is low (less than 5%).

Visualize Outputs

The performance of your base case may be visualized using the animation facility in VISTA's GIS. Open up your network in the GIS, then select **`Data Animation`** from the **`Data`** menu.



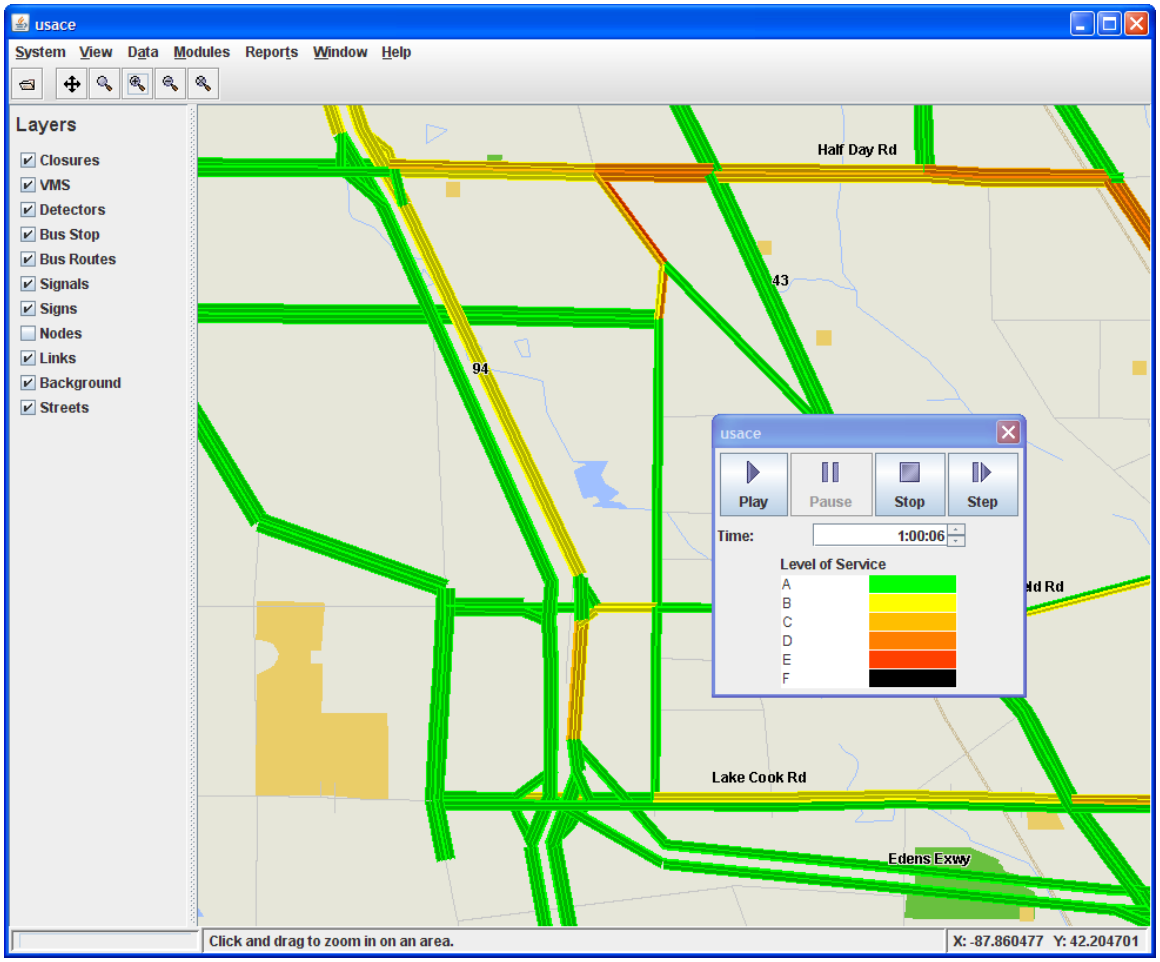
You can select to have links color-coded by density, travel time, inflow or outflow. During animation, a color-code legend will appear to show the values associated with each color. If the animation is by density, the colors indicate the proportion of density to jam density associated on each link, approximating a level of service.

If the animation is by travel time, the colors indicate the link travel time as a multiple of free flow travel time on each link.

If animation is by inflow or outflow, the colors indicate the number of vehicles entering or leaving the link during each time step.

You may enable signals, vehicles, and variable message signs to be animated by checking the respective boxes. Note that these will require the GIS to load a large amount of data before animation can begin. This can be a time consuming process.

When ready to animate, click **Ok**.



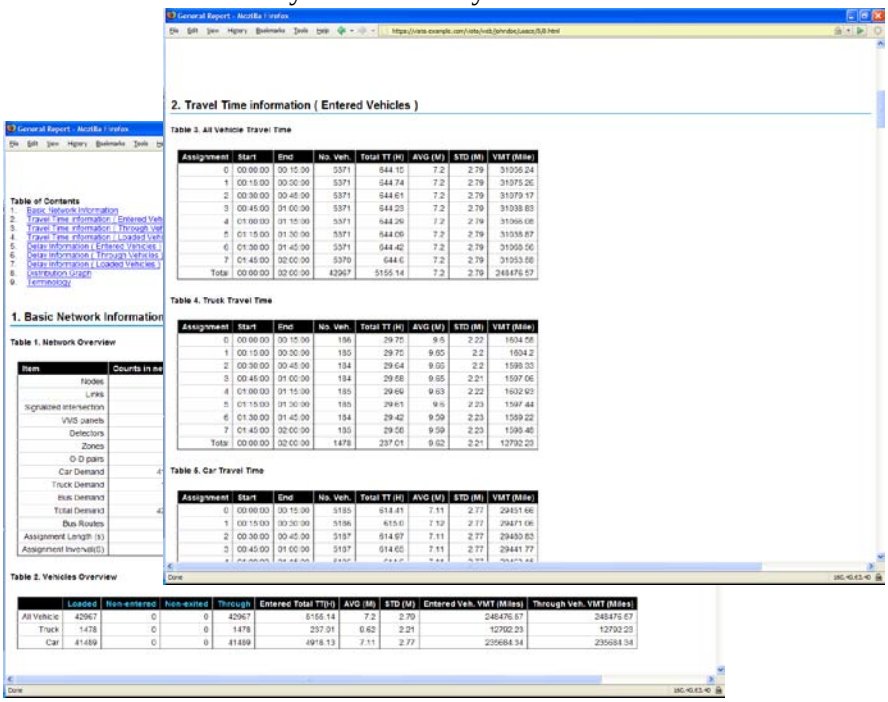
The animation control window allows you to play, pause, stop, and step (one timestep at a time) through an animation. When the animation is paused, you can edit the current time, then restart the animation.

Prepare Reports

VISTA provides a variety of reports for evaluating the performance of a given scenario. Before any report may be run, the results of the assignment must be imported.

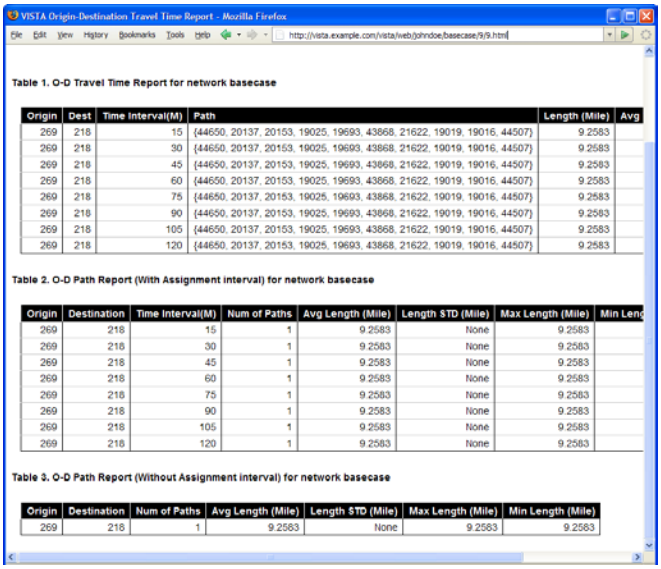
Run the **`Import Simulation Results`** module to bring the results of your assignment into the database. The assigned paths and vehicles will be stored in the **`vehicle_path`** and **`vehicle_path_time`** tables.

First, run **`General Report (short)`** in the web interface. Leave the options as-is. When complete, you will find a report similar to the one below in your task history.



Now, run the **`O-D Travel Time Report`** in the web interface. For the Destination ID, use **`218`**. For the Origin ID, use **`269`**. This OD pair is for northbound traffic on the expressway. Leave the other options as they are.

When complete, you will have a report similar to the one shown below.



VISTA Origin-Destination Travel Time Report - Mozilla Firefox

File Edit View History Bookmarks Tools Help http://vista.example.com/vista/web/johndoe/basecase/9/9.html

Table 1. O-D Travel Time Report for network basecase

Origin	Dest	Time Interval(M)	Path	Length (Mile)	Avg
269	218	15	{44650, 20137, 20153, 19025, 19693, 43868, 21622, 19019, 19016, 44507}	9.2583	
269	218	30	{44650, 20137, 20153, 19025, 19693, 43868, 21622, 19019, 19016, 44507}	9.2583	
269	218	45	{44650, 20137, 20153, 19025, 19693, 43868, 21622, 19019, 19016, 44507}	9.2583	
269	218	60	{44650, 20137, 20153, 19025, 19693, 43868, 21622, 19019, 19016, 44507}	9.2583	
269	218	75	{44650, 20137, 20153, 19025, 19693, 43868, 21622, 19019, 19016, 44507}	9.2583	
269	218	90	{44650, 20137, 20153, 19025, 19693, 43868, 21622, 19019, 19016, 44507}	9.2583	
269	218	105	{44650, 20137, 20153, 19025, 19693, 43868, 21622, 19019, 19016, 44507}	9.2583	
269	218	120	{44650, 20137, 20153, 19025, 19693, 43868, 21622, 19019, 19016, 44507}	9.2583	

Table 2. O-D Path Report (With Assignment interval) for network basecase

Origin	Destination	Time Interval(M)	Num of Paths	Avg Length (Mile)	Length STD (Mile)	Max Length (Mile)	Min Leng
269	218	15	1	9.2583	None	9.2583	
269	218	30	1	9.2583	None	9.2583	
269	218	45	1	9.2583	None	9.2583	
269	218	60	1	9.2583	None	9.2583	
269	218	75	1	9.2583	None	9.2583	
269	218	90	1	9.2583	None	9.2583	
269	218	105	1	9.2583	None	9.2583	
269	218	120	1	9.2583	None	9.2583	

Table 3. O-D Path Report (Without Assignment interval) for network basecase

Origin	Destination	Num of Paths	Avg Length (Mile)	Length STD (Mile)	Max Length (Mile)	Min Length (Mile)
269	218	1	9.2583	None	9.2583	9.2583

This report details the routes used by trips between the given origin in destination, group into time intervals, a summary of routes used per time interval, and a summary of all time intervals.

ADD LANE SCENARIO

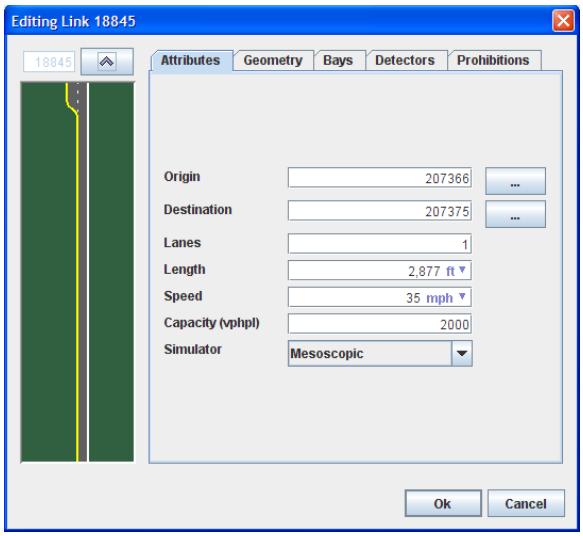
In this scenario, you will add additional lanes to some links in the traffic network, then compare the performance of this network with the base case prepared earlier.

Add Lanes

Bring up the **`Add Lanes`** network in the GIS.

To add a lane to a link, select **`Edit Link`** from the **`Links`** menu in the **`Data`** menu. Now, click on the link you wish to edit.

> Selecting links can be tricky, particularly when both directions of a link share the same geometry. Click next to a link to select the link whose lanes are nearest your mouse. Clicking directly on a link may select either direction.



The above window will be shown with attributes relevant to the link you selected. If you selected the wrong link, click **`Cancel`** and try again. If you clicked the link going the opposite direction of the link you want, click the upward-pointing arrow button in the upper-left corner of the window. This switches between links going in opposite directions.

Increase the number of lanes on the link, the click **`Ok`**.

Repeat this process for any other links to which you would like to add a lane.

Copy Assignment

Copy the assignment from your base case network to this network. This ensures that the scenario you are preparing is starting from the same conditions as your base case, and will therefore be directly comparable when running reports later.

Run the **`Manage Data`** module on the **`Base Condition`** network. Check the **`Copy Assignment`** option, and select the **`Add Lane Scenario`** network in the **`Copy to Network`** drop-down.

Do not run this module on the scenario network and copy to the base case network.

Assignment and Results

Repeat steps **`1`**, **`3`**, **`4`** and **`5`** from the base case preparation procedure.

You must re-run the cell generator any time you change the traffic network by changing a link.

You need not re-run the demand profiler since you have not changed the demand.

Both path generation and dynamic user equilibrium should be run to ensure the increased capacity of the links with additional lanes has the opportunity to attract traffic.

Watching the animation of the results will demonstrate any potential increases or reductions in congestion due to the additional lanes.

Comparative Reports

Repeat step **`6`** from the base case preparation procedure, but specify the **`Compare To`** network to be the **`Base Condition`** network. Leave the other options as that are.

The reports will appear as they did from the base case preparation, but will include results for both networks side-by-side. This will allow you to better analyze the differences between the two.

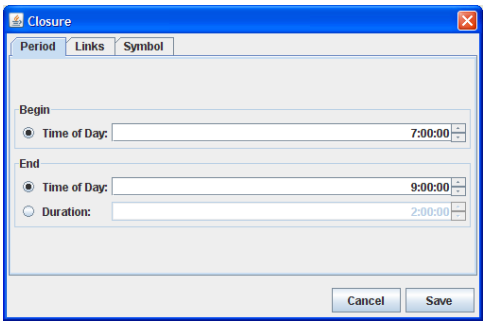
INCIDENT SCENARIO

In this scenario, you will be adding a temporary closure to the traffic network and analyzing the effects of the closure on traffic.

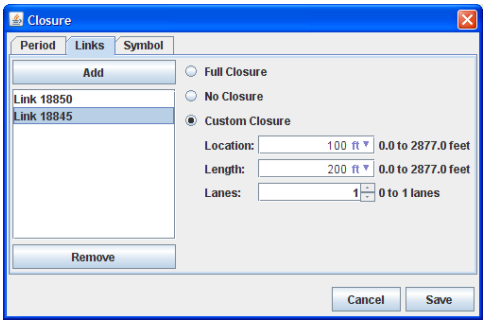
You will be performing this work on the **`Incident Analysis`** network.

Add a Closure

To create a closure, select **`Add Closure`** from the **`Data|Closures`** menu. The closure editing window will be displayed.



First, define the time during which the closure is in effect. Set the starting time in the **`Begin`** section. Set the ending time or duration in the **`End`** section. Now, click the **`Links`** tab at the top.



To add links to the closure, click the **`Add`** button. Then, click or drag on the map to select a group of links.

For each link you add to the closure, you must define the severity of the closure on that link. Select a link in the list on the left-hand side of the closure editing window. The form elements to the right will become available.

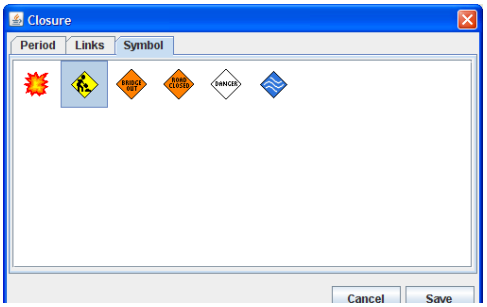
Select **`Full Closure`** to close all lanes for the entire length of the link.

Select **`No Closure`** to leave the link completely open to traffic.

Select **`Custom Closure`** to define your own severity. Input the **`Location`** at which the closure starts, which is the distance from the origin of the link. Input the **`Length`** of the closure, which is measured from the location towards the destination of the link. Finally, set the number of lanes closed. You must do this for every link in the closure.

To remove a link from the closure, select it in the list and click the **`Remove`** button.

Now, click on the **`Symbol`** tab at the top.



Select a symbol to represent the closure on the map. This has no effect on how the simulator handles the closure.

When you are done editing the closure, click the **Save** button.

Perform Worst Case Analysis

Repeat step **2** from the Add Lane Scenario procedure.

Run the **Simulate** module from the web interface. This will simulate traffic interacting with the closure using the existing base case assignment. Traffic will not reroute; it will instead be delayed by the closure until it clears.

When running reports for this scenario, be sure to put some text in the Notes field of each report run indicating which analysis of the scenario was conducted. Any notes you specify will be shown in the task history, making it easier to identify which reports are relevant to which analyses.

Repeat steps **4** and **5** from the base case preparation procedure.

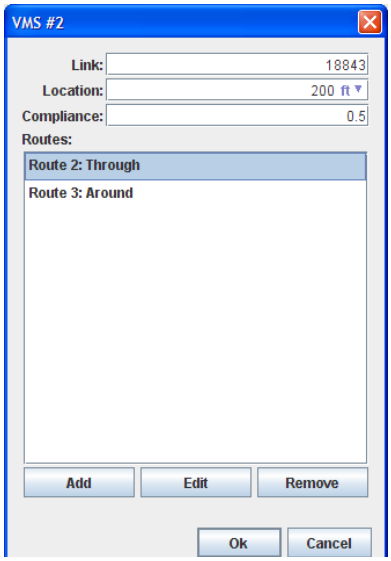
Repeat step **4** from the Add Lane Scenario procedure.

The comparative reports will demonstrate the relative impacts of adding this closure to your traffic network.

The addition of the closure to your network will likely cause delay to some vehicles. If no delay is observed, the closure may not be severe enough to affect the traffic flowing through the affected links, or the affected links may not carry any traffic to begin with.

Perform a VMS Analysis

Select **Add VMS** from the **Data|VMS** menu. Click on the link where you would like your new VMS to be located. The VMS editing window will be shown.



If you clicked on the wrong link, change the **`Link`** field to contain the correct link id.

Set the **`Location`** to the distance from the origin of the link at which the VMS is located.

The **`Compliance`** rate is a fractional value as discussed above. 1.0 means all vehicles comply. 0.0 means no vehicles comply.

To add routes to your VMS, click the **`Add`** button. This will bring up the route editing window.

Click the **`Add`** button to begin adding links to the route. Add links by clicking on successive links on the map.

To remove a link from your route, select the link in the list and click **`Remove`**.

When finished, click **`Ok`**.

You should add two or more routes to your VMS. With only one route, the vehicles passing the VMS will not have information available to make a rerouting decision.

The routes you add to your VMS should begin and end at the same node. Routes for different trips won't offer meaningful rerouting options to any vehicles. Also, routes must not include the VMS itself. Routes including the VMS will not be able to properly reroute vehicles.

Simulate the network and run reports as in the previous analysis.

Run the VMS report with the id number of the new VMS to obtain detailed performance measures on the VMS itself.

Perform Best Case Analysis

Remove the VMS added in the previous analysis step.

Repeat steps 3, 4 and 5 from the base case preparation procedure. This will ensure all traffic routes around the closure, providing the best possible performance of traffic in these conditions.

Run comparative reports as before.

APPENDIX C

STUDY ABROAD PROMOTIONAL MATERIALS

UAB ALABAMA-IN-GREECE PROGRAM BROCHURE, 2010

ALABAMA IN GREECE
Study Away @ UAB

June 2-24, 2010 GREECE: A Cultural Expedition

UAB in collaboration with the University of Alabama is offering students the opportunity to earn up to **six course credits** while visiting the most important archaeological and historical sites **in Greece** over the course of **three weeks.**

The program is under the direction of *Dr. Tatiana Tsakiropoulou-Summers (UA-Modern Languages & Classics)* and will be facilitated by *Dr. Virginia Sisiopiku (UAB-Engineering).* UAB students who successfully complete the program will earn 6 semester hours in CL 380 Ancient Greek Civilization and Culture through UA. These 6 semester hours will be transferred from UA to UAB and will satisfy **6 of the 12 required semester hours and the course sequence** requirement for the UAB Core Curriculum (AREA II).

Requirements and Conditions

- ✓ Students must have completed their freshman year
- ✓ Cumulative GPA of at least 2.7
- ✓ At least 18 years old

Only **five (5) spots** are currently available to UAB students on a first-come, first-serve basis with paid enrollment. If interested conduct Dr. Sisiopiku at vsisiopi@uab.edu to reserve a spot. Application deadline is *February 15th, 2010.*

Itinerary

June 2: Depart USA for Athens

June 3: Arrive to Santorini via Athens

June 4-6: Santorini

June 7: Sail to Athens

June 7-9: Athens

June 10: Corinth, Nafplio

June 11: Mycenae

June 12: Epidavros

June 13-14: Olympia

June 15: Delphi

June 16: Litohoro

June 17: Mt. Olympus

June 18: Dion

June 19: Vergina, Litohoro

June 20-23: Pefkohori

June 24: Depart for US from Thessaloniki

Course Description

CL 380- Ancient Greek Civilization & Culture (6 hrs)

This course examines the cultural milestones of Greek civilization and its remains that have survived for over 2500 years. Participating students will visit ancient monuments, temples, agoras, gymnasia, ruins of ancient cities, and a large number of museums, all of which will give visual reinforcement to the lectures through the study of artifacts directly related to the historic events discussed. In so doing, participating students will become familiar with the social, economic, technological, intellectual, military, cultural, and religious aspects of Greek civilization and culture from the pre-historic settlements to the beginnings of the Byzantine Empire. Background readings, tests, quizzes, essays and daily journals will help the students assimilate the information presented.

PROGRAM COST

The cost of the program is $3,300.
This includes:

- **Tuition & fees for 6 hours** of courses
- **International Student ID Card**
- **Student Health Insurance**
- **Transportation** in Greece with coach bus, boat, and hydrofoil
- **Group airport transfers**
- **Hotel rooms for 21 nights**
- **Breakfasts and some group dinners**
- **All entrance fees to museums & archaeological sites**

Students are responsible for purchasing their own airfare ticket.

ADDITIONAL INFORMATION

Additional information are available through the Study Away office, at http://www.eng.uab.edu/cee/faculty/vsisiopi/study_away.pdf, or directly from **Dr. Virginia Sisiopiku** (email: vsisiopi@uab.edu). Also, an information meeting will take place at UAB on November 17th, 2009. If interested, please email Dr. Sisiopiku to confirm location and time.

In preparation of the travel, a UA/UAB orientation meeting will be held in April 2010, where students will be given a booklet with information about Greece, travel preparations, and a list of suggested items to bring with them.

ALABAMA IN GREECE STUDY ABROAD PROGRAM

June 2 - June 24, 2010

General Information

UAB in collaboration with the University of Alabama is offering students the opportunity to earn up to **six course credits** while visiting the most important archaeological and historical sites **in Greece** over the course of **three weeks**.

The program is under the direction of Dr. Tatiana Tsakiropoulou-Summers (UA-Modern Languages & Classics) and will be facilitated by Dr. Virginia Sisiopiku (UAB-Engineering). Students who successfully complete the program will earn 6 semester hours in **CL 380 Ancient Greek Civilization and Culture** through UA. These 6 semester hours will be transferred from UA to UAB and will satisfy 6 of the 12 required semester hours and the course sequence requirement for the UAB Core Curriculum (AREA II). This option is only available for this particular study abroad course and will be treated as an exception to the UAB Core Curriculum requirements as outlined in the UAB Undergraduate Catalog.

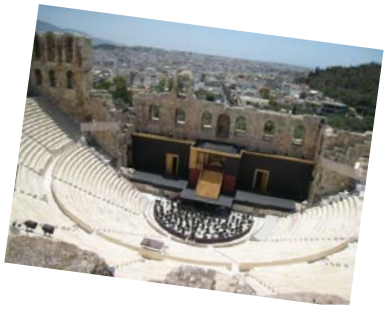
Pre-requisites and conditions: Students must have completed their freshman year, have a cumulative GPA of at least 2.7, and be at least 18 years old. **Only five (5) spots are available to UAB students** on a first-come, first-serve basis with paid enrollment. Application deadline is February 1st, 2010.

Course Description

CL 380- Ancient Greek Civilization & Culture (6 hrs.)

This course examines the cultural milestones of Greek civilization and its remains that have survived for over 2500 years. Students will visit ancient monuments, temples, agoras, gymnasia, ruins of ancient cities, and a large number of museums, all of which will give visual reinforcement to the lectures through the study of artifacts directly related to the historic events discussed. In so doing, students will become familiar with the social, economic, technological, intellectual, military, cultural, and religious aspects of Greek civilization and culture from the pre-historic settlements to the beginnings of the Byzantine Empire. Background readings, tests, quizzes, essays and daily journals will help the students assimilate the information presented.

Program Cost



The cost of the program is **$3,300** and includes

- Tuition & fees for **6 hours** of courses
- International Student ID Card
- Student Health Insurance
- Transportation in Greece with coach bus, boat, and hydrofoil
- Group airport transfers
- Hotel rooms for 21 nights
- Breakfasts and some group dinners (as funds permit)
- All entrance fees to museums and archaeological sites

Hotel Accommodations and Ratings

All hotels are first or second class and rooms are double or triple occupancy. Participants should be forewarned, however, that hotels in Europe tend to be smaller than US hotels and include fewer amenities.

Tentative Itinerary

The following itinerary is planned for the program. It follows roughly the chronological order of major events in the development of the ancient Greek civilization. Slight changes may be likely.

June 2 Depart the United States.

June 3 Arrive at Santorini via Athens. The island of Santorini is the site of an ancient catastrophic volcanic eruption, whose ashes preserved Akrotiri, a prehistoric village of the 17th century B.C. We begin, then, by examining the magnificent building remains of the Minoan civilization at that site and the brilliant artifacts found there, now exhibited at the museum. Spend the night at Thera [Blue Suites Hotel, 011-30-22860-25863].

June 4 First class lecture begins at 9:30 a.m. followed by a visit to the Museum of Prehistoric Thera. After that, you will have the chance to explore the island on your own. Spend the night at Thera.

June 5 Travel to Akrotiri to examine the remains of the ash-covered village. If Akrotiri is still closed, we will visit the acropolis of Ancient Thera. In the evening we will visit Ia to see one of the 10 most beautiful sunsets in the world. Spend the night at Thera.

June 6 Take a boat trip to the volcano's crater above the mythic Atlantis and later swim in the Thermal Springs. Spend the night at Thera.

June 7 Sail to Athens, a huge and bustling city and the capital of Greece. There we will study the famous Parthenon, the ancient Agora, where Socrates and Plato taught, and the National museum that holds treasures from all over Greece. Undoubtedly you will want to visit the Plaka area near the hotel, where you can stroll through the winding roads of the Old Town. Spend the night at Athens [Hotel Electra 011-30-21033-78000].

June 8 Visit the Acropolis, Mars Hill, the Parthenon, the Agora, and the Acropolis Museum. In the late afternoon, we will make our way to the Cape of Sounion, where the Temple of Poseidon sits on the edge of a promontory, to view the temple (where Lord Byron inscribed his name) and to see the magnificent sunset. Spend the night at Athens.

June 9 Visit Syntagma Square, the seat of Modern Greek government, and go by the University of Athens and the mansion of the archaeologist Heinrich Schliemann (who discovered the city of Troy), now housing the Ancient Numismatic Museum. Proceed to the National Archaeological Museum. Other sites you can visit on your free time are Lykavitos, the Epigraphical Museum, and the ancient cemetery of Kerameikos. In the evening, we will dine at "Ancient Tastes," a restaurant that recreates famously ancient Greek recipes-impressive enough to have hosted former President Clinton! Spend the night at Athens.

June 10 Travel to Nafplion. On the way, we will visit the ancient Agora of Corinth and its fortifications on the Acrocorinth. You will need <u>good</u> <u>hiking shoes</u> today! After we settle at the picturesque town of Nafplion, you will have the chance to climb the steps to the Medieval Castle of the city, Palamidi, explore the Old Town, or rent a boat to the Medieval prison on the island of Bourtzi [Agamemnon Hotel, 011-30-27520-28021].

June 11 Visit Mycenae, the palace of Agamemnon, and the famous "beehive" royal tombs. Bring a <u>flash light</u> to the site to explore the underground water fountain. Spend the night at Nafplion.

June 12 Visit Epidauros with one of the best preserved theaters from antiquity, an ancient hospital, the Asklepieion, and a museum. If you are so inclined, you may sing a song (no Rammer Jammers please!), play an instrument, recite a favorite poem or act out an excerpt from an ancient Greek play to test the marvelous acoustics of the ancient theater. Spend the night at Nafplion.

June 13 Drive to Olympia, the original home of the ancient Olympic Games and the chryselephantine statue of Zeus, counted among the Seven Wonders of the ancient world. Spend the night at Olympia [Hotel Antonios, 011-30-26240-22348].

June 14 Visit the site of the ancient Olympic Games and the Museum. We have a yearly tradition that those who want can run a foot race in the ancient Olympic stadium. The winning Olympians, one man and one woman, will be awarded the prize that was customary for the ancient Olympic victors! Spend the night at Olympia.

June 15 Travel to Delphi and visit the site of the oracle, where Apollo's priestess, the Pythia, gave predictions about the future. Bring a <u>flash light</u> to explore the underground tunnels. Spend the night at Delphi [Hotel Hermes, 011-30-22650-82318].

June 16 Travel to northern Greece. Litohoro is at the foothills of Mt. Olympus, the tallest mountain in Greece and the abode of the 12 mythological gods of ancient Greece. Spend the night at Litohoro [Hotel Pantheon, 011-30-23520-83931].

June 17 Today we will hike the foothills of Mt. Olympus along the Enipeus gorge. You will need hiking shoes and some provisions (water & snacks). Spend the night at Litohoro.

June 18 Travel to the site and museum of Dion, Alexander the Great's religious center, later transformed into a Roman colony. Spend the night at Litohoro.

June 19 Visit Vergina to see the palace and the magnificent tomb of Philip II, father of Alexander the Great. Spend the night at Litohoro.

June 20 Leave Litohoro and proceed to Pefkohori, a beach resort known for its clear water but also for its strategic geographic location, as it was through here that the Persians passed on their way to invade Greece ca. 490 B.C. We will spend the remaining days of the program at Pefkohori, where you will have the chance to complete your assignments before turning them in by June 23nd. [Adriana Studios 011-30-23740-61501]

June 24 Return to the US via Thessaloniki.

Attendance Policy

Attendance of class lectures at museums and archaeological sites is mandatory. Absences will seriously affect the student's final course grade.

What You Will Need

Students are responsible for obtaining their own passport (must allow at least 8 weeks for the process). U.S. citizens do not require visas or vaccinations to enter Greece.

Airline Tickets

The cost of the program does not include airfare tickets to and from Greece. Participants should purchase their own ticket, preferably through our agent, Gabriele Williams, at International Travel Consultants at 1-800-466-4660. Make plans to depart the U.S. on June 2nd and be on Santorini, Greece, on June 3rd (you lose one day traveling to Europe). June 4th is officially the first day of the program; class begins at 9:30 a.m. Hotel rooms and transportation are provided only for the duration of the program. Students who wish to travel elsewhere before or after the program dates are responsible for their own hotel and transportation arrangements.

Your airline itinerary should comply with these dates:
6/2 depart US; arrive Athens, GR
6/3 depart Athens; arrive Santorini, GR
6/24 depart Thessaloniki GR; arrive USA

Additional Information

Additional information can be obtained from **Dr. Virginia Sisiopiku** via email vsisiopi@uab.edu. Also, an information meeting will take place at UAB on November 17th, 2009. If interested, please email Dr. Sisiopiku to confirm location and time.

In preparation of the travel, a UA/UAB orientation meeting will be held in April 2010, where students will be given a booklet with information about Greece, travel preparations, and a list of suggested items to bring with them.

APPENDIX D

5TH ANNUAL STUDENT AWARDS LUNCHEON PROGRAM

5th ANNUAL STUDENT AWARDS LUNCHEON

Celebrating the Achievements of Transportation Students

Friday, November 19, 2010
11:30 a.m.-1:00 p.m.

The University of Alabama at Birmingham
Business and Engineering Complex (BEC) Room 215
1150 10th Avenue South, Birmingham, AL

AGENDA

11:30	Buffet Lunch and Networking	
11:45	Welcome	*Dr. Virginia P. Sisiopiku*, Associate Professor - Alabama at Birmingham
11:50	Student Competition Awards Presentation	*Dr. Mike Anderson*, Associate Professor - University of Alabama in Huntsville
12:00	Evaluation of Ramp Metering on Interstate 65 in Montgomery, AL	*Mr. Brian Wysock*, University of Alabama
12:20	Incident Management Study in the Birmingham Region	*Ms. Ozge Cavusoglu*, University of Alabama at Birmingham
12:40	New Factors for Disaggregation of Freight to a Local Level	*Ms. Tahmina Khan,* University of Alabama in Huntsville
1:00	Closing Remarks	*Dr. Virginia Sisiopiku*, Associate Professor University of Alabama at Birmingham

Congratulations to all 2010 UTCA Travel Award Recipients:
Rong Li (UA), Gaurav Mehta (UA), Zack Ryals (UA), Brian Wysock (UA), Ozge Cavusoglu (UAB), Bharat Kallem (UAB), Cheng Zhong (UAB), Tahmina Khan (UAH); Mary Catherine Dondipati (UAH), Dong Wang (UAH); Nitin Sharma (UAH).

This event is sponsored by the University Transportation Center for Alabama (UTCA) and the UAB ITE Student Chapter

http://maps.google.com/?q=1150+10th+Avenue+South+Birmingham+AL

Domain 2
Project 2

Development, Calibration and Testing of the Birmingham Prototype Model

Development, Calibration, and Testing of the Birmingham Prototype Model

Final Report

UAB UTC Domain 2: Development of a Dynamic Traffic Assignment and Simulation Model for Incident and Emergency Management Applications in the Birmingham Region (Aim 2)

Prepared By:

Virginia Sisiopiku, PhD
Department of Civil, Construction, and Environmental Engineering
University of Alabama at Birmingham

Curtis Barrett
Vista Transportation Group, VTG, Inc.

Ozge Cavusoglu, MSCE and Andrew Sullivan, MSCE, PE
Department of Civil, Construction, and Environmental Engineering
University of Alabama at Birmingham

Prepared for:

The UAB University Transportation Center

Birmingham, Alabama

DTRT06-G-0048

UAB UTC

January 2011

DRAFT

1. Report No. FHWA/CA/OR	**2. Government Accession No.**	**3. Recipient Catalog No.**
4 Title and Subtitle Development, Calibration, and Testing of the Birmingham Prototype Model UAB UTC Domain 2: Development of a Dynamic Traffic Assignment and Simulation Model for Incident and Emergency Management Applications in the Birmingham Region, Aim 2.		**5 Report Date** January 2011 **6 Performing Organization Code**
7. Author(s) Virginia P. Sisiopiku, Curtis Barrett, Ozge Cavusoglu, and Andrew J. Sullivan		**8. Performing Organization Report No.**
9 Performing Organization Name and Address University of Alabama at Birmingham 1075 13th Street South Birmingham, AL 35294-4554		**10 Work Unit No. (TRAIS)** **11 Contract or Grant No.**
12 Sponsoring Agency Name and Address UAB University Transportation Center 1530 3rd Avenue South Birmingham, AL 35294-2041		**13 Type of Report and Period Covered** **14 Sponsoring Agency Code**
15 Supplementary Notes		

16 Abstract

This report summarizes the steps taken toward the development of a regional prototype model of the Birmingham, AL area to meet the objectives of UAB UTC Domain 2 Project: Development of a Dynamic Traffic Assignment and Simulation Model for Incident and Emergency Management Applications in the Birmingham Region.

The model is built using the Visual Interactive System for Transport Algorithms (VISTA) environment. VISTA utilizes a mesoscopic simulator (RouteSim) and a Dynamic Traffic Assignment (DTA) routine to emulate the behavior of individual drivers and how they distribute themselves into the transportation network. The model enables the study of incidents' impacts as it generates spatial-temporal traffic flows for all origin-destination trips loaded into the network. Furthermore, the VISTA system can emulate the routes that the emergency vehicles should follow in order to arrive at the scene of an incident given the prevailing traffic conditions.

The prototype model of the Birmingham area represents a region that stretches north as far as Warrior, AL (26 miles from the city center), west as far as Adger, AL (33 miles), south as far as Calera, AL (35 miles), and east as far as Leeds, AL (18 miles). The network includes major freeways, highways and many local arterials of Birmingham and surrounding areas that are of great importance in serving the regional traffic demand needs.

This report provides background information on VISTA's features and capabilities, and discusses the Birmingham prototype model development and refinement process. The model supports the needs of UAB UTC Domain 2 project but also can be of great value to local planning, emergency management, and transportation agencies off-line incident response and emergency analyses, real-time implementation, and training exercises in the future.

17 Key Words VISTA, Dynamic Traffic Assignment, Model Development		**18 Distribution Statement** No restrictions.	
19 Security Classification (of this report) Unclassified	**20 Security Classification (of this page)** Unclassified	**21 No. of pages**	**22 Price**

TABLE OF CONTENTS

List of Figures iv
List of Tables v
ABSTRACT vi
1. INTRODUCTION 1
1.1 Visual Interactive System for Transportation Algorithms (VISTA) Background 3
1.2 Modelling Incident Management Options in VISTA 4
2. DEVELOPMENT OF THE BIRMINGHAM PROTOTYPE MODEL 5
2.1 Study Test Bed and Study Boundaries 6
2.2 Simulation Model Selection 7
2.2.1 VISTA Modules 9
2.2.2 VISTA Model Outputs 11
2.3 Data Needs and Sources 12
2.3.1 Network Data 13
2.3.2 Demand Data 13
2.3.3 Control Data 14
2.4 Development of the Birmingham Prototype Model 14
2.4.1 Methodology 14
2.4.2 Refinement and Calibration of the Birmingham Prototype Model 15
2.4.3 Development of GIS Layers for Emergency Response Information 16
2.4.4 Development of GIS Layers for Crash Data 19
2.5 Birmingham Prototype Model Calibration 20
2.5.1 Model Refinement 20
2.5.2 Model Calibration 20
2.5.3 VISTA Model Host 22
3. CONCLUSIONS 22
REFERENCES 24
APPENDIX A 26
Visual Interactive System for Transportation Algorithms Background 26

LIST OF FIGURES

FIGURE 1 DTA Model Framework 1

FIGURE 2 Study Testbed..... 7

FIGURE 3 Birmingham Emergency Shelters in ArcGIS..... 16

FIGURE 4 Birmingham Fire Stations and Police Stations in ArcGIS..... 17

FIGURE 5 Birmingham Fire Stations and Police Stations in the VISTA Model 17

FIGURE 6 Birmingham Hospitals in the VISTA Model 18

FIGURE 7 Birmingham Shelters in the VISTA Model 18

FIGURE 8 Crash Data Layer in the VISTA Birmingham Model Indicating Crash Severity ... 19

LIST OF TABLES

TABLE 1: Comparison of DTA Simulation Models (Sisiopiku and Li, 2006) 2

TABLE 2: VISTA Pre-Formatted Reports 11

TABLE 3: Input Data Needs 12

TABLE 4: Traffic Volume Data 21

TABLE 5: Sample Delay Time Calculations 21

TABLE 6: Sample Delay Time Comparisons for Model Calibration 22

ABSTRACT

This report summarizes the steps taken toward the development of a regional prototype model of the Birmingham, AL area to meet the objectives of UAB UTC Domain 2 Project: Development of a Dynamic Traffic Assignment and Simulation Model for Incident and Emergency Management Applications in the Birmingham Region.

The model is built using the Visual Interactive System for Transport Algorithms (VISTA) environment. VISTA utilizes a mesoscopic simulator (RouteSim) and a Dynamic Traffic Assignment (DTA) routine to emulate the behavior of individual drivers and how they distribute themselves into the transportation network. The model enables the study of incidents' impacts as it generates spatial-temporal traffic flows for all origin-destination trips loaded into the network. Furthermore, the VISTA system can emulate the routes that the emergency vehicles should follow in order to arrive at the scene of an incident given the prevailing traffic conditions.

The prototype model of the Birmingham area represents a region that stretches north as far as Warrior, AL (26 miles from the city center), west as far as Adger, AL (33 miles), south as far as Calera, AL (35 miles), and east as far as Leeds, AL (18 miles). The network includes major freeways, highways and many local arterials of Birmingham and surrounding areas that are of great importance in serving the regional traffic demand needs.

This report provides background information on VISTA's features and capabilities, and discusses the Birmingham prototype model development and refinement process. The model supports the needs of UAB UTC Domain 2 project but also can be of great value to local planning, emergency management, and transportation agencies off-line incident response and emergency analyses, real-time implementation, and training exercises in the future.

Keywords: VISTA, Dynamic Traffic Assignment, Model Development

1. INTRODUCTION

Dynamic Traffic Assignment (DTA) models are used to estimate time-varying network conditions by capturing traffic flow and route choice behavior. A basic characteristic of these models is the utilization of a traffic simulator to emulate the traffic conditions where it is very difficult to capture the dynamics of traffic through analytical techniques. This is a very useful feature in modeling incident conditions and incident management strategies. Under such conditions, the timing of incident occurrence, management, recovery, and the use of alternate routes are critical to roadway performance and driver experience. DTA models capability to account for such considerations is superior to that of traditionally used static models. The latter are based on average daily traffic and thus fail to identify and test the short-term control actions necessary to manage non-recurring events such as crashes or infrastructure failures (Wirtz et. al., 2005).

In general, simulation-based DTA models iterate between a traffic simulation module, a time-dependent shortest path module, and a network-loading module. First, given a set of vehicles and their travel paths, the traffic simulation module replicates complex traffic flow dynamics as the vehicles are propagated through the network. The link travel times reported by the simulator are then used to calculate the time dependent shortest paths. Those shortest paths are then combined with all previous sets of shortest paths, and the vehicles are loaded onto the network on those paths. A new iteration then begins as the simulator propagates vehicles through the network along the new combination of paths. The process stops when some user-specified convergence criterion is met. The DTA model framework is depicted in Figure 1.

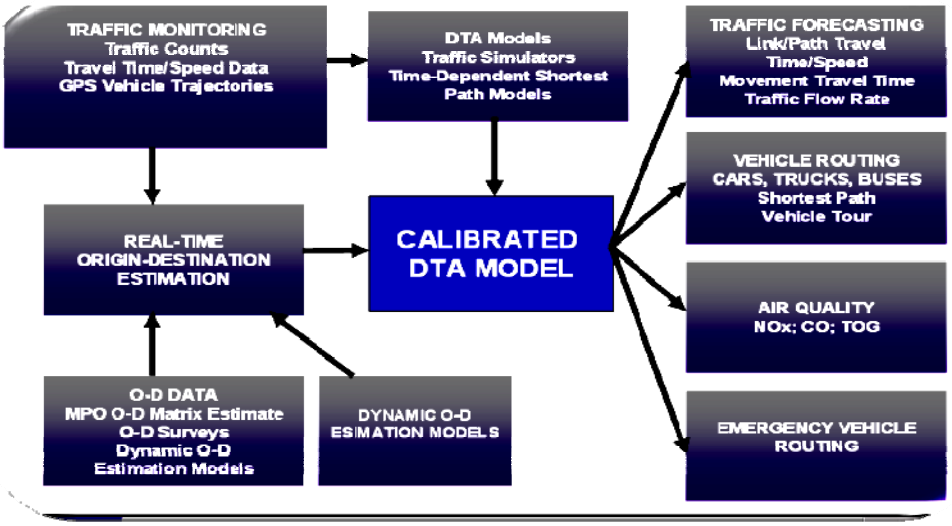


FIGURE 1 DTA Model Framework

There three commonly used platforms for DTA analysis, namely DynaMIT, DYNASMART-X, and VISTA. A comparison of features, strengths, and limitations of these DTA simulation platforms is offered in Sisiopiku and Li, 2006. A number of references provide details on

commonly used DTA methods and applications. A comprehensive overview of the literature on DTA models, along with a discussion of current and future challenges in DTA research and applications, can be found in Peeta and Ziliaskopoulos, 2001. Table 1 offers a comparison between the three common DTA platforms for easy reference.

TABLE 1: Comparison of DTA Simulation Models (Sisiopiku and Li, 2006)

MODELS	DynaMIT	DYNASMART	VISTA
Approach	• Heuristic • User equilibrium • Mesoscopic, moving queuing segments • Kalman Filtering methodology	• Heuristic • User equilibrium and system optimal • OD assignment • Mesoscopic, moving queuing segments • Greenshield-type speed-density relationships	• Exact and heuristic • User equilibrium and system optimal • OD assignment • Mesoscopic • Cell transmission model
Impacts that Can be Evaluated	• Short term infrastructure and operational changes; limited area coverage	• Short-term, long term infrastructure and operational changes; no limitation on area coverage	• Short-term, long term infrastructure and operational changes; no limitation on area coverage
Input Data Required	• Geometry, control and demand data inputs • Demand tables need to be arrival and/or departure time based • Text editor to modify input data	• OD trip table, link traffic flows, traffic control and detailed geometry	• OD trip table, link traffic flows, traffic control and detailed geometry • Networks must be created through either the VISTA client or through PSQL • Define a network with nodes and links • Can define controls, streets, zones, Variable Message Sign positions etc.
Direct Output	• Individual vehicle trajectories	• Link occupied by each vehicle at each time step	• Cell occupied by each vehicle at each time step • Vehicle path and travel time
Ease of Use	• Not so easy to implement and use, still at the research community level	• Not so easy to implement and use, still at the research community level	• Moderate training required • Software ready • Web-based
Typical time step	• 60 sec	• ≥ 6 sec	• 2-6 sec
Quality of Graphics	• Low	• Low	• Medium
Network Size	• Medium size	• Medium to large size	• Large to very large size networks; networks with 40,000 nodes have been solved
Calibration Required	• Demand and supply simulators calibration	• Traffic flows and travel time distributions	• Traffic flows and travel time distributions
Strengths	• Interfaces with the real world • Demand and supply calibration	• Bus movement included • Requires less calibration	• Bus movement included • Requires less calibration
Weaknesses	• Computation performance remains to be tested • Interface is not very user friendly • Bus/transit/background not modeled • Travel time is the only link impedance modeled	• Computation performance remains to be tested • Not modular • Mode and departure time assumed given	• Cannot precisely detect vehicle stops • Less emphasis on driver behavior

1.1 Visual Interactive System for Transportation Algorithms (VISTA) Background

The selected platform for model development and testing in this study is the VISTA model. Standing for Visual Interactive System for Transportation Algorithms, 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 utilizes a mesoscopic simulator called RouteSim and a DTA routine to emulate the behavior of individual drivers and how they distribute themselves into the transportation network. RouteSim is based on an extension of Daganzo's cell-transmission model introduced by Ziliaskopoulos and Lee (Ziliaskopoulos and Lee, 1996). Initially, the RouteSim simulator is run with vehicles assigned to the free flow shortest paths. The link travel times resulting from that assignment pattern are then used to calculate a new set of shortest paths, and the simulation is repeated with vehicles assigned to a combination of the previously calculated path set. Iterations continue between the mesoscopic simulation and vehicle assignment modules until the link flows converge. This procedure accounts for vehicle path choice with changes in traffic conditions (Chang and Ziliaskopoulos, 2003).

The principal characteristics of VISTA are as follows:

- The travelers' behavior is modeled using a Dynamic Traffic Assignment (DTA) model;
- A universal database model is utilized based on a spatial Geographic Information System (GIS) that can be easily interface with other databases/models;
- An integrated mesoscopic/microscopic traffic simulator is used to propagate traffic at each iteration based on the current network loading;
- It can model any size transportation network, and
- It is Internet and/or Intranet based.

It should be noted that 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. Principal features of VISTA that distinguish it from traditional simulation models and are valuable to the UAB UTC Domain 2 work include the following:

- **The model has the ability to achieve 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.

- **VISTA offers accessibility 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 provides 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. The VISTA emergency and evacuation modules can be used for off-line emergency analyses, real-time implementation, and training exercises. When fully functional, all Incident Management entities would 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 environment is capable to:

  (a) Support decision-making for emergency response, incident management, special event management, etc,

  (b) Assess impacts of the ITS and non-ITS technologies on the transportation network in the planning phase,

  (c) Assess impacts of different traffic operation and control strategies with fixed Origin Destination (O-D) demand for the analysis period,

- VISTA supports **transit, and emergency response operations**. The VISTA system can generate automated statistics per link, movement, an OD path as well as area wide statistics. Furthermore, the system is flexible enough to allow the user to conduct parametric analyses by allowing only a percentage of vehicles to change their original paths. This is a useful feature in case of rerouting, a common strategy implemented as part of incident management in order to minimize the impact of the incident on traffic operations.

1.2 Modelling Incident Management Options in VISTA

An incident management system is usually comprised by the traffic surveillance system, the incident response system and the travelers' information system. The traffic surveillance system can be emulated in VISTA through the "installation" of various types of detectors at various locations.

The incident response system refers to the procedures followed by the emergency services (e.g. police, EMS, Fire department, towing services, other) that are usually employed when an incident occurs. The VISTA system can emulate the routes that the emergency vehicles should follow in order to arrive at the scene of an incident given the prevailing traffic conditions.

The VISTA system could utilize its time-dependent shortest path algorithm to identify the best route for each emergency vehicle from its current location to the incident location and from the incident location to its final destination, e.g. hospital, firehouse, police station, other (Chien et. al., 2003).

Using VISTA, incident management analyses could be conducted on spatial location and response times to/from the incident of emergency services, impact of traveler information (e.g. VMS location and content) on the traffic conditions for either all vehicles or selected groups of vehicles, and evaluation of effectiveness of route diversion routes.

The VISTA system can generate automated statistics per link, movement, an OD path as well as area wide statistics. Furthermore, the system is flexible enough to allow the user to conduct parametric analyses by allowing only a percentage of vehicles to change their original paths. This is a useful feature in case of rerouting, a common strategy implemented as part of incident management in order to minimize the impact of the incident on traffic operations. A review of the VISTA model is provided in **Appendix A** to provide some additional insights on its features and capabilities.

2. DEVELOPMENT OF THE BIRMINGHAM PROTOTYPE MODEL

The capabilities of the VISTA simulation and optimization platform were used to develop the VISTA Birmingham prototype model. The purpose of the model is to:

a. Assess impacts of designed incident and emergency scenarios in the Birmingham region, and
b. Evaluate the effectiveness of candidate incident and emergency management plans.

The development and testing for the Birmingham prototype model in support of the research goals for UTC UAB Domain 2 project consists of the following five tasks:

1. Selection of the study test bed and definition of study boundaries
2. Selection of an appropriate simulation-based DTA model.
3. Identification of data needs and data sources.
4. Development of the prototype VISTA model for the test bed
5. Calibration and testing of the prototype model.

Details are provided in the sections that follow.

2.1 Study Test Bed and Study Boundaries

The Birmingham metropolitan area is an ideal test bed for model development and testing. Birmingham is a major economic and population center located in north-central Alabama in the foothills of the Appalachian Mountains. The seven county Birmingham metropolitan area has a population of over 1.2 million based on estimates by the U.S. Census Bureau in 2009, which is about one-quarter of the entire population of Alabama. Birmingham is a major center for banking and finance, healthcare services, education, and automotive manufacturing.

The transportation network around Birmingham is already strained during peak traffic periods. During times of incidents and emergencies the demands on the transportation systems could be substantially larger, compromising the ability of the system to provide a reasonable level of service. Moreover, the ability of emergency personnel to reach the affected location in a timely manner can be impacted, leading to delays that may in turn affect the effectiveness of response and recovery efforts.

In practice, large networks allow modelers to capture more trips from their origins to their destinations in totality. Otherwise, the assignment becomes constrained as it may miss some important routes that would have been chosen by the drivers. Therefore, in this project it was decided to perform simulation analysis at a regional level, as well as on extensive study boundaries, to represent the network more realistically. The study area covered the entire Jefferson county and a small part of three adjacent counties (namely, Shelby, St. Clair, and Blount).

More specifically, the prototype model of the Birmingham area developed in this study represents a region that stretches north as far as Warrior, AL (26 miles from the city center), west as far as Adger, AL (33 miles), south as far as Calera, AL (35 miles), and east as far as Leeds, AL (18 miles). The network includes major freeways, highways and many local arterials of Birmingham and surrounding areas that are of great importance in serving the regional traffic demand needs. Figure 2 shows a snapshot of the study testbed.

The regional simulation and DTA model of the Birmingham region developed in VISTA in this study is very extensive and detailed. As such, the development of a functional and realistic prototype model was a very time consuming, labor intensive and tedious undertaking. The successful Birmingham model development in VISTA is an accomplishment of major significance by itself. Not only it satisfies the needs of UAB UTC Domain 2 research but can be of value to the Alabama Department of Transportation (ALDOT), the Regional Planning Commission of Greater Birmingham (RPCGB), the University of Alabama at Birmingham, and other local and regional stakeholders for future research and analysis purposes.

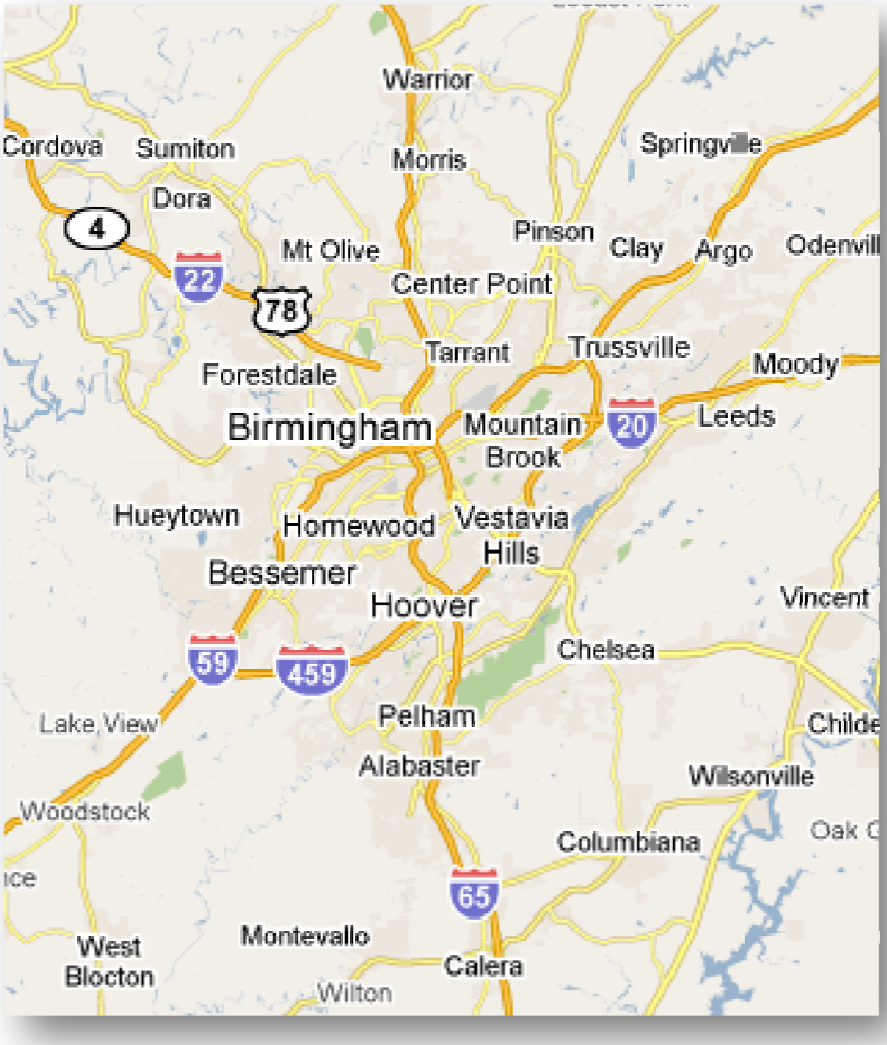


FIGURE 2 Study Testbed

When fully functional, the Birmingham VISTA model is envisioned to become a distributed warehouse for all data and models for traffic operators, engineers, emergency managers, and transportation planners in the Birmingham region. All these users would be able to access the same (consistent) data, run models, make decisions (real-time, operational or planning) and produce reports that can be shared among all stakeholders of the transportation system, an element of critical importance for pre planning and real time planning for emergency conditions.

2.2 Simulation Model Selection

The primary criteria considered for the selection of an appropriate simulation tool for modeling purposes in this study include the following:

- Considerations of model level of detail (i.e., microscopic, mesoscopic, or macroscopic)
- Ability to represent transportation network operations in a reliable manner
- Ability to simulate incident and emergency conditions
- Ability to model the response of individual drivers to the incidents and the response of emergency vehicles, and
- Ability to simulate networks that are large enough to contain not only the direct effects of incidents/emergencies and the pre-planned management strategies but also the indirectly impacted areas.

Consideration of the desirable features for the study tasks, review of the candidate model capabilities and limitations, and model availability issues led to the selection of VISTA as the simulation-based DTA tool for this study. The VISTA environment is appropriate for a wide range of transport applications, including planning, engineering and operation. The client graphic user interface (GUI) is built in JAVA, so that it can be used over the Internet. The database efficiently stores and retrieves spatio-temporal data, by associating geographic coordinates and time stamps. The database is designed to efficiently manage a wide range of historical and real time transportation data (Ziliaskopoulos and Barrett, 2002). In addition, VISTA can be easily interfaced to existing packages, e.g. SYNCHRO and NETSIM, by outputting data from the VISTA Data Warehouse (VDW) in a format compatible with these packages and then importing the results back to the VDW.

Since its first introduction in 2004, several agencies across the nation and in Europe have successfully utilized the VISTA platform for a variety of planning and operational applications. Examples of VISTA research and implementation studies that relate to the scope of the UAB UTC Domain 2 study include, but are not limited to:

- *US Army Corps of Engineers - Impact of Flooding*: Prediction of transportation impacts of flooding in various areas around the US. Work conducted by the US Army Corps of Engineers and Northwestern University.
- *Lake-Cook County - Evacuation Strategies on Lake-Cook Road*: Evaluation of multi-agency cooperation in emergency evacuation scenarios on Lake-Cook Road, Chicago. Funded by CATS and Lake-Cook County, Illinois.
- Athens 2004 - Simulation/DTA of the City of Athens network: Traffic Management Strategies for the Olympics, Athens, Greece.
- *Province of Bologna, Italy – Impact of accidents*: Model of the Province of Bologna network to support accident analysis. Sponsored by the European Union under the 6th Framework, Bologna, Italy.

These previous applications demonstrate the feasibility of using the VISTA model for satisfying the modeling objectives of the UAB UTC Domain 2 study and provide some confidence in the model's ability to reasonably capture the complexities of transportation network operations encountered under incident and emergency conditions.

2.2.1 VISTA Modules

Some discussion about VISTA capabilities is provided in Section 1 of this report. Below some additional details are provided on algorithms available in VISTA and used in the study. These include:

- Traffic simulation
- Dynamic Traffic Assignment
- Traffic control (isolated intersection and signal coordination)
- Capacity analysis
- Transit operations
- Demand calibration
- Routing

Large-Scale Mesoscopic Simulator (RouteSim)

As a software framework, RouteSim was designed with third-party extensibility in mind. Written in C++, it uses the Abstract Factory design pattern for the creation of objects. The purpose of the Abstract Factory is to provide an interface for creating families of related objects without specifying concrete classes. This allows for users to easily extend or add to the object structure without directly modifying the simulator. For instance, a new vehicle type can be inherited from the core vehicle class and the methods describing movement rules can be overridden. Each class in the simulator provides a convenient set of accessors and mutators to facilitate dynamic interactions between classes.

Planning Models

System optimum and user equilibrium static assignment algorithms have been implemented and can be invoked through VISTA. The algorithms are deterministic approaches based on Frank-Wolfe's convex combinations method (Sheffi, 1985); a stochastic user equilibrium model is currently under development using a paired combinatorial logit model. The demand tables are part of the input data, since no trip generation, distribution or mode split modules are currently implemented. VISTA, however, provides a convenient framework for embedding such models, and using them in conjunction with DTA models.

In addition, highway capacity analysis modules are currently being implemented so that the level of service for intersections and street segments can be computed for the equilibrium flows. The computational procedures are done according to the procedures of the Highway Capacity Manual.

Signal Control Models

Although not of concern in this study, signal timing plans can be computed for isolated intersections based on simple delay functions and offsets for intersections along an arterial. Network-wide signal optimization models are currently under development, although any of

the already existing models (e.g. TRANSYT, and SYNCHRO) can be easily interfaced. A user-friendly graphic interface for viewing (or modifying) the intersection signal timing plans is also available.

Dynamic Traffic Assignment

Various DTA models have been implemented within VISTA, a summary of which follows:

- A departure-based and fixed-arrival-time version of simulation-based User Equilibrium (UE) DTA approaches using RouteSim to propagate traffic and satisfy capacity constraints (Ziliaskopoulos and Rao, 1995).
- A modified version of DYNASMART-X (Mahmassani et al., 1998) that is capable of modeling multiple user classes including user equilibrium and System Optimum (SO) users. This version is departure time-based only, and uses DYNASMART to simulate traffic.
- Two analytical DTA models: a departure-time and an arrival-time approach; both approaches are linear programming and are solved with CPLEX.
- A combined departure and arrival-time-based analytical model that is also solved using CPLEX (Li et. al., 1999).

All of these DTA models use the same geometry, control, and demand data inputs; the demand tables need to be arrival and/or departure time based, depending on the model invoked. The DTA modules access the simulator module, time-dependent least time and cost path modules, as well as various other modules. Since these systems work in an iterative scheme, the computational time of sub-modules becomes of great importance. DTA models are the most time-consuming models, but many of these modules have operations that can be run in parallel. For instance, the time-dependent shortest path algorithms have the ability to be distributed over multiple processors (Ziliaskopoulos et al., 1997).

Origin-Destination Demand Calibration

A unique capability of VISTA enables users to calibrate Origin-Destination trip tables based on observed link flows. This is a heuristic algorithm that allows users to adjust the trip tables so that the observed 15-minute link flows are replicated on the network. Usually, there are many adjusted trip tables that can meet this requirement; the module identifies the one that deviates the list from the original target trip table.

Routing Algorithms

Various routing algorithms can be invoked through VISTA: static and dynamic shortest path algorithms based on time or cost on the links. Versions of the dynamic algorithms that simultaneously optimize route and departure time are also being developed. The algorithms are implemented in C++. Implementation details can be found in Ziliaskopoulos and Mahmassani (1993). The routing algorithms require as input link travel times and/or costs,

and network geometry, and have the capability to account for intersection movement delays. The output is typically a tree, rooted at the origin or destination.

2.2.2 VISTA Model Outputs

The outputs generated by VISTA can be link specific, aggregated for multiple links (such as a group of links connecting a specific OD pair), and network wide. Examples of available outputs or performance measures generated by the software include the cell occupied by each vehicle at each time step, vehicle path for each individual vehicle, and various MOEs such as travel times, delays, and emissions. The main MOEs considered in this study included travel time, delay, and vehicle miles traveled (VMT).

The outputs are mainly generated as pre-formatted reports that are currently given in three formats i.e., PDF file, Excel file, or Web format. The pre-formatted report results must be viewed in the Web interface. Another format of outputs generated by VISTA that can be viewed through the client interface is various link specific plots. For instance, VISTA provides a link travel time plot, which is a plot of the average vehicle travel time versus the simulation time for a link of interest.

Table 2 provides a summary of the pre-formatted reports offered by VISTA. Among those reports, the one that contains the most commonly used Measures of Effectiveness (MOEs) is the General Report. The General Report gives general network statistics, such as number of nodes, links, controls and OD pairs. It also gives aggregate travel statistics; including total system travel time and average, maximum and minimum OD travel times. Further, the distributions of OD travel times and vehicles departure times are shown. The level of detail of the distributions can be increased by setting a smaller Time Interval. The General Report is extensively used in this study to obtain results of interest when modeling traffic, incident, and emergency scenarios.

TABLE 2: VISTA Pre-Formatted Reports

REPORT TYPE	REPORT CONTENT
Bus Travel Time Report	Bus performance statistics
Bus Schedule Adherence Report	Bus schedule statistics
Detector Report	Detector performance statistics
General Report	System-wide travel time, distance, and delay statistics
Link Traffic Composition Analysis	Link performance statistics
Origin-Destination Travel Time Report	Trip-specific travel time, distance and delay statistics
Signal Report	Signal performance statistics
Transmit Detector Report	Electronic toll collector statistics
Variable Message Sign Report	VMS performance statistics

In addition, the VISTA users may execute queries and commands on the network database to request specific reports on the various network elements. For instance, the user may produce a new data layer highlighting some links or some nodes by using the link or node query tools in VISTA. Then a report may be requested to provide specific MOEs relevant to the new data layer of interest. The outputs of these queries may be viewed directly in the VISTA web interface or downloaded and imported into Excel.

2.3 Data Needs and Sources

One of the main challenges in developing a mesoscopic/microscopic regional simulation model to serve the needs and requirements of the UAB UTC Domain 2 research is the availability of extensive geometric, traffic count, OD, travel control, and travel time data. Such data are required to support of model development, calibration, and validation purposes. Table 3 provides a summary of data typically required for defining in detail the network characteristics and travel patterns.

TABLE 3: Input Data Needs

DATA CATEGORY	DATA TYPE
Infrastructure Data	GIS, roadway geometry, location of signs, pavement, bridges, tunnels
Traffic Control Data	Signal timing, roadway signs, lane designation, ramp metering, speed limits
Origin-Destination Data	Automobile, bus, train, truck, person
Traffic Count Data	Automobile, bus, truck, bicycle, pedestrians
Travel Time Data	Link, path
Crash Data	Automobile, bus, train, bicycle, pedestrian
Other	Construction related closures, EMS locations, Emergency Shelters

In order to acquire some of these data, the research team capitalized on earlier efforts to model traffic operations in the Birmingham area using TRANPLAN, CORSIM, VISTA, SYNCHRO and other traffic simulation tools. During the VISTA model development we merged inputs from existing models into

the VISTA Birmingham model prototype and supplemented data as needed in order to develop a model that is detailed and realistic but also available in a reasonably short time. Data not readily at hand were solicited and obtained through local agencies including:

- Regional Planning Commission of Greater Birmingham (RPCGB),
- Alabama Department of Transportation (ALDOT),

- City of Birmingham,
- Birmingham Regional Emergency Medical Services System (BREMSS),
- Center for Advanced Public Safety (CAPS), and
- Birmingham Jefferson County Transportation Authority (BJCTA).

In addition, field travel time data collection at selected network locations took place to support the calibration effort and assist in model refinement.

2.3.1 Network Data

Although VISTA can be accessed through either the Web interface or the client interface, networks cannot be created in VISTA through the Web interface. They must be created through either the client interface or PSQL (a terminal-based front end to PostgreSQL, which is an open source software object relational database management system). VISTA network data are in a node-link format; the user can define a network with nodes and links (Ziliaskopoulos and Barrett 2005). As an alternative, the user can also directly import existing network data from other software such as TRANPLAN and CORSIM by use of conversion tools provided.

In this study, the basic network was imported directly from the regional TRANPLAN network provided by the Regional Planning Commission of Greater Birmingham (RPCGB). Refinement of the network was conducted manually after the importation. The network covers the whole of Jefferson county and parts of three adjacent counties (namely, Shelby, St. Clair, and Blount). The network is very extensive and includes 5,408 nodes and 11,463 links. The large area coverage is beneficial since it allows more trips to be captured from their origins to their destinations in totality. Otherwise, the assignment becomes constrained since it may miss some important routes that could have been chosen by the drivers.

2.3.2 Demand Data

The demand data in VISTA are in the format of OD trip matrices. The model used in VISTA is dynamic in nature, but dynamic demand information is not always available in practice. For this reason, VISTA allows the user to input either dynamic demand or static demand. Dynamic OD trip matrices are departure time based, and the number of seconds after the beginning of the simulation at which the vehicle enters the network is given. In contrast, static demand is a flat value for the total number of vehicles going from one zone/node to another for a given period. For example, the user may enter the number of vehicles moving in a 24-hour period.

In this study, OD trip tables were first extracted from TRANPLAN files and inputted into VISTA. The data from TRANPLAN include the origin, destination, vehicle type, and number of vehicles moving in a 24-hour period. A total of 1,898,417 vehicles have been loaded into the network. At first, the demand data were static, with flat numbers for a 24-hour period. A module called "Demand Profiler" was then used to create demand data that better represent

actual demand fluctuations within the 24-hour period. This module profiles the demand on the basis of a curve for the simulation period. The curve is defined by using traffic counts by the hour of day obtained from demand profiles provided by ALDOT and by inputting points on the curve.

2.3.3 Control Data

In VISTA control data include traffic signals, signs (stop and yield), ramp meters, and signal preemption options. These control data can be inputted from the client interface. Ideally, detailed signal definition data such as signal locations and signal-phasing and -timing plans should be available for all intersections in the created model; however, in reality, such data are very difficult to obtain, especially for large-scale networks. Under such circumstances, VISTA can assign optimal signal-timing plans based on the flows generated by the simulation for those intersections where signal data are not available.

In this study, detailed signal data for major intersections and along major corridors were obtained from ALDOT and the City of Birmingham. Great effort was made to model in detail traffic control at locations of interest to the UAB UTC Domain 2 study, such as the downtown Birmingham region, major corridors such as the US-31 corridor etc. All signal timings used reflect current field timings and were coded into the network in great detail. When actual signal control data were not available, the intersection signal optimization module provided in VISTA was utilized to generate signal-phasing and -timing plans for all the intersections while using algorithms to calculate cycle and green phase times. The signal timings were set to allow the traffic volume on all approaches to pass through the intersections. Thus, original timing plans were taken over by newly optimized timings to improve the distribution of traffic in the network.

2.4 Development of the Birmingham Prototype Model

2.4.1 Methodology

The project team started with a 2002 version of the TRANPLAN regional planning model data from the Birmingham Metropolitan Planning Organization (RPCGB), which was updated to reflect the current traffic network. The original data were first imported into VISTA, and then updated using the VISTA GIS. Changes were made to network topology and roadway characteristics as deemed appropriate. Errors in the original model data, such as nonexistent roads or roads going in the wrong direction, were corrected.

VISTA requires an accurate operational traffic network to model effectively. This means that all intersections and interchanges must be defined with proper connectivity, and all roadway attributes (number of lanes, speed limit, etc.) must be given as their real values. Many static traffic models use speed limits, capacities, or other attributes which are altered to represent some operational characteristic of the road network. Because VISTA models traffic flowing

through the network, these operational characteristics are an output from the model, not an input to the model.

Static planning capacities are typically much lower than the ideal capacity for a given roadway. When importing the traffic network into VISTA, the given capacities were discarded. Ideal capacities were determined using HCM-style analysis of the other roadway attributes. When speed limits were undefined, the actual speed limit was either checked in the field or determined using reasonable speed limits from upstream and/or downstream of the offending road segment.

Two hundred seventy four traffic signals were added to the network manually, to better reflect the operational characteristics of the region. These data are rarely, if ever, provided with static planning network data. As such, many hours were spent checking traffic signal locations and updating signal timings to reflect current timing plans. The signal optimization functionality within VISTA was used to refine timing plans for the added traffic signals, where no known timing plan was available.

Bus routes and schedules were collected from the BJCTA website and imported into VISTA manually. A total of 21 bus routes were modeled with a 109 vehicles of bus demand.

2.4.2 Refinement and Calibration of the Birmingham Prototype Model

The travel demand provided with the original planning model data covered a single 24-hour period, which is inadequate to support the modeling needs of the UAB UTC Domain 2 project. The project team collected hourly traffic counts from ALDOT detectors within the study region, which were then used to prepare a demand profile for a 24-hour period. The original travel demand was sliced up using this profile, to prepare a set of 15-minute trip tables, for each of the six trip types defined in the original data. These include:

- HBW = Home based to work trips
- HBO = Home based to other trips
- NHB = Non-home based Trips
- TTX = trucks and taxis
- IEX = internal/external trips
- EEX = external/external trips

Successive model runs performed on the base condition (without-incident scenario) allowed for further refinement of the travel demand being loaded onto the network, using the same traffic count data involved in profiling the travel demand.

To support emergency responder trips, the traffic network was further augmented with additional infrastructure to represent facilities from which responders depart (e.g., fire stations, EMS locations etc) or to which they arrive (e.g. hospitals and shelters). This also involved adding additional trips to the travel demand to represent these trips.

2.4.3 Development of GIS Layers for Emergency Response Information

Geospatial data describing the location and attributes of shelters, hospitals, fire stations, and police stations in the study region were collected from various sources to supplement the specific needs of the UAB UTC Domain 2 study. A total of 90 shelters, 45 hospitals, 124 fire stations, and 84 police stations were coded in ArcGIS software (Figure 3 and 4).

These were imported directly into VISTA and refined to mesh with the existing traffic network. Because the location data provided were in a different coordinate system, they had to be transformed to longitude-latitude to line up with the traffic network. This procedure allowed these facilities to easily be mapped as origins and destinations for responder traffic in the incident scenarios.

Figures 5, 6, and 7 show snap shots of the Birmingham VISTA prototype model depicting the locations of fire and police stations, hospitals, and shelters in the Birmingham region, respectively.

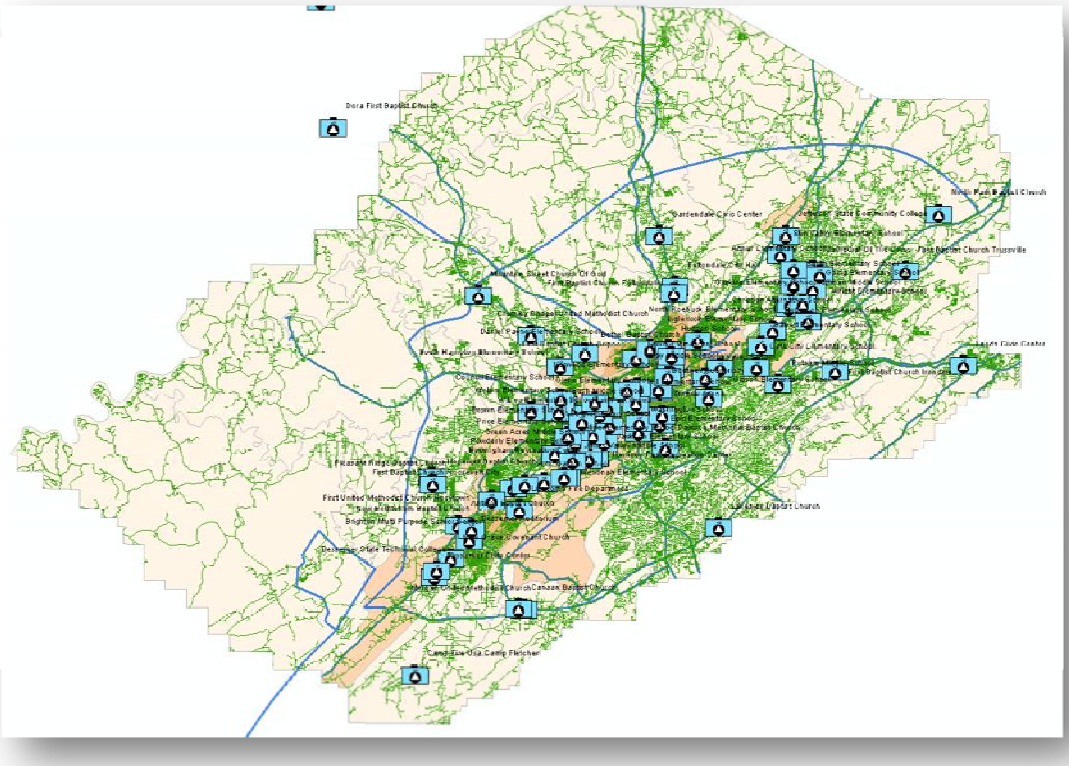


FIGURE 3 Birmingham Emergency Shelters in ArcGIS

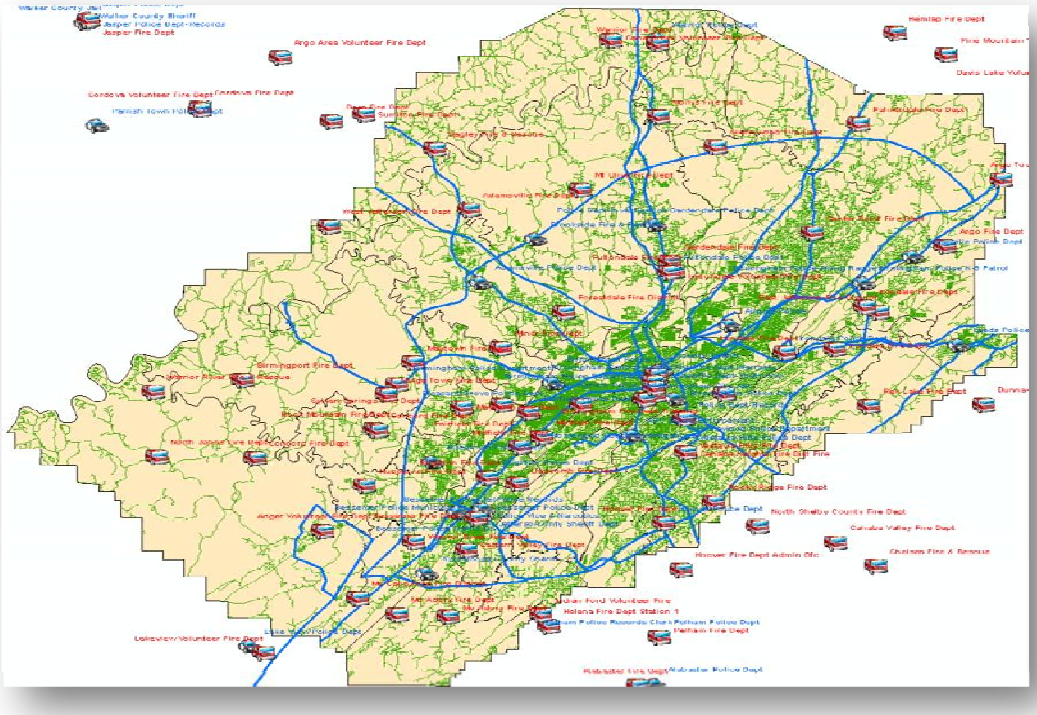


FIGURE 4 Birmingham Fire Stations and Police Stations in ArcGIS

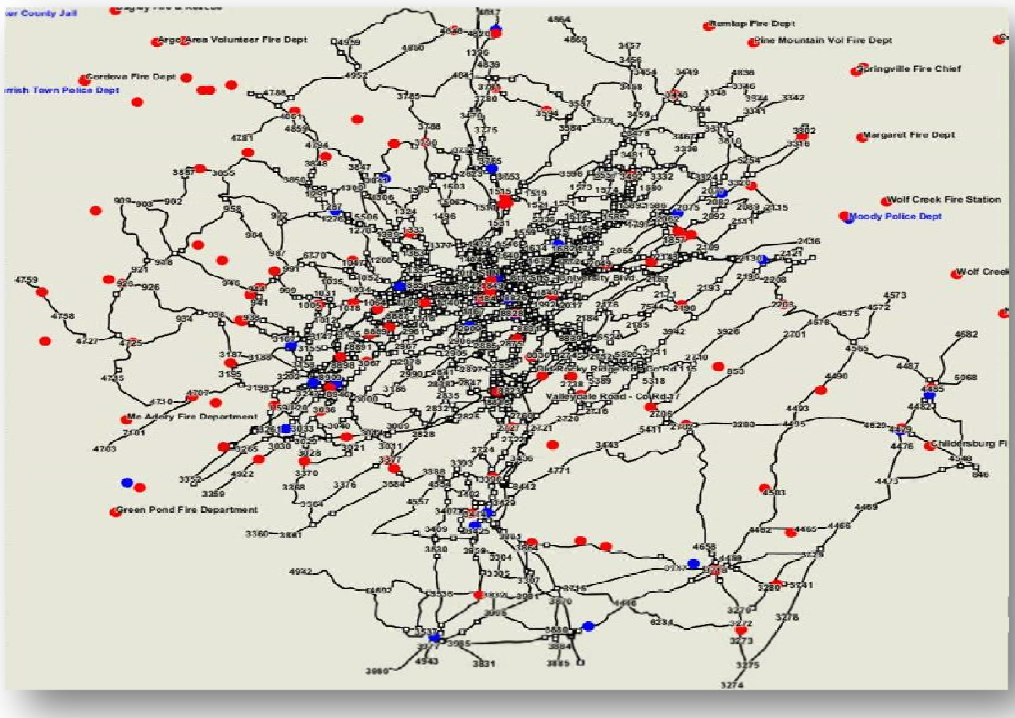


FIGURE 5 Birmingham Fire Stations and Police Stations in the VISTA Model

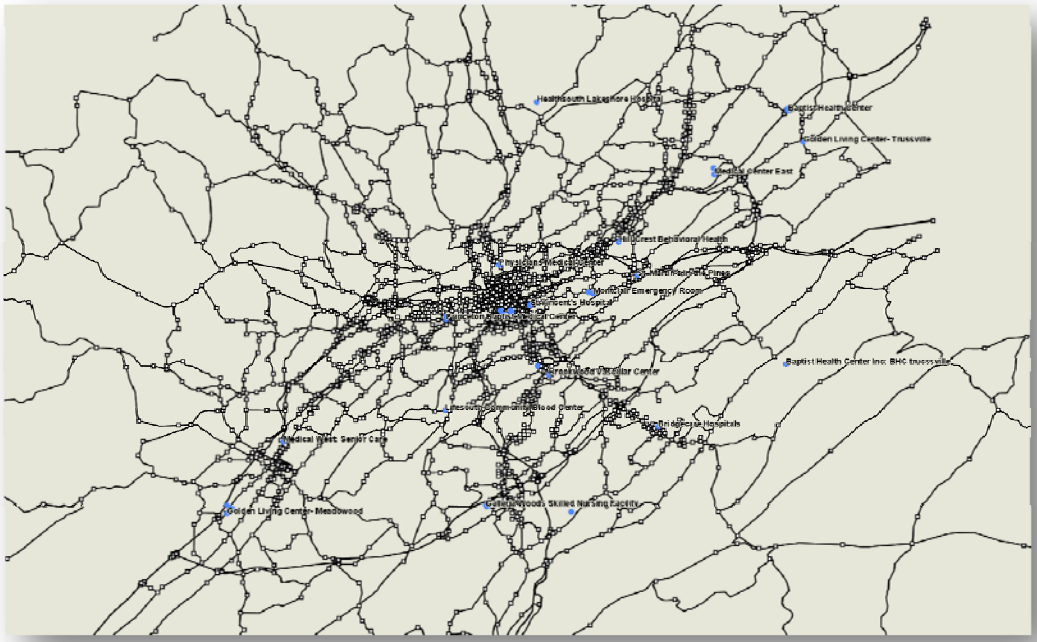


FIGURE 6 Birmingham Hospitals in the VISTA Model

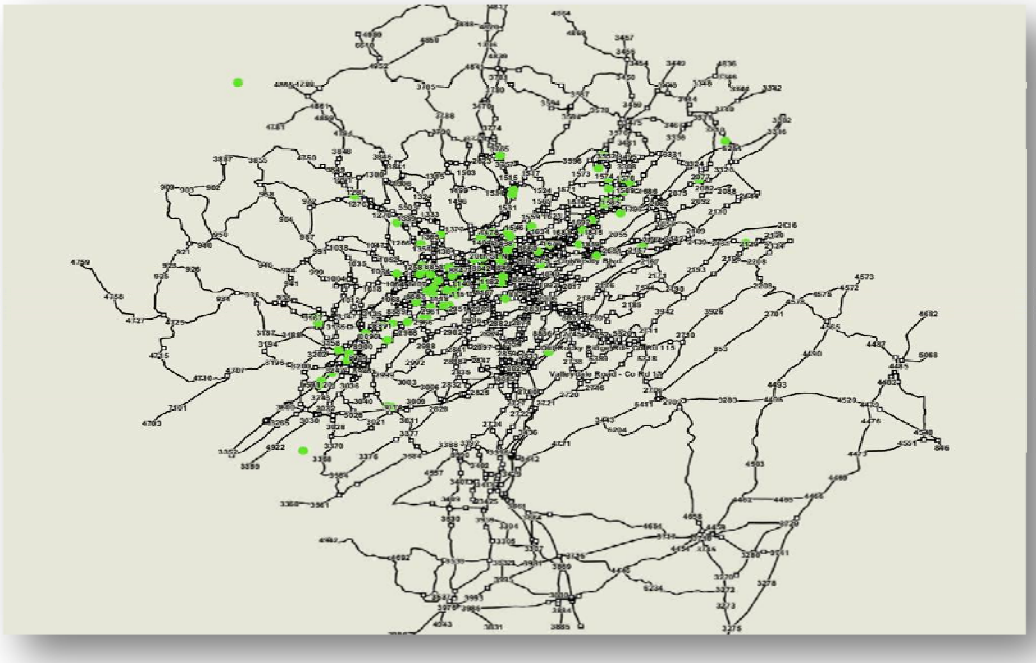


FIGURE 7 Birmingham Shelters in the VISTA Model

2.4.4 Development of GIS Layers for Crash Data

In order to develop realistic incident and emergency scenarios for analysis in later parts of the UAB UTC Domain 2 project, an analysis of historical crash records took place based on data from the Critical Analysis Reporting Environment (CARE 9.1.1.5) database. CARE provides the capability of locating crashes and summarizing a number of variables that describe crash characteristics, contributing factors, and other pertinent information of interest to the study such as the crash severity, police notification delay, police arrival delay and ambulance arrival delay.

Geospatial data describing the location and attributes of past traffic accidents were obtained from CARE by county and year. After importing all these data into VISTA, the data were merged into one GIS layer for each year. Moreover, the attributes describing the accidents were cleaned up. For example, the research team converted record attribute values such as "3 injuries" to just "3" for the attribute describing the number of injuries, to ease selection and filtering of accident data for scenario selection.

All accident data were provided with longitude-latitude, so they could be mapped to the network. This allowed us to establish a visual map of accidents in the region, as seen in Figure 8 below.

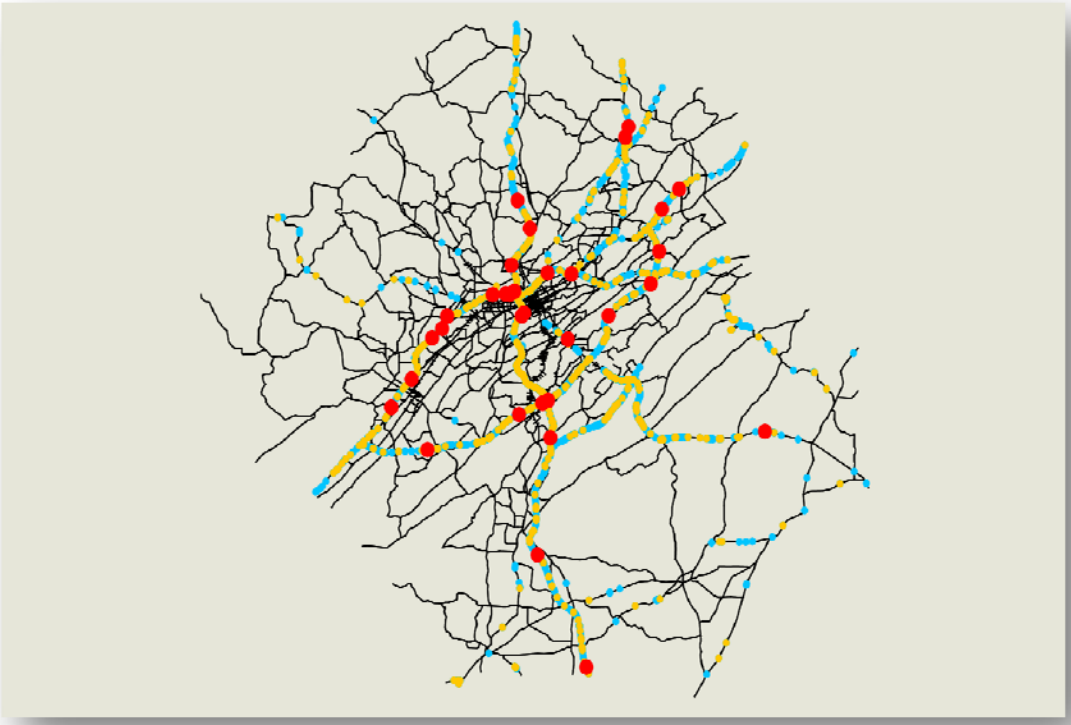


FIGURE 8 Crash Data Layer in the VISTA Birmingham Model Indicating Crash Severity

In the above map, accidents with fatalities are indicated by red dots; accidents with only injuries are indicated by yellow dots; accidents with no injuries or fatalities are indicated by blue dots. The incorporation of crash data into the VISTA prototype model aided in selection of the incident location(s) for scenario analysis.

2.5 Birmingham Prototype Model Calibration

2.5.1 Model Refinement

After the VISTA prototype simulation model was developed, it was thoroughly checked for errors and inconsistencies to ensure that it performs as intended. Errors encountered in simulation models are typically associated with improper coding of the network geometric data, the demand data and/or the various model parameters.

First, we carefully checked the software and input coding for potential errors. The error check for input data included checking the connectivity of the modeled roadway links, the number of lanes and link capacities, functional classification, traffic controls at major intersections, prohibited movements, and free-flow speeds. In several occasions errors or omissions were found and corrected. This was a time consuming but necessary process as it improved the model quality as well as the confidence on the model results. Also the demand data were carefully checked to ensure that the trip generation and O-D data are properly incorporated in the model.

Then, initial runs were performed and the model outputs were reviewed to ensure that the results obtained were rational and consistent. General reports and queries were utilized to inspect the model performance and evaluate its reliability and soundness. In addition we used visual observations from the simulation animation to identify potential problematic locations such unexpected bottlenecks. These locations were carefully examined and adjustments were made, as needed. The examination for errors or unexpected model output is an excellent approach for model inspection and further refinement of the simulation tool.

2.5.2 Model Calibration

As part of the model calibration process, traffic volume data collected by the Alabama Department of Transportation (ALDOT) from loop detectors were used for the VISTA model calibration and refinement (Table 4). Moreover, a series of field travel time studies took place that enabled the comparison of actual (field) travel times to those generated by the prototype model developed in this study. The travel time data were collected along the I-65 corridor (between Valleydale Rd and I-20/59) for three weeks in the fall of 2009, on Tuesdays, Wednesdays and Thursdays during morning and afternoon rush hours. Table 5 shows a sample calculation of delay time data for selected exits on I-65 corridor during AM rush hour. Table 6 shows a comparison of field delay time and VISTA delay time data on the same selected exits. Overall, a close agreement between field observations and simulated delay times was observed.

TABLE 4: Traffic Volume Data

DATA CATEGORY	DATA
Counter IDIN	37-95
Station	95
County	37
City	35
Route	65
Mile point	250.08
AADT 2009	**115,150**
AADT 2008	113,900
AADT 2007	118,520
AADT 2006	117,930
AADT 2005	117,800
AADT 2004	115,060
AADT 2003	113,300
AADT 2002	109,720
AADT 2001	110,210
K	10
D	65
TDHV	8
TADT	11
Heavy	70
Functional Class	11

TABLE 5: Sample Delay Time Calculations

I-65 North Bound AM				
I-65 Exits	Field Travel Time (min:sec.msec)	Field Travel Time (sec)	Ideal Travel Time (sec)*	Delay Time (sec)
247 - 250	03:37.3	926	660	266
250 - 252	03:57.5			
252 - 254	02:50.0			
254 - 255	01:50.5			
255 - 256A	01:12.0			
256A - 258	02:00.4			
258 - 259	01:59.7	264	180	84
259 - 260	00:54.0			
260 - 261A	01:31.6			

* Posted Speed Limit is 60 mph on I-65 corridor

TABLE 6: Sample Delay Time Comparisons for Model Calibration

I-65 North Bound AM				
I-65 Exits	Calculated Delay Time (sec)	Calculated Delay Time (min)	Vista Links Corresponding to I-65 Exits	Vista Delay Time (min)
247 - 250	266	4.43	9090 (247-250)	4.62
250 - 252			9038, 9046 (250-252)	
252 - 254			6913, 12749 (252-254)	
254 - 255			6995, 7003 (254-255)	
255 - 256A			12132, 12131 (255-256)	
256A - 258			7069, 7063 (256-258)	
258 - 259	84	1.40	2402, 2419 (258 - 259)	1.41
259 - 260			4561, 10307, 12299, 5629 (259-260)	
260 - 261A			5797, 5994 (260 - 261A)	

2.5.3 VISTA Model Host

This project used *Version 2010.2* of the *VISTA Web Client*, built on *February 16, 2010.* This VISTA installation is licensed to the City College of New York, New York, NY. The Birmingham VISTA model developed in this study was hosted by the CCNY-CUNY Universal Transportation Model Simulation Center (UTMSC) SGI Altix 4700 supercomputer. The research team has established an agreement with the UTMSC for the unlimited utilization of the UTMSC's computing facilities and running of the VISTA software over the duration of the project. Technical support to the study was provided by VISTA Transport Group, Inc.

3. CONCLUSIONS

This report summarized the steps taken toward the development of a regional prototype model of the Birmingham, AL area to meet the objectives of UAB UTC Domain 2 Project: Development of a Dynamic Traffic Assignment and Simulation Model for Incident and Emergency Management Applications in the Birmingham Region.

The Birmingham prototype model was built using the VISTA environment, a mesoscopic simulation-based DTA model. The unique features of VISTA made it an appropriate simulation tool for studying incident and emergency management strategies and operations, as well as for achieving the overall goals and objective of this study.

The development of the Birmingham test bed was a time consuming and tedious process due to the size and complexity of the study network. It involved identification of data requirements and data sources; demand, infrastructure and control data acquisition; establishment of the prototype VISTA model of the Birmingham region; extensive model testing and refinement; introduction of GIS layers of special interest such as EMS locations, crash data, shelters etc; and model calibration, as needed, in order to bring it to a suitable level of representation of existing and anticipated output.

The deliverable from this effort supports the immediate needs of UAB UTC Domain 2 project for successful execution of its research objectives. Furthermore, it is expected to be of great value in the future for a variety of off-line incident response and emergency analyses, real-time implementation, and training exercises.

REFERENCES

Chang, E., and Ziliaskopoulos, A., 2003. “Data Challenges in Development of a Regional Assignment: Simulation Model to Evaluate Transit Signal Priority in Chicago.” Transportation Research Record, 1841. pp 12-22.

Chien S., Mouskos K.C., Ziliaskopoulos A., and Barrett C., 2003. “Development of a Simulation/Assignment Model for the NJDOT I-80 ITS Priority Corridor”, Final Report to the NJDOT, New Jersey, NJ.

Li, I.Y., A.K. Ziliaskopoulos and S.T. Waller (1999). “Linear Programming Formulations for System Optimum Dynamic Traffic Assignment with Arrival Time Based and Departure Time Based Demands,” *Transportation Research Record, No. 1832, p. 121-142.*

Mahmassani, H.S. et al., (1998). "DYNASMART-X; Volume II: Analytical and Algorithmic Aspects", Technical Report ST067-85-Volume II, Center for Transportation Research, University of Texas at Austin.

Peeta, S. and Ziliaskopoulos, A. K., 2001. “Foundations of dynamic traffic assignment: The past, the present and the future.” Networks and Spatial Economics. vol. 1, No. 3-4, 233-65.

Sheffi, Y. (1985). *Urban Transportation Networks: Equilibrium Analysis with Mathematical Programming Methods*, Prentice-Hall, NJ.

Sisiopiku, V.P., and Li, X., 2006. “Overview of Dynamic Traffic Assignment Options”. Proceedings of the 2006 Transportation Simulation Symposium (TSS 06), Spring Simulation Multiconference 2006, Huntsville, AL.

Wirtz, J.J., Schofer, J.L.and Schulz, D.F. 2005. “Using Simulation to Test Traffic Incident Management Strategies: Illustrating the Benefits”. Proceedings of the 84th Annual Meeting of the Transportation Research Board, Washington, D.C., January 2005, CD ROM.

Ziliaskopolos, A.K. and C. Barrett (2002). Visual Interactive System for Transportation Algorithms. Department of Civil and Environmental Engineering, Northwestern University. http://vista.civil.northwestern.edu/documentation/overview/

Ziliaskopoulos, A.K., D. Kotzinos and H.S. Mahmassani (1997). "Design and Implementation of Parallel Time-Dependent Shortest Path Algorithms for Real-Time Intelligent Transportation Systems," *Transportation Research, Part C, Vol. 5, No.2, 95-107.*

Ziliaskopoulos, A. K., and Lee, S., 1996. ‘‘A Cell Transmission Based Assignment-Simulation Model for Integrated Freeway/Surface Street Systems.’’ Presented at the 75th Transportation Research Board Annual Meeting, Washington, D.C.

Ziliaskopoulos, A.K. and H.S. Mahmassani (1993). "A Time-Dependent Shortest Path Algorithm for Real-Time Intelligent Vehicle/Highway Systems," *Transportation Research Record, No.1408 p. 94-104.*

Ziliaskopoulos, A.K. and L. Rao (1999). “A Simultaneous Route and Departure Time Choice Equilibrium Model on Dynamic Networks,” *International Transactions of Operational Research, vol.6, no.1, p.21-37.*

APPENDIX A

Visual Interactive System for Transportation Algorithms Background

Visual Interactive System for Transportation Algorithms

1. Overview

VISTA is a transportation modeling framework providing Dynamic Traffic Assignment, traffic simulation, reporting over the Internet. Developed at Northwestern University, the VISTA model has been successfully used on transportation projects across the USA and Europe. VISTA can simulate the movements of multiple modes across large networks and incorporate the effects of Intelligent Transportation Systems and traveler information systems into driver behavior.

The system may be deployed at the state, regional, or city level, or for an academic institution or private firm. For government deployments, the State Department of Transportation (DOT), the Metropolitan Planning Organizations (MPO's), County Engineers, City Engineers, Transit Agencies, Freight Agencies, and other stakeholders will have access to the system at various authorization levels to obtain/maintain data, run models and perform analysis. Policy makers at the Federal, State and Local governments will be able to monitor projects, obtain data, evaluate impacts of policies and make decisions.

Academic institutions with VISTA installations may provide support to transportation projects within their region or state. VISTA may also be used as a research tool to evaluate new models for assignment, simulation, or routing.

One unique feature of VISTA is that it is fully capable of being accessed over the Internet. A typical VISTA installation is hosted and run on 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 users' 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 wireless devices provides an added incentive for users to have current data wherever they are located.

2. Data Warehouse

The core of any VISTA installation is the data warehouse. VISTA uses the relational database package PostgreSQL, combined with the PostGIS geo-spatial extension, to store all network data. All network, control, and demand data is stored within the database. The outputs of some modules and reports are also stored in the database, making it possible for the user to construct a variety of queries to inspect or analyze the results directly.

Some assignment and simulation outputs are stored outside of the database for efficiency reasons. VISTA includes an extension to PostgreSQL which allows these outputs to be queried directly from the database. These data may be imported into the database for quicker analysis.

3. Modules

3.1 Dynamic Traffic Assignment

VISTA includes a flexible dynamic traffic assignment module. Our DTA model can solve for both User Equilibrium and System Optimal constraints.

The Dynamic User Equilibrium implementation searches for assignments that place as much demand as possible on least-cost routes. While travel time is generally used as the cost, any other cost metric may be substituted. This method has been developed over a number of years and used successfully in multiple projects.

The VISTA System Optimal implementation searches for assignments that place as much demand as possible on routes so that the overall performance of the network is improved. Again, travel time is the most commonly used cost, though other cost metrics may be used. This method has been developed more recently, and will be included in VISTA soon.

The assignment module recognizes multiple vehicles classes, class-based roadway restrictions, closures, and controls. Currently, all vehicles are departure-time based. Ongoing development will add arrival-time based trips, multi-destination trips, and intermodal trips.

3.2 Dynamic Routing

VISTA has support for both static and dynamic routing. Our route generation procedure uses results produced from VISTA's simulator to develop time-varying costs for using any piece of infrastructure within the network. These costs are using in producing routes for travelers. VISTA's costs are not limited to travel time, and may also include distance, travel modes, pricing, and a variety of other factors. Traveler preferences may also be incorporated into the comparison of these costs to model certain behavior types.

3.3 Traffic Simulation

The VISTA Simulator is a mixed-model route-based traffic simulator incorporating elements such as controls, variable message signs, ramp meters, and detectors.

The simulator includes an enhanced cell-transmission model, with support for variable-sized cells and signalized intersections. This allows the simulator to accurately handle large amounts of traffic in large networks, both inside and outside of urban regions. The simulator also includes a car-following model for microscopic simulation. Portions of the network may be marked as microscopic, allowing greater detail to be captured in the movements of traffic.

Controls supported by the simulator include traffic signals, ramp meters, and stop and yield signs. Traffic signals may be pre-timed, actuated, and include support for signal priority.

Any type of vehicle may be modeled within the simulator. Moreover, closures, such as floods or construction zones, are modeled.

A variety of traffic detectors and detection types can be included for modeling ITS applications. A number of predefined detectors are included, or a custom detector may be defined.

Variable message signs are supported, with the option of rerouting traffic based on network performance reported through such signs.

Bus transit operations are correctly modeled within simulated traffic flows.

4. Database Interface

VISTA may be accessed by any application with ODBC support. This allows users to operate on VISTA data from Microsoft Access, or query results directly into an Excel spreadsheet. The VISTA web interface also allows reports, data tables, and query results to be downloaded in a format compatible with Microsoft Excel, so they may be analyzed in any way the user desires.

5. GIS Interface

The VISTA Editor is a customized GIS interface for operating on VISTA data. The editor supports typical GIS operations such as zooming, panning, and styling of individual data layers.

The Editor provides interfaces for managing VISTA data, such as nodes, links, controls, closures, transit, variable message signs, and more.

The Editor also provides graphical reporting options, such as highlighting portions of the network relevant to module results, or performing animations of time-varying data (such as travel time). A basic graphing facility is included for display time-varying data for specific infrastructure.

Exhibit A. Example of Level of Service Animation

6. Web Interface

The web interface to VISTA allows access to all non-visual functionalities of the VISTA framework. Users authenticate login to the web interface hosted on their VISTA installation. Using the web interface, they may run any module, report, or query on their own networks and scenarios. The web interface also provides convenient links to documentation and support resources.

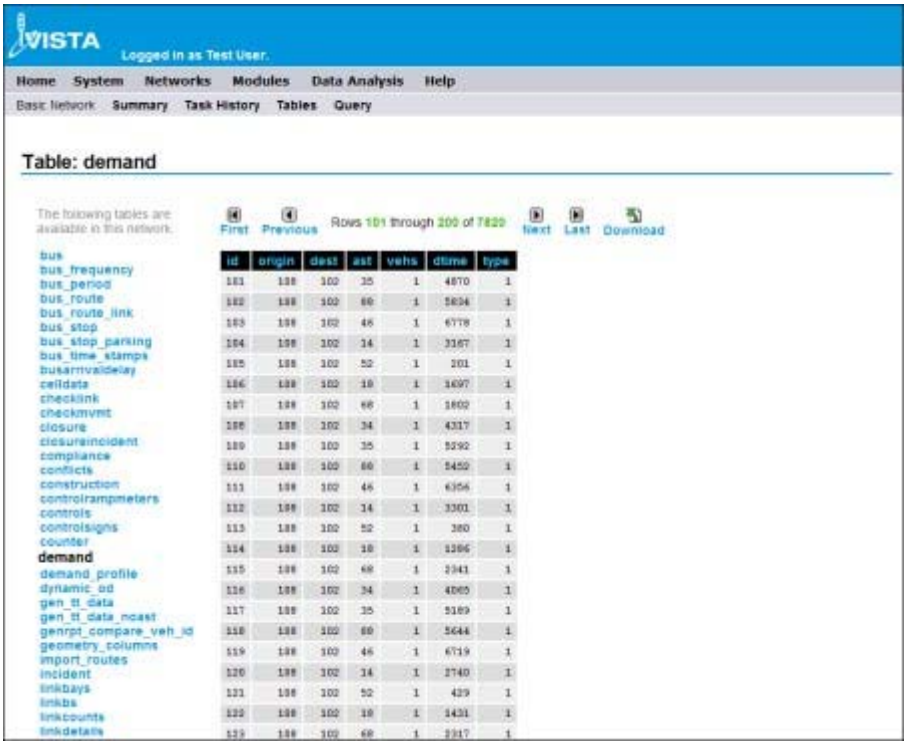


Exhibit B. A table being viewed in the web interface.

7. Applications

VISTA provides a general framework for supporting a variety of traffic applications. Some of the more common applications include:

7.1. Flood Analysis

VISTA may be used to study the impact of time-varying flooding scenarios on a traffic network. As flood waters rise and recede, network capacity decreases and increases, forcing traffic to find alternate routes. Using VISTA's DTA and simulation modules, a number of scenarios for each potential flooding event may be evaluated. The impact of the flood can be quantified in terms of extra travel time, extra mileage, extra emissions, or any other output of the system. VISTA is capable of running multi-day scenarios for studying prolonged floods.

7.2. Incident Management

VISTA offers a framework for conducting incident management using the models already included within the system. DTA and traffic simulation are used to perform pred. VISTA's dynamic routing capabilities are used to model and plan emergency service operations, such as ambulance, fire, towing, police, etc. All stakeholders and participants are capable of accessing VISTA from their offices, homes, or from wireless devices in the field. VISTA can be used for off-line analysis, real-time operations, or training purposes.

A powerful feature of VISTA is the incorporation of real-time traffic 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 detectors, cell-phone tracking, and other vehicle devices. This data makes real-time incident management possible. DTA 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 and operation can be emulated and a set of alternatives could be evaluated in real-time.

7.3. Evacuation Planning

In addition to the routing, simulation, and assignment models already discussed, VISTA supports lane-reversal for major evacuation scenarios. Roadways may be entirely reversed to allow full use to evacuating traffic, or partially closed to retain capacity for emergency vehicles. As before, DTA and simulation may be used to evaluate different closure and reversal scenarios both before and during an emergency.

7.4. Traffic Studies

VISTA is capable of performing basic traffic studies. The impact of new development within the study area can be evaluated by performing scenarios for each variation of the planned development and the traffic the development will produce and attract. VISTA includes planning models for doing trip generation and distribution, allowing the entire planning process to be done within VISTA using our database and models.

8. Benefits

There are a number of benefits to using VISTA. Some of these are:

- **Data Consistency:**
  The system ensures the use of the same data by all participating agencies and professionals.
- **Efficiency:**
  Data duplication and redundant data collection activities will be eliminated.
- **Economies of Scale:**
  Resources could be pooled by various agencies to obtain additional data or functionality that will benefit all. In addition, the value of collecting additional data or developing an additional model can be easily identified; this can help ensure equity for all participating entities.
- **New Data Collection and other Approaches:**
  The acceptance of this new technology can act as a catalyst for new approaches to be considered by agencies. For example, the fact that the system is accessible over the Internet, makes it open to the general public. Travelers could use it to obtain traffic and transit information, either pre-route or en-route. At the same time, though, the system could obtain data from the travelers, such as origin-destination node, time of travel and possibly other type of information that traditionally is obtained through surveys.

- **Data Availability:**
  Authorized users can access the system and functionality at any time, at any location, as long as they have access to the Internet.
- **Productivity Improvement:**
  It will enable transportation professionals to better do their job by freeing them from tedious tasks of data conversion and manipulation as well as help them better interact with other professionals since they are using consistent data and models. In addition, having all tools and data at hand at any place and time helps them easily perform look-up tasks and presenting their results. Information on any component of the transportation system will be available on-line, enabling time sensitive decisions to be taken within a much shorter time frame. Implementation of the models will be conducted seamlessly and on time.
- **Creation of a Professional Community:**
  Communication among users could provide for the creation of virtual professional communities. Secondary data, reports, analysis and actions can be available to all responsible parties via the database. This will allow for not only information but also for knowledge exchange. If a county engineer has difficulties performing a task, he can access expertise at another county or state office with a click of a button.
- **New Product Development:**
  The open architecture of the system will enable developers to validate and test new models based on the same data that all other transportation professionals use, providing credibility to their work and reducing the time to enter the market. Furthermore, the proposed system will enable new users to develop transportation software based on a common platform, reducing software development and implementation costs.
- **Transparency and Accountability:**
  By using electronic signatures, agencies will know who did, what, when and for what purpose.

Domain 2
Project 3

Emergency Dispatchers' Survey Final Report

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

Aim 3. Emergency Dispatchers' Survey

Final Report

Prepared By:

Andrew Sullivan, MSCE and Virginia Sisiopiku, PhD
Department of Civil, Construction, and Environmental Engineering
University of Alabama at Birmingham

Prepared for:

The UAB University Transportation Center
Birmingham, Alabama
DTRT06-G-0048

UAB UTC

1. Report No. FHWA/CA/OR	**2. Government Accession No.**	**3. Recipient Catalog No.**
4 Title and Subtitle Development of a Dynamic Traffic Assignment and Simulation Model for Incident and Emergency Management Applications in the Birmingham Region: Aim 3. Emergency Dispatchers' Survey		**5 Report Date** September 2010 **6 Performing Organization Code**
7. Author(s) Andrew J. Sullivan and Virginia P. Sisiopiku		**8 Performing Organization Report No.**
9 Performing Organization Name and Address University of Alabama at Birmingham 1075 13th Street South Birmingham, AL 35294-4554		**10 Work Unit No. (TRAIS)** **11 Contract or Grant No.**
12 Sponsoring Agency Name and Address UAB University Transportation Center 1530 3rd Avenue South Birmingham, AL 35294-2041		**13 Type of Report and Period Covered** **14 Sponsoring Agency Code**
15 Supplementary Notes		

16 Abstract

Traffic congestion is a primary concern during major incident and evacuation scenarios and can create difficulties for emergency vehicles attempting to enter and exit affected areas; however, many of the dispatchers who would be responsible for directing the movements of emergency response units during emergencies have not been trained to cope with severe congestion nor have they been given the tools that would allow them to consider traffic congestion in the dispatching process.

This paper presents the results of a survey of emergency dispatchers in Alabama conducted by the University Transportation Center at the University of Alabama at Birmingham. The survey sought to assess the current practices of emergency dispatchers with respect to traffic congestion. The survey also solicited input from dispatchers regarding the degree to which they feel congestion is a problem in their jurisdiction along with recommendations for addressing the issue. Finally, the survey results were compared to the findings of a similar survey of emergency responders in Alabama which solicited their views on congestion and emergency response.

17 Key Words emergency dispatch, traffic congestion		**18 Distribution Statement** No restrictions.	
19 **Security Classification (of this report)** Unclassified	20 **Security Classification (of this page)** Unclassified	**21 No. of pages**	**22 Price**

Contents

Contents iii
List of Tables iv
List of Figures iv
Abstract v

1. Introduction 1
    1.1 Objective 1
    1.2 Methodology 2

2. Survey Results 3
    2.1 Selected Survey Results 3
        2.1.1 Training 3
        2.1.2 Use of computer aided dispatch systems (CAD) 3
        2.1.3 Impacts of congestion 3
        2.1.4 Is congestion perceived as a significant problem? 4
        2.1.5 Do dispatchers consider traffic congestion when dispatching? 5
        2.1.6 Do dispatchers receive real-time traffic information in the dispatch center? 5
        2.1.7 Would real-time traffic information be helpful to dispatching? 5
        2.1.8 Do dispatchers alert emergency units to congestion in their area? 6
        2.1.9 Quality of information provided by 9-1-1 callers 6
        2.1.10 Would public education reduce emergency response times? 7
        2.1.11 Impacts of automatic crash notification systems 7
        2.1.12 Accuracy of cell phone location information 8
        2.1.13 Training for large scale emergencies 9
        2.1.14 Suggestions for improving dispatching 9

3. Discussion 11
    3.1 Summary of Survey Results 11
    3.2 Comparison to Results of the Emergency Responder Survey 11

Appendix A – Dispatcher Survey Form 13

Appendix B – Survey Responses 22

List of Tables

Number Page
2.1 Suggested Enhancements 2

List of Figures

Number Page
2.1 Have you received training to cope with traffic congestion? 3
2.2 How often are emergency vehicles impeded by traffic congestion when responding? 4
2.3 Traffic congestion is a significant problem (all respondents)? 4
2.4 Traffic congestion is a significant problem (weekday & afternoon shifts)? 5
2.5 Do you consider traffic conditions when selecting a vehicle to dispatch? 5
2.6 Would real-time traffic information be helpful when dispatching emergency units? 6
2.7 Do you ever alert emergency response units to traffic congestion in their area? 6
2.8 Callers to 9-1-1 provide accurate information concerning the *location* of the emergency? 6
2.9 Callers to 9-1-1 provide accurate information concerning the *nature* of the emergency? 7
2.11 Public education would help to decrease response times 7
2.10 Impact of Automatic Crash Notification Systems 8
2.11 Location information provided by the cell phone carrier is accurate? 8
2.12 Have you received training to operate during large-scale emergencies? 9
2.13 Does your agency drill/train to prepare for large-scale emergencies? 9

Abstract

Traffic congestion is a primary concern during major incident and evacuation scenarios and can create difficulties for emergency vehicles attempting to enter and exit affected areas; however, many of the dispatchers who would be responsible for directing the movements of emergency response units during emergencies have not been trained to cope with severe congestion nor have they been given the tools that would allow them to consider traffic congestion in the dispatching process.

This paper presents the results of a survey of emergency dispatchers in Alabama conducted by the University Transportation Center at the University of Alabama at Birmingham. The survey sought to assess the current practices of emergency dispatchers with respect to traffic congestion. The survey also solicited input from dispatchers regarding the degree to which they feel congestion is a problem in their jurisdiction along with recommendations for addressing the issue. Finally, the survey results were compared to the findings of a similar survey of emergency responders in Alabama which solicited their views on congestion and emergency response.

Keywords: Emergency dispatch, traffic congestion, Alabama.

2. INTRODUCTION

Traffic congestion is a primary concern during incident response and evacuation scenarios and can create difficulties for emergency vehicles attempting to enter and exit affected areas; however, many of the dispatchers who would be responsible for directing the movements of emergency response units during emergencies have not been trained to cope with congestion nor have they been given the tools that would allow them to consider traffic congestion in the dispatching process. A review of available literature found that while many computer aided dispatch (CAD) systems have the capability to incorporate real-time traffic data into their dispatch algorithms, few agencies nationwide actually use this feature. Furthermore, an informal survey of emergency response agencies in the Birmingham, Alabama area found that traffic conditions are typically not considered when dispatching a response unit.

1.1 Objective

In an effort to explore these concerns the University of Alabama at Birmingham (UAB) University Transportation Center sought to answer some fundamental questions concerning traffic congestion and emergency response in Alabama, specifically:

- To what degree do emergency dispatchers believe traffic congestion impacts response times in their jurisdiction and how does this compare with the actual experiences of the emergency responders in the field?
- To what degree, if at all, do emergency dispatchers consider traffic conditions when selecting a unit to dispatch?
- Do emergency dispatchers receive training to cope with traffic congestion? Do they have tools that allow them to consider traffic conditions when dispatching a unit?
- What tools would be most useful to dispatchers to enhance the current dispatch process?

In order to gain a better understanding of current dispatching practices as they relate to congestion the UAB University Transportation Center (UTC) undertook two separate surveys of emergency service providers across the state. The first was a survey of emergency responders (i.e., the units in the field) to gauge how often they encounter traffic congestion during calls and the extent to which they feel it increases response times. The second was a survey of emergency dispatchers designed to gauge the extent to which they believe traffic congestion impacts emergency response times and what tools they use to address it. This report presents the results of the dispatcher survey but also includes some comparisons to results from the responder survey.

1.2 Methodology

Initial interviews with emergency responders and dispatchers in the Birmingham area found significant differences in how these two groups perceive traffic congestion and its impacts. In general, our interviews indicated that dispatchers tended to see congestion as less of a problem than responders did. Responders, in turn, expressed a lack of confidence in the accuracy of information conveyed to them by the dispatchers, both with respect to traffic congestion and the nature and location of the emergency. To investigate these differences it was decided to administer separate but similar surveys for each group.

The responder and dispatcher surveys were developed in parallel and designed to obtain similar information from each group. Initial meetings were held with responders and dispatchers in the

Birmingham region to better understand current dispatch and response practices and identify the types of issues each group feels are important to their jobs. Meetings with the groups were scheduled separately (i.e., dispatchers and responders were not present at the same meetings) and this made the research group aware of differences in how each group perceives the impacts of traffic congestion. Survey questions were developed based on these meetings and in part designed to clarify some of these differences.

The dispatcher survey solicited the following types of information:

- Employing agency, type of area served (urban or rural), typical volume of calls handled;
- Dispatcher duties, typical work shifts, types of dispatching and monitoring equipment used;
- Dispatcher experience and training;
- Views of congestion and its impact on response times;
- Systems available to monitor or consider congestion in dispatching;
- Suggestions for improving the dispatch process;

Alabama has numerous medium and small-sized urban areas and well as large portions of the state that are rural. It was decided to survey dispatchers in both urban and rural areas in order to gain an understanding of how congestion impacts emergency response under different levels of population. It was also decided that while the survey would focus on EMS dispatchers, we would also survey police and fire dispatchers since these duties are shared in many smaller cities and rural areas.

The survey tool used in this study was electronic and is available online at:

https://spreadsheets.google.com/viewform?formkey=dHI5RFE5NVlBbkladTJrZjJyYUEyV3c6MA

A copy of the survey is provided in Appendix A of this report. Paper surveys were not used.

The initial surveys were broadcast via listservs used by emergency dispatchers in the state. The response rate for this initial solicitation, however, was poor. To increase the response rate, selected public safety access points (PSAPs) in the state were contacted to solicit their participation in the survey. The PSAP's are the primary 9-1-1 call centers serving police, fire, and rescue services in a given area. In many cases the PSAP's serve only as an initial contact point and transfer calls to secondary centers where the emergency response units are actually dispatched. There is, however, no directory of these secondary dispatch centers available, so the research team obtained information about the emergency departments served by selected PSAP's and attempted to contact the secondary EMS, fire, and police dispatch centers directly. This effort did improve the response rate.

3. SURVEY RESULTS

We received a total of 54 survey responses from agencies in both urban and rural areas. A full summary of results is provided in Appendix B. Selected results are discussed in the following sections.

2.1 Selected Survey Results

Responses to selected questions, particularly those that relate to the impacts of congestion on emergency response, are discussed in the following sections. Most of the results have been summarized according to whether the agency serves a predominantly urban or rural area. This distinction was made because traffic congestion impacts urban and rural areas differently and we expected there might be differences in how congestion is perceived in each.

2.1.1 Training

100% of respondents stated that they have received some type of training to prepare them to serve as dispatchers, but less than a quarter said that they have received training specifically on ways to cope with traffic congestion. This was true in both urban and rural areas.

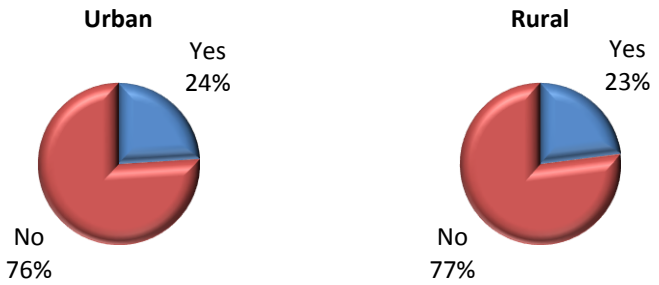


Figure 2.1 - Have you received training to cope with traffic congestion?

2.1.2 Use of computer aided dispatch systems (CAD)

Respondents were asked whether their agency uses a computer aided dispatch (CAD) system. This is important because most CAD systems have the capability to incorporate real-time traffic information into the dispatch process. 81% of the agencies serving urban areas and 74% of those serving rural areas indicated that they use a CAD system. None of the respondents in either urban or rural areas said that their CAD system currently incorporates real-time traffic data into the dispatch process.

2.1.3 Impacts of congestion

Dispatchers were asked how often emergency vehicles in their jurisdiction are impeded by traffic congestion. 52% of urban dispatchers and 42% of rural dispatchers responded “Some of the time”. Perhaps more interesting, 48% of urban and 54% of rural dispatchers responded that traffic congestion rarely or never impacts vehicle response times. The data were checked to see whether these respondents worked primarily on shifts where traffic levels are typically low (e.g., overnight). It was found that overnight shift workers accounted for half the “Rarely” responses in urban areas and 20% of the “Rarely” responses in rural areas.

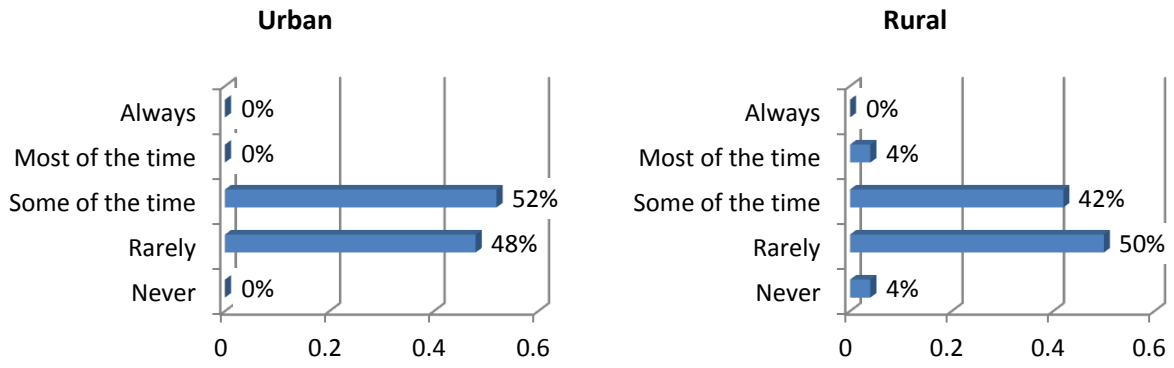


Figure 2.2 – How often are emergency vehicles impeded by traffic congestion when responding?

2.1.4 Is congestion perceived as a significant problem?

When asked if they feel traffic congestion is a significant problem that contributes to increased response times, only 33% of urban dispatchers and 31% of rural dispatchers have said that they "agree" or "somewhat agree". In fact, 48% of urban dispatchers and 50% of rural dispatchers said that they "disagree" or "somewhat disagree".

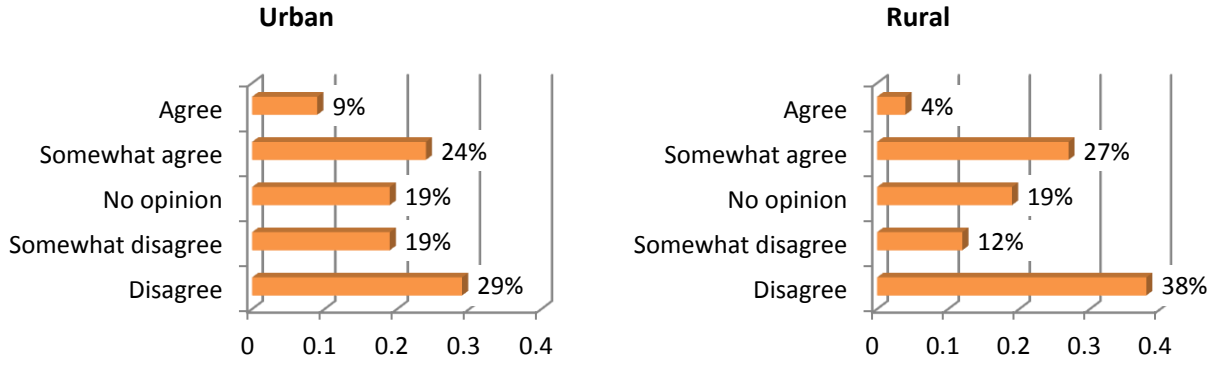


Figure 2.3 – Traffic congestion is a significant problem that causes increased emergency response times (All respondents)

The data were checked to see what portion of the latter responses came from dispatchers who worked primarily overnight or weekend shifts when traffic volumes are typically lower. When these respondents were removed from the sample the distributions shown in Figure 2.4 were computed. Still, only 40% of weekday dispatchers responded "Agree" or "Somewhat Agree" while for rural dispatchers the percentages was 37%.

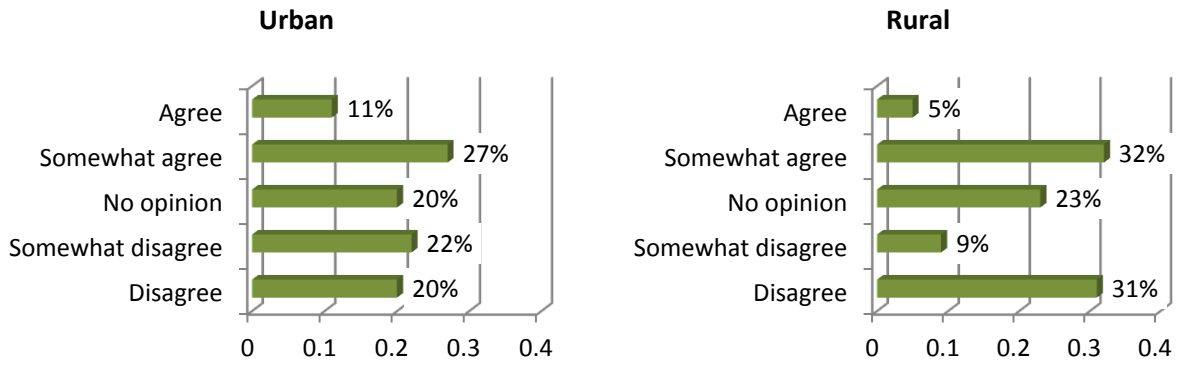


Figure 2.4 – Traffic congestion is a significant problem that causes increased emergency response times (Weekday morning and afternoon shifts only)

2.1.5 Do dispatchers consider traffic conditions when dispatching?

Dispatchers were asked if they consider traffic conditions when selecting a vehicle to dispatch. In both urban and rural areas only about 15% replied that they do. The most likely reason is that the dispatchers do not have access to real-time traffic information in the dispatching centers.

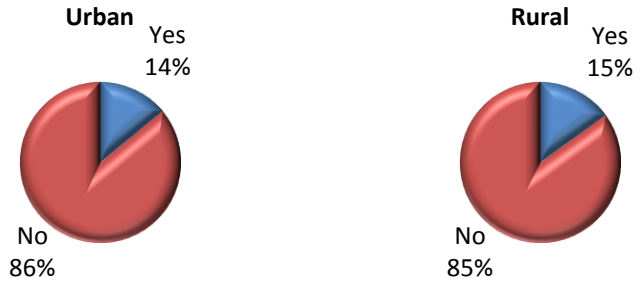


Figure 2.5 – Do you consider traffic conditions when selecting a vehicle to dispatch?

2.1.6 Do dispatchers receive real-time traffic information in the dispatch center?

None of the respondents reported that they had access to real-time traffic information in the dispatch center. This is consistent with the interviews we held with local dispatchers, who stated that the dispatchers are largely unaware of existing traffic conditions and congestion. The primary source for traffic information appears to be information relayed by the emergency responders in the field.

2.1.7 Would real-time traffic information be helpful to dispatching?

Dispatchers were asked if having access to real-time traffic information in the dispatch center would be helpful to the dispatching process. 72% of urban dispatchers responded that it would be “very helpful” or “helpful” while only 54% of rural dispatchers said the same.

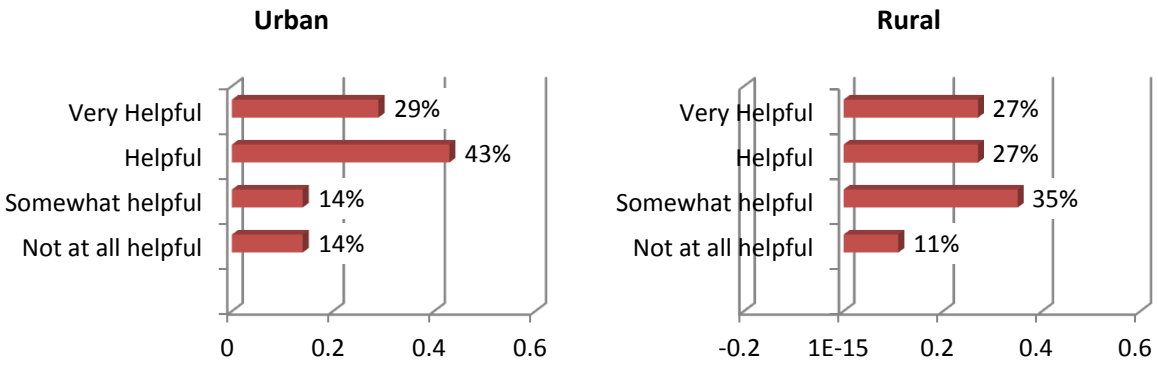


Figure 2.6 – Would real-time traffic information be helpful when dispatching emergency units?

2.1.8 Do dispatchers alert emergency units to congestion in their area?

Dispatchers were asked whether they ever alert emergency units to congestion in their area. Despite the fact that none of the respondents said they have access to real-time traffic data, over 50% of dispatchers said that they do, at least on occasion, alert units in the field to traffic congestion in their vicinity. Based on other survey results, it is assumed that most of this information is provided by other units in the field.

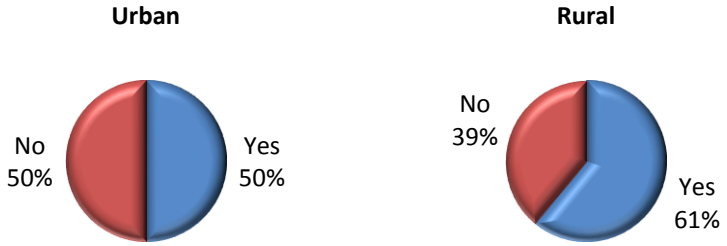


Figure 2.7 – Do you ever alert emergency response units to traffic congestion in their area?

2.1.9 Quality of information provided by 9-1-1 callers

In interviews emergency responders expressed some frustration with the quality of information provided by dispatchers, both with respect to the location and nature of emergencies. Dispatchers indicated in interviews that they are usually just relaying information provided by 9-1-1 callers and cannot always verify its accuracy. The survey asked dispatchers to rate the accuracy of information provided by 9-1-1 callers:

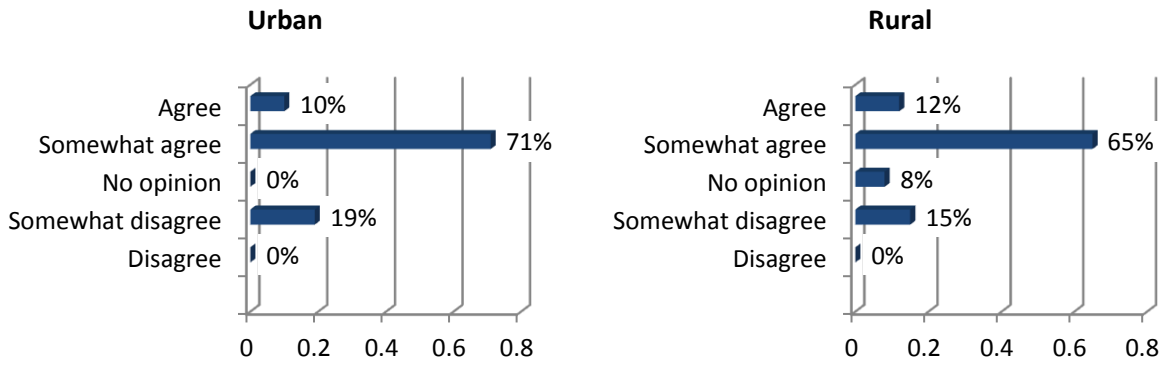


Figure 2.8 – Callers to 9-1-1 provide accurate information concerning the *location* of the emergency?

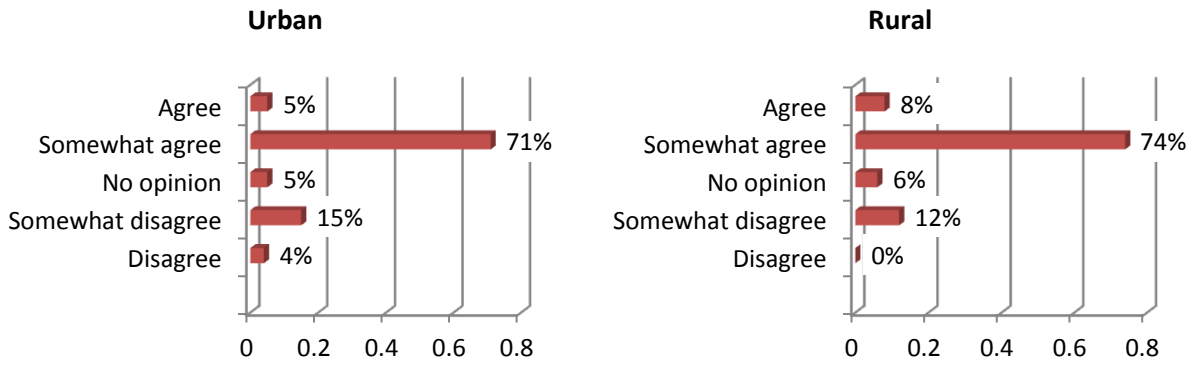


Figure 2.9 – Callers to 9-1-1 provide accurate information concerning the *nature* of the emergency?

Over 75% of respondents stated that they either 'agree' or 'somewhat agree' with the statements that the information provided 9-1-1 callers regarding the location and nature of emergencies is accurate. Less than 20% answered 'somewhat disagree' or 'disagree', reflecting general confidence in the information provided.

2.1.10 Would public education about how to provide accurate information to dispatchers reduce emergency response times?

Dispatchers were asked whether they believed public education about how to provide accurate information to 9-1-1 call takers and emergency dispatchers would help to decrease response times to emergency scenes. Despite the fact that they generally felt that the public provides accurate information, 100% or urban dispatchers and 88% of rural dispatchers either 'agreed' or 'somewhat agreed' that some type of public education could help reduce response times.

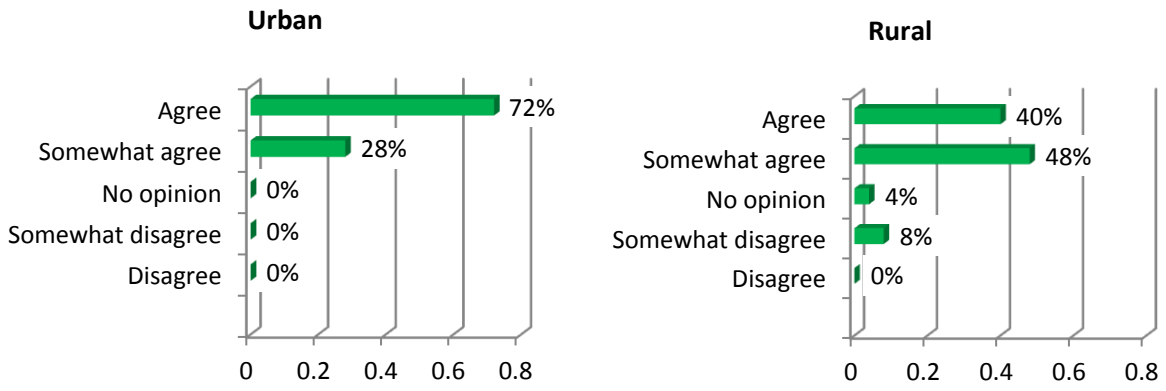


Figure 2.10 – Public education about how to provide accurate information to dispatchers would help to decrease response times to emergency scenes

2.1.11 Impacts of automatic crash notification systems on emergency response

Dispatchers were asked whether they felt automatic crash notification systems such as On-Star would have a beneficial effect on the timeliness of emergency response. Large majorities of both urban and rural dispatchers felt that it would.

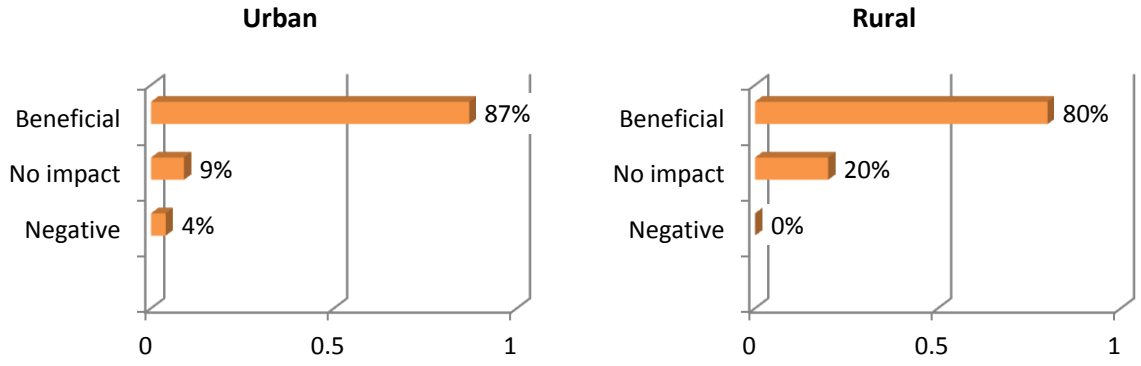


Figure 2.11 – Do you feel that Automatic Crash Notification systems (e.g., OnStar) will have a beneficial, negative, or no impact on the timeliness of EMS response?

2.1.12 Accuracy of cell phone location information

Dispatchers were asked whether 9-1-1 caller location information provided by cell phone companies is accurate. In interviews, some dispatchers had expressed frustration with the quality of the cell phone location data provided. At times the location information was inaccurate or would merely provide the location of the nearest cellular tower. This concern was confirmed in the survey, more so among urban dispatchers, 62% of whom said that cell phone location information is correct only some of the time or rarely. By contrast, 60% of rural dispatchers said cell phone location information is accurate always or most of the time.

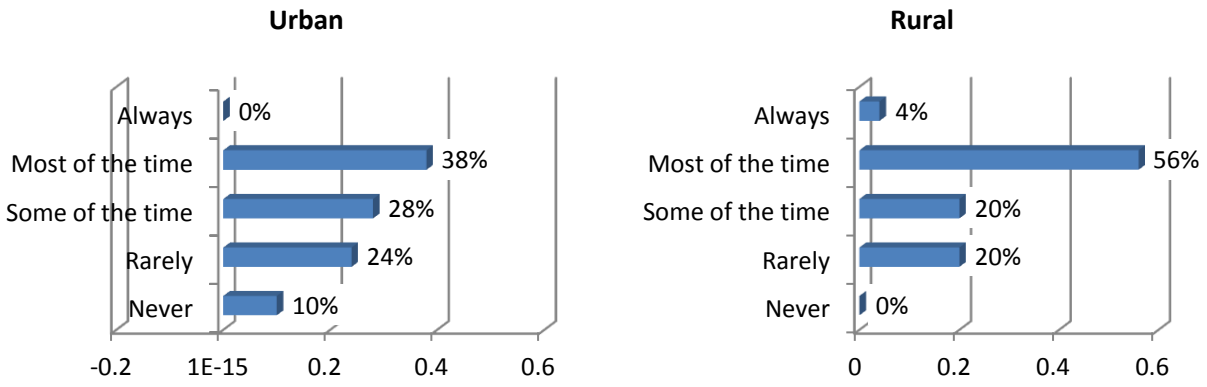


Figure 2.12 – When the caller is using a cell phone, the location information provided by the cell phone carrier is accurate

2.1.13 Training for large-scale emergencies

Since one of the broader goals of this research program is to model the performance of emergency response units in large-scale emergencies, we asked dispatcher whether they have received training to deal with large scale emergencies (e.g., natural disasters or evacuations) and whether their agency drills/trains for such emergencies. The response in both urban and rural areas was that most agencies do train and practice for large scale emergencies.

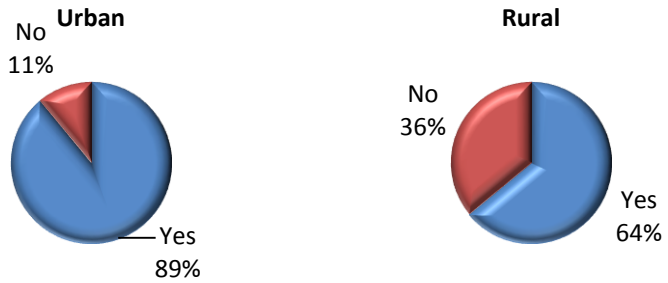


Figure 2.13 – Have you received training to operate during large-scale emergencies?

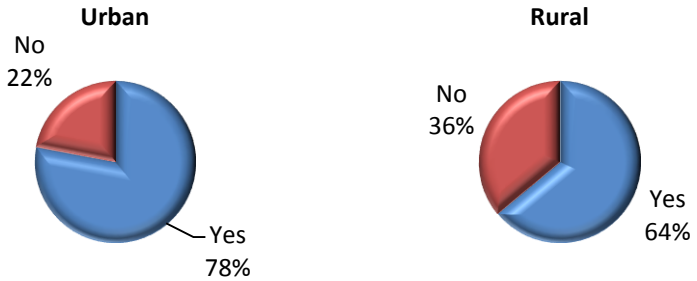


Figure 2.14 – Does your agency drill/train to prepare for large-scale emergencies?

2.1.14 Suggestions for Improving Dispatching

Dispatchers were asked to name two enhancements they felt would most enhance their current dispatch process. The most common responses are listed below. The most commonly suggested enhancement was the deployment of automatic vehicle location systems (AVL) which would allow dispatchers to track the location of units in the field. Other common suggestions included improved caller location information for both cell phone and voice-over-IP (VOIP) systems, more efficient call transfers from the 9-1-1 centers to the secondary agencies, and consolidating police/fire/rescue dispatch systems. Rural dispatchers also cited the need for better CAD systems and installation of mobile data terminals in the response units. Having real-time traffic information available in the dispatch center ranked very low in both urban and rural agencies. Traffic congestion was generally not viewed as a major concern among the dispatchers surveyed.

Table 2.1 - Suggested Enhancements (most suggested to least suggested)

Urban Dispatchers	Rural Dispatchers
Automatic Vehicle Location (AVL)	Automatic Vehicle Location (AVL)
Better 9-1-1 call transfer	Consolidated fire/police/rescue dispatch
Improved caller ID for VOIP services	Improved caller location for cell phones
Improved caller location for cell phones	Mobile Data Terminals in vehicles
Consolidated fire/police/rescue dispatch	Better CAD system
Public education	Better 9-1-1 call transfer
Better CAD system	Improved training
Improved training	Improved caller ID for VOIP services
Multi-jurisdictional 9-1-1 center	More dispatchers
Real-time traffic information	Real-time traffic information
Upgraded equipment (general)	More dispatchers

3. DISCUSSION

3.1 Summary of Results Related to Traffic Congestion

The survey results lead to several interesting conclusions as they relate to traffic congestion and emergency response:

- A majority of dispatchers, even those who work during peak traffic periods in urban areas, do not perceive traffic congestion to be a significant problem that causes increased emergency response times. Over 90% of dispatchers said that emergency vehicles are impeded by congestion only 'some of the time' or 'rarely'.

- None of the dispatchers who responded to the survey have access to real-time traffic information in their dispatch center. Only about 15% of dispatchers say that they consider current traffic conditions when dispatching a vehicle.

- A majority of dispatchers felt that having access to real-time traffic information would be helpful to the dispatching process. 72% of urban dispatchers felt it would be helpful.

- The improvements dispatchers felt would most benefit the dispatching process related to:

    - In-vehicle equipment such as automatic vehicle location (AVL) systems so that they can better track units in the field,

    - Improved coordination between dispatching agencies, in particular smoother transfer of calls from primary 9-1-1 call centers (PSAPs) to secondary dispatch centers, and

    - Improved accuracy for the location of 9-1-1 callers, particularly those using cell phones and voice-over-IP (VOIP) services.

- Access to real-time traffic information ranked low on the list of improvements most commonly recommended by dispatchers. Addressing traffic congestion does not appear to be a high priority for most dispatching agencies.

The reported lack of access to real-time traffic information was not unexpected, given that there is currently very limited real-time traffic information available in Alabama. The systems required to collect and disseminate that information are only now being brought on line. And if dispatchers do not have access to real-time traffic information they are less likely to perceive congestion as a problem. The broader concern for this study is that dispatchers do not have access to either information or systems that would allow them to manage a large scale emergency that involve severe traffic congestion or congestion over a broad area.

3.2 Comparison to the Results of the Emergency Responders Survey

The design of the modern, centralized dispatch center offers many benefits in terms of improved communication and cooperation among response agencies. However, one issue that still remains unresolved is the disconnect between dispatching decisions and conditions in the field. The full results of the emergency responder survey (also being performed under the UAB UTC) have not yet been

published. This report will be updated when those results become available. There are, however, preliminary results available that allow us to make some comparisons.

- While approximately 60% of emergency responders reported that they encounter traffic congestion during an emergency call only 'sometimes' or 'rarely', over 90% of dispatchers believed that responders encounter congestion only 'sometimes' or 'rarely'. This would indicate that congestion is a more common issue than dispatchers are aware.

- Only 12% of emergency responders reported using ALDOT web-cams for information on traffic conditions. Only 7% of dispatchers reported the same.

- 50% of dispatchers in urban areas and over 60% in rural areas report that they have provided information in congestion to units in the field. Only 28% of emergency responders stated that they have received congestion information from a dispatcher.

- Similar percentages of dispatchers and responders (about 86%) felt that automatic crash notifications systems such as On-Star will help to reduce emergency response times.

As more information becomes available these comparisons will be expanded.

APPENDIX A

DISPATCHER SURVEY FORM

UAB EMERGENCY DISPATCHER SURVEY

This survey is being conducted by the UAB University Transportation Center as part of a federally funded study to identify ways to improve response times for emergency services. We greatly appreciate your input.

What is your year of birth (yyyy)? ☐

Describe your occupation (check all that apply)

- ☐ EMS dispatcher
- ☐ Police dispatcher
- ☐ Fire/Rescue dispatcher
- ☐ Dispatching Supervisor
- ☐ 9-1-1 Director/Administrator/Coordinator
- ☐ Other

For which fire/police/EMS/dispatch agency do you work?

Does your department serve a mostly urban or rural population?

- ○ Mostly urban
- ○ Mostly rural

What hours do you typically work for your dispatching job (e.g., 6:00 AM to 2:00 PM)? ☐

What days of the week do you typically work (dispatching job only)?

- ○ Weekdays (Mon-Fri)
- ○ Weekends (Sat-Sun)
- ○ Both weekdays and weekends

Does your dispatch center serve multiple fire/police/EMS jurisdictions?

- Yes
- No

Does your agency use a computer aided dispatch system (CAD)?

- Yes
- No

On a typical shift, how many EMS calls do you personally dispatch? 0 to 5

Did you receive training as part of your dispatching job?

- Yes
- No

Has any part of your dispatcher training taught you strategies to deal with traffic congestion?

- Yes
- No

Are you EMD certified?

- Yes
- No

How often are emergency vehicles in your jurisdiction impeded by traffic congestion when responding to a call?

- Always
- Most of the time
- Some of the time
- Rarely
- Never

Traffic congestion is a significant problem that causes increased emergency response times in our jurisdiction.

- Agree
- Somewhat agree
- No opinion
- Somewhat disagree
- Disagree

Do you take into account traffic conditions when choosing which unit to dispatch?

- Yes
- No

Does your CAD system take into account traffic conditions when selecting a unit to dispatch?

- Yes
- No
- Don't Use CAD System

Would real-time information on traffic conditions be helpful to you when dispatching emergency units?

- Very helpful
- Helpful
- Somewhat helpful
- Not at all helpful

Is your agency made aware of road construction and potential lane blockages (e.g., utility work) in advance?

- Almost always
- Sometimes
- Rarely
- Never

Would knowledge of road construction and lane blockages be helpful to you when dispatching emergency units?

- Very helpful
- Helpful
- Somewhat helpful
- Not at all helpful

When the caller is using a cell phone, the location information provided by the cell phone carrier is accurate.

- Always
- Most of the time
- Some of the time
- Rarely
- Never

Does your agency use automatic vehicle location (AVL) to track your emergency vehicles?

- Yes
- No

If your agency uses AVL, do you use this information when selecting a unit to dispatch?

- Yes
- No
- Don't use AVL

If your agency does not currently use AVL, are there plans to implement it in the future?

- Yes
- No

Does your agency receive real-time traffic information?

- Yes
- No

If you answered yes to question 23, do you use real-time traffic information in your dispatch process?

- Yes
- No

If you answered yes to question 24, describe how real-time traffic information is used in your dispatch process.

Do you ever alert emergency response units to traffic congestion in their area?

- Yes
- No

How long is the average dispatch time for EMS calls (from call receipt to unit dispatch)?

- less than 30 seconds
- 30 sec. - 1 minute
- 1 - 2 minutes
- 2 - 3 minutes
- >3 minutes

Callers to emergency services provide accurate information regarding the LOCATION of the emergency.

- Agree
- Somewhat agree
- No opinion
- Somewhat disagree
- Disagree

Callers to emergency services provide accurate information regarding the NATURE of the emergency.

- Agree
- Somewhat agree
- No opinion
- Somewhat disagree
- Disagree

Public education about how to provide accurate information to emergency dispatchers would help to decrease response times to emergency scenes.

- Agree
- Somewhat agree
- No opinion
- Somewhat disagree
- Disagree

Does your agency use ALDOT or local webcams to determine if certain routes are blocked by traffic congestion or trains?

- Yes
- No

There is good communication among emergency agencies in my area.

- Agree
- Somewhat agree
- No opinion
- Somewhat disagree
- Disagree

Better communication among emergency agencies in my area would lead to improved repsonse times.

- Agree
- Somewhat agree
- No opinion
- Somewhat disagree
- Disagree

Have you received training to operate during large scale emergencies (e.g., natural disasters or evacuations)?

- Yes
- No

Does your agency drill/train to prepare for large scale emergencies?

- Yes
- No

My agency is equipped and prepared to handle large scale emergencies.

- Agree
- Somewhat Agree
- No Opinion
- Somewhat Disagree
- Disagree

Do you feel that Automatic Crash Notification systems (e.g., OnStar) will have a beneficial, negative, or no impact on the timeliness of EMS response?

- Beneficial
- Negative
- No Impact

List two improvements to the current dispatch process that you believe would most enhance the effectiveness of your emergency response system.

Please enter your e-mail address (optional).

Thank you very much for your time. Please use the space below for any additional comments.

0

Submit

APPENDIX B

SURVEY RESPONSES

UAB EMERGENCY DISPATCHER SURVEY

This survey is being conducted by the UAB University Transportation Center as part of a federally funded study to identify ways to improve response times for emergency services. We greatly appreciate your input.

What is your year of birth (yyyy)? [ ]

Describe your occupation **(check all that apply)**

- ☐ EMS dispatcher **[50%]**
- ☐ Police dispatcher **[34%]**
- ☐ Fire/Rescue dispatcher **[43%]**
- ☐ Dispatching Supervisor **[11%]**
- ☐ 9-1-1 Director/Administrator/Coordinator **[14%]**
- ☐ Other **[6%]**

For which fire/police/EMS/dispatch agency do you work?

Multiple Responses

Does your department serve a mostly urban or rural population?

- ○ Mostly urban **[45%]**
- ○ Mostly rural **[55%]**

What hours do you typically work for your dispatching job (e.g., 6:00 AM to 2:00 PM)? Varies

What days of the week do you typically work (dispatching job only)?

- ○ Weekdays (Mon-Fri) **[20%]**
- ○ Weekends (Sat-Sun) **[0%]**
- ○ Both weekdays and weekends **[80%]**

Does your dispatch center serve multiple fire/police/EMS jurisdictions?

- Yes **[61%]**
- No **[39%]**

Does your agency use a computer aided dispatch system (CAD)?

- Yes **[79%]**
- No **[21%]**

On a typical shift, how many EMS calls do you personally dispatch? 0 to 5

Did you receive training as part of your dispatching job?

- Yes **[98%]**
- No **[2%]**

Has any part of your dispatcher training taught you strategies to deal with traffic congestion?

- Yes **[23%]**
- No **[77%]**

Are you EMD certified?

- Yes **[59%]**
- No **[41%]**

How often are emergency vehicles in your jurisdiction impeded by traffic congestion when responding to a call?

- Always **[0%]**
- Most of the time **[2%]**
- Some of the time **[48%]**
- Rarely **[48%]**
- Never **[2%]**

Traffic congestion is a significant problem that causes increased emergency response times in our jurisdiction.

- Agree **[6%]**
- Somewhat agree **[26%]**
- No opinion **[20%]**
- Somewhat disagree **[15%]**
- Disagree **[33%]**

Do you take into account traffic conditions when choosing which unit to dispatch?

- Yes **[15%]**
- No **[85%]**

Does your CAD system take into account traffic conditions when selecting a unit to dispatch?

- Yes **[0%]**
- No **[82%]**
- Don't Use CAD System **[18%]**

Would real-time information on traffic conditions be helpful to you when dispatching emergency units?

- Very helpful **[28%]**
- Helpful **[21%]**
- Somewhat helpful **[37%]**
- Not at all helpful **[13%]**

Is your agency made aware of road construction and potential lane blockages (e.g., utility work) in advance?

- Almost always **[59%]**
- Sometimes **[39%]**
- Rarely **[2%]**
- Never **[0%]**

Would knowledge of road construction and lane blockages be helpful to you when dispatching emergency units?

- Very helpful **[57%]**
- Helpful **[28%]**
- Somewhat helpful **[15%]**
- Not at all helpful **[0%]**

When the caller is using a cell phone, the location information provided by the cell phone carrier is accurate.

- Always **[1%]**
- Most of the time **[49%]**
- Some of the time **[23%]**
- Rarely **[23%]**
- Never **[4%]**

Does your agency use automatic vehicle location (AVL) to track your emergency vehicles?

- Yes **[28%]**
- No **[72%]**

If your agency uses AVL, do you use this information when selecting a unit to dispatch?

- Yes **[17%]**
- No **[13%]**
- Don't use AVL **[70%]**

If your agency does not currently use AVL, are there plans to implement it in the future?

- Yes **[54%]**
- No **[46%]**

Does your agency receive real-time traffic information?

- Yes **[0%]**
- No **[100%]**

If you answered yes to question 24, do you use real-time traffic information in your dispatch process?

- Yes **[0%]**
- No **[100%]**

If you answered yes to question 24, describe how real-time traffic information is used in your dispatch process.

Do you ever alert emergency response units to traffic congestion in their area?

- Yes **[57%]**
- No **[43%]**

How long is the average dispatch time for EMS calls (from call receipt to unit dispatch)?

- less than 30 seconds **[22%]**
- 30 sec. - 1 minute **[53%]**
- 1 - 2 minutes **[19%]**
- 2 - 3 minutes **[2%]**
- >3 minutes **[4%]**

Callers to emergency services provide accurate information regarding the LOCATION of the emergency.

- Agree **[7%]**
- Somewhat agree **[71%]**
- No opinion **[7%]**
- Somewhat disagree **[17%]**
- Disagree **[0%]**

Callers to emergency services provide accurate information regarding the NATURE of the emergency.

- Agree **[6%]**
- Somewhat agree **[72%]**
- No opinion **[7%]**
- Somewhat disagree **[13%]**
- Disagree **[2%]**

Public education about how to provide accurate information to emergency dispatchers would help to decrease response times to emergency scenes.

- Agree **[74%]**
- Somewhat agree **[20%]**
- No opinion **[2%]**
- Somewhat disagree **[4%]**
- Disagree **[0%]**

Does your agency use ALDOT or local webcams to determine if certain routes are blocked by traffic congestion or trains?

- Yes **[2%]**
- No **[98%]**

There is good communication among emergency agencies in my area.

- Agree **[33%]**
- Somewhat agree **[47%]**
- No opinion **[9%]**
- Somewhat disagree **[11%]**
- Disagree **[0%]**

Better communication among emergency agencies in my area would lead to improved response times.

- Agree **[52%]**
- Somewhat agree **[26%]**
- No opinion **[20%]**
- Somewhat disagree **[0%]**
- Disagree **[2%]**

Have you received training to operate during large scale emergencies (e.g., natural disasters or evacuations)?

- Yes **[74%]**
- No **[26%]**

Does your agency drill/train to prepare for large scale emergencies?

- Yes **[71%]**
- No **[29%]**

My agency is equipped and prepared to handle large scale emergencies.

- Agree **[32%]**
- Somewhat Agree **[43%]**
- No Opinion **[11%]**
- Somewhat Disagree **[7%]**
- Disagree **[7%]**

Do you feel that Automatic Crash Notification systems (e.g., OnStar) will have a beneficial, negative, or no impact on the timeliness of EMS response?

- Beneficial **[84%]**
- Negative **[2%]**
- No Impact **[14%]**

List two improvements to the current dispatch process that you believe would most enhance the effectiveness of your emergency response system.

Thank you very much for your time. Please use the space below for any additional comments.

0

Submit

Evaluation of Incident and Emergency Management Options in the Birmingham Region

Final Report

UAB UTC Domain 2: Development of a Dynamic Traffic Assignment and Simulation Model for Incident and Emergency Management Applications in the Birmingham Region (Aim 4)

Prepared By:

Virginia Sisiopiku, PhD, Ozge Cavusoglu, MSCE, and Andrew Sullivan, MSCE
Department of Civil, Construction, and Environmental Engineering
University of Alabama at Birmingham

Natalia Ruiz Juri, PhD
Network Modeling Center, the University of Texas at Austin

Kyriacos Mouskos, PhD
City College of New York

Curtis Barrett
Vista Transportation Group, VTG, Inc.

Prepared for:

The UAB University Transportation Center

Birmingham, Alabama

DTRT06-G-0048

UAB UTC

September 2011

1. Report No.	2. Government Accession No.	3. Recipient Catalog No.
FHWA/CA/OR		

4 Title and Subtitle	5 Report Date
Evaluation of Incident, and Emergency Management Options in the Birmingham Region UAB UTC Domain 2: Development of a Dynamic Traffic Assignment and Simulation Model for Incident and Emergency Management Applications in the Birmingham Region, Aim 4.	September 2011
	6 Performing Organization Code
7. Author(s) Virginia P. Sisiopiku, Ozge Cavusoglu, Andrew J. Sullivan, Natalia Ruiz Juri, Kyriacos Mouskos, and Curtis Barrett,	**8. Performing Organization Report No.**
9 Performing Organization Name and Address University of Alabama at Birmingham 1075 13th Street South Birmingham, AL 35294-4554	**10 Work Unit No. (TRAIS)**
	11 Contract or Grant No.
12 Sponsoring Agency Name and Address UAB University Transportation Center 1530 3rd Avenue South Birmingham, AL 35294-2041	**13 Type of Report and Period Covered**
	14 Sponsoring Agency Code

15 Supplementary Notes

16 Abstract

Traffic crashes and other emergencies have impacts on traffic operations in transportation networks, often resulting in non-recurring congestion. Congestion, in turn, may impede the ability of EMS (Emergency Medical Services) to provide timely response to those in need of medical attention. Thus, it is important to understand the potential impacts of incidents and emergencies on traffic network operations and develop response strategies with a potential of minimizing such impacts on traffic operations and the safety of the traveling public.

The work in this report investigated the impact of incidents of varying severity and duration on transportation network performance in the Birmingham area. The intensity and extent of the impact over space and time were assessed on the basis of average speeds. The analysis of various incident scenarios was performed using the Visual Interactive System for Transport Algorithms (VISTA) platform. Detailed models were developed to capture driver route choices in the event of an incident given availability of incident information (or the lack of). Moreover, first responders travel times to the scene of the incident were collected to identify best units for responding of the incident, in an effort to improve current dispatching practices. Finally, a secondary incident on the EMS to the hospital was considered to further demonstrate the superiority of Dynamic Traffic Assignment (DTA) over traditional static assignment methods in capturing dynamically changing traffic conditions.

The report summarizes pertinent literature, discusses the study methodology and provides details on the simulation/optimization model used in the analysis, presents and interprets study results, and summarizes major findings and conclusions.

The study provides insights on the impacts of incidents on traffic operations and emergency response using the I-65 corridor in Birmingham as a test bed. The developed tool is expected to benefit the transportation planners, traffic engineers, emergency responders, and policy makers by allowing them to assess various response strategies to major incidents and emergencies and select the ones that minimize their potential impacts.

17 Key Words	18 Distribution Statement
Traffic Incident Management, EMS response, Dynamic Traffic Assignment (DTA), VISTA, Birmingham, AL, I-65.	No restrictions.

19 Security Classification (of this report)	20 Security Classification (of this page)	21 No. of pages	22 Price
Unclassified	Unclassified	105+vii	

TABLE OF CONTENTS

LIST OF FIGURES ..... **V**

LIST OF TABLES ..... **VII**

ABSTRACT ..... **VIII**

1. INTRODUCTION **1**

1.1. Study Objectives 1

2. LITERATURE REVIEW **2**

2.1. Traffic Incident Management Background 2

2.1.1. Benefits of Traffic Incident Management *3*

2.1.2. Stages of Traffic Incident Management *4*

2.1.3. Evaluation the Effectiveness of Traffic Incident Management *13*

2.2. Dynamic Traffic Assignment Background 15

2.2.1. Dynamic Traffic Assignment Applications in Traffic Incident Management *16*

3. METHODOLOGY **18**

3.1. Study Approach 18

3.2. Simulation-based DTA Model Selection 18

3.3. Development of Simulation Model for the Birmingham Region 19

3.4. Study Site 21

3.5. Simulation Study Scenarios 23

4. RESULTS **25**

4.1. Base Case Scenario Results – Scenario 1 25

4.2. Primary Incident Scenario Results – Scenario 2 (S2) 27

4.2.1. Primary Incident Results–No Information Provision– Scenario 2-S *27*

4.2.2. Primary Incident Results - With Information Provision – Scenario 2-D *43*

4.3. Secondary Incident Scenario Results – Scenario 3 46

5. STUDY CONCLUSIONS **49**

REFERENCES **51**

APPENDIX: DETAILED RESULTS OF SIMULATION RUNS **56**

15-min Speed Results by Sub Segment 57

15-min Speed Profiles by Sub Segment ……..……..……70
Comparison of Results from Study Scenarios ……..…..……80
Comparison of Base Case, S2-11S and S2-12S …….82
Comparison of Base Case, S2-21S and S2-22S ……...82
Comparison of Base Case, S2-31S and S2-32S …….84
Comparison of Base Case, S2-11D and S2-12D …….87
Comparison of Base Case, S2-21D and S2-22D …….90
Comparison of Base Case, S2-31D and S2-32D …….92
Comparison of Base Case, S2-11S and S2-11D …….93
Comparison of Base Case, S2-12S and S2-12D …….93
Comparison of Base Case, S2-13S and S2-13D……..95
Comparison of Base Case, S2-21S and S2-21D …….97
Comparison of Base Case, S2-22S and S2-22D …….99
Comparison of Base Case, S2-31S and S2-31D ……..…101
Comparison of Base Case, S2-32S and S2-32D……103

LIST OF FIGURES

FIGURE 2-1 Benefits from TIM Strategies Considering Different Stakeholders 3

FIGURE 2-2 Traffic Incident Management Process 5

FIGURE 2-3 List of Traffic Incident Responders 7

FIGURE 2-4 Typical Incident Scene 9

FIGURE 2-5 Real-time Traveler Information Program 12

FIGURE 2-6 FHWA Suggested Performance Measurement 14

FIGURE 3-1 Birmingham Network Coded in VISTA 19

FIGURE 3-2 Birmingham Fire and Police Stations in the VISTA Model 20

FIGURE 3-3 Medical Facilities in the VISTA Model 20

FIGURE 3-4 Incident Rates by Time of Day at the I-65/I-459 Junction 21

FIGURE 3-5 Primary and Secondary Incident Locations 22

FIGURE 4-1 Base Case Scenario Segment Speeds 25

FIGURE 4-2 Base Case Scenario 15-min Segment Speeds (Exit 260 –Exit256) 26

FIGURE 4-3 Base Case 15-min Segment Speeds (Exit 255 –Exit252) 26

FIGURE 4-4 Base Case 15-min Segment Speeds (Exit 250 –Exit247) 27

FIGURE 4-5 Segment Speeds in S2-11S Scenario 28

FIGURE 4-6 S2-11S 15-min Segment Speeds (Exit 260 –Exit 256) 28

FIGURE 4-7 S2-11S 15-min Segment Speeds (Exit 255 –Exit252) 29

FIGURE 4-8 S2-11S 15-min Segment Speeds (Exit 250 –Exit 247) 29

FIGURE 4-9 Segment Speeds in S2-12S Scenario 30

FIGURE 4-10 S2-12S 15-min Segment Speeds (Exit 260 –Exit 256) 31

FIGURE 4-11 S2-12S 15-min Segment Speeds (Exit 255 –Exit 252) 31

FIGURE 4-12 S2-12S 15-min Segment Speeds (Exit 250 –Exit 247) 32

FIGURE 4-13 Segment Speeds in S2-21S Scenario..... 32

FIGURE 4-14 S2-21S 15-min Segment Speeds (Exit 260 –Exit256) 33

FIGURE 4-15 S2-21S 15-min Segment Speeds (Exit 255 –Exit 252) 33

FIGURE 4-16 S2-21S 15-min Segment Speeds (Exit 250 –Exit 247) 34

FIGURE 4-17 Segment Speeds in S2-22S Scenario..... 34

FIGURE 4-18 S2-22S 15-min Segment Speeds (Exit 260 –Exit 256) 35

FIGURE 4-19 S2-22S 15-min Segment Speeds (Exit 255 –Exit 252) 35

FIGURE 4-20 S2-22S 15-min Segment Speeds (Exit 250 –Exit 247) 36

FIGURE 4-21 Segment Speeds in S2-31S Scenario..... 37

FIGURE 4-22 S2-31S 15-min Segment Speeds (Exit 260 –Exit 256) 37

FIGURE 4-23 S2-31S 15-min Segment Speeds (Exit 255 –Exit 252) 38

FIGURE 4-24 S2-31S 15-min Segment Speeds (Exit 250 –Exit 247) 38

FIGURE 4-25 Segment Speeds in S2-32S Scenario..... 39

FIGURE 4-26 S2-32S 15-min Segment Speeds (Exit 260 –Exit 256) 39

FIGURE 4-27 S2-32S 15-min Segment Speeds (Exit 255 –Exit 252) 40

FIGURE 4-28 S2-32S 15-min Segment Speeds (Exit 250 –Exit 247) 40

FIGURE 4-29 Comparison of Base Case, S2-22S and S2-22D: Alford Ave/Exit 254 45

FIGURE 4-30 EMS Vehicle Path to UAB Hospital in S3-22S 47

FIGURE 4-31 EMS Vehicle Path to UAB Hospital with Diversion in S3-22D 47

LIST OF TABLES

TABLE 2-1 Agencies involved in Scene Management and Traffic Control 8

TABLE 3-1 I-65 Study Corridor Segments 22

TABLE 3-2 Percentages in the Study Scenarios 24

TABLE 3-3 Case Study Scenarios 24

TABLE 4-1 Comparison of Average Speed Results without Information Provision (mph) 41

TABLE 4-2 Comparison of Delay Results without Information Provision (min) 42

TABLE 4-3 First Emergency Responders Arrival Times and Travel Times 43

TABLE 4-4 Comparison of Average Speed Results With Information Provision (mph) 44

TABLE 4-5 Comparison of Delay Results with Information Provision (min) 46

TABLE 4-6 EMS Vehicle Travel Times to the Hospital 48

ABSTRACT

Traffic crashes and other emergencies have impacts on traffic operations in transportation networks, often resulting in non-recurring congestion. Congestion, in turn, may impede the ability of EMS (Emergency Medical Services) to provide timely response to those in need of medical attention. Thus, it is important to understand the potential impacts of incidents and emergencies on traffic network operations and develop response strategies with a potential of minimizing such impacts on traffic operations and the safety of the traveling public.

The work in this report investigated the impact of incidents of varying severity and duration on transportation network performance in the Birmingham area. The intensity and extent of the impact over space and time were assessed on the basis of average speeds. The analysis of various incident scenarios was performed using the Visual Interactive System for Transport Algorithms (VISTA) platform. Detailed models were developed to capture driver choices in the event of an incident given familiarity with network alternative routes (or the lack of familiarity). Moreover, first responders travel times to the scene of the incident were collected to identify best units for responding of the incident, in an effort to improve current dispatching practices. Finally, a secondary incident on the EMS to the hospital was considered to further demonstrate the superiority of Dynamic Traffic Assignment (DTA) over traditional static assignment methods in capturing dynamically changing traffic conditions.

The report summarizes pertinent literature, discusses the study methodology and provides details on the simulation/optimization model used in the analysis, presents and interprets study results, and summarizes major findings and conclusions.

The study provides insights on the impacts of incidents on traffic operations and emergency response using the I-65 corridor in Birmingham as a test bed. The developed tool is expected to benefit the transportation planners, traffic engineers, emergency responders, and policy makers by allowing them to assess various response strategies to major incidents and emergencies and select the ones that minimize their potential impacts.

Keywords: Traffic Incident Management, EMS response, Dynamic Traffic Assignment (DTA), VISTA, Birmingham, Alabama, I-65.

1. INTRODUCTION

Traffic incidents and other emergencies are highly likely to impact transportation network performance when they occur. Increase in delays, reduction in traveling speeds and formation of queues are commonly observed upstream of incident sites. Reduction in supply associated with lane closures and/or increase in demand as a result of traffic bottlenecks may also impede the ability of first responders to reach the scene of the incident and transport victims to emergency rooms in an rapid and efficient manner.

Understanding the impacts of incidents on traffic operations is very important as it enables authorities to: a. better manage the traffic so that it minimizes undesirable impacts on traffic operations, and b. manage effectively the flow of first responders to/from the site of the incident. Lessons learned from past experiences confirm that in case of incidents or emergencies, effective real-time traffic management is essential to avoid deterioration of traffic conditions (Liu et al., 2007). Therefore, in support of incident management, there is a need for models which can capture the fast changing dynamic traffic conditions taking into consideration traffic management measures implemented to meet the management objectives stated above and potential infrastructure failures. It should be also stated that in the case of emergencies, drivers behaviors are also altered, which makes existing models not directly applicable. In order to address the above stated considerations, simulation-based Dynamic Traffic Assignment (DTA) models can be utilized in estimating time-varying network conditions by capturing fast changing dynamic traffic flows and route choice behavior (Sisiopiku et al., 2007a).

1.1. Study Objectives

The objective of this study was to demonstrate the use of simulation-based DTA applications as a tool for evaluating the impacts of incidents of varying duration and intensity on traffic operations. The work focused on the development of a comprehensive regional model of the Birmingham region in the VISTA model to be used as a training and evaluation test bed. Special attention was placed on optimizing decision-making in responding to traffic incidents in the Birmingham region.

2. LITERATURE REVIEW

2.1. Traffic Incident Management Background

As mentioned earlier, regardless their scales, incidents and emergencies have likely impacts on traffic flows, which can cause costly travel delays, secondary incidents, air pollution, and fuel waste. Since the 90s, more than 10 million vehicle crashes occur in the U.S. on an annual basis (Census Bureau, 2008). The National Traffic Incident Management Coalition (NTIMC) indicated that traffic incidents are the major contributor to congestion and congestion-related delays on the U.S. urban roads (NTIMC, 2006a). In 2009 alone, it is estimated that more than 4.8 billion travel hours and more than 3.9 billion gallons of gas were wasted due to congestion on the Nation's roads. The total congestion cost was $115 billion (Schrank et al., 2010), one fourth of which (25%) is directly linked to traffic crash-induced congestion.

According to Census Bureau reports, between 2006 and 2008, more than 120,000 Americans died and 7.4 million were injured in traffic incidents (Census Bureau, 2011). Besides, several hundreds of emergency responders are killed annually in struck-by incidents, where passing motorists hit responders at an incident scene. Last but not least, rapid emergency response to a scene of a crash and efficient transportation of victims to hospitals can have a significant impact on the patient's survivability and recovery from sustained injuries.

Thus, it is important to maximize the efficiency of roadway operations following an incident occurrence. One such strategy is the Traffic Incident Management (TIM) approach that aids in returning travel lanes to traffic as quickly as possible and enhancing safety for the traveling public as well as incident responders. The Federal Highway Administration (FHWA) defined TIM as "*a planned and coordinated program to detect and remove incidents and restore traffic capacity as safely and as quickly as possible*" (Carson, 2010).

There are two types of traffic incidents, namely predictable and unpredictable. While work zones, special events and adverse weather conditions are defined as predictable incidents; motor vehicle crashes, debris, hazardous spills, and disabled or abandoned vehicles on the road and other non-recurring conditions such as terrorist attacks or stray animals are classified under unpredictable incidents (TDOT, 2003).

Since the predictable incidents are known in advance, their impacts can be estimated ahead of time and adequate traffic incident management strategies can be implemented prior to and during the event to minimize their consequences on traffic operations. On the other hand, unpredictable traffic incidents are more complex as they may include different types of vehicles, occur at different locations, on a different day, at a different time throughout the day and require different agencies to respond. Therefore, each unpredictable incident needs a custom-tailored response (TDOT, 2003). The scope of this study is limited to unpredictable incidents which are referred to as "traffic incidents" herein.

Responding to a traffic incident requires a systematic, multi-agency effort using involving various resources namely transportation, fire and rescues, towing and recovery, law enforcement,

public safety communications and emergency medical services fields (Corbin, 2010). Each agency often has its own operational approach and response protocols, which often creates coordination and communication conflicts between agencies during an incident response (Feyen and Eseonu, 2009).

2.1.1. Benefits of Traffic Incident Management

The TIM programs aim to assist motorists and protect public health and safety, by conducting necessary investigations, minimizing travel delays, efficiently removing damaged vehicles or cargo, and returning the travel lanes to traffic as quickly as possible (TDOT, 2003). Thereby, it TIM is beneficial to traffic, economic, safety and environmental related concerns in the society. Figure 2-1 shows how various stakeholders can drive possible benefits from effective TIM strategies. NTIMC states that every minute that a freeway is blocked during peak periods leads to four minutes of travel delay after an incident is cleared. Decreasing incident related delays on roadways results in important savings (NTIMC, 2006b) and should be a priority for transportation professionals in traffic incident management programs.

	Firefighters	Law Enforcement	Emergency Medical Services	Private Sector Towing & Recovery; and Traffic Control Services	Transportation Agencies	Highway Users
Congestion Relief	●	●	●	●	●	●
Economic Savings	●	●	●	●	●	●
Fuel Savings	●	●	●	●	●	●
Personnel Savings	●	●	●			
Emissions Reductions						●
Crash / Secondary Crash Reductions	●	●	●	●	●	●
Faster Incident Detection, Verification, Dispatch & Response Time	●	●	●	●	●	●
Reduced Mortality	●	●	●		●	●
Reduced Morbidity	●	●	●		●	●
Increased Responder Safety	●	●	●	●	●	
Increased Customer Satisfaction	●	●	●	●	●	●

FIGURE 2-1 Benefits from TIM Strategies Considering Different Stakeholders (NTIMC, 2006b)

Improving the flow of traffic during and after an incident and reducing incident related travel delays through TIM is associated with economic and environmental benefits as they lead to reductions in fuel consumption, and vehicle emissions. Moreover, containing incident-related congestion helps improve roadway safety by preventing secondary crashes (NTIMC, 2006b).

The literature states that the likelihood of occurrence a secondary incident is 2 % to 15 % of that of initial incidents (Khattak et al., 2011) and every minute the initial incident persists, the potential for secondary crash occurrence increases by 2.8 %. Secondary incidents are typically attributed to sudden change in traffic conditions such as dramatic drops in travel speeds due to abrupt braking. Successful TIM programs aid in preventing secondary incidents by ensuring quick clearance of primary incidents and providing incident related information to travelers during their trips including rerouting.

Another issue of concern is that congestion resulting from traffic incidents could block emergency responders' access to incident scene, restricting their ability to provide timely response to those in need of medical attention. Rapid incident detection improves the incident response time as well as the potential of saving lives by transporting seriously injured victims to hospitals so that they can be treated within the 'golden hour' after the crash. Thus, successful TIM programs have significant benefits on public health and safety (NTIMC, 2006b).

Furthermore, TIM programs help to improve the safety of emergency responders at the incident scene through improvements in controlling traffic incident scenes, minimizing their exposure time, as well as establishing coordination and communication capabilities among agencies (NTIMC, 2006b).

2.1.2. Stages of Traffic Incident Management

The TIM process involves various necessary actions to help maintain the traffic flow as well as protect the public while providing quick clearance on the incident scene. Thus, an effective traffic incident response demonstrates both operational (action-based) and institutional (relation-based) characteristics. In general, operational characteristics deal with detection and verification, notification and response, traveler information, scene management and traffic control and, clearance and recovery. On the other hand, agency relations, training, communications, technology, resource availability and funding are points of interest of institutional characteristics in traffic incident management programs (Carson, 2010). A successful traffic incident response system requires an interaction between these functional areas as illustrated in Figure 2-2 (TDOT, 2003). However, TIM practitioners often encounter challenges in order to perform these duties (Carson, 2010).

The incidents in urban areas are usually first detected by the passing drivers. However, drivers may provide inaccurate incident information, as far as the severity or precise location of the incident are concerned, which in turn may misguide the responder personnel to dispatch unnecessary, inadequate or insufficient equipment to the incident scene. Enhancing roadway reference markers could help drivers in providing more accurate information about the incident location. In Ohio, every 0.2 miles, a roadway reference marker is provided to help motorists identifying the incident location accurately (Carson, 2010). Even so, the verification of the incident is required, especially when the detection is done by an untrained observer (Karl, 2007).

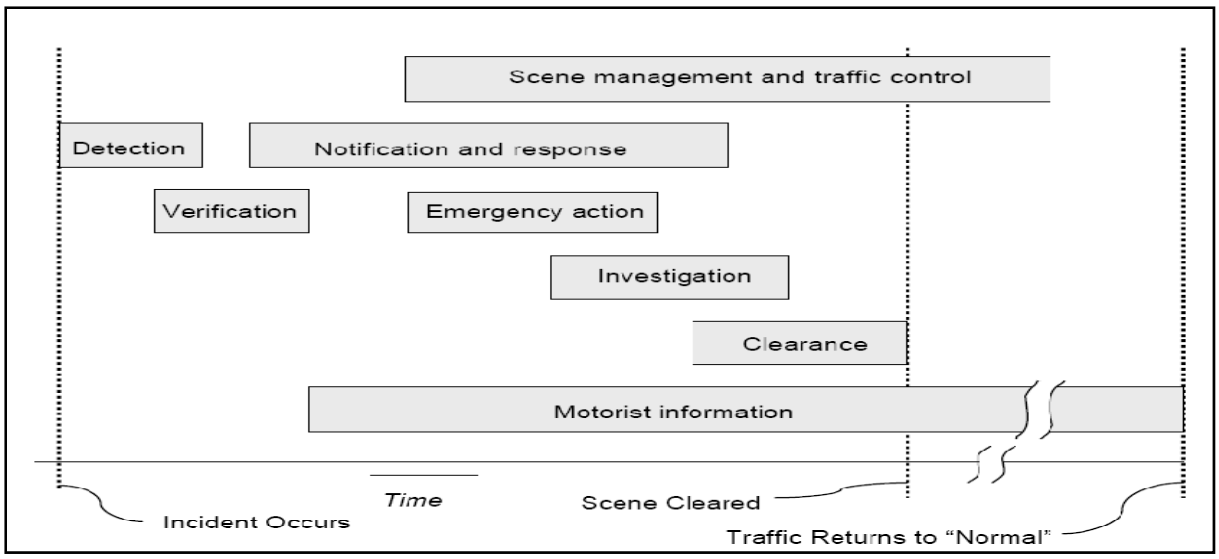


FIGURE 2-2 Traffic Incident Management Process (TDOT, 2003)

Incident verification refers to actions taken to verify the detail information, such as precise location and the nature of the incident. The information gathered in the verification step is used to notify the appropriate responder to dispatch the proper equipment to the incident scene (TDOT, 2003; Carson, 2010).

The most common detection-verification tool used in the United States is the combination of electronic loop detectors and closed-circuit television cameras (CCTV). Under this arrangement, incidents are detected by electronic loops whereas CCTV cameras assist in the verification process. Limitations of this approach include the CCTV camera operators' 'blank stare' syndrome, which is the inability of the operator in the verification of the incident, even if it is visible on the screen. Moreover, the coverage of CCTV cameras may be limited and unable to cover every incident on the roadways (Carson, 2010).

Faster detection provides faster medical attention to those injured in incidents. This becomes considerably important in rural areas, since the incidents may not be detected immediately after they happen (TDOT, 2003). Thus, enhanced 9-1-1 and automated positioning systems technologies can be utilized to provide accurate and rapid incident detection both in rural and urban areas. For example, in the Hudson Valley region in New York, the emergency patrol vehicles are equipped with in-car cameras to transfer real time information to responders to ensure dispatching the proper equipment in a timely manner to the incident scene (Carson, 2010).

2.1.2.1. Notification and Response

If the detection is done by trained personnel, the notification process may start right after the incident detection without the need to wait for the completion of the verification process (Karl, 2007). In case of an incident, law enforcement agencies are notified first through 9-1-1 calls along with the fire and rescue, and emergency medical services (EMS) (Carson, 2010). Transportation agencies are typically not notified by the incident management process, when incidents are simple enough to handle (Carson, 2010; TDOT, 2003). However, the number of

agencies included in the notification and response process increases, when the severity and complexity of incident increase (TDOT, 2003). A list of potential responders is shown in Figure 2-3 along with their responsibilities (Birenbaum et al., 2009).

When an incident creates severe conditions on the network, then the involvement of the transportation agencies is inevitable. This is because transportation agencies are qualified to take actions to manage the background traffic by setting appropriate traffic control devices (Brooke et al., 2004) and/or providing traveler information and guidance to assist motorists to navigate around the incident site.

An efficient incident response requires accurate information about the incident such as precise knowledge of its location, number and types of vehicles involved, number and severity of injuries, involvement of hazardous materials, etc (Carson, 2010). However, having accurate information about the incident cannot guarantee quick response, since the length of the response process depends heavily on dispatching efficiency as well as the time that emergency responders spend on the road to reach to the incident scene after they are notified (Feyen and Eseonu, 2009). It is of outmost importance to ensure appropriate and rapid EMS response to traffic incident sites as lives may depend on the response time (Carson, 2010). Therefore, in incident response, the information management has an important role (Carson, 2010) in providing quick, efficient and appropriate response by considering real-time traffic conditions and exchanging information between agencies (Brooke et al., 2004).

2.1.2.2. Traveler Information

Traveler information systems are responsible for gathering, analyzing, and disseminating reliable travel advisory and/or guidance information based on real time information about traffic conditions (TDOT, 2003). Management of information is not only needed in order to provide quick response to incidents but is also used to inform travelers about travel conditions and options as they approach the scene of the incident, or prior to their departures from their origins (Carson, 2010).

The process starts right after the verification of the incident and continues until traffic returns to normal flowing conditions. The information gathered during detection, verification and notification steps is analyzed and transmitted to the road users to inform them about the incident presence, and possible alternate routes (TDOT, 2003). Such input is aidful for some drivers to avoid the incident and reduce the chance of secondary crashes. Rerouting motorists around the affected site is also helpful in reducing the network-wide impacts of the incident. Variable Message Signs (VMS) and highway advisory radio (HAR) are the most popular outlets used in motorist information dissemination process (Feyen and Eseonu, 2009).

2.1.2.3. Scene Management and Traffic Control

The scene management and traffic control is the most challenging phase in incident management, since securing the incident scene and controlling its after-affect background traffic need a multi-action effort between agencies (TDOT, 2003). As illustrated in Figure 2-4, the listed agencies have different responsibilities in order to ensure the safety of a major-incident scene both for

Response Agency	Roles and Responsibilities
Law Enforcement (state patrols, sheriffs, local police departments)	• Assist in incident detection and verification • Determine severity of incident and condition of victims and relay information to dispatch • Isolate and secure incident scene • Provide emergency medical aid until help arrives • Serve as incident commander, as conditions warrant • Supervise scene clearance • Direct traffic • Conduct crash investigations
Fire Rescue (career and/or volunteer fire departments)	• Protect and contain incident scene • Suppress fire • Rescue crash victims from damaged vehicles and treat injuries • Arrange transportation for injured • Provide initial hazardous material (HazMat) response and request additional clean-up resources • Serve as incident commander, as conditions warrant • Assist in incident clearance
911 and Other Dispatch	• Receive 911 calls from land lines, cell phones, and call boxes • Dispatch appropriate response agencies
EMS	• Provide advanced emergency medical care • Determine destination and transportation requirements for injured • Coordinate evacuation with fire, police, ambulance, or airlift • Stabilize and transport incident victims
Department of Transportation (DOT) Personnel – Maintenance	• Provide initial and short-term traffic control • Provide special equipment or resources as requested • Contain minor spills if possible • Coordinate with law enforcement regarding alternate routes • Coordinate personnel resources for DOT • Assess infrastructure damage
DOT Personnel – Traffic Operations	• Assist in incident detection and verification • Operate intelligent transportation systems (ITS) field devices per approved response plans • Provide traveler information to public and media • Dispatch service patrols • Notify other agencies of incident as required
DOT Personnel – Construction	• Similar duties as DOT maintenance personnel, but within work zone • Coordinate with contractor for traffic control and repairs
Service Patrol (Public and Private)	• Assist in incident detection and verification • Secure incident scene • Assist with and relocate disabled vehicles • Provide emergency medical aid until help arrives • Provide containment of minor spills • Provide initial traffic control
Towing/Wrecker Services	• Protect victims' property and safely remove vehicles from the scene when authorized • Remove debris from roadway • Clean up minor vehicle spills • Provide transportation for uninjured vehicle occupants • Provide minor repairs on scene • Serve as incident commander as conditions change from rescue to recovery
Hazardous Material Responders	• Manage fluid spill cleanup
Media/Information Service Providers	• Distribute traveler information via radio, television, internet, and 511 telephone services • Provide real-time information • Provide advance information regarding planned events and proper procedures
Coroners/Medical Examiners	• Investigate fatalities

FIGURE 2-3 List of Traffic Incident Responders (Birenbaum et al., 2009)

traveling public and emergency responders (Feyen and Eseonu, 2009). Injured individuals need to be immediately attended to at the incident site, while the incident scene needs to become protected. Besides, the traffic flow needs to be managed as best as possible throughout the impacted corridor. It should be noted that the various agencies involved have different primary goals as highlighted in Table 2-1.

TABLE 2-1 Agencies involved in Scene Management and Traffic Control (Feyen & Eseonu, 2009)

Agency	**Primary Goal**
Department of Transportation	Minimize disruption to normal traffic flow (frequency and duration
Public Safety Personnel (Police, Highway patrol, etc)	Protect and serve the public
Fire Services	Contain fires and related hazards as well as prevent further damage
Emergency Medical Services	Provide appropriate and timely medical interventions (triage, treatment and transport)
Towing and Recovery	Recover vehicles and clear roadways
Media	Alert and inform public regarding current incidents

The complexity increases when multiple vehicles or specialty vehicles are involved in the traffic incident. For example, when a heavy vehicle is involved in a major incident, a plans should be formulated to clean the debris and the clearance could take several hours (DRI, 2010), especially if the truck happens to carry hazardous materials. Therefore, the effective site management relies on well-designed interagency coordination and communication as well as properly envisioned traffic control and management strategies (Carson, 2010). To ensure these, the incident itself needs to be assessed accurately and priorities should be well defined (TDOT, 2003).

Traffic control devices and strategies are used by transportation agencies to assist drivers and minimize the adverse impact of the traffic incident on network performance as well as provide a safe environment to responders at the incident scene (Carson, 2010). Figure 2-4 shows a typical incident scene (ODOT, 2007). In Brisbane City, Australia, the incident site is bordered by inner and outer cordons to increase safety both for emergency responders and traveling public. While the inner cordon is managed by police or fire agency, the outer cordon is being managed by city transportation agency (Charles et al. 2003).

While the immediate area of the incident may be protected, the back of the traffic queue may have the highest potential risk of secondary incidents due to sudden changes in travel speed that propagate upstream as a result of asymptotic instability of the traffic stream. In general, the shorter the duration of incident presence, and the smaller the speed difference between the vehicles upstream of the incident and approaching traffic, the smaller the likelihood of secondary incidents.

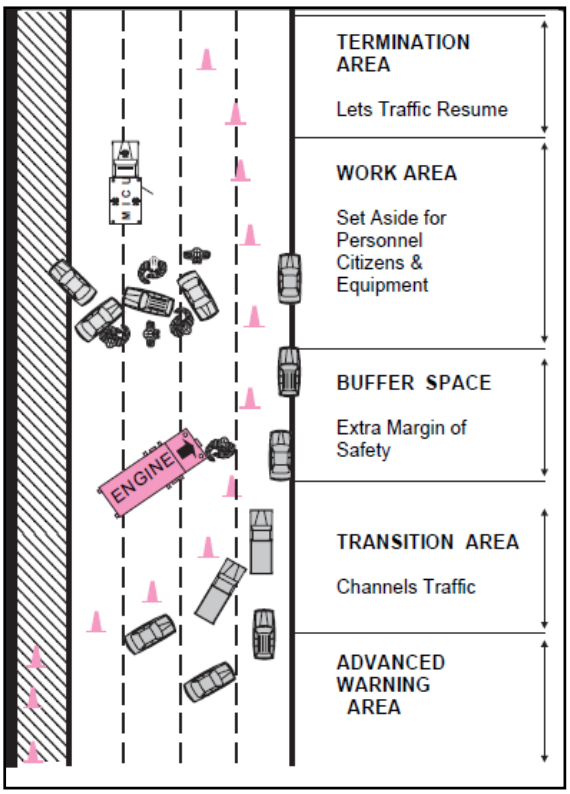


FIGURE 2-4 Typical Incident Scene (ODOT, 2007)

The Manual on Uniform Traffic Control Devices (MUTCD) defines the standards of using temporary traffic control at traffic incident management areas in order to inform road users about incidents and provide guidance information to help them pass through the incident scene (MUTCD, 2009). Proper actions should be taken in a timely manner to divert drivers to alternate routes before traffic creates back-ups. The traffic diversion plans for major corridors should be developed in advance (Karl, 2007), especially in locations with a history of high crash occurrence. In Florida, pre-developed alternate route plans are distributed in electronic format, to all agencies participating in traffic incident management. In Anaheim, CA, a real-time knowledge-based decision support tool is used to assist the traffic operation center personnel in assigning the alternate routes after occurrence of an incident (Carson, 2010). The tool is capable of selecting the proper route among a pre-developed set of alternate routes based on additional incident information provided, such as the length of any existing queues observed on CCTV and the best estimate of incident clearance time. The tool has also the ability to select an optimum combination of traffic control options using a predefined signal control timing plans, freeway ramp meter strategies, and traffic diversion information on changeable message signs (RITA, 2001).

In order to provide additional safety to responders and motorists at the incident scene, almost all of the states have 'Move Over' laws in the U.S. The law requires the passing vehicles to move over to an adjacent lane when approaching an authorized emergency vehicle that is stopped on a multilane highway. If the lane change is unsafe, the law requires vehicles to slow down to a

certain speed. For example, the ‘Alabama Move Over Act’ mandates drivers when driving on an interstate highway to vacate the closest lane to the law enforcement vehicle, and if not safe to change lanes, then to reduce their speed at least 15 miles per hour below the posted speed limit (ALISON, 2009). ‘Move Over’ laws have benefits on quick clearance of incident scenes and improvement of traffic safety (Birenbaum et al., 2009).

Another law enforced in many states in the U.S. is ‘Move It’ or ‘Steer It/Clear It’ law, which mandates drivers involved in property damage only incidents to move their vehicles from the travel lanes, if they are able to do so. The ‘Move It’ laws have great benefits in congestion relief by providing a quick clearance of incident scene, which is also resulted in contributions to secondary crash reductions (Birenbaum et al., 2009).

2.1.2.4. Clearance and Recovery

The final step of traffic incident management is the clearance of the incident scene. The required response to the incidents is determined based on the incident severity. If the incident is a minor one, usually a response from a single agency or company is enough to handle the problem. In fact, some minor incidents can be easily cleared with a collective work of drivers involved in the incident, without notifying any first responders. On the other hand, major traffic incidents usually have bigger impacts on the network and mostly require response from multiple agencies or companies (Carson, 2010). In such incidents, the damaged vehicles and if there is any spilled cargo, debris or hazardous material need to be removed from the roadway in order to return the travel lanes to normal traffic flow (TDOT, 2003). Towing and recovery companies are in charge of removing the vehicles and the debris on the incident scene (ODOT, 2007). It is important to use appropriate equipment for an effective and rapid clearance of incident scenes (Carson, 2010). The detail description of vehicles involved in the incident, type of cargo transported and incident location is essential for towing companies to determine proper vehicle dispatching for efficient clearance of the site. In several states digital photos are sent over phones to ensure that the correct service and equipment is requested (ODOT, 2007), thus reducing the chance for unnecessary delays.

The temporary traffic controls installed during scene management are also removed in this stage (TDOT, 2003). Thereafter, the road is restored to its full capacity, which is the main objective of the incident clearance step (Carson, 2010). It should be noted that the clearance of an incident should not be initiated before incident investigation is completed (Karl, 2007). Another important point is an incident site should not be announced as ‘cleared’ until the traffic goes back to initial operating flows. Otherwise the information could give the public the wrong impression about the road conditions, which could affect negatively the credibility and the trustfulness of the agency (Carson, 2010).

2.1.2.5. Interagency Coordination and Communication

As mentioned before, responding to major incidents may require multi-agency involvement. Varying motives, missions and methods among agencies may burden the communication and coordination among agencies. For example, failure to dispatch a towing and recovery service vehicle on time could create longer delays on roadway or inefficient incident scene management

could create unsafe environment for both responders and the traveling public. Moreover, poor communication with approaching travelers could lead to prolonged delays as well as secondary incidents. Adequate information about the incident would help agencies involved in incident response and recovery, traffic management and related tasks perform their responsibilities in a timely and efficient manner (Ang-Olson and Latoski, 2006; Corbin, 2003). Therefore, involved agencies need to have a high level of interagency communication, collaboration and coordination in order to provide safety and mobility to all road users (Corbin, 2003). The collective work between agencies should be built upon trust, and agencies should transfer command and control when it is needed in an effective and secure manner (Ang-Olson and Latoski, 2006).

Statistics show that every year, approximately 21,000 people involved in vehicle crashes die after transported to a medical facility, mainly because victims are taken there too late to be saved (CenTIR, 2010). Therefore, by informing EMS vehicles to take more time-efficient routes on their way to the incident scene savings in response time to those injured persons are expected. Equally important is the availability of real time information on network conditions that will allow the EMS vehicle leaving an incident scene to rush to a nearby hospital using the fastest route possible give the present state of traffic conditions on the network.

Exchanging en route information between on- and off-scene agencies may be the most critical component of communication process, especially when the vital effects on human health are taken into consideration (Carson, 2010). The overall success of traffic incident response depends on agency commitment in sharing and exchanging information (Corbin, 2003) and the willingness of agencies to collaborate (Brooke et al., 2004).

2.1.2.6. Technology

Advanced technologies from the area of Intelligent Transportation Systems (ITS) can provide significant improvements in TIM, which increase the efficiency of traffic incident management, response and recovery, especially when the urgent nature of incidents is considered (Chien et al., 2005). Among other systems, the closed-circuit television (CCTV) is a commonly used technology in support of incident verification. The incident images taken from CCTV cameras help responders to communicate with proper agencies and request the dispatch of appropriate equipment. In the recent years, Automated Vehicle Location (AVL) and geographic information system (GIS) technologies are gaining ground as technologies often employed for incident location verification (Carson, 2010). Advanced Traveler Information Systems (ATIS) applications are used to provide dynamic route guidance for the traveling public and emergency responders alike (Yu et al, 2010).

Accurate real time information on traffic and weather conditions, lane closures, as well as other incidents on the network is also essential for emergency responders while en-route to the hospital. During the 2003 San Diego fires, travelers had hard time reaching real-time information to know which roads were open, how to avoid congestion and delay, and how to avoid conflict with emergency responders. For that reason, in 2006, an ATIS/511 system has been implemented in San Diego as a decision support system to help the traveling public manage their trips and make informed decisions on trip details. Similar systems are operational in most states serving travel information dissemination need. In Arizona, the Arizona 511 system, provides real-time

road, weather, traffic conditions, and transit information as well as airport and tourism assistance, both via telephone and the internet. The system has been used to warn emergency responders and the traveling public in urban areas about road closures and possible diversion routes. The 511 system used in the state of Florida proved very beneficial during the 2004 hurricane season by informing people which road to use and the real-time traffic conditions to expect. The integration of the technology into ATIS/511 keeps expanding with the usage of broadcast and cable TV, broadcast and satellite radio, internet, telephone, and PDAs. Moreover, many auto companies have included a real-time ATIS/511 system in their dashboard navigation systems (Lively et al., 2006).

Advanced technologies used in monitoring real time traffic conditions at intersections have been lately combined with the traveler information system in a computer aided program called Program Arterial Signal Synchronization and Travel Guidance (PASSAGE). Demonstrated in Lake County, Illinois, the system provides information to travelers through a free iPhone application (Figure 2-5). The application allows users to get real time road views by clicking on one of about 200 camera icons. Users are even able to report incidents that they encounter along with a photo. Moreover, the system has a capability of contacting the Highway Advisory Radio (HAR) 1620 AM to get the latest traffic conditions on selected corridors (PASSAGE, 2010).

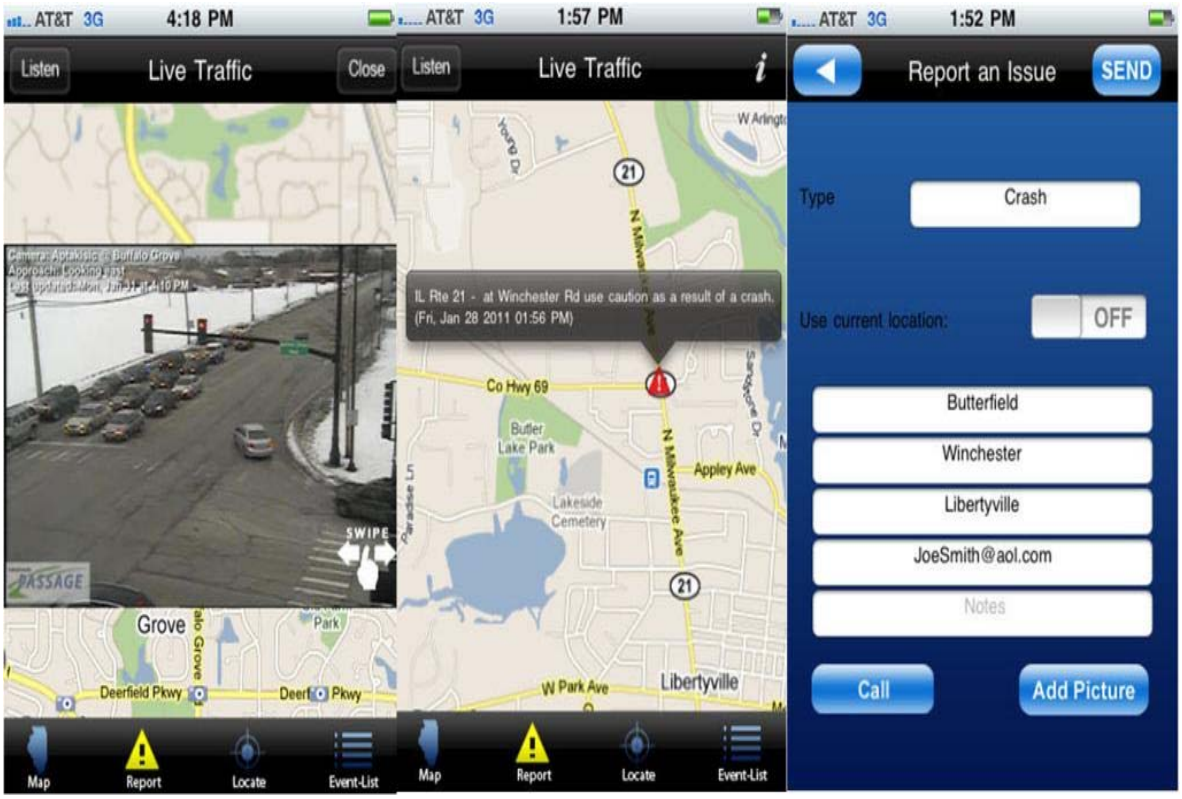


FIGURE 2-5 Real-time Traveler Information Program

The City of New York has introduced a system called Integrated Incident Management System (IIMS) in 2000. With the IIMS technology, incident response personnel are able to transmit real-time data about an incident to the other responders and dispatchers by using in-vehicle equipment. With the Global Positioning System (GPS) integrated into the system, it is possible to identify the exact location of incidents. The system also allows creating an incident log, which includes incident time and duration data (Newton et al., 2007).

In other applications, advanced technologies in traffic signal systems along with AVI applications are used to reduce travel times for emergency vehicles along signalized arterials by providing priority treatment. However, the lack of standards hinders the technology application, since until now the existing standards are typically developed by certain industries with certain system components (Carson, 2010).

Another communication system used in emergencies is traditional radio systems. Limitations in using conventional radio communication systems led to the emergence of a new approach, called Voice-over-Internet Protocol (VOIP) or Radio-over-Internet Protocol (ROIP). With an IP network, any radio system can be used just like any other kind of voice, video, or data traffic. The best part of using VOIP/ROIP in case of an incident is that if the key staff is out of the range of traditional radio, they are still able to join the radio channel using cell phones, landline phones, IP phones, or any kind of PCs.

With the broad implementation of vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and vehicle-to-device (V2D) technologies, responders, emergency vehicles, and emergency response devices will be able to communicate cooperatively and be integrated with the roadwayinfrastructure, as well as other essential entities such as hospitals, affected individuals, and their vehicles. Thus emergency responders will be able to reach the incident scene in a quick and safe manner by circumventing the congestion. Some good examples of V2V applications are “Blue Wave” and “Virtual Cones” that have been developed by the European Commission Integrated Project. The “Blue Wave” application is a warning system of a fast moving ground emergency vehicle. V2V technologies are used to warn the equipped vehicles that an emergency vehicle is approaching from the rear and/or side. On the other hand, the “Virtual Cones” application is used to warn the vehicles approaching to a traffic incident and give travelers an opportunity to re-route and avoid the incident (Flanigan et al., 2010).

Besides challenges already identified in the previous paragraphs, resources and funding, agency training and public education areas should also be evaluated and integrated into traffic incident management programs to maximize effectiveness.

2.1.3. Evaluation the Effectiveness of Traffic Incident Management

In order to evaluate the effectiveness of traffic incident management programs, performance measures are used. Incident frequency, incident rate, detection time, response time, clearance time, number of secondary incidents, time to normal flow and incident delay are the examples of performance measures used in traffic incident management evaluations (Karl, 2007). Measuring network performance gives feedback to traffic incident management practitioners necessary to continue to improve their operations (Carson, 2010).

It is generally accepted among transportation professionals that effective traffic incident management provides decreased delay and improved safety. However, the effect of incidents on traffic could be misevaluated if recurring bottlenecks and weather impacts already affect roads (Margiotta et al., 2004). Thus the effects of incidents on road operations should be studied after isolating the impacts of other contributing factors such as recurring congestion and weather related congestion.

Furthermore, the importance of the development of nationwide definitions and measures to quantify the effects of incidents in a systematic manner was recognized (Babiceanu et al., 2007). In response, in 2009, the Federal Highway Administration (FHWA) introduced three national-level TIM performance measurements (Figure 2-6) that states should use to evaluate the effectiveness of their incident management programs. These measures are 'roadway clearance' time, 'incident clearance' time and number of secondary incidents (Owens et al., 2009).

TIM Program Objective	Related Performance Measure
1. **Reduce "roadway clearance" time** defined as the time between awareness of an incident and restoration of lanes to full operational status).	Time between first recordable awareness of incident by a responsible agency and first confirmation that all lanes are available for traffic flow.
2. **Reduce "incident clearance" time** (defined as the time between awareness of an incident and removal of all evidence of the incident, including debris or remaining assets, from shoulders).	Time between first recordable awareness of incident by a responsible agency and time at which the last responder has left the scene.
3. **(NEWEST) Reduce the number of secondary incidents**—specifically unplanned incidents for which a response or intervention is taken, where a collision occurs either a) within the incident scene or b) within the queue (which could include opposite direction) resulting from the original incident.	Number of unplanned incidents beginning with the time of detection of the primary incident where a collision occurs either a) within the incident scene or b) within the queue, including the opposite direction, resulting from the original incident.

FIGURE 2-6 FHWA Suggested Performance Measurement (Owens et al., 2009)

The effectiveness indicator used in most of the TIM programs in the U.S. is the incident clearance time. Several states, such as California, Washington State, and Florida, set statewide incident clearance goals, which aim to clear the incident within 90 minutes. On the other hand, the practice used in Utah is based on the severity of the incident. The clearance goal is 30 minutes for fender-benders, 60 minutes for injury crashes, and 90 minutes for fatalities. In Arizona, although a Statewide Incident Management Plan was developed in 2000, no specific threshold value is set to clear the incidents.

Overall, TIM initiatives are effective in minimizing impacts of traffic incidents when properly coordinated and supported by technologies. In 2005, the MnDOT achieved a 38-million-vehicle-hours deduction in travel delay on major roads by utilizing a TIM program. It should be noted that the comprehensive traffic incident management plan was developed with the collaboration of legislative, transportation, law enforcement, fire, medical, towing industry, and other incident related stakeholders. Another statewide TIM policy was developed by the Minnesota Department of Transportation's (MnDOT) Responder Safety Committee. As part of the TIM program, MnDOT Responder Safety Committee offered an incident management course to emergency responders coming from different backgrounds such as MnDOT, the State Patrol and the State Fire Marshall's Office, law enforcement, EMS, and towing companies (NTIMC, 2006c).

Maryland's Coordinated Highways Action Response Team (CHART) program is viewed as one of the most comprehensive statewide TIM program in the U.S. The Statewide Operations Center and the Satellite Traffic Operations Center founded within the TIM program are responsible for providing the 24/7 statewide control and handling the peak-period traffic, respectively. The statistics show that with implementation of the CHART program, in 2005 the average incident duration was reduced by 23%.

The same year, a program called SAFEclear was implemented in the city of Houston. The formation of the model was based on a 'private sector freeway service patrol', where qualified towing companies make a contract with the city to provide an average of 6 minutes responding time to incidents. Thus, contracted tow companies should patrol the freeways continually to be able to respond to incidents in less than 6 min (NTIMC, 2006c). In the first year of the SAFEclear program, the incidents were cleared in less than 20 min. In 2008, a reduction of approximately 1,440 incidents per year was observed with an economic savings of $49 million (Carson, 2010).

2.2. Dynamic Traffic Assignment Background

In modeling incidents and studying their impacts this study uses a simulation model (namely VISTA) that finds best paths for all vehicles traveling in the network given their origins (O), destinations (D), network characteristics, and prevailing conditions. This is done through the so-called traffic assignment. Traffic assignment is the fourth step of the traditional transportation planning process, which determines the total number of vehicles that a particular route can expect to serve as a result of travelers' route choice decisions.

Traffic assignment models assist in replicating the complex traffic flows and can be either static or dynamic. Dynamic Traffic Assignment (DTA) models are particularly appropriate for modeling highway incidents because the timing of incident occurrence, management, recovery, and the use of alternate routes are critical to roadway performance and driver experience. Static methods, on the other hand, are based on average daily traffic and thus fail to identify and test the short-term control actions necessary to manage non-recurring events such as crashes or infrastructure failures (Wirtz et. al., 2005).

DTA models are used for traffic modeling purposes as part of a traffic simulator. The simulator is utilized to determine a local optimal Dynamic User Equilibrium (DUE) solution. Such a

solution assigns vehicles to the best path possible, i.e. the path that minimizes a user specific criterion such as travel time, delay, etc. To achieve equilibrium, an iterative process is used in simulation-based DTA models between a traffic simulation module, a time-dependent shortest path module, and a network-loading module. The process takes into account the complex interactions between supply and demand in a transportation network (Sisiopiku et al., 2007a). Since supply-demand interaction is a major challenge in no-notice emergencies (Zheng et al., 2010), DTA models are used to compute the spatio-temporal path for every vehicle while considering real-time driver behavior, which is a great advantage over conventional models using Static Traffic Assignment (STA) such as CORSIM (Sisiopiku et al., 2007a). STA-based traffic models use predefined vehicle routes and flows meaning that speed and density of links are unchanged throughout the simulation process. For that reason, link travel times are also at a steady-state level (Chiu et al., 2011). Besides this, STA-based traffic models split traffic at intersections instead of tracking the movement of individual vehicles (Sisiopiku et al., 2007a); and significantly underestimate congestion levels (Lu and Gao, 2010).

On the other hand, DTA-based simulation models can represent the drivers' route choices in great detail, thus, it is possible to incorporate rich traveler-behavior-models into simulations, to model the traffic dynamics at the required level of detail (Sisiopiku et al., 2007a). Therefore, DTA applications have a major role in aiding traffic incident response (Balakrishna et al., 2008) and are utilized as a tool in Traffic Management Centers (TMC) to improve the performance of transportation networks using advanced technologies supported by real-time intelligent software systems (Ben-Akiva et al., 2002).

DTA models have capabilities to effectively evaluate the performance of the transportation system in incidents and emergency conditions via modeling Intelligent Transportation System (ITS) strategies (Sisiopiku et al., 2007a). Furthermore, the technological and algorithmic developments in Advanced Traveler Information Systems (ATIS) and Advanced Traffic Management Systems (ATMS) applications also resulted in developing DTA algorithms in TIM programs (Sawaya et al., 2005).

2.2.1. Dynamic Traffic Assignment Applications in Traffic Incident Management

It is difficult to model a transportation system analytically when an incident occurs and creates sudden changes in the network. It is often important to quickly divert traffic approaching the incident site to alternate routes capable of absorbing the extra demand, in order to bring much needed relief into the system. This in turn increases network efficiency and public safety. The operations mentioned above require monitoring the conditions on the transportation network in real-time (Sawaya et al., 2005). Thus, real-time traffic management has been becoming more effective in incident and emergency response applications (Liu et al., 2007) and dynamic traffic assignment applications are used in Traffic Management Centers (TMC) to support real-time applications (Balakrishna et al., 2008).

One of the DTA systems used for advanced traffic network management is DYNASMART (Dynamic Network Assignment Simulation Model for Advanced Road Telematics) simulation tool which has been used in several applications including a pilot study for urban transportation

planning in El Paso, TX (FHWA, 2011) and an experimental research effort in the Irvine-Orange County, CA region (Sisiopiku et al., 2007b).

After the unfortunate accident in the Three Mile Island nuclear power plant, the simulation tool named Dynamic Network Evacuation (DYNEV) was developed for emergency evacuation preparedness (Hardy et al., 2010). A dynamic traffic flow model for a no-notice mass evacuation has been developed using Dynamic Urban Systems in Transportation (DynusT) software, which is a mesoscopic simulation and assignment tool (Zheng et al., 2010).

In other efforts, DynaMIT has been successfully integrated into Los Angeles TMC, where DynaMIT automatically obtains freeway and arterial data every 5 to 15-minutes and predicts traffic conditions for the next hour (Balakrishna et al., 2008).

3. METHODOLOGY

3.1. Study Approach

In this research a simulation study was performed to examine the impacts of major incidents and determine the best response time of emergency units. For that reason a regional model of the Birmingham network was developed. More specifically, the study employed a simulation-based DTA platform to model normal operations (base case) and incident conditions. In the incident scenarios considered in this study, the number of lanes closed and the duration of lane closures was varied to represent incidents of various levels of severity. Furthermore, the selection of vehicles best travel paths took under consideration information availability and network familiarity. In the presence of an incident, drivers are expected to stay at their original paths if they had no information about potential diversion (simulation scenarios). On the other hand, driver knowledge of the incident and familiarity with diversion options would allow them to seek new, improved paths in order to avoid delays due to the incident (DTA scenarios).

Detail information about the simulation model selected, study site used, and the simulation scenarios considered is presented in the following paragraphs.

3.2. Simulation-based DTA Model Selection

The simulation model capabilities that are required to meet the objectives of this research include the ability to simulate transportation network operations and driver behaviors under normal and incident conditions, the ability to determine network-wide, corridor-wide measures of performance such as delay, travel time and speed, and the ability to track individual vehicles in the network so that one can track the response time of emergency vehicles to/from the incident site. Furthermore, the model needs to simulate networks that are large enough to contain not only the direct effects of incidents and the pre-planned management strategies, but also the indirectly impacted areas.

A detailed review of the model approaches, capabilities, and limitations, along with the availability of models and other resources, led to the selection of VISTA as tool of choice for this study is VISTA. VISTA utilizes a mesoscopic simulator (RouteSim) and a Dynamic Traffic Assignment (DTA) routine to emulate the behavior of individual drivers and how they distribute themselves into the transportation network. RouteSim is based on an extension of Daganzo's cell transmission model introduced by Ziliaskopoulos and Lee (Ziliaskopoulos and Lee, 1996). In this model, the road is divided into small cells where the cells are adjustable in length; bigger cells are used for a mid-section of a long highway segment, and smaller cells are used for intersections and interchanges. Vehicles are considered to be moving from one cell to another in platoons. The simulator keeps track of the flow in each cell and, every time step, calculates the number of vehicles that are transmitted between adjacent cells. The model enables the study of incidents' impacts as it generates spatial-temporal traffic flows for all origin-destination trips loaded into the network. Furthermore, the VISTA system can emulate the routes that the emergency vehicles should follow in order to arrive at the scene of an incident given the prevailing traffic conditions.

3.3. Development of Simulation Model for the Birmingham Region

The study network of the Birmingham region was built in VISTA using background geometric and annual average daily traffic (AADT) volume data from the TRANPLAN (TRANsportation PLANning) model provided by the Regional Planning Commission of Greater Birmingham (RPCGB). More than 1.8 million trips with more than 35 million route options were simulated for each afternoon peak period starting from 4:00 pm to 7:00 pm. The coded network consists of about 11,500 links including the major freeways and some arterial facilities serving to the Birmingham metropolitan region such as I-65, I-459 and, I-20/59. The I-65 highway serves north-south directions, and I-459 and I-20/59 freeways run through east-west. Figure 3-1 shows the Birmingham network coded in VISTA. It should be noted that the study network is very extensive and that the coding and development of a simulation model of this size and complexity was a major accomplishment by itself. For the purpose of the study, existing fire and police stations as well as medical facility locations were included to the simulation model (Figure 3-2). Moreover, locations of shelters and medical facilities were also incorporated (Figure 3-3).

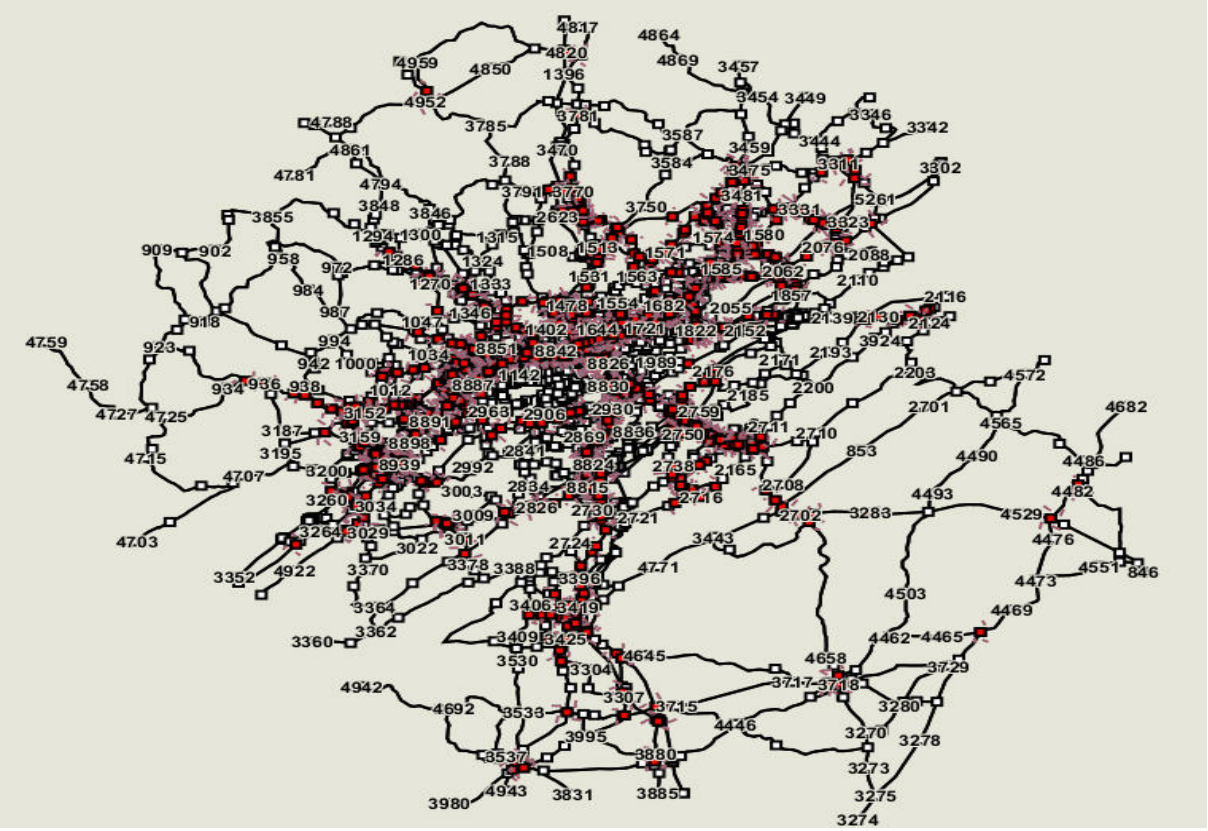


FIGURE 3-1 Birmingham Network Coded in VISTA

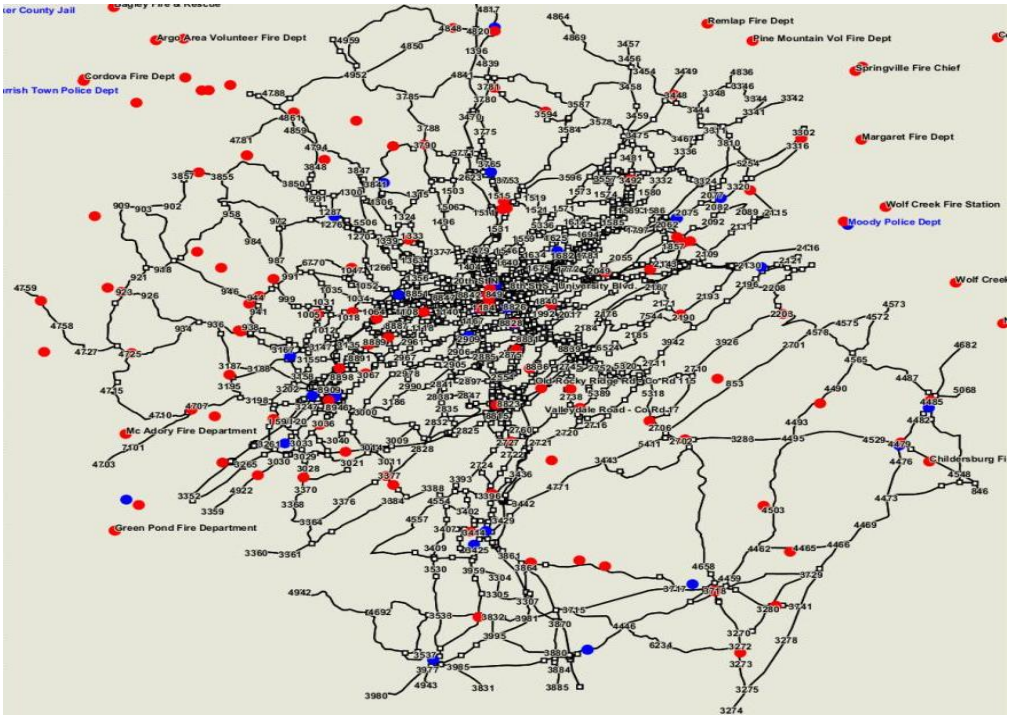


FIGURE 3-2 Birmingham Fire and Police Stations in the VISTA Model

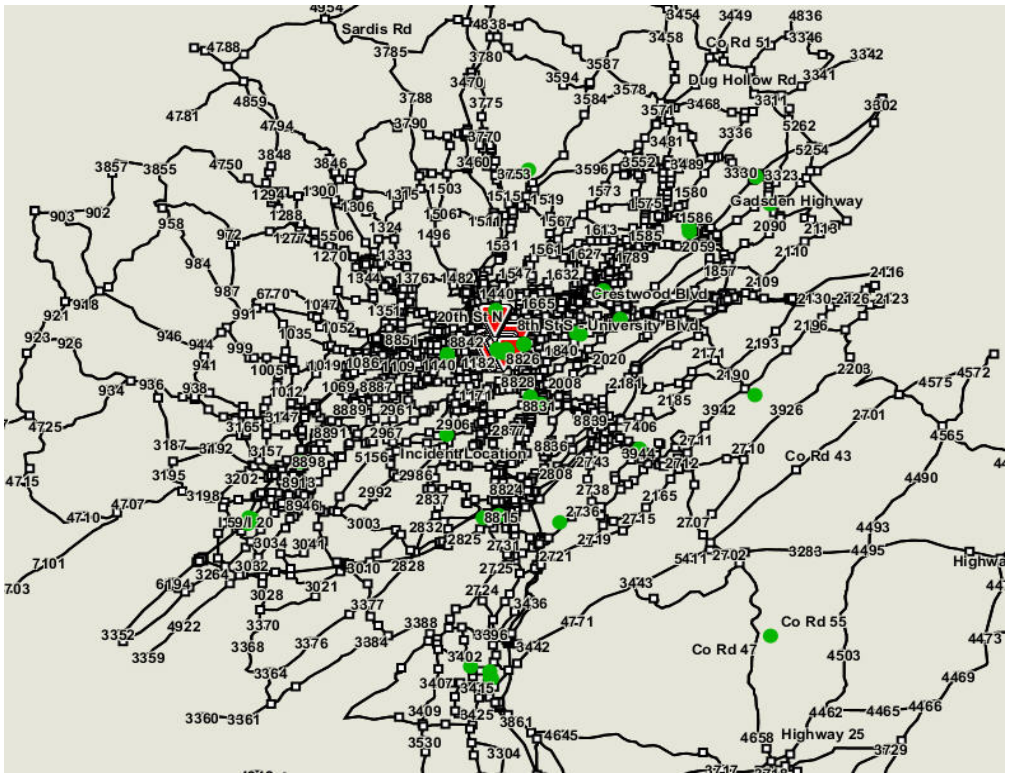


FIGURE 3-3 Medical Facilities in the VISTA Model

3.4. Study Site

Analysis of historical crash data from the CARE database took place to identify a good candidate location for the generation of a traffic incident within the study area. Records show that more than 200 traffic incidents occurred in 2008 at the I-65/I-459 junction, with a clearance time ranging between 10 and over 180 minutes. Using this input the primary incident for the incident scenarios was created on southbound I-65 highway just upstream of the I-459 junction (US-31/Montgomery Hwy between exits 252 and 250). In VISTA, the incident was modeled on link #12,750, which is an 8,500 foot-long 4-lane interstate segment with a capacity of 2,300 vphpl, and a free flow speed of 65 mph. Moreover, historical records show that PM peak hours experience the highest incident rates at this junction as illustrated in the graph in Figure 3-4, thus, afternoon peak was used as the analysis period in this study.

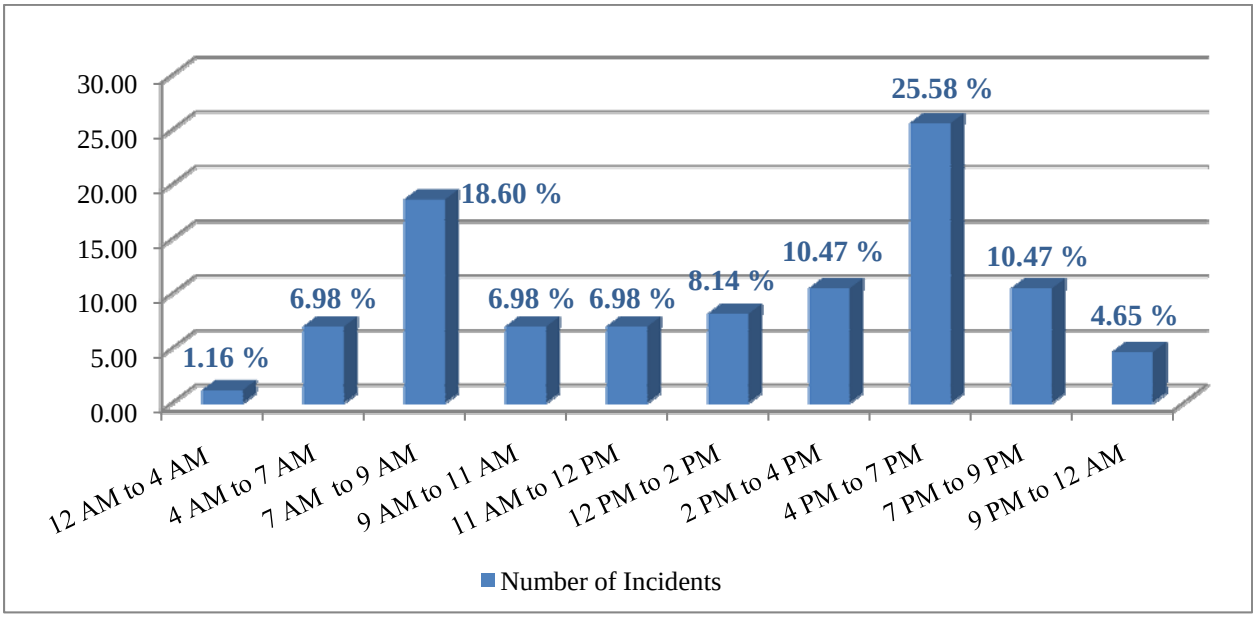


FIGURE 3-4 Incident Rates by Time of Day at the I-65/I-459 Junction

While the entire regional network was considered in the simulation runs performed, in depth analysis of network performance was deemed more appropriate in the vicinity of the incident. Thus a 13-mile length segment of I-65 was chosen as the study corridor for which results were obtained and analysed in greater detail. The segment was divided into 12 sub segments, which were defined based on the actual highway exit points, namely 6th Ave N (Exit 260), 3rd Ave N (Exit 260B), 4th Ave S (Exit 259B), 6th Ave S (Exit 259A), AL-149/University Blvd (Exit 259), Green Springs Ave (Exit 258), Oxmoor Rd (Exit 256), Lakeshore Dr. (Exit 255), Alford Ave (Exit 254), US-31/Montgomery Hwy (Exit 252 –Incident Location), I-459 (Exit 250), and CR-17/Valleydale Rd (Exit 247). The details are provided in Table 3-1.

TABLE 3-1 I-65 Study Corridor Segments

	Segments	From Exit on I-65	To Exit on I-65
1	6th Ave N	Exit 260	Exit 260B
2	3rd Ave N	Exit 260B	Exit 259B
3	4th Ave S	Exit 259B	Exit 259A
4	6th Ave S	Exit 259A	Exit 259
5	AL-149/University Blvd	Exit 259	Exit 258
6	Green Springs Ave	Exit 258	Exit 256
7	Oxmoor Rd	Exit 256	Exit 255
8	Lakeshore Dr.	Exit 255	Exit 254
9	Alford Ave	Exit 254	Exit 252
10	US-31/Montgomery Hwy	Exit 252	Exit 250
11	I-459	Exit 250	Exit 247
12	CR-17/Valleydale Rd	Exit 247	Exit 246

A secondary incident was created at the I-65/Lakeshore Dr. junction, along the route of the best response emergency unit to the main hospital as needed. The secondary incident was created and run in VISTA model on link #7,003. The link is a 6,019 foot-long 3-lane interstate segment with a capacity of 2,300 vphpl, and a free flow speed of 65 mph. Figure 3-5 shows both incident locations in the VISTA model.

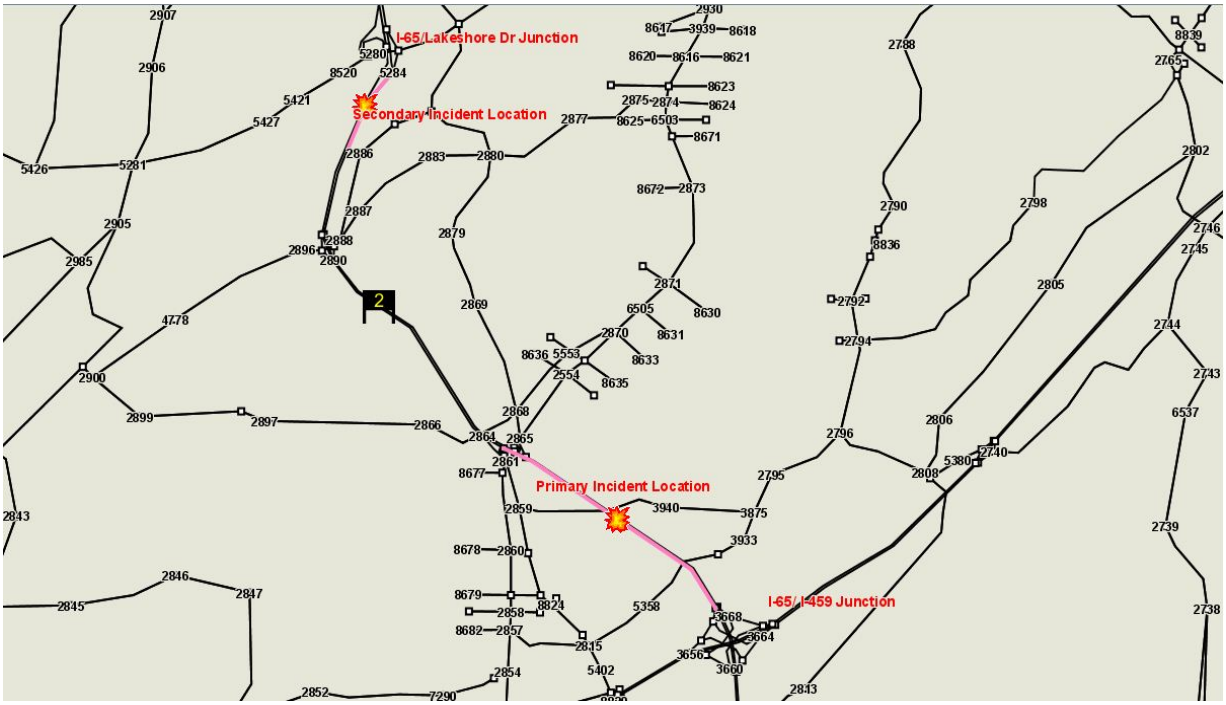


FIGURE 3-5 Primary and Secondary Incident Locations

3.5. Simulation Study Scenarios

When modeling incidents in VISTA, the user can specify: 1) the location of the incident, 2) its severity (number of lanes closed or percentage of capacity reduced) and 3) its expected duration. Accordingly, three main incident scenarios were designed for the Birmingham network to analyze the impacts of incidents of varying severity and study emergency response. For this purpose, six different incident severity levels were defined by varying the incident duration and the number of lanes closed due to the incident. Details of the incident scenarios considered in the Birmingham case study follow.

Scenario 1(S1) describes the network operations under non-incident conditions and provides the baseline for comparisons.

In *Scenario 2(S2)* a sensitivity analysis takes place to illustrate the impact of the incident severity on travel times, delays, and response times of emergency units. Thus in *Scenario 2* the incident duration varies in 60 minute increments under one-to-two full lane blockage conditions and the relative changes in model response are observed. The scenario assumed the occurrence of the primary traffic incident on southbound I-65 at the junction of I-65 and I-459 starting at 4:00 pm. Scenarios S2-11 and S2-12 assumed an incident lasting for 1hr and closing 1 and 2 lanes respectively. Scenarios S2-21 and S2-22 assumed an incident duration of 2 hrs with 1 and 2 lane reduction respectively. Finally, in scenarios S2-31 and S2-32 the simulate incident persisted for 3 hrs with 1 or 2 lane closures respectively.

In *Scenario 3 (S3)*, the primary incident conditions were assumed the same as in S2-22 (i.e., two lanes closed for 2 hours), however, a secondary incident was introduced along the route of the best available responding EMS unit to the main hospital. The secondary incident was assumed to result in a two-lane blockage at the I-65/Lakeshore Dr. on I-65 northbound. The blockage started at 4:20 pm and lasted for at least 30 minutes. The objective of this scenario was to study the impact of the secondary accident on travel times of emergency units heading toward a hospital.

Two sets of runs were performed for each incident scenario introduced above. The first set (denoted by S) assumed that the drivers had no information about the incident presence. Under these assumption the Simulation Module of VISTA was run for the study scenarios presented above (S2-11S, S2-12S, S2-21S, S2-22S, S2-31S, S2-32S, and S3-22S). The RouteSim simulator utilized the existing paths from the base case to produce the impact of the incident on the same OD paths, since the drivers remained in the same paths, despite of the incident occurrence due to lack of information.

The second set of runs (denoted by D) assumed that drivers knew about the incident and they redistribute themselves in the network according to the DTA principles in order to optimize their paths –if needed, given the presence of the incident. During the VISTA DTA/DUE procedure, the RouteSim initially assigns the vehicles to the free flow shortest paths. The link travel times resulting from that assignment pattern are then used to calculate a new set of shortest paths, and the simulation is repeated with vehicles assigned to a combination of the previously calculated path set. Iterations continue between the mesoscopic simulation and vehicle assignment modules

until a user-specified convergence criterion is met. In this study the convergence criterion was set to a 4% gap, in order to increase the accuracy and confidence in the model findings.

Thus using its DTA/DUE module, VISTA recalculated all vehicle paths and re-optimize routes given the incident presence for the scenarios considered above (S2-11D, S2-12D, S2-21D, S2-22D, S2-31D, S2-32D, and S3-22D). The gaps achieved in the various scenarios considered are summarized in Table 3-3.

TABLE 3-2 Percentages in the Study Scenarios

Scenarios	Gap Percentage (the percentage of total time)
S1	3.29%
S2-11D	3.20%
S2-12D	3.89%
S2-21D	3.56%
S2-22D	3.21%
S2-31D	3.60%
S2-32D	3.84%
S3-22D	3.22%

The comparison between the results of a simulation only and DTA/DUE optimization scenario allows the analyst to study the effect of information provision on network performance. Table 3-4 summarizes the study scenarios and the corresponding VISTA module used to determine the network performance.

TABLE 3-3 Case Study Scenarios

Scenario	Name	Incident Duration (hr)	Lane Blockage (# of lanes)	Information Provision	VISTA Module
Scenario 1- Base Case	S1	0	0	-	DTA/DUE
Scenario 2 - Primary Incident only	S2-11S	1	1	no	Simulation
	S2-12S	1	2	no	Simulation
	S2-21S	2	1	no	Simulation
	S2-22S	2	2	no	Simulation
	S2-31S	3	1	no	Simulation
	S2-32S	3	2	no	Simulation
	S2-11D	1	1	yes	DTA/DUE
	S2-12D	1	2	yes	DTA/DUE
	S2-21D	2	1	yes	DTA/DUE
	S2-22D	2	2	yes	DTA/DUE
	S2-31D	3	1	yes	DTA/DUE
	S2-32D	3	2	yes	DTA/DUE
Scenario 3 - Secondary Incident	S3-22S	0.5	2	no	Simulation
	S3-22D	0.5	2	yes	DTA/DUE

4. RESULTS

VISTA provides general reports summarizing network performance measures such as travel times, vehicle throughput, and speeds. Moreover, queries can be executed to obtain detailed information about facilities of interest. Such queries where utilized to obtain speeds for twelve I-65 links located upstream and downstream of the incident location. To allow evaluation of incident impacts over space and time, both average speeds (i.e., link speeds over the 4hr simulation period), and 15-min speeds for each link were obtained. The results are reported and compared in the sections that follow. Summary delay results are also provided and interpreted.

4.1. Base Case Scenario Results – Scenario 1

The base case scenario assumes non- incident conditions in the network. Figure 4-1 reports average speed by link for the corridor of interest. Over the reference period of 3:00 pm to 7:00 pm speeds along the corridor varied from 42 to 66 mph, depending on the location.

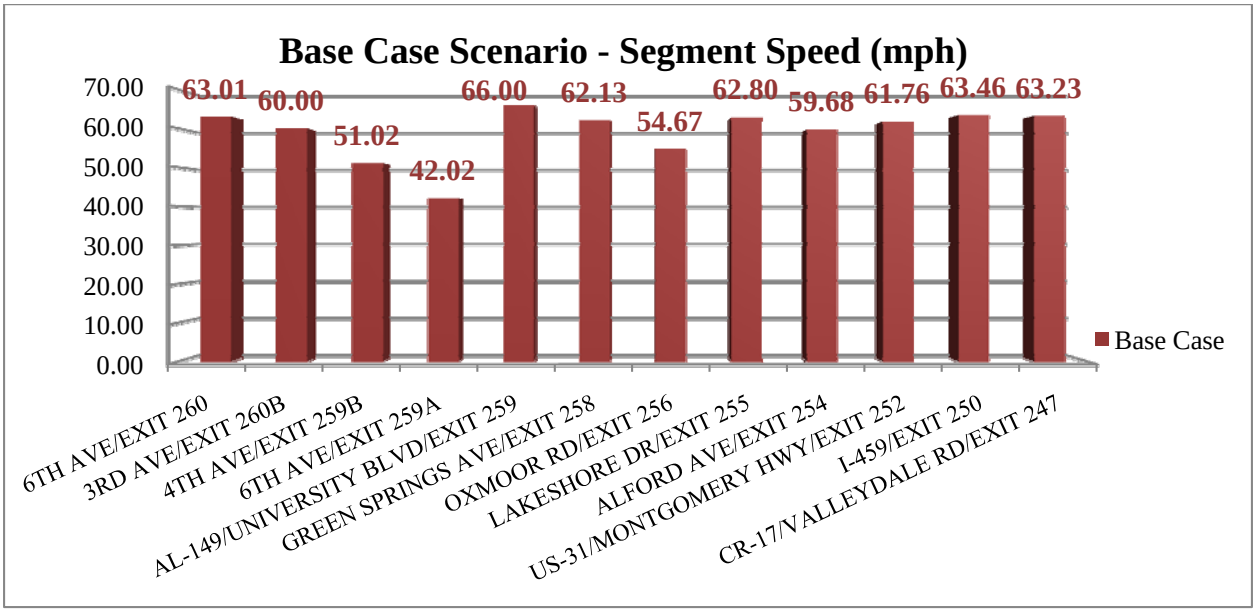


FIGURE 4-1 Base Case Scenario Segment Speeds

Figures 4-2, 4-3 and 4-4 illustrate the 15-min speed results from base case scenario in the same time frame. According to the results, vehicles are traveling at steady speeds during the afternoon peak period between 6th Ave N and Lakeshore Dr (Figures 4-2 and 4-3). Lowest speeds are experienced at the 6th Ave N link, followed by the 4th Ave N link throughout the study period (42 and 51 mph respectively). Furthermore, Figure 4-3 shows deterioration of traffic conditions due to recurrent congestion at the Alford Ave link which is evidenced by a speed decrease from 65.22 mph at 3:30-3:45 pm to 37.63 mph at 4:30-4:45 pm. It can be observed that it takes two full hours for speed to recover and the free flow speed of 65.22 mph is restored at 5:30-5:45 pm (Figure 4-3). The I-459 and Valleydale Rd segments have steady speeds, as shown in Figure 4-4.

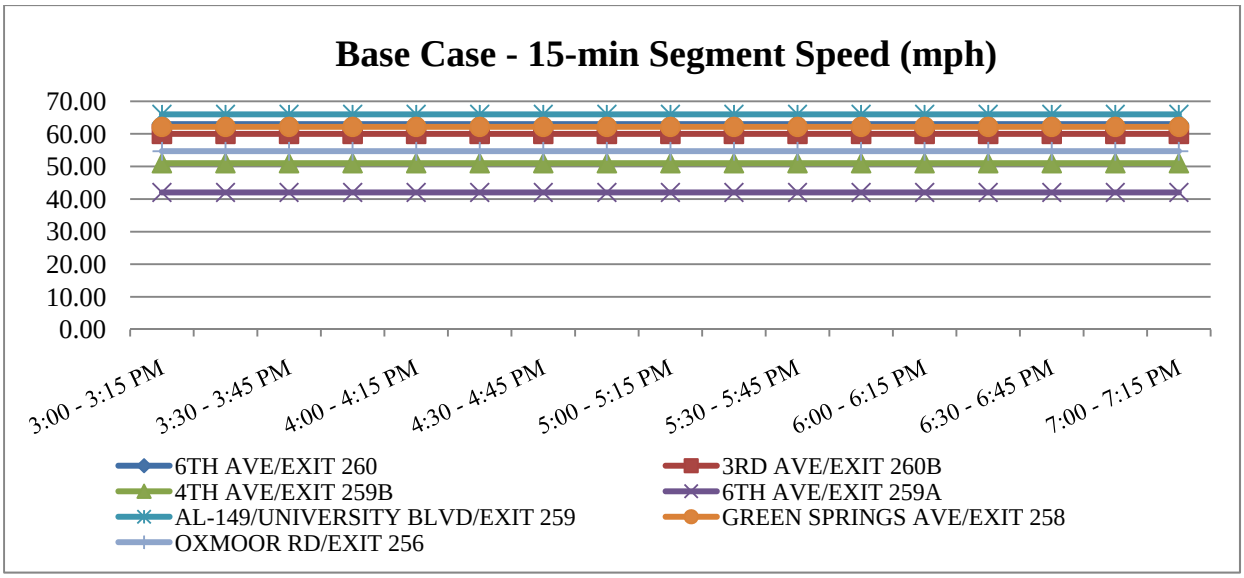


FIGURE 4-2 Base Case Scenario 15-min Segment Speeds (Exit 260 –Exit 256)

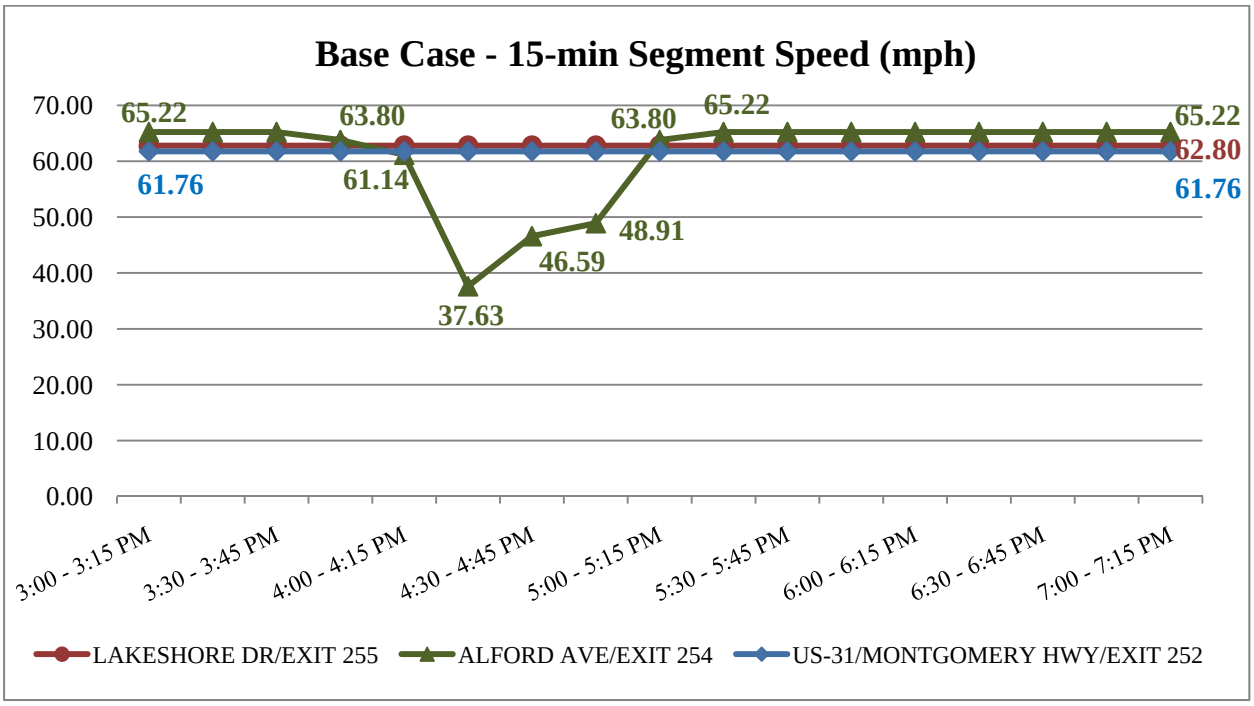


FIGURE 4-3 Base Case 15-min Segment Speeds (Exit 255 –Exit 252)

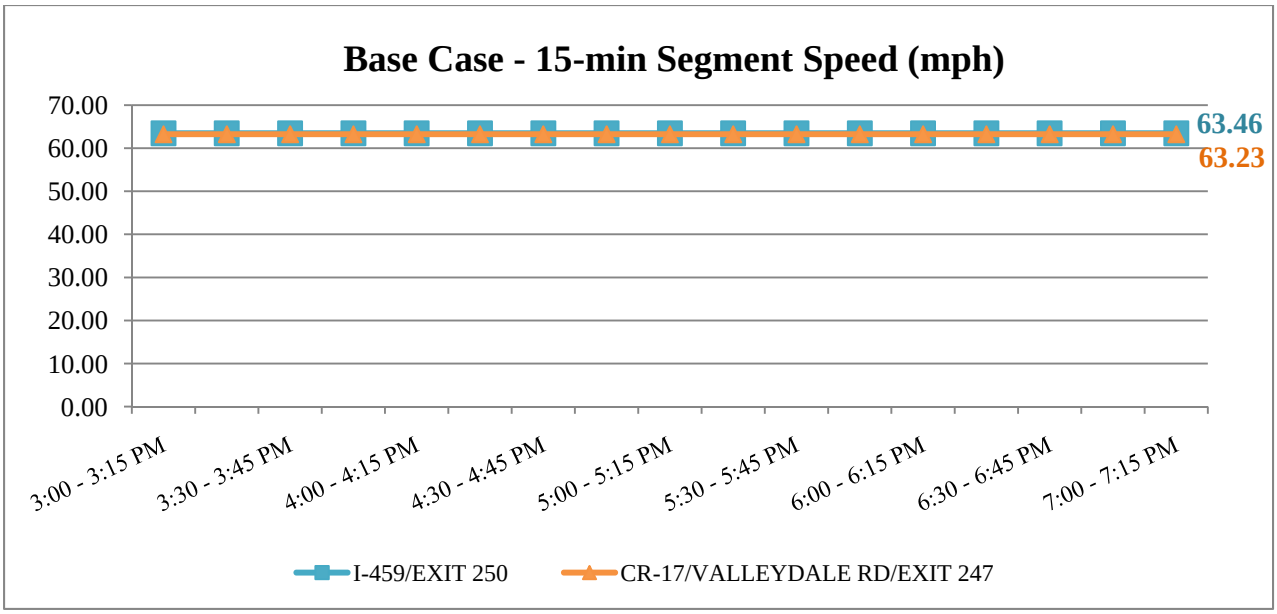


FIGURE 4-4 Base Case 15-min Segment Speeds (Exit 250 –Exit 247)

4.2. Primary Incident Scenario Results – Scenario 2 (S2)

4.2.1. Primary Incident Results–No Information Provision– Scenario 2-S

The following paragraphs summarise the results from the parametric analysis performed for incident scenario 2 assuming that the travellers have no knowledge of the incident and thus cannot select alternate routes to improve their travel times and speeds.

4.2.1.1. One-Hour One-Lane Closure (S2-11S)

In scenario S2-11S, an incident was assumed to occur at 4:00 pm on the US-31/Montgomery Hwy link blocking one-full lane for one hour. Figure 4-5 illustrates the average speeds obtained on a link-by-link basis along the study corridor (i.e., between 6th Ave N and CR-17/Valleydale Rd) under the scenario S2-11S assumptions. Figures 4-6 through 4-8 showcase the variations in speeds by 15-min interval.

Observation of the results displayed in Figure 4-7 shows that the minor incident in S2-11S had some effect on the speeds of the incident link (US-31/Montgomery Hwy) and the links upstream (Alford Ave and Lakeshore Dr). Compared to the base case (Figure 4-1), average speeds on those links were reduced slightly whereas on the remaining links they remained practically unaffected. Figure 4-7 shows the congestion spillback and recovery on the 2 links upstream of the incident link as a result of the incident introduced in the network. Due to the low severity of the incident the effects are minor and localized.

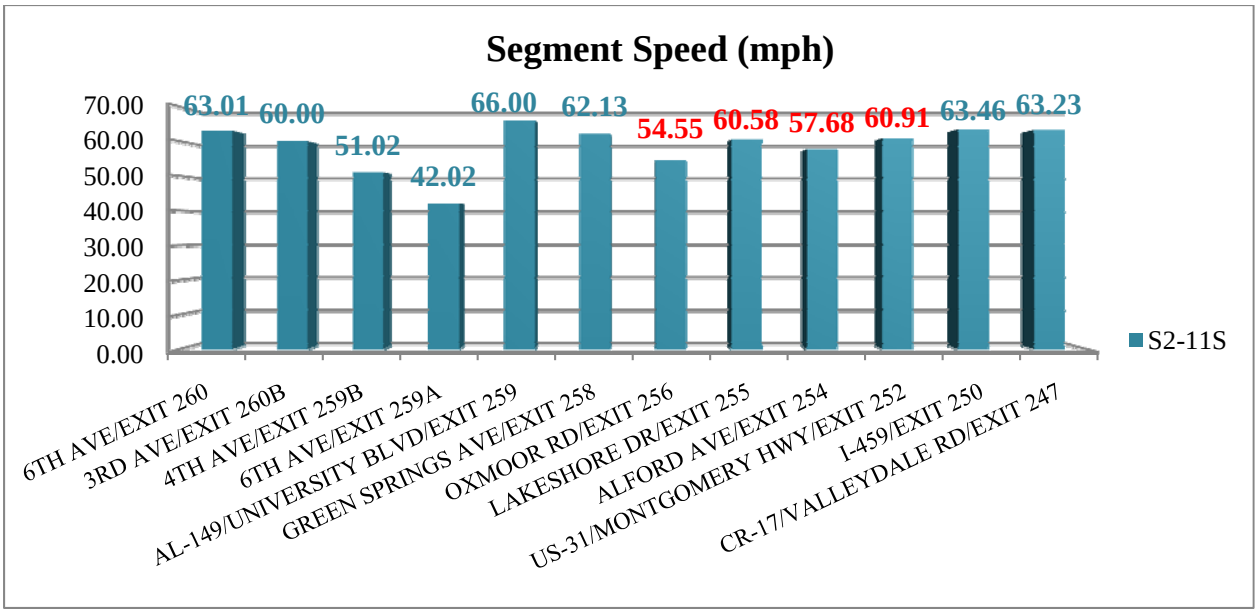


FIGURE 4-5 Segment Speeds in S2-11S Scenario

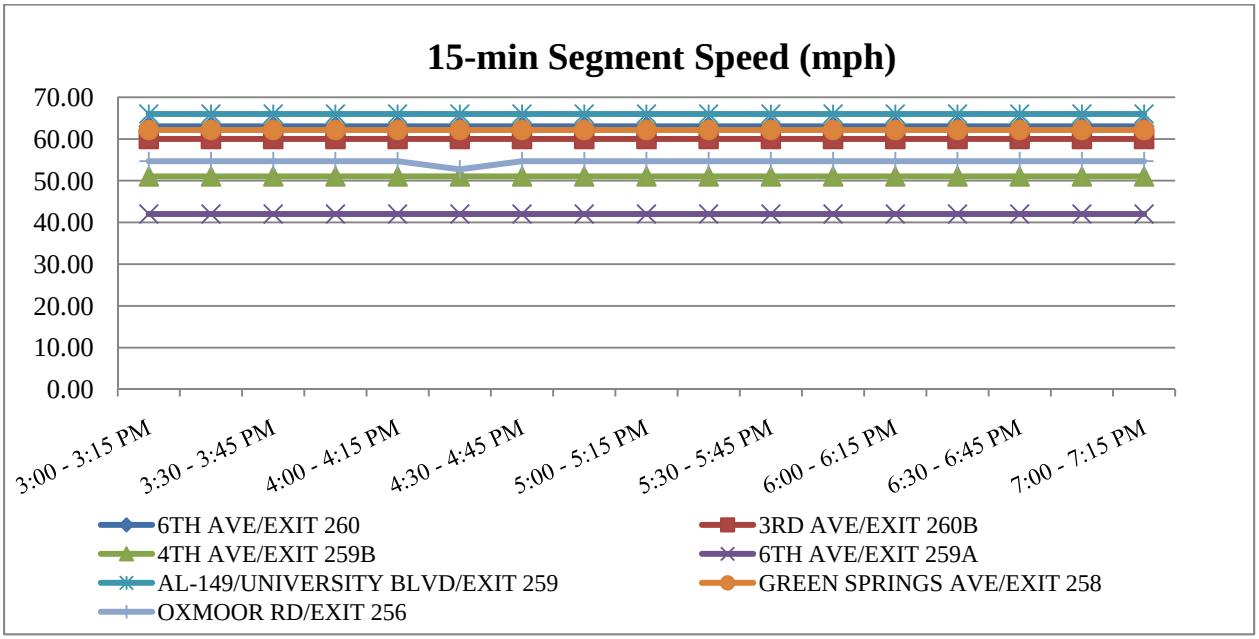


FIGURE 4-6 S2-11S 15-min Segment Speeds (Exit 260 –Exit 256)

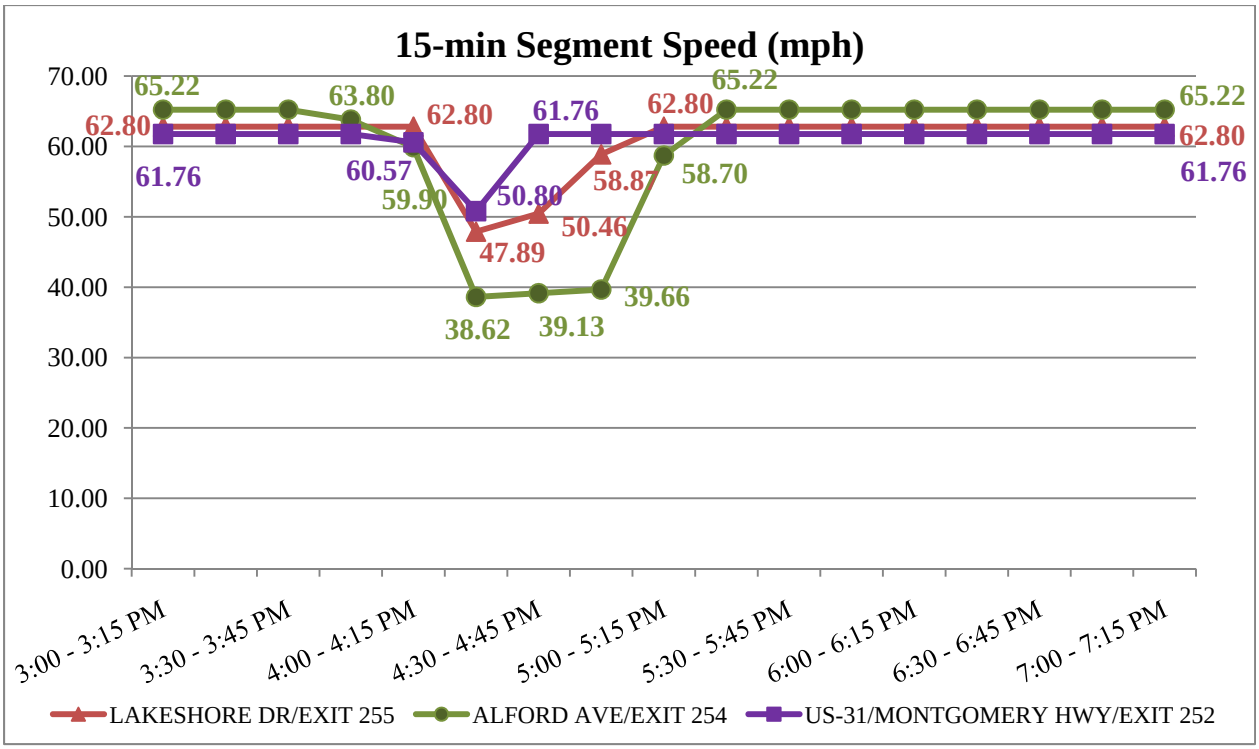


FIGURE 4-7 S2-11S 15-min Segment Speeds (Exit 255 –Exit 252)

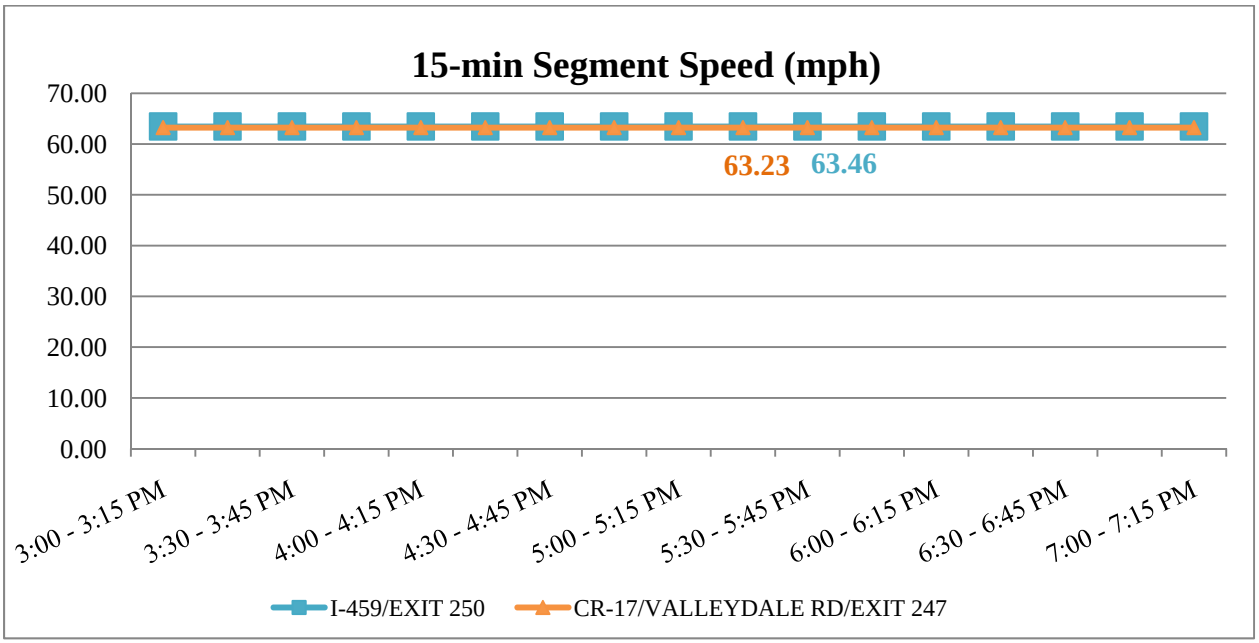


FIGURE 4-8 S2-11S 15-min Segment Speeds (Exit 250 –Exit 247)

4.2.1.2.One-Hour Two-Lane Closure (S2-12S)

In scenario S2-12S, the simulated incident starts again at 4:00 pm and lasts for 1 hr blocking two full lanes of traffic along the US-31/Montgomery Hwy link blocking. Figure 4-9 summarizes the average speeds and Figures 4-10 through 4-12 illustrate the variations in speeds by 15-min interval for the scenario S2-12S assumptions.

The VISTA results show that the two-lane closure in S2-12S created a bottleneck that resulted in a breakdown of links upstream of the incident link. This is evidenced by the lower speeds and higher delays on three links upstream of the incident link. Speeds on Alford Ave, Lakeshore Dr., and Oxmoor Rd were reduced by 66.1%, 64.5% and 47.5% respectively, a significant reduction compared to the base case (Table 4-1).

Examination of Figures 4-11 and 4-12 and comparisons with their counterparts in S2-11S confirms that the impact of the two lane closure extends much further in space and time than that of the one lane closure. As such it affects the performance of three links (instead of two) and results in significant deterioration of the quality of service. It should also be noted that although the incident is cleared by 5:00 pm at which time all lanes are returned back to traffic, the impact of the accident on the 2 upstream links persists for much longer. As Figure 4-12 shows, Lakeshore Dr resume normal operations at 5:45-6:00 pm and Alford Ave at 6:00-6:15pm, one full hour after removal of the incident and restoration of traffic conditions at the incident link (US-31).

As expected the links further upstream and downstream of the incident are not affected and thus their operational performance remains similar to the baseline.

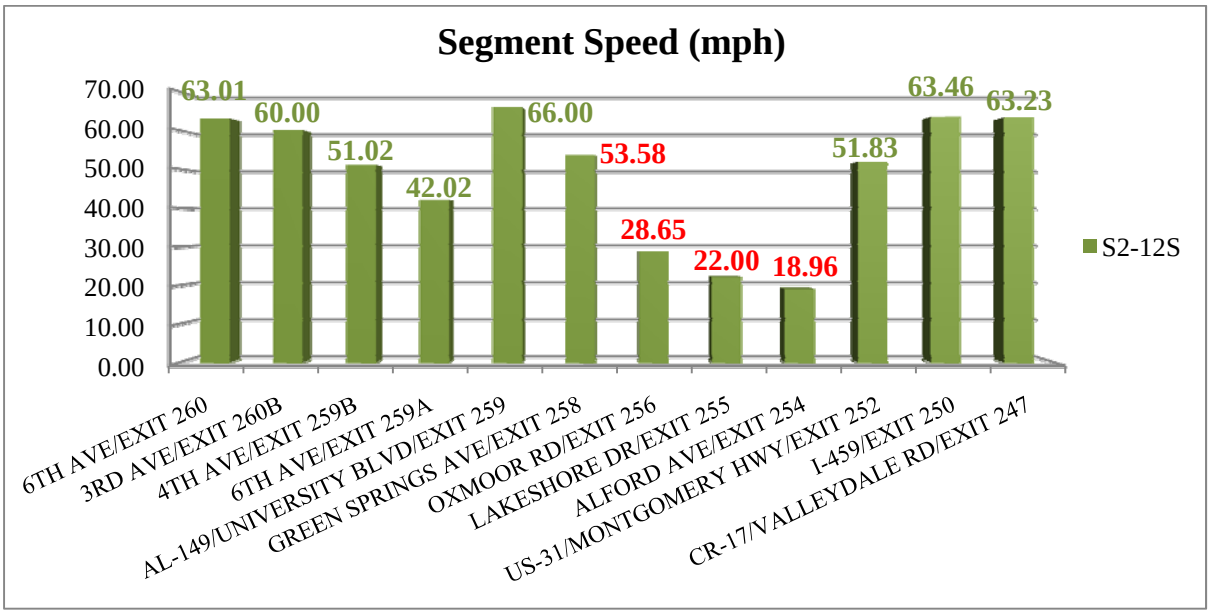


FIGURE 4-9 Segment Speeds in S2-12S Scenario

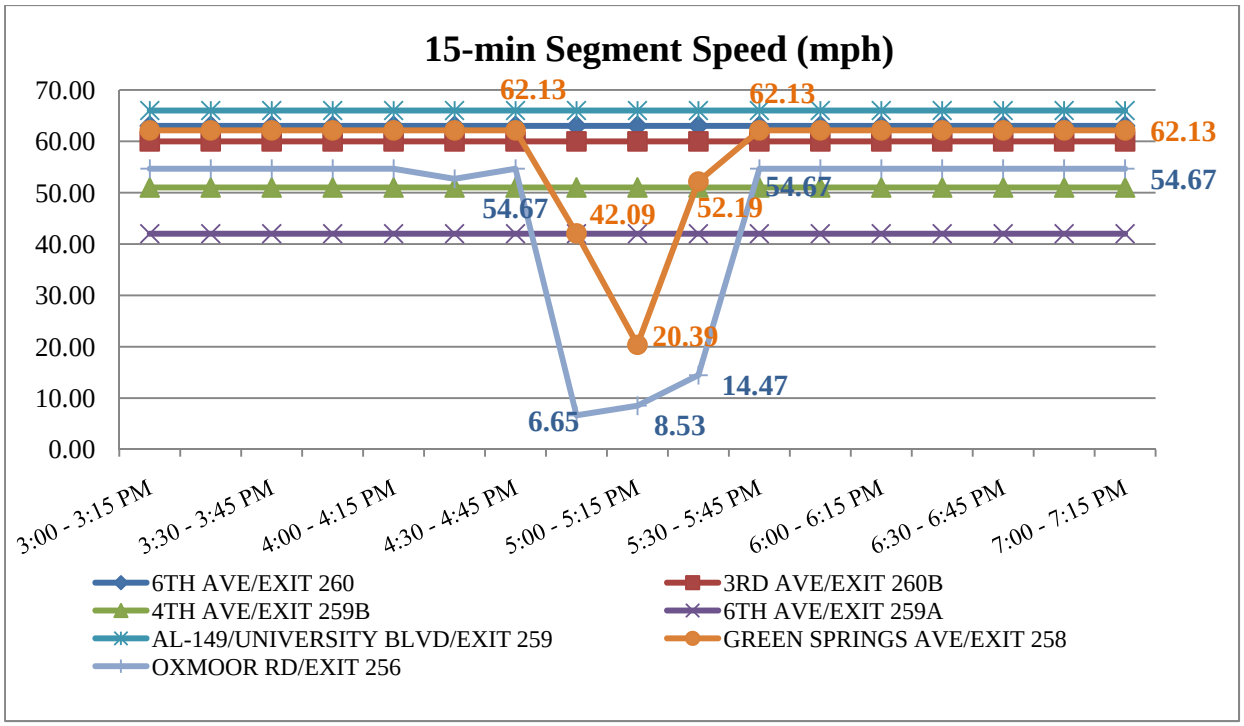


FIGURE 4-10 S2-12S 15-min Segment Speeds (Exit 260 –Exit 256)

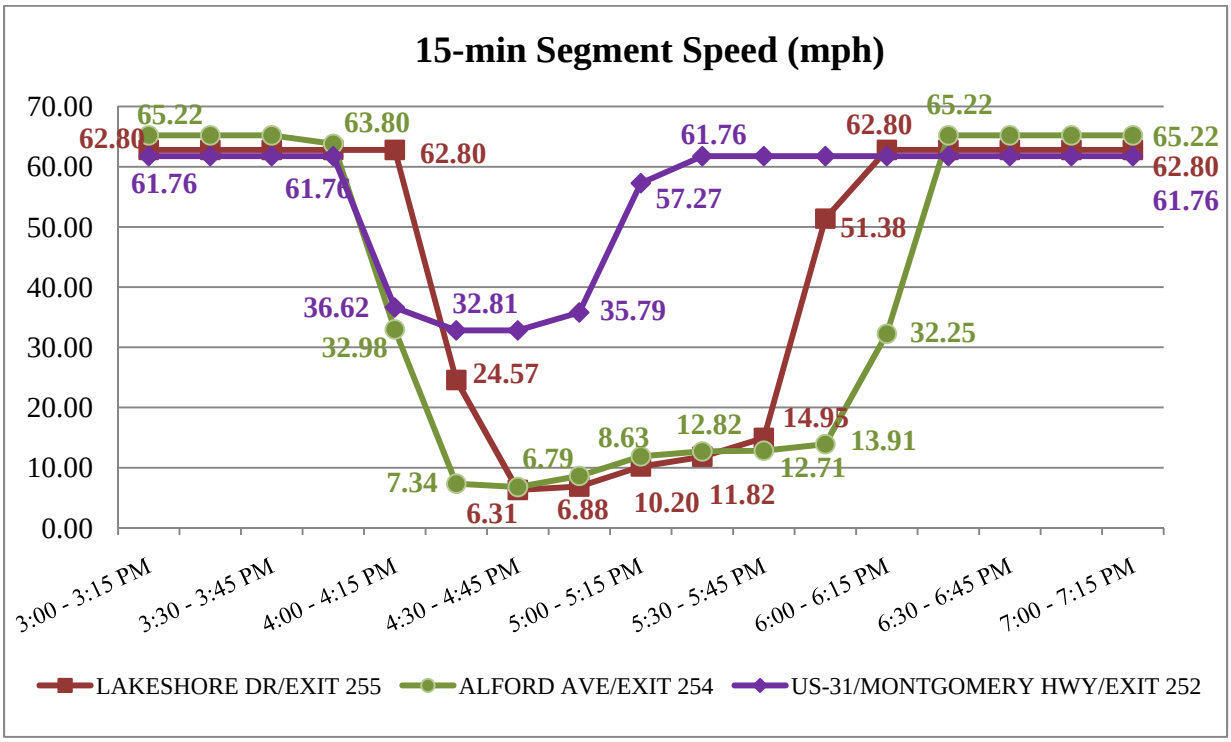


FIGURE 4-11 S2-12S 15-min Segment Speeds (Exit 255 –Exit 252)

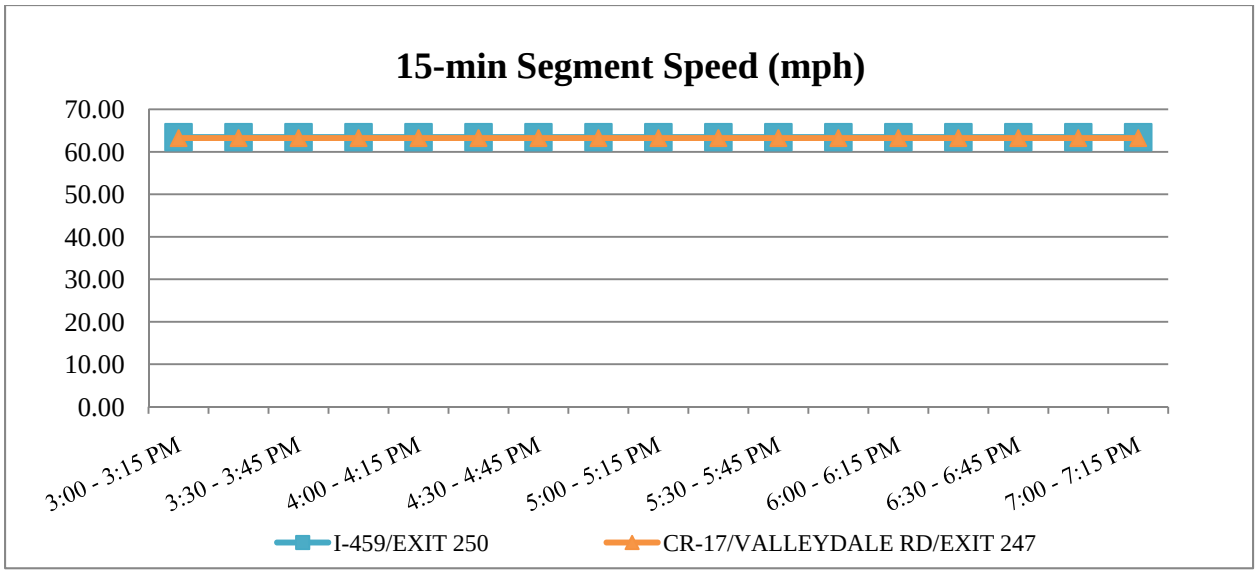


FIGURE 4-12 S2-12S 15-min Segment Speeds (Exit 250 –Exit 247)

4.2.1.3. Two-Hour One-Lane Closure (S2-21S)

In the S2-21S incident scenario one lane closure is assumed lasting for 2 hrs. The simulation results are summarized in Figures 4-13 through 4-16. Examination of the findings reveals close similarities to S2-11 results. In other words, the longer incident duration (2hrs instead of 1hr) shows little impact on corridor performance when only one lane of traffic is closed.

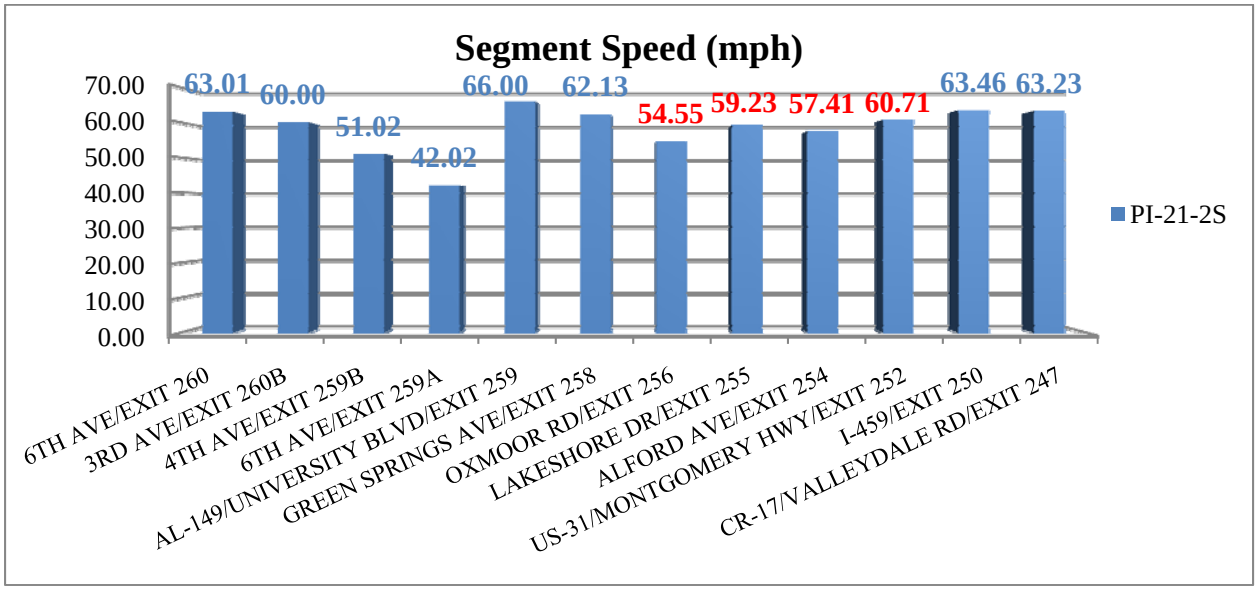


FIGURE 4-13 Segment Speeds in S2-21S Scenario

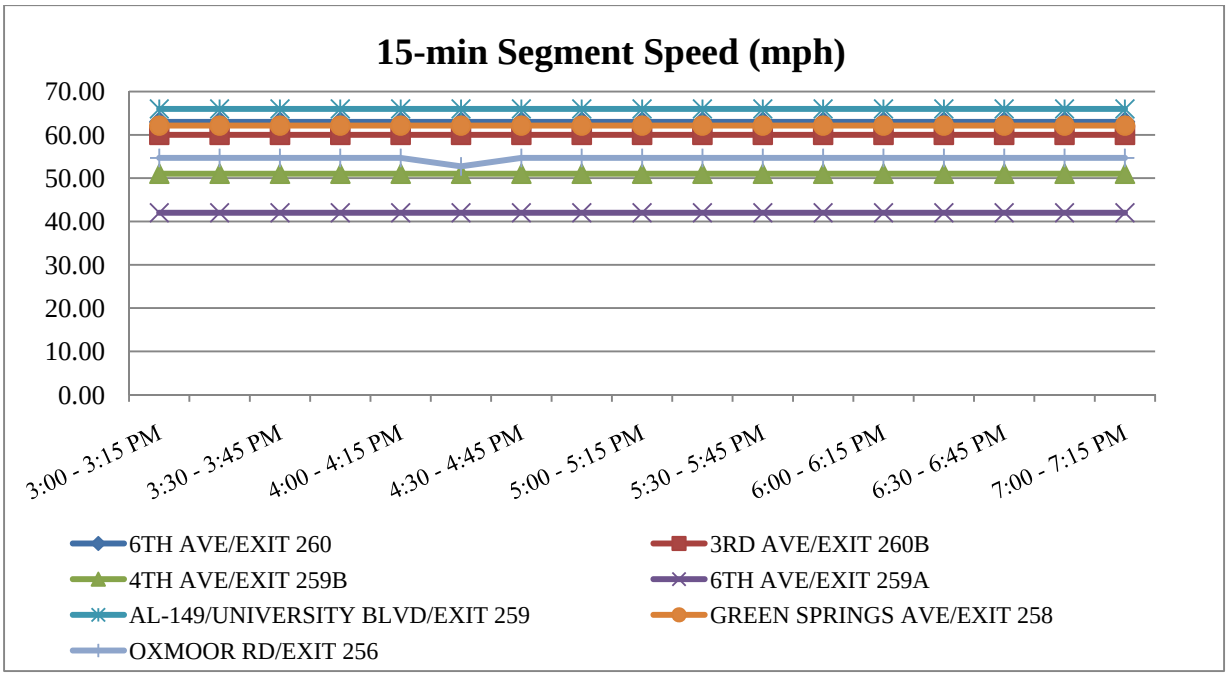


FIGURE 4-14 S2-21S 15-min Segment Speeds (Exit 260 –Exit 256)

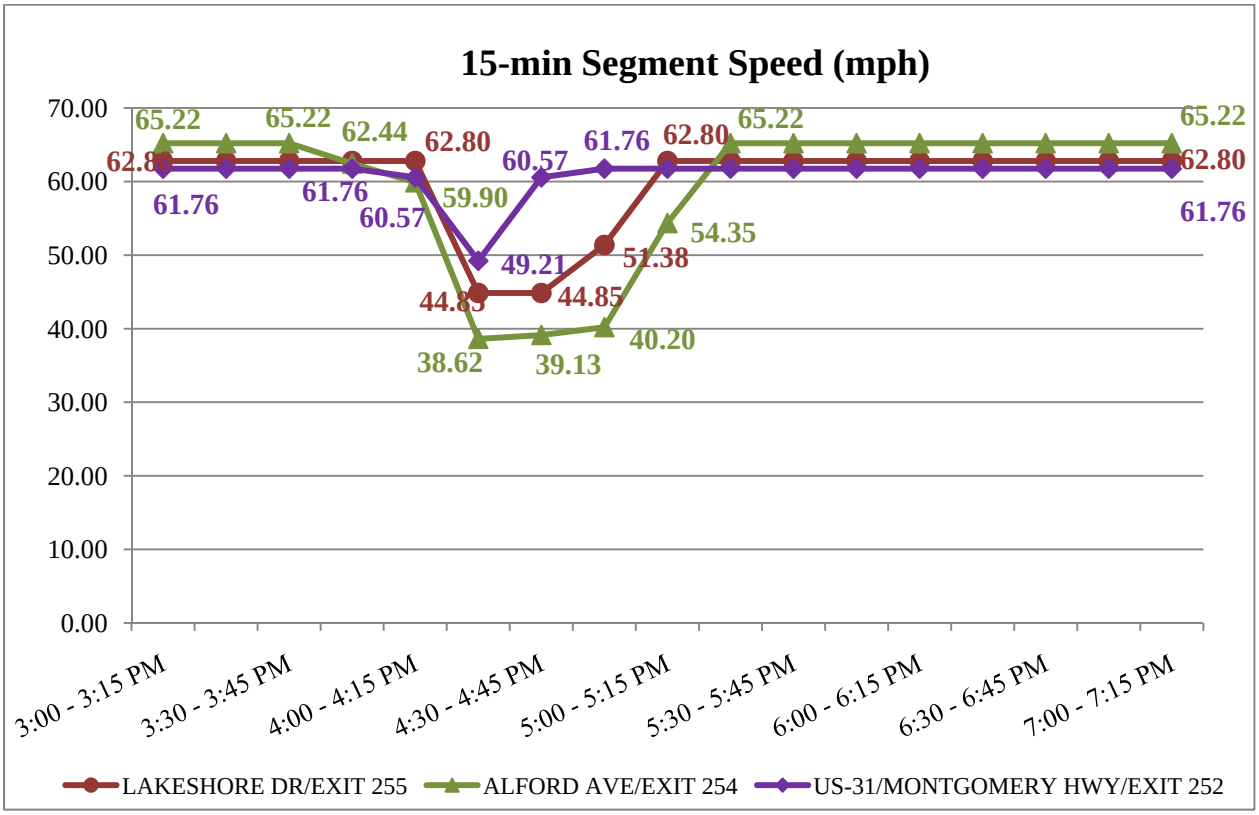


FIGURE 4-15 S2-21S 15-min Segment Speeds (Exit 255 –Exit 252)

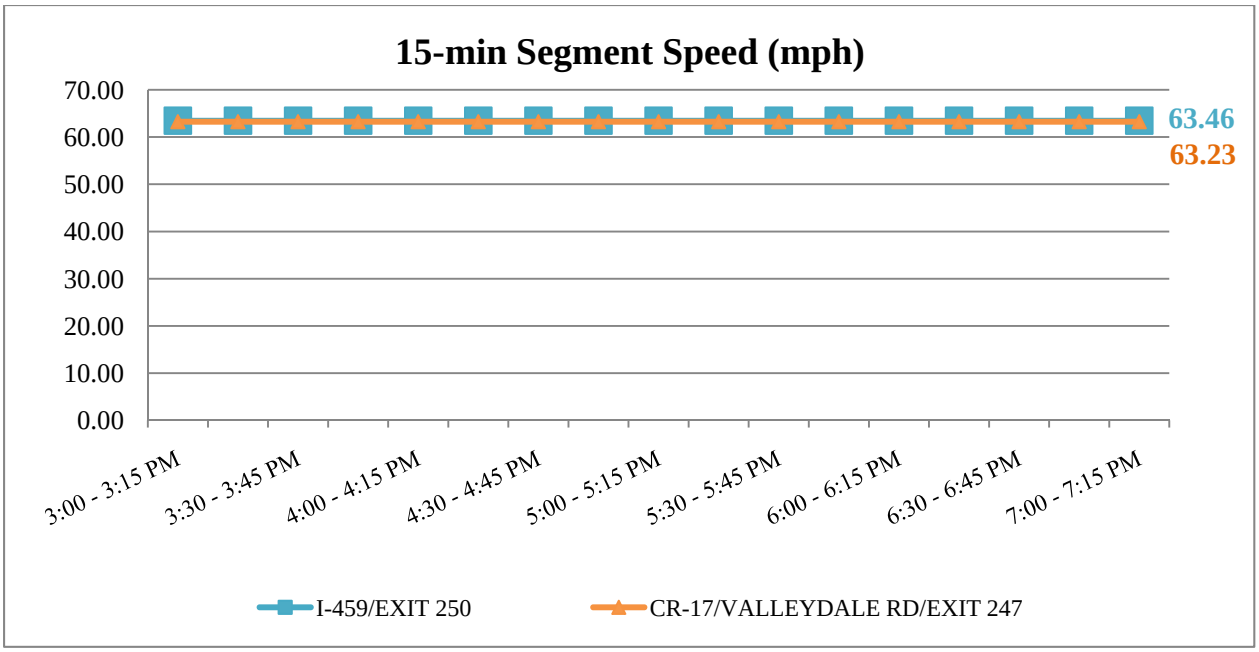


FIGURE 4-16 S2-21S 15-min Segment Speeds (Exit 250 –Exit 247)

4.2.1.4. Two-Hour Two-Lane Closure (S2-22S)

The S2-22S scenario assumes a 2-hr long incident presence resulting in a two-lane closure. The simulated speeds for this scenario are displayed in Figures 4-17 through 4-20.

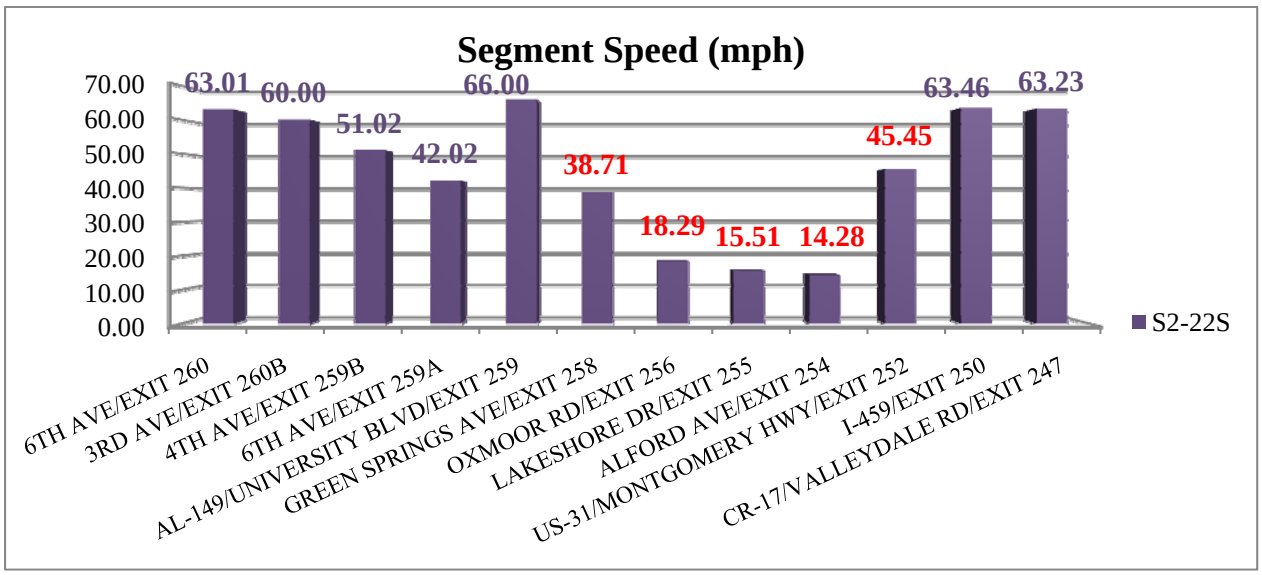


FIGURE 4-17 Segment Speeds in S2-22S Scenario

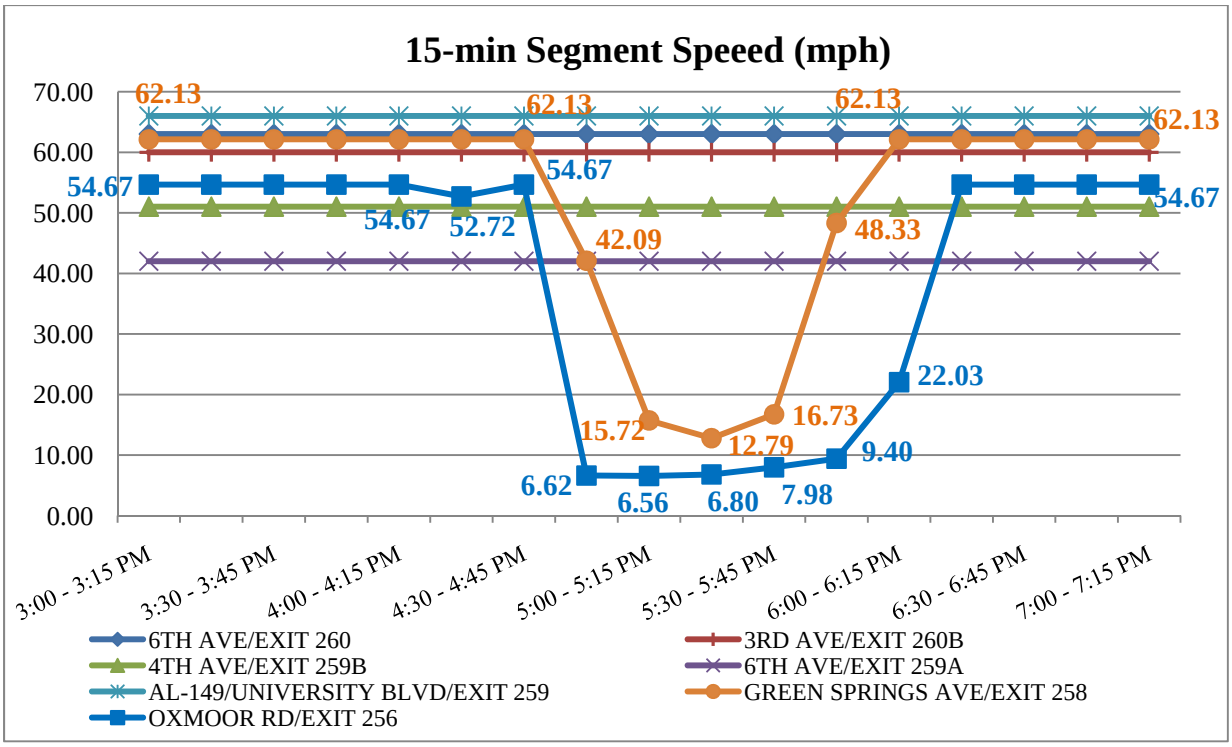


FIGURE 4-18 S2-22S 15-min Segment Speeds (Exit 260 –Exit 256)

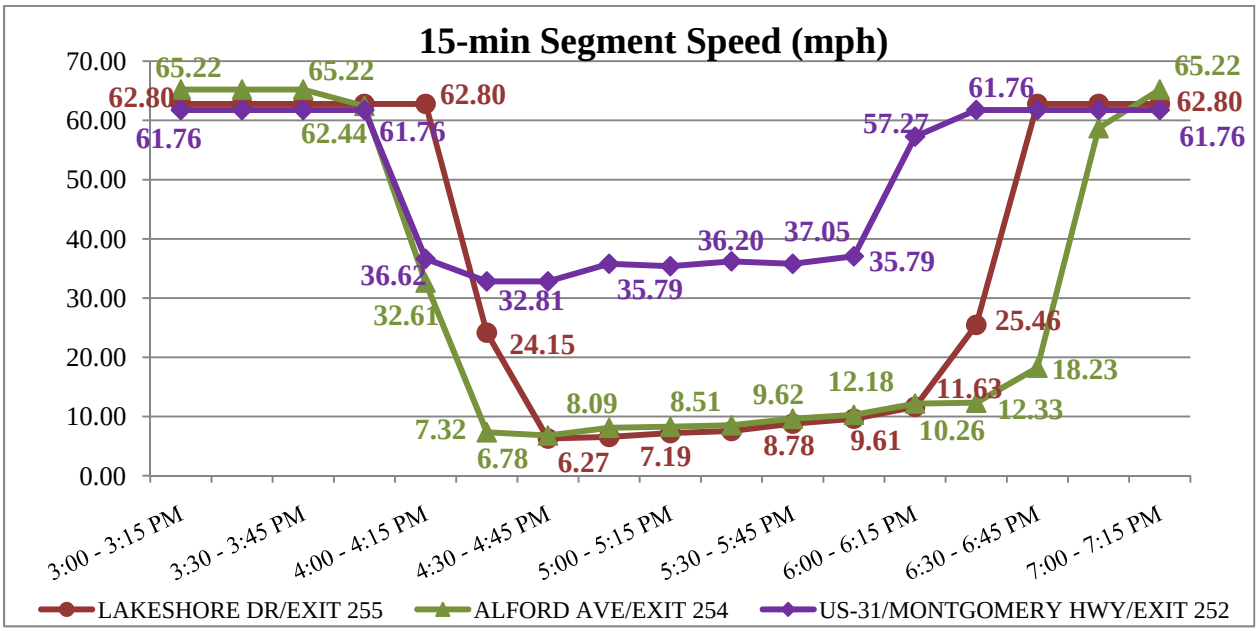


FIGURE 4-19 S2-22S 15-min Segment Speeds (Exit 255 –Exit 252)

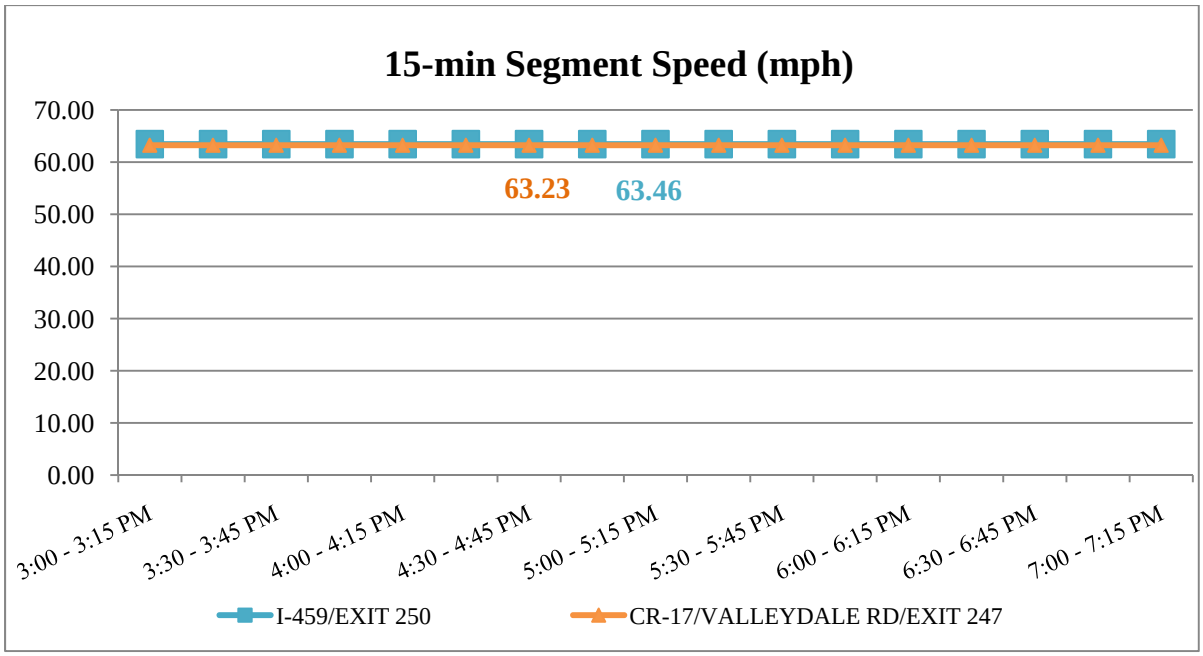


FIGURE 4-20 S2-22S 15-min Segment Speeds (Exit 250 –Exit 247)

Comparison between the results from S2-22S and previous scenarios shows that a 2 lane closure over 2 hrs at the study site has a severe impact on traffic performance. Compared to the base case, five links now experience a drop in speeds by over 25% (as opposed to three in S2-12S) with Alford Ave and Lakeshore Dr. links showing nearly 75% drops in speed compared to the non-incident condition (S1). As Figure 4-19 clearly illustrates, while speed recovery starts at 6:00 pm when the fully roadway capacity is restored, the complete restoration of speeds in the study corridor does not occur until 7:00-7:15 pm.

4.2.1.5. Three-Hour One-Lane Closure (S2-31S)

Figures 4-21 through 4-24 display results from scenario S2-31S that considered a 3 hr, one lane closure along the US-31/Montgomery Hwy link due to an incident. As with the S2-11S and S2-21S cases, the S2-31S results do not demonstrate any significant drops in speeds in any of the links of interest compared to the baseline (S1).

It is also worth noting that, despite the longer incident duration, the impacts on performance under S2-31S are very similar to those observed under two hour, one lane closure (S2-31S). This is a clear indication that the network has enough reserve capacity to absorb the traffic demand during the extra hour of lane closure (from 6:00-7:00 pm) and thus no degradation of the link and corridor performance is detected.

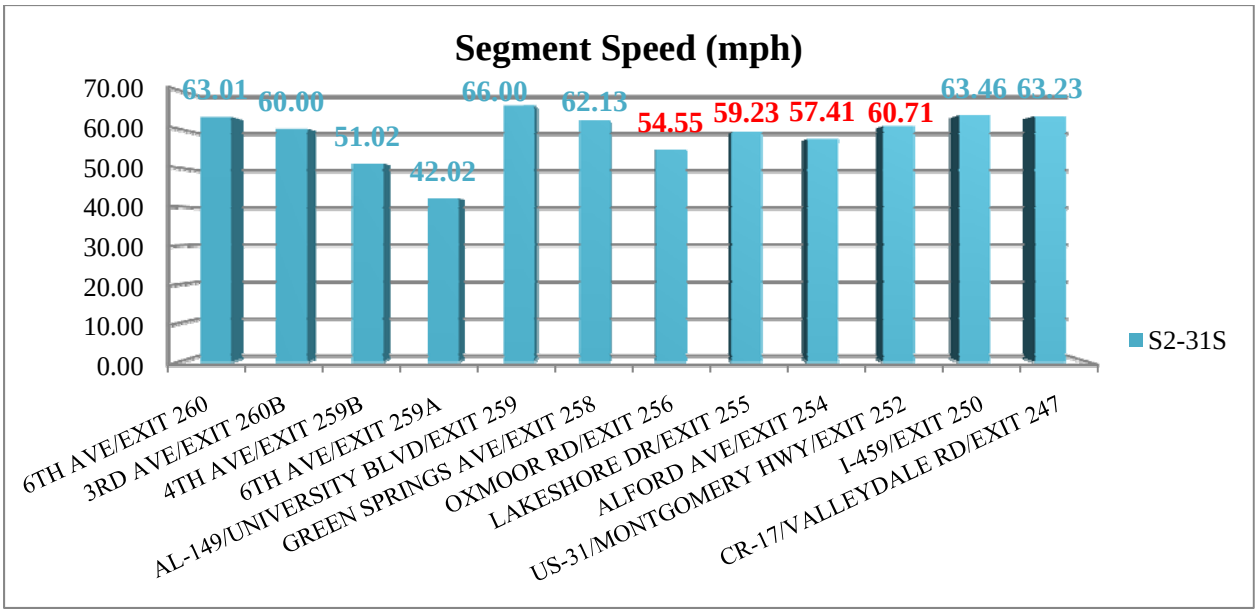


FIGURE 4-21 Segment Speeds in S2-31S Scenario

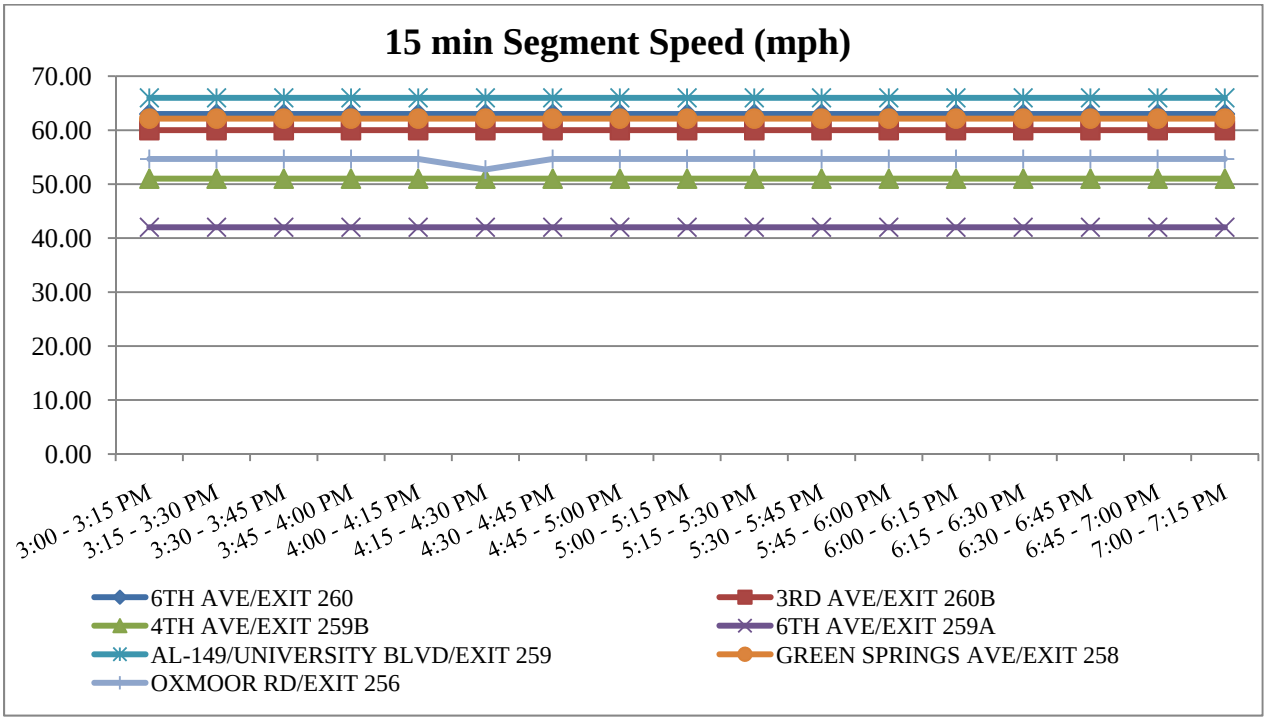


FIGURE 4-22 S2-31S 15-min Segment Speeds (Exit 260 –Exit 256)

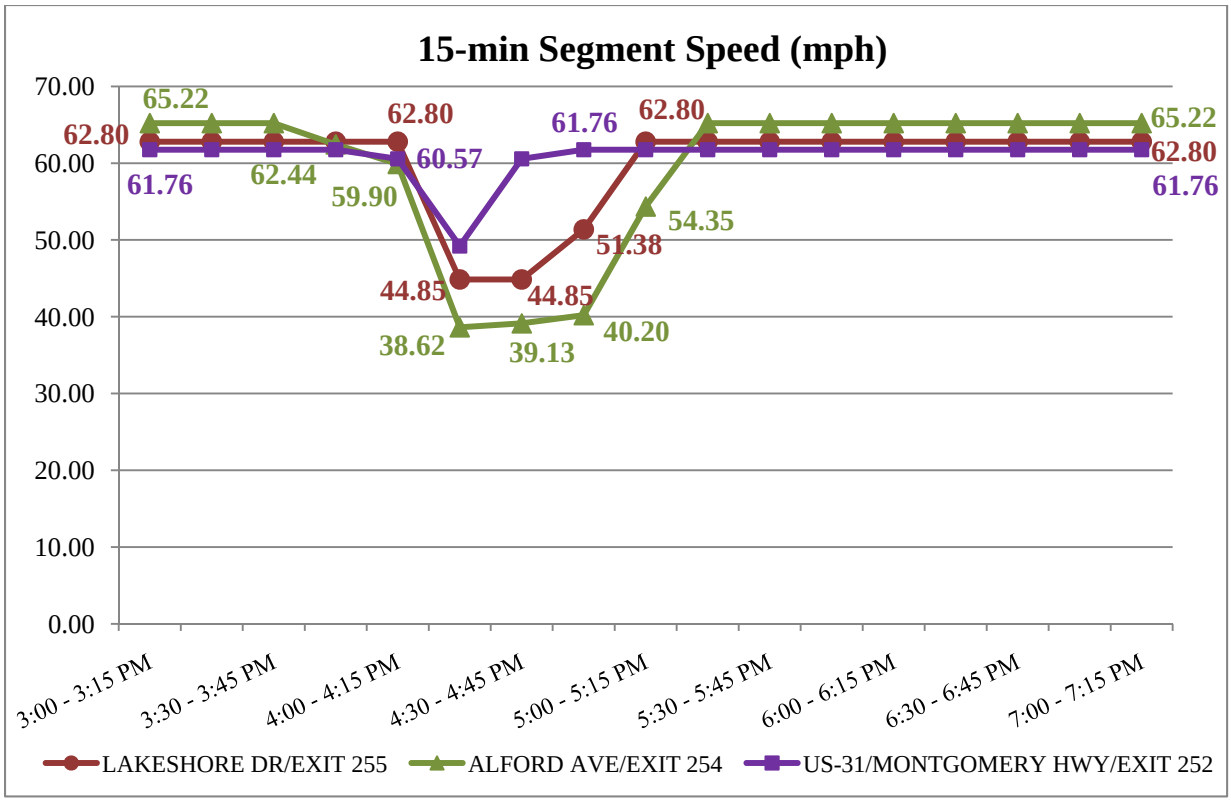


FIGURE 4-23 S2-31S 15-min Segment Speeds (Exit 255 –Exit 252)

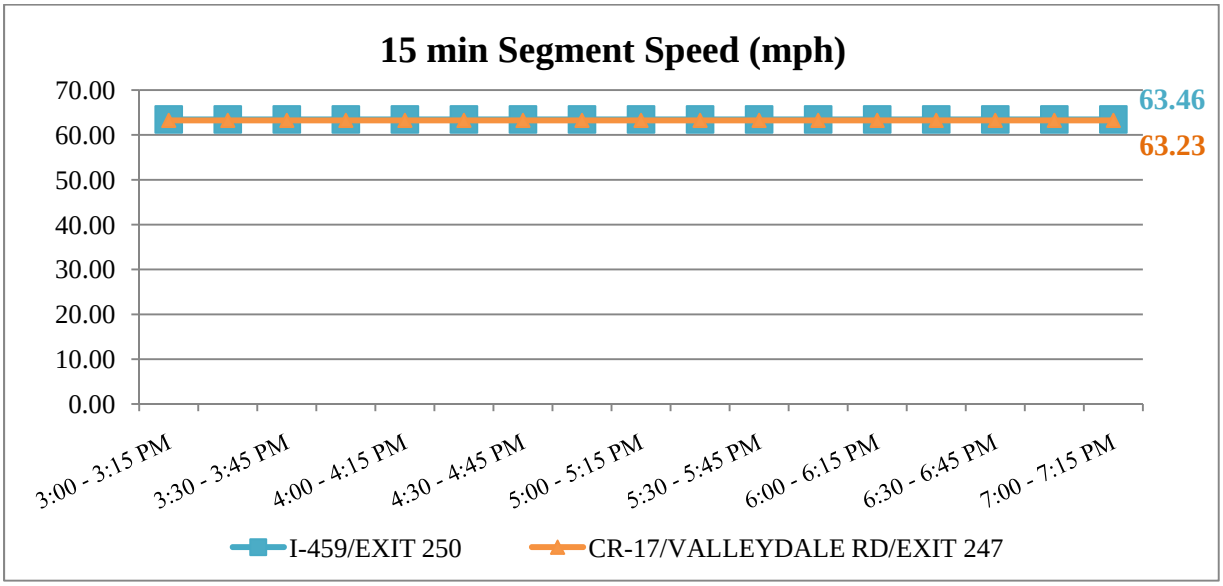


FIGURE 4-24 S2-31S 15-min Segment Speeds (Exit 250 –Exit 247)

4.2.1.6. Three-Hour Two-Lane Closure (S2-32S)

In scenario S2-32S, the simulated incident lasts for 3 hrs blocking two full lanes of traffic. Figure 4-25 summarize the average speeds and Figures 4-10 through 4-12 depict speed variations within the study period for the scenario S2-31S assumptions.

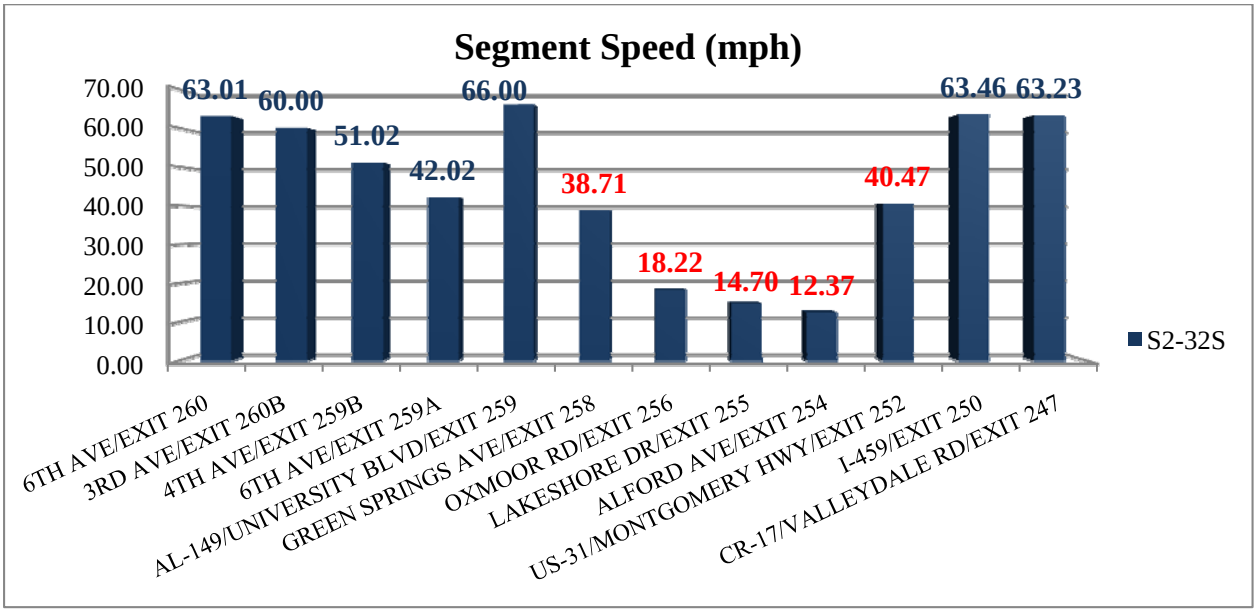


FIGURE 4-25 Segment Speeds in S2-32S Scenario

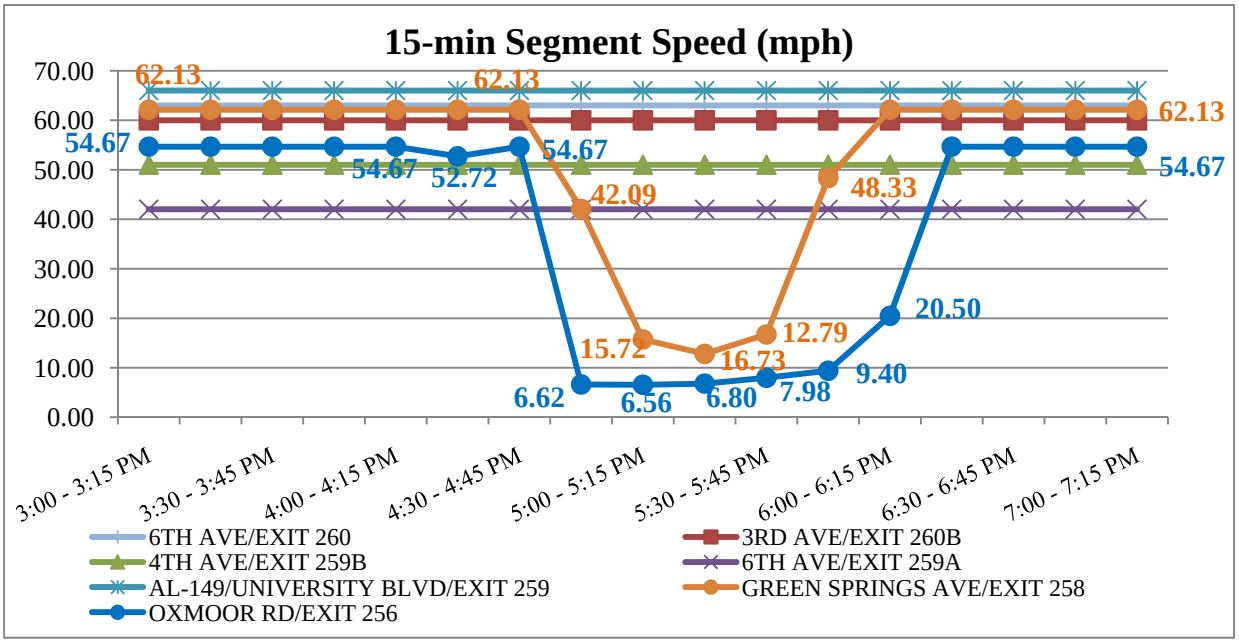


FIGURE 4-26 S2-32S 15-min Segment Speeds (Exit 260 –Exit 256)

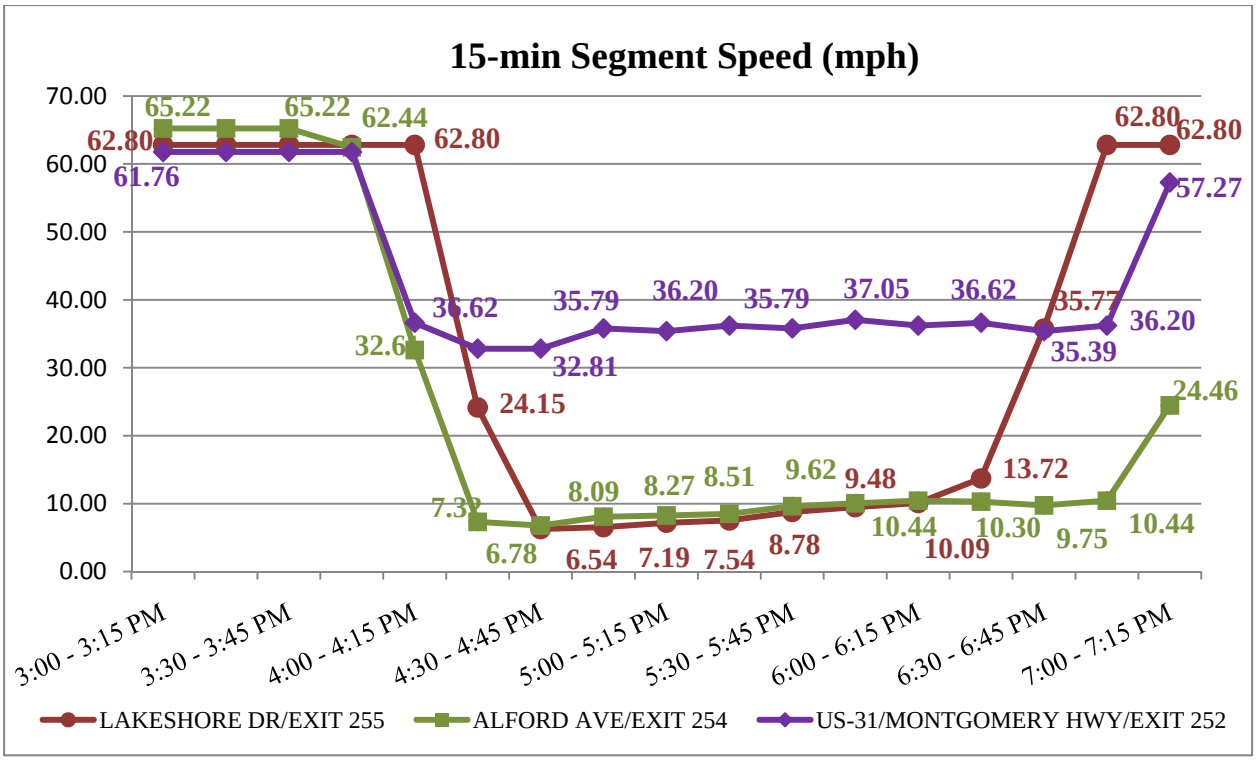


FIGURE 4-27 S2-32S 15-min Segment Speeds (Exit 255 –Exit 252)

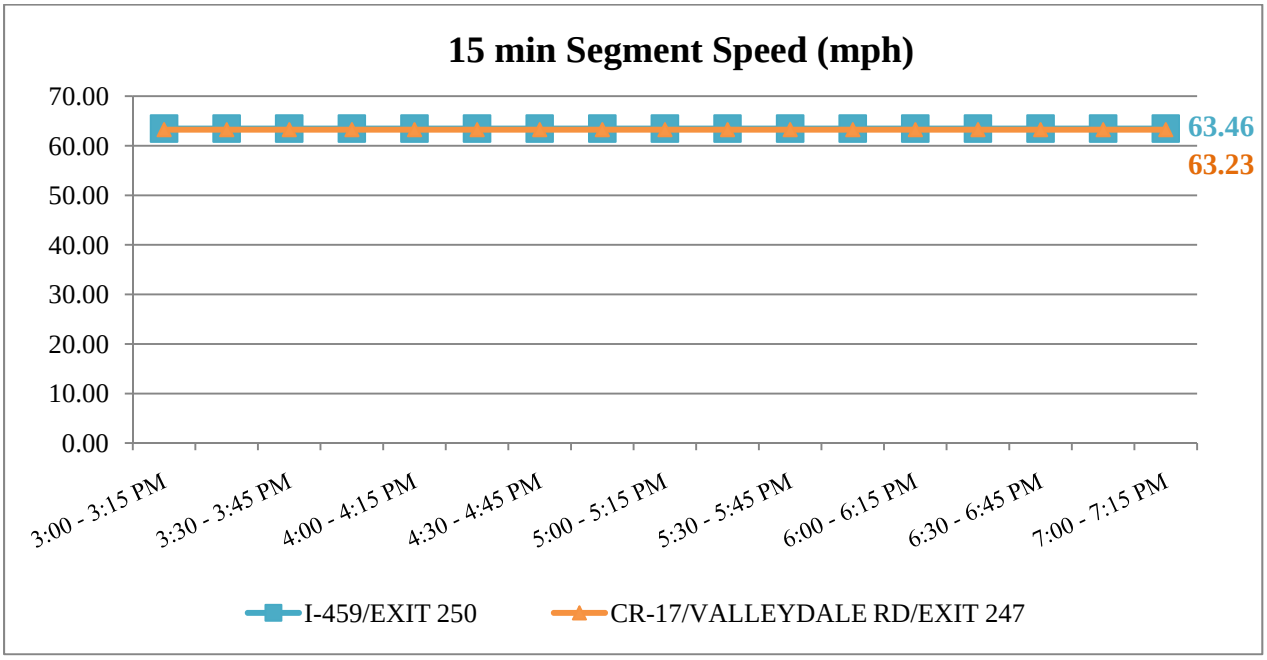


FIGURE 4-28 S2-32S 15-min Segment Speeds (Exit 250 –Exit 247)

Examination of the scenario results and comparisons with average speeds and speed profiles obtained from the base case (S1) confirm significant reductions of speeds for five study links in S2-32S ranging from 34.5% to 77.9%. However, when compared with S2-22S results, the links upstream of the incident experience only minor lower speeds as a result of the extension of the lane closures from 2 to 3 hrs. This is consistent with observations reported earlier in this study. Moreover, as shown in Figure 4-27, the impact of the incident extends beyond 7:00 pm, i.e., the incident clearance time.

4.2.1.7. Scenario S2-S Summary Results

The **average speed results** presented in the previous paragraphs are summarized in Table 4-1 below for easy reference. The highlighted entries show speeds on links that were affected by the incident presence. As evidenced by the results, the extent and intensity of speed reduction is greatly associated with available capacity (i.e., number of lanes that remain open).

TABLE 4-1 Comparison of Average Speed Results without Information Provision (mph)

Segments	**Base - S1**	**S2-11S**	**S2-12S**	**S2-21S**	**S2-22S**	**S2-31S**	**S2-32S**
6th AVE/Exit 260	63.01	63.01	63.01	63.01	63.01	63.01	63.01
3rd AVE/Exit 260B	60.00	60.00	60.00	60.00	60.00	60.00	60.00
4th AVE/Exit 259B	51.02	51.02	51.02	51.02	51.02	51.02	51.02
6th AVE/Exit 259A	42.02	42.02	42.02	42.02	42.02	42.02	42.02
University Blvd/Exit 259	66.00	66.00	66.00	66.00	66.00	66.00	66.00
Green Springs Ave/Exit 258	62.13	62.13	**53.58**	62.13	**38.71**	62.13	**38.71**
Oxmoor Rd/Exit 256	54.55	54.55	**28.65**	54.55	**18.29**	54.55	**18.22**
Lakeshore Dr./Exit 255	61.91	**60.58**	**22.00**	**59.23**	**15.51**	**59.23**	**14.70**
Alford Ave/Exit 254	55.87	**57.68**	**18.96**	**57.41**	**14.28**	**57.41**	**12.37**
US-31/Exit 252 (incident)	61.76	**60.91**	**51.83**	**60.71**	**45.45**	**60.71**	**40.47**
I-459/Exit 250	63.46	63.46	63.46	63.46	63.46	63.46	63.46
Valleydale Rd/Exit 247	63.23	63.23	63.23	63.23	63.23	63.23	63.23

It is clear that given the existing demand along the corridor of interest during the study period, the facility has enough reserve capacity to absorb one lane drop lasting from 1 to 3 hrs without any noticeable change in performance (S2-11S, S2-21S, S2-31S). However, when a second lane is closed, significant speed reductions were observed on links located upstream of the incident, as compared to the base case. The impact of the incident on traffic operations extended over five links (nearly 6 miles) and intensified when the 2 lane closure lasted for 2 hrs (S2-22S) instead of one (S2-12S). However, further extension of the incident duration (i.e., 3 hrs in S2-32S) had only minor incremental effects on speed reduction compared to S2-22S.

Table 4-2 summarizes **changes in delays** observed when compared to the base line from all simulation runs assuming incident presence and no information provision. The changes in the

TABLE 4-2 Comparison of Delay Results without Information Provision (min)

Segments	Delay Difference Compared to Base Case (min)					
	S2-11S	S2-12S	S2-21S	S2-22S	S2-31S	S2-32S
6th AVE/Exit 260	0.00	0.00	0.00	0.00	0.00	0.00
3rd AVE/Exit 260B	0.00	0.00	0.00	0.00	0.00	0.00
4th AVE/Exit 259B	0.00	0.00	0.00	0.00	0.00	0.00
6th AVE/Exit 259A	0.00	0.00	0.00	0.00	0.00	0.00
University Blvd/Exit 259	0.00	0.00	0.00	0.00	0.00	0.00
Green Springs Ave/Exit 258	0.00	**0.22**	0.00	**0.85**	0.00	**0.85**
Oxmoor Rd/Exit 256	0.00	**0.82**	0.00	**1.79**	0.00	**1.80**
Lakeshore Dr./Exit 255	**0.05**	**2.78**	**0.09**	**4.57**	**0.09**	**4.91**
Alford Ave/Exit 254	**0.08**	**3.55**	**0.09**	**5.24**	**0.09**	**6.30**
US-31/Exit 252 (incident)	**0.02**	**0.33**	**0.03**	**0.61**	**0.03**	**0.89**
I-459/Exit 250	0.00	0.00	0.00	0.00	0.00	0.00
Valleydale Rd/Exit 247	0.00	0.00	0.00	0.00	0.00	0.00

delay results are consistent with those observed when reviewing the speed results. For a driver that traverses the entire study segment (i.e., from 6th AVE/Exit 260 to Valleydale Rd), an one lane closure does not introduce any measurable delays (S2-11S, S2-21S, S2-31S). On the contrary, an one hour long two lane closure due to an incident (S2-12S) will introduce 7.7 min of extra delay to an average driver that traverses the entire study segment, in addition to the regular recurrent delay that he experiences in the base case. When the 2-lane closure persists for 2 hours (S2-22S), the average incident-induced delay increases further to 13.06 min (14.75 min for a 2-lane, 3-hr closure in S2-32S). This is significant as it is nearly doubles the average corridor travel time compared to free flow conditions.

Last but not least, the VISTA model results provided information about expected **emergency responders travel times** to the incident location given prevailing traffic conditions. Such information is very valuable **for dispatching purposes** as at times the unit that appears closer to an incident location may take longer than an alternate unit to arrive at the scene due to congestion.

As an example, for scenario S2-22S, among 227 emergency responder units considered, a responder unit from Hoover Fire Department - Station 1 was found to the best one to be dispatched at the site since it can reach the incident scene within 210 sec, or 3.5 min. The best police unit to be dispatched to the site was from Hoover Police Department with an expected travel time to the scene of 306 seconds (just over 5 min). Finally, the best EMS vehicle to be dispatched to the scene was from Galleria Woods Skilled Nursing Facility with a response time of 564 seconds (or 9.4 min). As Table 4-3 shows, due to incident-induced congestion the best responding units have longer response times to the incident compared to travel times from their position to the incident under normal conditions (base). When such differences are large they

TABLE 4-3 First Emergency Responders Arrival Times and Travel Times

Scenarios	Emergency Responder	Arrival Time (pm)	Travel Time sec (min)	Distance Traveled (mile)
Base Case	Hoover Fire Department (Station 1)	4:08:18	198 (3.3)	2.81
	Hoover Police Department	4:09:06	246 (4.1)	3.50
	Baptist Health Center - 1	4:11:30	390 (6.5)	6.42
S2-22S	Hoover Fire Department (Station 1)	4:08:30	210 (3.5)	2.81
	Hoover Police Dept	4:10:06	306 (5.1)	3.50
	Galleria Woods Skilled Nursing Facility	4:14:24	564 (9.4)	5.88

may even lead to the selection of an alternate unit with an expected shorter response time as in the case of EMS unit dispatching in S2-22S. Based on the position of the vehicle and expected travel time to the incident location under normal operations, a dispatcher would have selected to dispatch an EMS unit from Baptist Health Center –1. However, as the study analysis indicates, when considering the incident impact on traffic conditions, the best EMS unit to be dispatched is actually one originating from Galleria Woods Skilled Nursing Facility, instead.

Moreover, queries in VISTA can be identify the **best routes to the incident site and** from the incident site to **the hospital location**. These details were considered in Scenario 3, the results of which are presented in a following section.

4.2.2. Primary Incident Results - With Information Provision – Scenario 2-D

The following paragraphs summarise the parametric analysis findings for incident scenario 2 assuming that the travellers have knowledge of the incident and thus they re-evaluate their original routes and select optimal paths that minimize their user cost (i.e., delay, travel time etc) under present (i.e. incident) traffic conditions. To analyze this route choice driver behavior, the VISTA DTA/DUE Module was employed along with the RouteSim simulator.

The summary results from the parametric analysis performed are displayed in Table 4-4 while a complete set of results for all six S2-D scenarios (similar to the ones presented for the S2-S scenarios) is available in the Appendix.

4.2.2.1. Scenario S2-D Summary Results

Table 4-4 displays the **average speed results** for all S2-D scenarios, i.e., scenarios considering the impact of incident information dissemination on network performance. Scenarios S2-11D, S2-21D, and S2-31D assumed 1 lane closure for 1, 2, 3 hrs respectively and Scenarios S2-12D, S2-22D, and S2-32D considered 2 lane closures for 1, 2, 3 hrs respectively. The highlighted entries show speeds on links that were affected by the incident presence.

As shown in Table 4-4, in all cases considered, speed reductions above 25% due to the incident occur only on one link (i.e., Alford Ave.) located directly upstream of the incident link (US-31) compared to 4 links in the corresponding S2-S scenarios (Table 4-1).

TABLE 4-4 Comparison of Average Speed Results With Information Provision (mph)

Segments	Base-S1	S2-11D	S2-12D	S2-21D	S2-22D	S2-31D	S2-32D
6th AVE/Exit 260	63.01	63.01	63.01	63.01	63.01	63.01	63.01
3rd AVE/Exit 260B	60.00	60.00	60.00	60.00	60.00	60.00	60.00
4th AVE/Exit 259B	51.02	51.02	51.02	51.02	51.02	51.02	51.02
6th AVE/Exit 259A	42.02	42.02	42.02	42.02	42.02	42.02	42.02
University Blvd/Exit 259	66.00	66.00	66.00	66.00	66.00	66.00	66.00
Green Springs Ave/Exit 258	62.13	62.13	62.13	62.13	62.13	62.13	62.13
Oxmoor Rd/Exit 256	54.55	54.67	54.67	54.67	54.67	54.67	54.67
Lakeshore Dr./Exit 255	61.91	62.80	**55.86**	**62.80**	**62.80**	**62.71**	**62.80**
Alford Ave/Exit 254	55.87	59.97	**22.16**	**60.70**	**28.76**	**60.26**	**21.80**
US-31/Exit 252	61.76	61.12	**49.21**	**61.19**	**46.76**	**60.57**	**45.11**
I-459/Exit 250	63.46	63.46	63.46	63.46	63.46	63.46	63.46
Valleydale Rd/Exit 247	63.23	63.23	63.23	63.23	63.23	63.23	63.23

Similarly to the S2-S scenarios the impact of the number of lanes closed on performance was far more pronounced than that of the duration of the lane closure. Under the 1 lane closure scenarios (S2-11D, S2-21D, and S2-31D), the link-by-link average speeds are, in fact, fairly similar to those obtained under the base line non-incident conditions (Scenario S1). On the other hand, the2 lane closure led to significant reductions in average speeds along Alford Ave ranging from 48.5% to 61% (as compared with the baseline speeds), but still lower than their counterparts in the S2-S case that ranged from 66% to 77.9%. As expected scenario S2-32D showed the lowest speeds on the affected links amongst all scenarios considered but results were close to those observed under the other 2 lane closure scenarios (S2-12D and S2-22D).

The average speed comparisons provide above paint the overall picture of the differences between recurrent speeds and speeds under incident conditions with and without traveler information availability. Detailed comparisons between base case (S1), and all S2-S and S2-D scenarios on a link-by-link basis and on a 15 min aggregation time interval were also performed and the results are available in the **Appendix**. For demonstration purposes, a sample such graph is provided in Figure 4-29. The graph compares speeds on the Alford Ave link located immediately upstream of the incident link under a. Base Case, b. S2-22S and c. S2-22D conditions (i.e. two lane closures, two hours without and with traveler information provisions).

A number of valuable findings can be extracted from close observation of Figure 4-29. From the base case data one can see that the link starts to experience recurrent congestion around 4:00 PM with a recovery time of around 5:00 PM. The peak 15-min period is at 4:15-4:30 when the speed

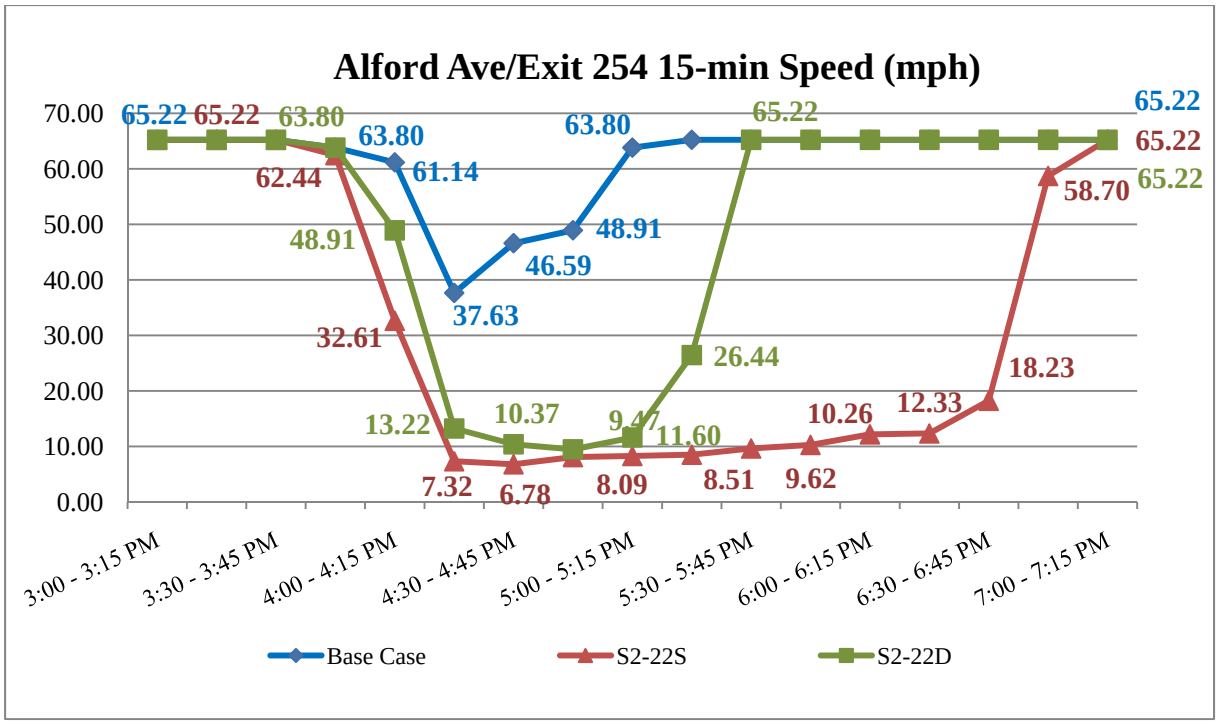


FIGURE 4-29 Comparison of Base Case, S2-22S and S2-22D: Alford Ave

drops to 37.5 mph, or almost half the free flow speed. The introduction of the incident in S2-22S results in crawling speed of 7.32 mph during the same 15-min period. Clearly the link experiences breakdown conditions which remain present for three full hours, from 4:00 PM to 7:00 PM. When drivers are aware of the incident and some divert to alternate paths (S2-22D) the impact of the incident on link operation is more tolerable. While rapid deterioration of conditions starts again around 4:00 PM, the first signs of recovery occur around 5:15 and the full recovery takes place at 5:30, or 1.5 hrs earlier compared to S2-22S.Similar conclusions can be derived by observation of **changes in delays** due to the incident presence, given availability of incident-related information. Table 4-5 summarizes the results. It can be seen that when drivers are informed about the incident presence, they have the opportunity to choose alternate routes that would optimize their travel.

As a result, the average additional delay experienced by a driver that traverses the entire study corridor in S2-12D is 3.42 min as compared to 7.7 min in S2-12S. Note that the difference in delays is due to the information availability as the number of lanes closed (2 lanes) and closure duration (1 hour) is the similar in those two scenarios. The delay savings in the scenarios considering information provision are very impressive and become even more notable as the duration of the lane closure increases (3.5 min additional delay in S2-32D compared to 14.75 min in S2-32S). Such comparisons further support the conclusion that the negative effects of an incident on traffic operations can be reduced if drivers are aware of the incident and willing to reroute so as to optimize their travel.

TABLE 4-5 Comparison of Delay Results with Information Provision (min)

Segments	Delay Difference Compared to Base Case (min)					
	S2-11D	**S2-12D**	**S2-21D**	**S2-22D**	**S2-31D**	**S2-32D**
6th AVE/Exit 260	0.00	0.00	0.00	0.00	0.00	0.00
3rd AVE/Exit 260B	0.00	0.00	0.00	0.00	0.00	0.00
4th AVE/Exit 259B	0.00	0.00	0.00	0.00	0.00	0.00
6th AVE/Exit 259A	0.00	0.00	0.00	0.00	0.00	0.00
University Blvd/Exit 259	0.00	0.00	0.00	0.00	0.00	0.00
Green Springs Ave/Exit 258	0.00	0.00	0.00	0.00	0.00	0.00
Oxmoor Rd/Exit 256	0.00	0.00	0.00	0.00	0.00	0.00
Lakeshore Dr./Exit 255	0.00	**0.19**	0.00	0.00	0.00	0.00
Alford Ave/Exit 254	**0.02**	**2.80**	0.00	**1.79**	**0.01**	**2.87**
US-31/Exit 252 (incident)	**0.02**	**0.43**	**0.02**	**0.55**	**0.03**	**0.63**
I-459/Exit 250	0.00	0.00	0.00	0.00	0.00	0.00
Valleydale Rd/Exit 247	0.00	0.00	0.00	0.00	0.00	0.00

4.3. Secondary Incident Scenario Results – Scenario 3

As stated earlier, in *Scenario 3 (S3)*, the primary incident conditions were assumed the same as in S2-22 (i.e., two lanes closed for 2 hours), however, a secondary incident was introduced along the of the responding EMS unit route to the main hospital resulting in a two-lane blockage at the I-65 N/Lakeshore Dr. junction. The secondary incident blockage started at 4:20 pm and lasted for at least 30 minutes.

Assuming an incident notification, verification, and dispatching time of 5 min, the EMS vehicle arrived at the scene at 4:14 pm and departed en route to UAB Children's Hospital with an injured person on 4:35 pm. Scenario S3-22S assumed that the EMS driver followed his original best path to the hospital (Figure 4-30) while S3-22D assumed that the EMS driver was given information and was rerouted around the secondary incident to avoid congestion (Figure 4-31).

The results summarized in Table 4-6 show that the occurrence of a secondary incident along the route of the EMS response vehicle to the hospital resulted in a significant increase in travel time (as compared to S2-22S). This is due to the location, severity, and timing of the secondary incident. When the EMS driver followed a diversion, a delay savings of over 2 min was realized.

It should be noted that the scenarios and findings presented above are illustrative of the types of analyses and outputs that one can expect by running various incident scenarios on the VISTA Birmingham test bed. While different incident scenario assumptions are expected to lead to different results, the extensive model testing undertaken in this study demonstrates the model capabilities, confirms that model validity and realism, and allows for follow up studies in support of incident and emergency management in the future.

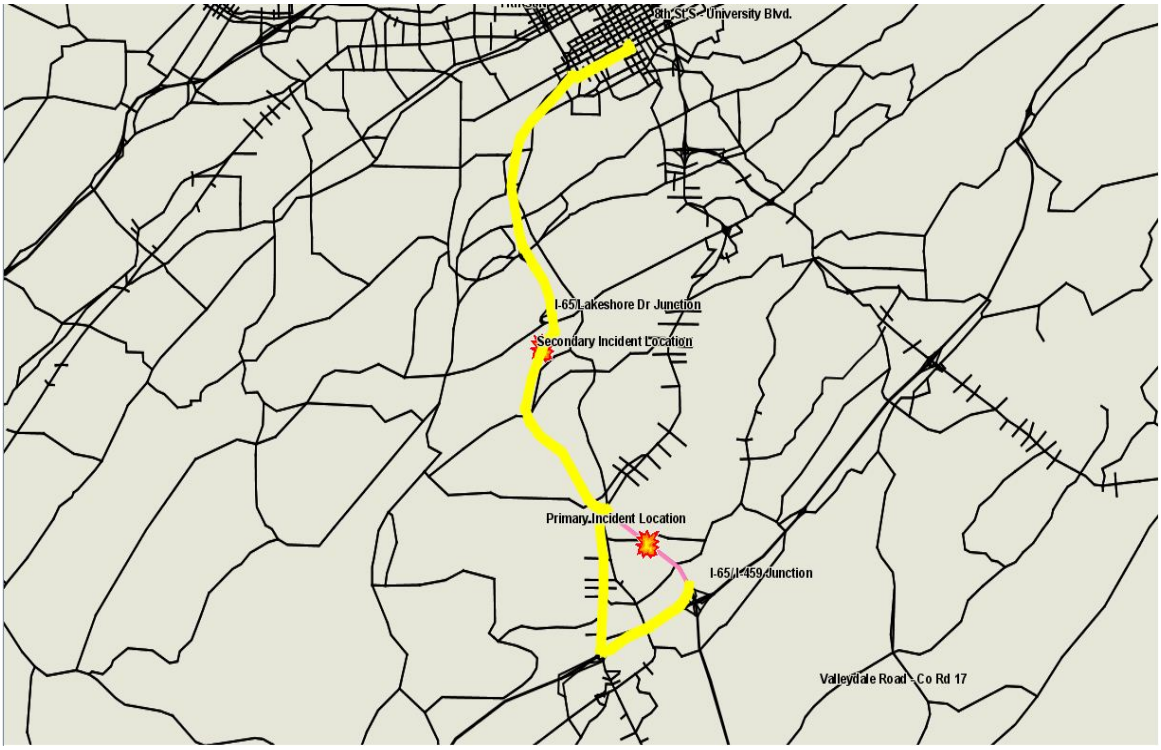


FIGURE 4-30 EMS Vehicle Path to UAB Hospital in S3-22S

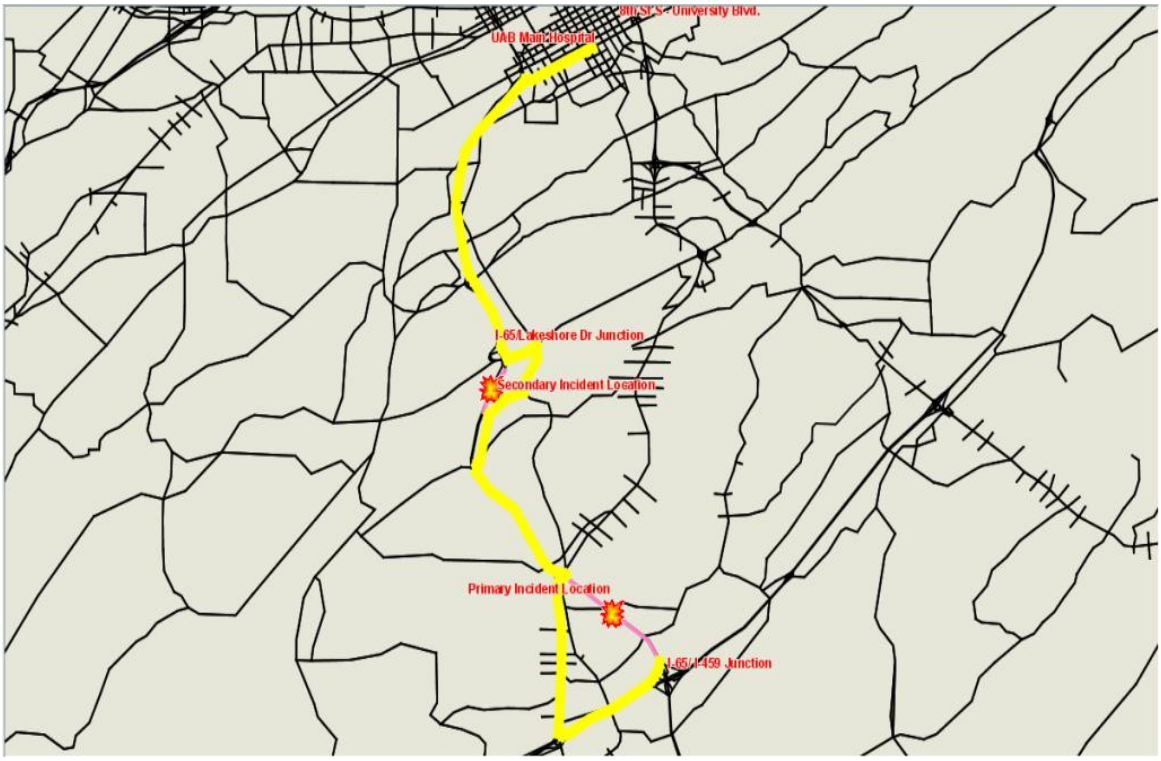


FIGURE 4-31 EMS Vehicle Path to UAB Hospital with Diversion in S3-22D

TABLE 4-6 EMS Vehicle Travel Times to the Hospital

Scenario Name	Travel Time (sec)	Travel Time (min)	Information Provision	Secondary Incident
S2-22S	1242	20.7	N	N
S3-22S	2322	38.7	N	Y
S3-22D	2196	36.6	Y	Y

5. STUDY CONCLUSIONS

Successful traffic incident management programs depend on strong interagency involvement and commitment. To meet the safety and mobility needs of all affected parties, traffic incidents require a high level of collaboration and coordination (Corbin, 2003). Furthermore, consideration of actual traffic conditions in the event of an incident plays an important role in minimizing the incident impact on network operations and emergency response.

Dynamic Traffic Assignment (DTA) models are capable of capturing dynamically changing traffic conditions, and thus are superior to more widely used static models for incident and emergency management applications. Using the Visual Interactive System for Transport Algorithms (VISTA) platform, a recently emerged DTA simulation and optimization model, this study investigated the impact of incidents of varying severity and duration on transportation network performance in the Birmingham area. The intensity and extent of the impact over space and time were assessed on the basis of average speeds. Moreover, delays and travel times were considered in order to gain a complete picture of incident-induced impacts on traffic operations and emergency response. Detailed models were developed to capture driver route choices in the event of incident information provision (or the lack of). Moreover, first responders travel times to the scene of the incident were collected to identify best units for responding of the incident, in an effort to improve current dispatching practices. Finally, a secondary incident on the EMS to the hospital was considered to further demonstrate the superiority of Dynamic Traffic Assignment (DTA) over traditional static assignment methods in capturing dynamically changing traffic conditions.

One of the contributions of this work is that it shows how a mesoscopic dynamic traffic-assignment model can be used to assist decision making for incident management and emergency response at the regional level. Given the limited studies of this nature, details are offered on simulation-model selection, data collection, model development, assumptions made, and scenario development and testing.

The development of the VISTA prototype model for the Birmingham region was a major accomplishment in itself. It involved extensive data collection and processing, customized data coding, and model refinement. More than 1.8 million trips with more than 35 million route options were simulated for each afternoon peak period starting from 4:00 pm to 7:00 pm for each run performed for each of the study scenarios. The availability of the model eliminates the need for repetition of this tedious process in the future, a significant benefit from this effort. Since the model is accessible through the internet it can become available and used beyond the scope of this study by a variety of users for future testing and evaluation studies, with minimum requirements for data collection and coding.

The results of the incident case studies considered in this work demonstrate clearly that the number of lane closures in the event of an incident have greater and longer lasting impacts on network operations than the duration of the lane closures.

Under the study assumptions, a 1-lane closure had minimal impact on average speeds and delays as compared to normal traffic conditions. This implies that the incident link and upstream links have enough reserve capacity to absorb the changes in the traffic demand during the lane closure without noticeable degradation of the link and corridor performance. On the other hand, lane closures of two lanes had significant impacts on traffic operations, that extended further into space and time as the duration of the two lane closure increased from 1 to 2 or 3 hours. For example, compared to the base case, an 1-hour long 2-lane closure due to an incident (S2-12S) introduced 7.7 min of extra delay to the average driver that traversed the study corridor, while a 2-hour 2-lane closure resulted in 14.75 min of non-recurrent delay.

Congestion spillback and time for traffic recovery were also significantly impacted when a 2-lane close occurred. It should be noted that the impact of the incident on traffic operations extended over five links (nearly 6 miles) and intensified when the 2 lane closure lasted for 2 hrs (S2-22S) instead of one (S2-12S) in which case the incident affected only 3 links. However, extension of the incident duration to 3 hours had only minor incremental effects on speed reduction compared to that observed under the two hours incident assumption.

Furthermore, the results from the parametric analysis clearly show the impact of incident information dissemination on incident response and recovery. The findings confirm that the negative effects of an incident on traffic operations can be reduced noticeably if drivers are aware of the incident and willing to reroute so as to optimize their travel. Significant reductions in both the severity and extent of congestion were observed in scenarios that considered information provision (S2-S) when compared to their counterparts considering uninformed travelers (S2-D). More specifically, the delay savings in the scenarios considering information availability become more notable as the number and the duration of lane closures increased (from 3.5 min additional delay in S2-32D to 14.75 min in S2-32S). These findings stress the importance of Intelligent Transportation Systems (ITS) technologies for the collection and dissemination of information to the public during incidents and emergencies. ITS applications provide effective ways to collect information on road and traffic conditions and to deliver information to the public in a timely manner, thus assisting in incident management. An assessment of existing ITS capabilities and needs around incident prone locations in the Birmingham area is recommended in an effort to improve incident management in the future.

Last but not least, the case study results allowed for selection of the best units to respond to the incident, as well as best routes to the incident site and from the incident site to the hospital location taking under consideration actual traffic conditions in the network during the incident presence. This model capability allows for improved dispatching decisions, that in turn can improve incident response and recovery.

It should be noted that in this study the developed model performed only off-line analyses. Ultimately, the model should be expanded to support decision making during the course of an incident event in real time. More specifically, a module should be designed in VISTA that will a) allow incorporation of real-time data into the model and b) be capable of running faster than real time. Using such a module for incident management, effects from dynamic events on the roadway capacity and driver behaviors can be emulated and optimized solutions can be obtained to minimize on traffic operations and emergency response.

REFERENCES

1. Alabama Legislation Information System Online (ALISON). Alabama Move Over Act: Moving Over or Reducing Speed when Approaching Law Enforcement or Emergency Vehicles. Section 32-5A-58.2. Act 2009-577, p. 1695, §§1-3. Retrieved from: http://alisondb.legislature.state.al.us/acas/ACASLoginMac.asp

2. Ang-Olson, J. and S. Latoski. Simplified Guide to the Incident Command System for Transportation Professionals. Technical Report of the U.S. Department of Transportation Federal Highway Administration (FHWA). Report No: FHWA-HOP-06-004. February 2006.

3. Babiceanu, S.E., Smith, B.L., Park, B. and C.C. McGhee. Development of Statewide System Operations Performance Measures: Virginia Case Study. TRB 86th Annual Meeting Compendium of Papers CD-ROM, Paper #07-2405. Transportation Research Board of the National Academies, Washington, D.C., 2007.

4. Balakrishna, R., Y.Wenn, M. B. Akiva and C. Antoniou. Simulation-Based Framework for Transportation Network Management for Emergencies. Transportation Research Record: Journal of the Transportation Research Board. Volume 2041, Transportation Research Board of the National Academies, Washington, D.C., 2008, pp. 80-88.

5. Ben-Akiva, M., Bierlaire, M., Koutsopoulos, H. N., and R. Mishalani. Real-time simulation of traffic demand-supply interactions within DynaMIT. Transportation and Network Analysis: Current Trends by Gendreau, M. and Marcotte, P., editors, Miscellenea in honor of Michael Florian. Kluwer Academic Publishers, 2002, pp. 19-36.

6. Birenbaum, I., Creel, C and S. G. Wegmann. Traffic Control Concepts for Incident Clearance. Technical Report of the U.S. Department of Transportation Federal Highway Administration (FHWA). Report No: FHWA-HOP-08-057. January 2009.

7. Brooke, K., Dopart, K., Smith, T. and A. Flannery. Sharing Information between Public Safety and Transportation Agencies for Traffic Incident Management. National Cooperative Highway Research Program (NCHRP) Report 520. Transportation Research Board of the National Academies, Washington, D.C., 2004.

8. Bunn, M.D. and G.T. Savage. Integrated Traffic Management and Emergency Response: Success Factors. Final Report of the University Transportation Center for Alabama (UTCA). Report No: 01101. September, 2003.

9. Caltrans Division of Research and Innovation (DRI). Preliminary Investigation on Measuring and Improving Performance in Incident Management. CTC & Associates LLC. March, 2010.

10. Carson, J.L. Best Practices in Traffic Incident Management. Technical Report of the U.S. Department of Transportation Federal Highway Administration (FHWA). Report No:

FHWA-HOP-10-050. September 2010. Retrieved from http://www.ops.fhwa.dot.gov/publications/fhwahop10050/fhwahop10050.pdf

11. Center for Transportation Injury Research (CenTIR). Rationale for Crash Response Research. February, 2010. Retrieved from: http://www.cubrc.org/centir/index_response.html

12. Charles, P., Dunn, K, Fitzgerald, P., Peters, N. and Reardon, G. Establishing Inter–Agency Regional Incident Management in Brisbane Australia. 10th World Congress and Exhibition on Intelligent Transport Systems and Services. Paper 3045. Madrid, Spain, 2003.

13. Chien, S.I., Mouskos, K. and A.K. Ziliaskopoulos. Development of a Simulation/Assignment Model for the NJDOT I-80 ITS Priority Corridor. Final Report of New Jersey Department of Transportation (NJDOT). Report No: FHWA-NJ-2005-011. June 2005.

14. Chiu, Y.C., J. Bottom, M. Mahut, A.Paz, R. Balakrishna, T. Waller, and J. Hicks. Dynamic Traffic Assignment A Primer. Transportation Research Circular E-C153. Transportation Research Board, Transportation Network Modeling Committee, June 2011.

15. Corbin, J. A National Unified Goal for Traffic Incident Management: Perspective on Progress, Foundation for the Future. Presentation notes from National NUG Summit: A Summit on the National Unified Goal for Traffic Incident Management, September, 2010. Retrieved from http://www.i95coalition.org/i95/Portals/0/Public_Files/pm/presentations/NUG%20Summit%20All%20PresentationsFINAL.pdf

16. Corbin, J. and P.B. Notes. Traffic Incident Management Planning: The Case for Mainstreaming. ITE Journal. Volume 73(2), February 2003.

17. Feyen, R.G. and C.I. Eseonu. Identifying Methods and Metrics for Evaluating Interagency Coordination in Traffic Incident Management. Center for Transportation Studies (CTS) Final Report: CTS 09-13, Department of Mechanical and Industrial Engineering University of Minnesota Duluth and Northland Advanced Transportation Systems Research Laboratory (NATSRL) University of Minnesota Duluth, May 2009.

18. Flanigan, M., A.Blatt, M. Russell and R. Batta. Emergency Response Technology and the Integrated Active Transportation System (IATS); State of the Art and Vision for the Future. TRB 89th Annual Meeting Compendium of Papers DVD. Paper # 10-2441. Transportation Research Board of the National Academies, Washington, D.C., 2010.

19. Hardy, M., K. Wunderlich, J. Bunch, T. Smith and L. Dodge. Structuring Modeling and Simulation Analyses for Evacuation Planning and Operations. TRB 89th Annual Meeting Compendium of Papers DVD, Paper # 10-0703. Transportation Research Board of the National Academies, Washington, D.C., 2010.

20. Highway Capacity Manual (HCM). Transportation Research Board, National Research Council, Washington, D.C., 2000.

21. Karl, C. Improving Traffic Incident Management: Literature Review. Austroads Research Report: AP-R296/07, Austroads Incorporated. Sydney, 2007.

22. Khattak, A., Wang, X. and H. Zhang. IMIT: A Tool for Dynamically Predicting Incident Durations, Secondary Incident Occurrence, and Incident Delays. TRB 90th Annual Meeting Compendium of Papers DVD, Paper # 11-0803. Transportation Research Board of the National Academies, Washington, D.C., 2011.

23. Lake County PASSAGE Live Traffic. Elements of PASSAGE. 2010. Retrieved from: http://www.lakecountypassage.com/about/index.html

24. Liu, H. X., J. X. Ban, W. Ma, and P. B. Mirchandani. Model Reference Adaptive Control Framework for Real-Time Traffic Management under Emergency Evacuation. *Journal of Urban Planning and Development © ASCE*, Volume 133(1), March 2007, pp 43-50.

25. Lively, D., O. Elhamshary and W, Tournay. Advanced Traveler Information Systems: An Overview of California's System Application and Its Performance as Part of Emergency Response Planning. TRB 85th Annual Meeting Compendium of Papers CD-ROM, Paper # 06-1340. Transportation Research Board of the National Academies, Washington, D.C., 2006.

26. Louwers, B. Distraught man attempts suicide along I-696. C&G Newspapers Webpage. 2009. Retrieved from: http://www.candgnews.com/Homepage-Articles/2009/5-6-09/Warren-I-696-man-jump.asp

27. Lu, X. and S. Gao. Using Travel Demand Forecasting Software for Emergency Planning in Small and Medium-Sized Regions. TRB 89th Annual Meeting Compendium of Papers DVD, Paper #10-1415. Transportation Research Board of the National Academies, Washington, D.C., 2010.

28. Manual on Uniform Traffic Control Devices (MUTCD) 2009 Edition Chapter 6I: Control of Traffic through Traffic Incident Management Areas. The Federal Highway Administration (FHWA), 2009.

29. Margiotta, R., Voorhies, K. and T. Lomax. Measuring and Communicating the Effects of Traffic Incident Management Improvements. National Cooperative Highway Research Program Research Results Digest. Number 289. Transportation Research Board of the National Academies, Washington D.C., May 2004.

30. National Traffic Incident Management Coalition (NTIMC). Benefits of Traffic Incident Management. National Unified Goal (NUG) for Traffic Incident Management. 2006b. Retrieved from http://www.transportation.org/sites/ntimc/docs/Benefits11-07-06.pdf

31. National Traffic Incident Management Coalition (NTIMC). Technical Briefs on Traffic Incident Management Topics. Example Strategies for Building Stronger State TIM Programs. National Unified Goal (NUG) for Traffic Incident Management. 2006c. Retrieved from http://www.transportation.org/sites/ntimc/docs/Institutional%20Models.pdf

32. National Traffic Incident Management Coalition (NTIMC). Traffic Incident Facts, 2006a. Retrieved from http://timcoalition.org/?siteid=41&pageid=595

33. Newton, D., Owens, N., Carter, M. and C. Mitchell. New York Integrated Incident Management System Evaluation Project Final Report. Science Applications International Corporation (SAIC). March 2007. Retrieved from: http://ntl.bts.gov/lib/30000/30900/30995/14479_files/IIMS_final_032307.pdf

34. Ohio Department of Transportation (ODOT). Ohio QuickClear: Professional Responders Guide for Safe and Effective Highway Incident Management. October 2007.

35. Owens, N. D., Armstrong, A. H., Mitchell, C. and R. Brewster. Federal Highway Administration Focus States Initiative: Traffic Incident Management Performance Measures Final Report. The U.S. Department of Transportation Federal Highway Administration (FHWA). Report No: FHWA-HOP-10-010. December 2009. Retrieved from http://www.ops.fhwa.dot.gov/publications/fhwahop10010/fhwahop10010.pdf

36. Palma, A. and F. Marchal. Measurement of Uncertainty Costs with Dynamic Traffic Simulations. TRB 87th Annual Meeting Compendium of Papers DVD, Paper # 08-1092. Transportation Research Board of the National Academies, Washington, D.C., 2008.

37. Pearce, V. What Have We Learned about Freeway, Incident, and Emergency Management and Electronic Toll Collection? Booz Allen Hamilton Consulting Firm. 2000. Retrieved from: http://plan4operations.dot.gov/docs/what_lrnd.pdf

38. Sawaya, O.B., A. K. Ziliaskopoulos, K. C. Mouskos and D. Kamaryiannis. A Methodology for Computing Time-Dependent Alternate Routes around Freeway Incidents. Journal of Intelligent Transportation Systems. Volume 9(3), 2005, pp. 123-132.

39. Schrank, D., Lomax, T and S. Turner. The 2010 Urban Mobility Report. Technical Report of Texas Transportation Institute, the Texas A&M University System, 2010. Retrieved from http://tti.tamu.edu/documents/mobility_report_2010.pdf

40. Sisiopiku, V. P., X. Li, K. C. Mouskos, C. Kamga, C. Barrett, and A.M. Abro. Dynamic Traffic Assignment Modeling For Incident Management. Transportation Research Record: Journal of the Transportation Research Board. Volume 1994, Transportation Research Board of the National Academies, Washington, D.C., 2007a, pp. 110-116.

41. Sisiopiku, V.P., Li, X, Abro, A.M., and R.W. Peters. Transportation Facilities Management under Emergencies. . Final Report of the University Transportation Center for Alabama (UTCA) Report No: 06202. March 2007b.

42. Tennessee Department of Transportation (TDOT). Strategic Plan for Highway Incident Management in Tennessee. Office of Incident Management, Tennessee Department of Transportation, Transportation Management Center and Vanderbilt Center for Transportation Research. 2003.

43. U.S. Census Bureau. Motor Vehicle Accidents–Number and Deaths: 1980 to 2008. [Data file]. 2008. Retrieved from http://www.census.gov/compendia/statab/2011/tables/11s1102.pdf

44. U.S. Census Bureau. The 2011 Statistical Abstract: Motor Vehicle Accidents and Fatalities. The National Data Book. Retrieved from http://www.census.gov/compendia/statab/2011/tables/11s1102.pdf

45. U.S. Department of Transportation Federal Highway Administration (FHWA). DYNASMART-P. Research and Technology Innovation Delivery. 2011. Retrieved from: http://www.fhwa.dot.gov/research/deployment/dynasmart.cfm

46. U.S. Department of Transportation, Research and Innovative Technology Administration (RITA). Benefits Database. Intelligent Transportation Systems Joint Program Office. 2001. Retrieved from: http://www.itsbenefits.its.dot.gov/its/benecost.nsf/ID/CE350754B5A7361285256C53005B6646?OpenDocument&Query=BApp

47. Yu, J., S.Y. Park and G.L. Chang. An Advanced Travelers Information System for Guiding Route Choice to Ocean City, Maryland. TRB 89th Annual Meeting Compendium of Papers DVD, Paper # 10-2981. Transportation Research Board of the National Academies, Washington, D.C., 2010.

48. Zheng, H., Y.C. Chiu, P. B. Mirchandani and M. Hickman. Modeling of Evacuation and Background Traffic for an Optimal Zone-Based Vehicle Evacuation Strategy. TRB 89th Annual Meeting Compendium of Papers DVD, Paper # 10-3093. Transportation Research Board of the National Academies, Washington, D.C., 2010.

49. Ziliaskopoulos, A. K., and S. Lee. A Cell Transmission Based Assignment-Simulation Model for Integrated Freeway/Surface Street Systems. Proceedings of the 75th Annual Meeting of TRB. Transportation Research Board of the National Academies, Washington, D.C., 1996.

APPENDIX: DETAILED RESULTS OF SIMULATION RUNS

15-min Speed Results by Sub Segment

Table A-1 Base Case 15-min Speed Results by Sub Segment between 3:30 pm and 7 pm

Sub Segments	3:30 - 3:45 PM	3:45 - 4:00 PM	4:00 - 4:15 PM	4:15 - 4:30 PM	4:30 - 4:45 PM	4:45 - 5:00 PM	5:00 - 5:15 PM	5:15 - 5:30 PM	5:30 - 5:45 PM	5:45 - 6:00 PM	6:00 - 6:15 PM	6:15 - 6:30 PM	6:30 - 6:45 PM	6:45 - 7:00 PM	7:00 - 7:15 PM
6th Ave N - Exit 260	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01
3rd Ave N - Exit 260B	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
4th Ave S - Exit 259B	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
6th Ave S - Exit 259A	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02
AL-149/University Blvd - Exit 259	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00
Green Springs Ave - Exit 258	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13
Oxmoor Rd - Exit 256	54.67	54.67	54.67	52.72	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67
Lakeshore Dr. - Exit 255	62.80	62.80	62.80	53.32	58.87	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80
Alford Ave - Exit 254	65.22	63.80	59.90	34.94	34.13	35.36	58.70	65.22	65.22	65.22	65.22	65.22	65.22	65.22	65.22
US31/Montgomery Hwy - Exit 252	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76
I-459 - Exit 250	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46
CR-17/Valleydale Rd - Exit 247	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23

Table A-2 S2-11S 15-min Speed Results by Sub Segment between 3:30 pm and 7 pm

Sub Segments	3:30 - 3:45 PM	3:45 - 4:00 PM	4:00 - 4:15 PM	4:15 - 4:30 PM	4:30 - 4:45 PM	4:45 - 5:00 PM	5:00 - 5:15 PM	5:15 - 5:30 PM	5:30 - 5:45 PM	5:45 - 6:00 PM	6:00 - 6:15 PM	6:15 - 6:30 PM	6:30 - 6:45 PM	6:45 - 7:00 PM	7:00 - 7:15 PM
6th Ave N - Exit 260	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01
3rd Ave N - Exit 260B	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
4th Ave S - Exit 259B	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
6th Ave S - Exit 259A	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02
AL-149/University Blvd - Exit 259	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00
Green Springs Ave - Exit 258	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13
Oxmoor Rd - Exit 256	54.67	54.67	54.67	52.72	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67
Lakeshore Dr. - Exit 255	62.80	62.80	62.80	47.89	50.46	58.87	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80
Alford Ave - Exit 254	65.22	63.80	59.90	38.62	39.13	39.66	58.70	65.22	65.22	65.22	65.22	65.22	65.22	65.22	65.22
US31/Montgomery Hwy - Exit 252	61.76	61.76	60.57	50.80	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76
I-459 - Exit 250	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46
CR-17/Valleydale Rd - Exit 247	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23

Table A-3 S2-12S 15-min Speed Results by Sub Segment between 3:30 pm and 7 pm

Sub Segments	3:30 - 3:45 PM	3:45 - 4:00 PM	4:00 - 4:15 PM	4:15 - 4:30 PM	4:30 - 4:45 PM	4:45 - 5:00 PM	5:00 - 5:15 PM	5:15 - 5:30 PM	5:30 - 5:45 PM	5:45 - 6:00 PM	6:00 - 6:15 PM	6:15 - 6:30 PM	6:30 - 6:45 PM	6:45 - 7:00 PM	7:00 - 7:15 PM
6th Ave N - Exit 260	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01
3rd Ave N - Exit 260B	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
4th Ave S - Exit 259B	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
6th Ave S - Exit 259A	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02
AL-149/University Blvd - Exit 259	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00
Green Springs Ave - Exit 258	62.13	62.13	62.13	62.13	62.13	42.09	20.39	52.19	62.13	62.13	62.13	62.13	62.13	62.13	62.13
Oxmoor Rd - Exit 256	54.67	54.67	54.67	52.72	54.67	6.65	8.53	14.47	54.67	54.67	54.67	54.67	54.67	54.67	54.67
Lakeshore Dr. - Exit 255	62.80	62.80	62.80	24.57	6.31	6.88	10.20	11.82	14.95	51.38	62.80	62.80	62.80	62.80	62.80
Alford Ave - Exit 254	65.22	63.80	32.98	7.34	6.79	8.63	11.88	12.71	12.82	13.91	32.25	65.22	65.22	65.22	65.22
US31/Montgomery Hwy - Exit 252	61.76	61.76	36.62	32.81	32.81	35.79	57.27	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76
I-459 - Exit 250	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46
CR-17/Valleydale Rd - Exit 247	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23

Table A-4 S2-21S 15-min Speed Results by Sub Segment between 3:30 pm and 7 pm

Sub Segments	3:30 - 3:45 PM	3:45 - 4:00 PM	4:00 - 4:15 PM	4:15 - 4:30 PM	4:30 - 4:45 PM	4:45 - 5:00 PM	5:00 - 5:15 PM	5:15 - 5:30 PM	5:30 - 5:45 PM	5:45 - 6:00 PM	6:00 - 6:15 PM	6:15 - 6:30 PM	6:30 - 6:45 PM	6:45 - 7:00 PM	7:00 - 7:15 PM
6th Ave N - Exit 260	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01
3rd Ave N - Exit 260B	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
4th Ave S - Exit 259B	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
6th Ave S - Exit 259A	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02
AL-149/University Blvd - Exit 259	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00
Green Springs Ave - Exit 258	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13
Oxmoor Rd - Exit 256	54.67	54.67	54.67	52.72	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67
Lakeshore Dr. - Exit 255	62.80	62.80	62.80	44.85	44.85	51.38	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80
Alford Ave - Exit 254	65.22	62.44	59.90	38.62	39.13	40.20	54.35	65.22	65.22	65.22	65.22	65.22	65.22	65.22	65.22
US31/Montgomery Hwy - Exit 252	61.76	61.76	60.57	49.21	60.57	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76
I-459 - Exit 250	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46
CR-17/Valleydale Rd - Exit 247	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23

Table A-5 S2-22S 15-min Speed Results by Sub Segment between 3:30 pm and 7 pm

Sub Segments	3:30 - 3:45 PM	3:45 - 4:00 PM	4:00 - 4:15 PM	4:15 - 4:30 PM	4:30 - 4:45 PM	4:45 - 5:00 PM	5:00 - 5:15 PM	5:15 - 5:30 PM	5:30 - 5:45 PM	5:45 - 6:00 PM	6:00 - 6:15 PM	6:15 - 6:30 PM	6:30 - 6:45 PM	6:45 - 7:00 PM	7:00 - 7:15 PM
6th Ave N - Exit 260	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01
3rd Ave N - Exit 260B	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
4th Ave S - Exit 259B	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
6th Ave S - Exit 259A	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02
AL-149/University Blvd - Exit 259	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00
Green Springs Ave - Exit 258	62.13	62.13	62.13	62.13	62.13	42.09	15.72	12.79	16.73	48.33	62.13	62.13	62.13	62.13	62.13
Oxmoor Rd - Exit 256	54.67	54.67	54.67	52.72	54.67	6.62	6.56	6.80	7.98	9.40	22.03	54.67	54.67	54.67	54.67
Lakeshore Dr. - Exit 255	62.80	62.80	62.80	24.15	6.27	6.54	7.19	7.54	8.78	9.61	11.63	25.46	62.80	62.80	62.80
Alford Ave - Exit 254	65.22	62.44	32.61	7.32	6.78	8.09	8.27	8.51	9.62	10.26	12.18	12.33	18.23	58.70	65.22
US31/Montgomery Hwy - Exit 252	61.76	61.76	36.62	32.81	32.81	35.79	35.39	36.20	35.79	37.05	57.27	61.76	61.76	61.76	61.76
I-459 - Exit 250	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46
CR-17/Valleydale Rd - Exit 247	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23

Table A-6 S2-31S 15-min Speed Results by Sub Segment between 3:30 pm and 7 pm

Sub Segments	3:30 - 3:45 PM	3:45 - 4:00 PM	4:00 - 4:15 PM	4:15 - 4:30 PM	4:30 - 4:45 PM	4:45 - 5:00 PM	5:00 - 5:15 PM	5:15 - 5:30 PM	5:30 - 5:45 PM	5:45 - 6:00 PM	6:00 - 6:15 PM	6:15 - 6:30 PM	6:30 - 6:45 PM	6:45 - 7:00 PM	7:00 - 7:15 PM
6th Ave N - Exit 260	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01
3rd Ave N - Exit 260B	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
4th Ave S - Exit 259B	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
6th Ave S - Exit 259A	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02
AL-149/University Blvd - Exit 259	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00
Green Springs Ave - Exit 258	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13
Oxmoor Rd - Exit 256	54.67	54.67	54.67	52.72	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67
Lakeshore Dr. - Exit 255	62.80	62.80	62.80	44.85	44.85	51.38	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80
Alford Ave - Exit 254	65.22	62.44	59.90	38.62	39.13	40.20	54.35	65.22	65.22	65.22	65.22	65.22	65.22	65.22	65.22
US31/Montgomery Hwy - Exit 252	61.76	61.76	60.57	49.21	60.57	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76
I-459 - Exit 250	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46
CR-17/Valleydale Rd - Exit 247	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23

Table A-7 S2-32S 15-min Speed Results by Sub Segment between 3:30 pm and 7 pm

Sub Segments	3:30 - 3:45 PM	3:45 - 4:00 PM	4:00 - 4:15 PM	4:15 - 4:30 PM	4:30 - 4:45 PM	4:45 - 5:00 PM	5:00 - 5:15 PM	5:15 - 5:30 PM	5:30 - 5:45 PM	5:45 - 6:00 PM	6:00 - 6:15 PM	6:15 - 6:30 PM	6:30 - 6:45 PM	6:45 - 7:00 PM	7:00 - 7:15 PM
6th Ave N - Exit 260	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01
3rd Ave N - Exit 260B	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
4th Ave S - Exit 259B	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
6th Ave S - Exit 259A	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02
AL-149/University Blvd - Exit 259	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00
Green Springs Ave - Exit 258	62.13	62.13	62.13	62.13	62.13	42.09	15.72	12.79	16.73	48.33	62.13	62.13	62.13	62.13	62.13
Oxmoor Rd - Exit 256	54.67	54.67	54.67	52.72	54.67	6.62	6.56	6.80	7.98	9.40	20.50	54.67	54.67	54.67	54.67
Lakeshore Dr. - Exit 255	62.80	62.80	62.80	24.15	6.27	6.54	7.19	7.54	8.78	9.48	10.09	13.72	35.77	62.80	62.80
Alford Ave - Exit 254	65.22	62.44	32.61	7.32	6.78	8.09	8.27	8.51	9.62	10.05	10.44	10.30	9.75	10.44	24.46
US31/Montgomery Hwy - Exit 252	61.76	61.76	36.62	32.81	32.81	35.79	35.39	36.20	35.79	37.05	36.20	36.62	35.39	36.20	57.27
I-459 - Exit 250	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46
CR-17/Valleydale Rd - Exit 247	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23

Table A-8 S2-11D 15-min Speed Results by Sub Segment between 3:30 pm and 7 pm

Sub Segments	3:30 - 3:45 PM	3:45 - 4:00 PM	4:00 - 4:15 PM	4:15 - 4:30 PM	4:30 - 4:45 PM	4:45 - 5:00 PM	5:00 - 5:15 PM	5:15 - 5:30 PM	5:30 - 5:45 PM	5:45 - 6:00 PM	6:00 - 6:15 PM	6:15 - 6:30 PM	6:30 - 6:45 PM	6:45 - 7:00 PM	7:00 - 7:15 PM
6th Ave N - Exit 260	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01
3rd Ave N - Exit 260B	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
4th Ave S - Exit 259B	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
6th Ave S - Exit 259A	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02
AL-149/University Blvd - Exit 259	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00
Green Springs Ave - Exit 258	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13
Oxmoor Rd - Exit 256	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67
Lakeshore Dr. - Exit 255	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80
Alford Ave - Exit 254	65.22	65.22	65.22	63.80	61.14	39.66	46.59	48.91	63.80	65.22	65.22	65.22	65.22	65.22	65.22
US31/Montgomery Hwy - Exit 252	61.76	61.76	61.76	61.76	60.57	55.26	59.43	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76
I-459 - Exit 250	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46
CR-17/Valleydale Rd - Exit 247	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23

Table A-9 S2-12D 15-min Speed Results by Sub Segment between 3:30 pm and 7 pm

Sub Segments	3:30 - 3:45 PM	3:45 - 4:00 PM	4:00 - 4:15 PM	4:15 - 4:30 PM	4:30 - 4:45 PM	4:45 - 5:00 PM	5:00 - 5:15 PM	5:15 - 5:30 PM	5:30 - 5:45 PM	5:45 - 6:00 PM	6:00 - 6:15 PM	6:15 - 6:30 PM	6:30 - 6:45 PM	6:45 - 7:00 PM	7:00 - 7:15 PM
6th Ave N - Exit 260	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01
3rd Ave N - Exit 260B	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
4th Ave S - Exit 259B	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
6th Ave S - Exit 259A	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02
AL-149/University Blvd - Exit 259	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00
Green Springs Ave - Exit 258	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13
Oxmoor Rd - Exit 256	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67
Lakeshore Dr. - Exit 255	62.80	62.80	62.80	62.80	62.80	28.54	32.86	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80
Alford Ave - Exit 254	63.80	44.47	26.68	9.32	6.49	6.83	10.33	20.52	65.22	65.22	65.22	65.22	65.22	65.22	65.22
US31/Montgomery Hwy - Exit 252	61.76	61.76	32.81	29.16	28.63	30.29	54.30	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76
I-459 - Exit 250	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46
CR-17/Valleydale Rd - Exit 247	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23

Table A-10 S2-21D 15-min Speed Results by Sub Segment between 3:30 pm and 7 pm

Sub Segments	3:30 - 3:45 PM	3:45 - 4:00 PM	4:00 - 4:15 PM	4:15 - 4:30 PM	4:30 - 4:45 PM	4:45 - 5:00 PM	5:00 - 5:15 PM	5:15 - 5:30 PM	5:30 - 5:45 PM	5:45 - 6:00 PM	6:00 - 6:15 PM	6:15 - 6:30 PM	6:30 - 6:45 PM	6:45 - 7:00 PM	7:00 - 7:15 PM
6th Ave N - Exit 260	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01
3rd Ave N - Exit 260B	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
4th Ave S - Exit 259B	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
6th Ave S - Exit 259A	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02
AL-149/University Blvd - Exit 259	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00
Green Springs Ave - Exit 258	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13
Oxmoor Rd - Exit 256	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67
Lakeshore Dr. - Exit 255	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80
Alford Ave - Exit 254	65.22	63.80	61.14	39.66	48.91	54.35	65.22	65.22	65.22	65.22	65.22	65.22	65.22	65.22	65.22
US31/Montgomery Hwy - Exit 252	61.76	61.76	60.57	55.26	60.57	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76
I-459 - Exit 250	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46
CR-17/Valleydale Rd - Exit 247	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23

Table A-11 S2-22D 15-min Speed Results by Sub Segment between 3:30 pm and 7 pm

Sub Segments	3:30 - 3:45 PM	3:45 - 4:00 PM	4:00 - 4:15 PM	4:15 - 4:30 PM	4:30 - 4:45 PM	4:45 - 5:00 PM	5:00 - 5:15 PM	5:15 - 5:30 PM	5:30 - 5:45 PM	5:45 - 6:00 PM	6:00 - 6:15 PM	6:15 - 6:30 PM	6:30 - 6:45 PM	6:45 - 7:00 PM	7:00 - 7:15 PM
6th Ave N - Exit 260	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01
3rd Ave N - Exit 260B	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
4th Ave S - Exit 259B	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
6th Ave S - Exit 259A	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02
AL-149/University Blvd - Exit 259	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00
Green Springs Ave - Exit 258	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13
Oxmoor Rd - Exit 256	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67
Lakeshore Dr. - Exit 255	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80
Alford Ave - Exit 254	65.22	63.80	48.91	13.22	10.37	9.47	11.60	26.44	65.22	65.22	65.22	65.22	65.22	65.22	65.22
US31/Montgomery Hwy - Exit 252	61.76	61.76	37.50	32.14	33.15	33.51	33.51	34.24	40.90	60.57	61.76	61.76	61.76	61.76	61.76
I-459 - Exit 250	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46
CR-17/Valleydale Rd - Exit 247	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23

Table A-12 S2-31D 15-min Speed Results by Sub Segment between 3:30 pm and 7 pm

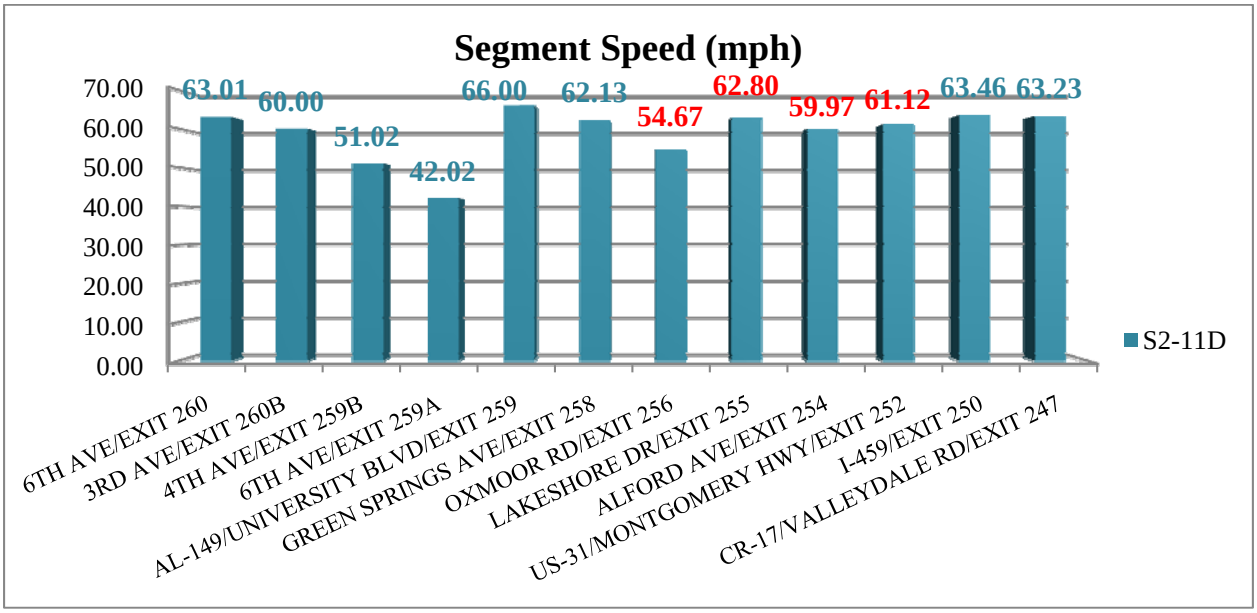
Sub Segments	3:30 - 3:45 PM	3:45 - 4:00 PM	4:00 - 4:15 PM	4:15 - 4:30 PM	4:30 - 4:45 PM	4:45 - 5:00 PM	5:00 - 5:15 PM	5:15 - 5:30 PM	5:30 - 5:45 PM	5:45 - 6:00 PM	6:00 - 6:15 PM	6:15 - 6:30 PM	6:30 - 6:45 PM	6:45 - 7:00 PM	7:00 - 7:15 PM
6th Ave N - Exit 260	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01
3rd Ave N - Exit 260B	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
4th Ave S - Exit 259B	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
6th Ave S - Exit 259A	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02
AL-149/University Blvd - Exit 259	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00
Green Springs Ave - Exit 258	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13
Oxmoor Rd - Exit 256	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67
Lakeshore Dr. - Exit 255	62.80	62.80	62.80	61.43	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80
Alford Ave - Exit 254	65.22	62.44	59.90	39.66	49.74	50.60	63.80	65.22	65.22	65.22	65.22	65.22	65.22	65.22	65.22
US31/Montgomery Hwy - Exit 252	61.76	61.76	60.57	49.99	59.43	59.43	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76	61.76
I-459 - Exit 250	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46
CR-17/Valleydale Rd - Exit 247	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23

Table A-13 S2-32D 15-min Speed Results by Sub Segment between 3:30 pm and 7 pm

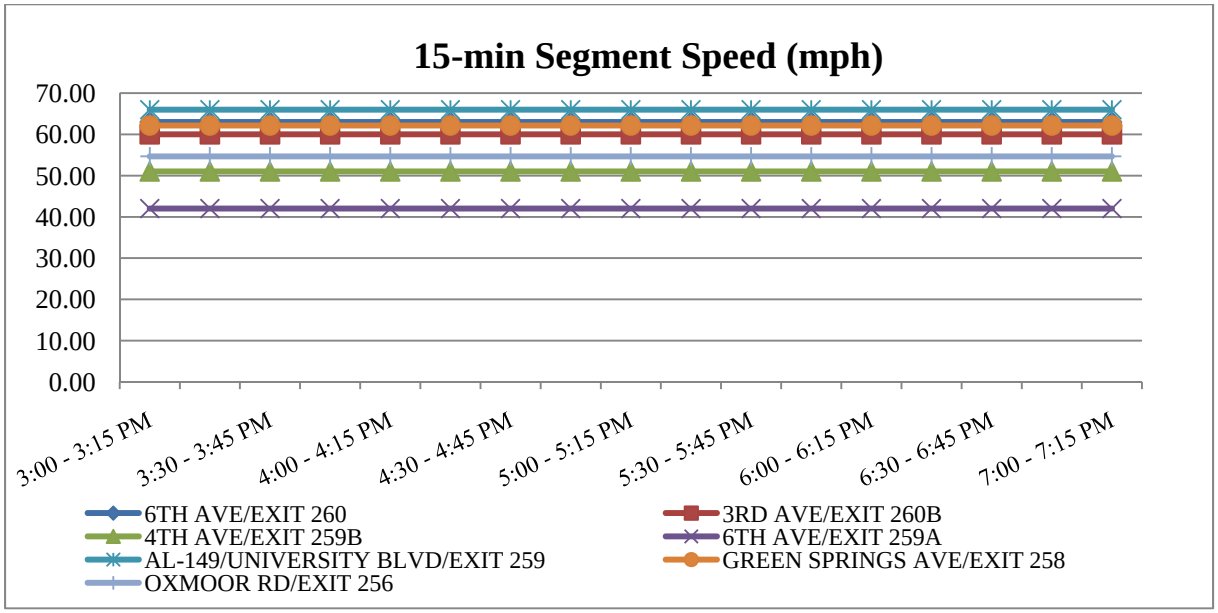
Sub Segments	3:30 - 3:45 PM	3:45 - 4:00 PM	4:00 - 4:15 PM	4:15 - 4:30 PM	4:30 - 4:45 PM	4:45 - 5:00 PM	5:00 - 5:15 PM	5:15 - 5:30 PM	5:30 - 5:45 PM	5:45 - 6:00 PM	6:00 - 6:15 PM	6:15 - 6:30 PM	6:30 - 6:45 PM	6:45 - 7:00 PM	7:00 - 7:15 PM
6th Ave N - Exit 260	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01	63.01
3rd Ave N - Exit 260B	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
4th Ave S - Exit 259B	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
6th Ave S - Exit 259A	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02
AL-149/University Blvd - Exit 259	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00
Green Springs Ave - Exit 258	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13	62.13
Oxmoor Rd - Exit 256	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67	54.67
Lakeshore Dr. - Exit 255	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80	62.80
Alford Ave - Exit 254	65.22	62.44	43.16	10.91	8.09	7.04	7.81	12.03	29.35	65.22	65.22	65.22	65.22	65.22	65.22
US31/Montgomery Hwy - Exit 252	61.76	61.76	36.62	32.14	31.81	32.81	33.51	33.87	33.87	49.21	61.76	58.33	60.57	60.57	61.76
I-459 - Exit 250	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46	63.46
CR-17/Valleydale Rd - Exit 247	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23	63.23

15-min Speed Profiles by Segment

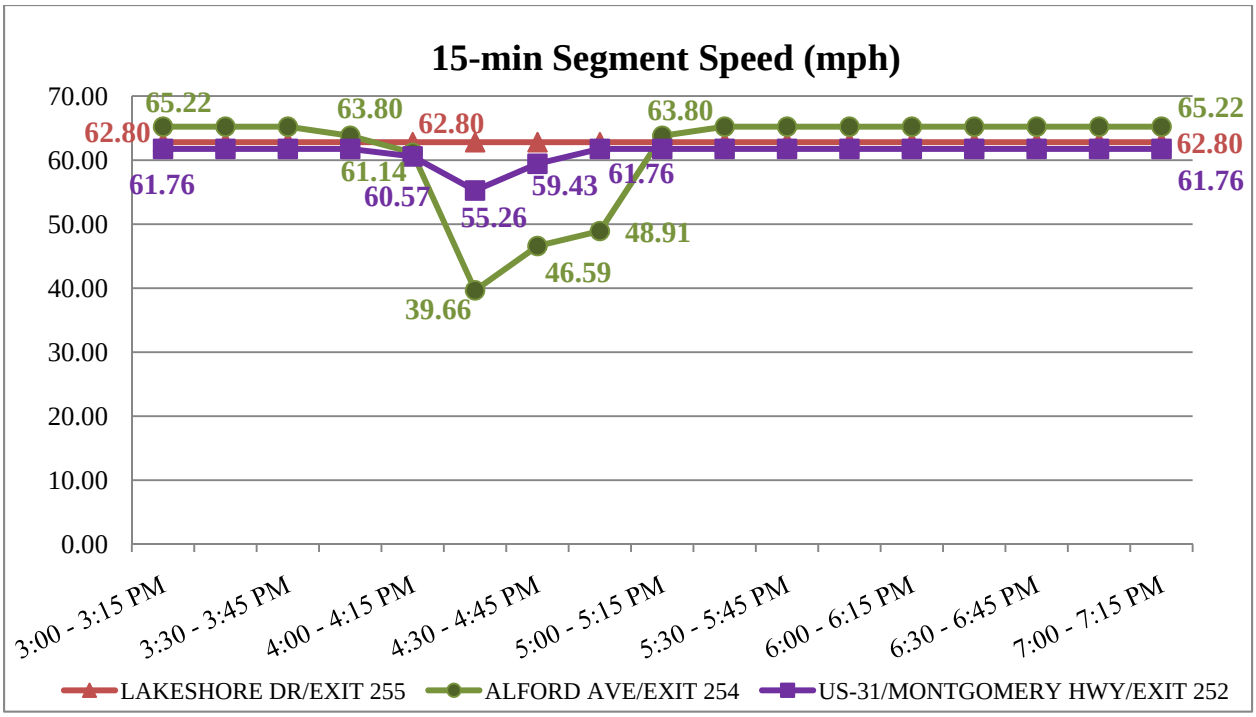
One-Hour One-Lane Closure (S2-11D)



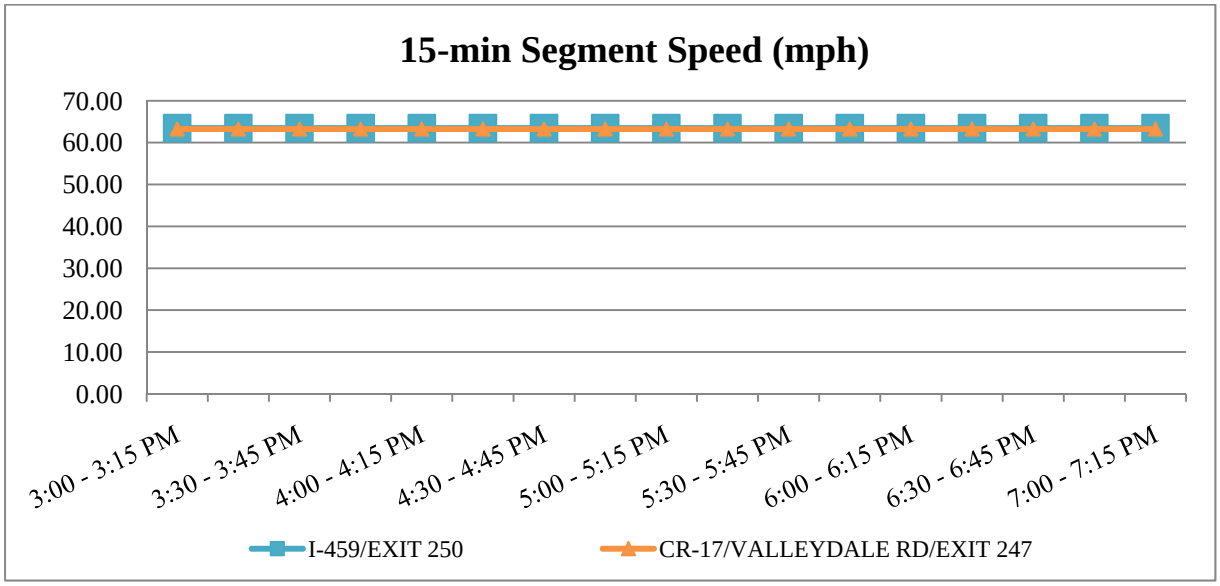
Segment Speeds in S2-11D Scenario



S2-11D 15-min Segment Speeds (Exit 260 –Exit256)

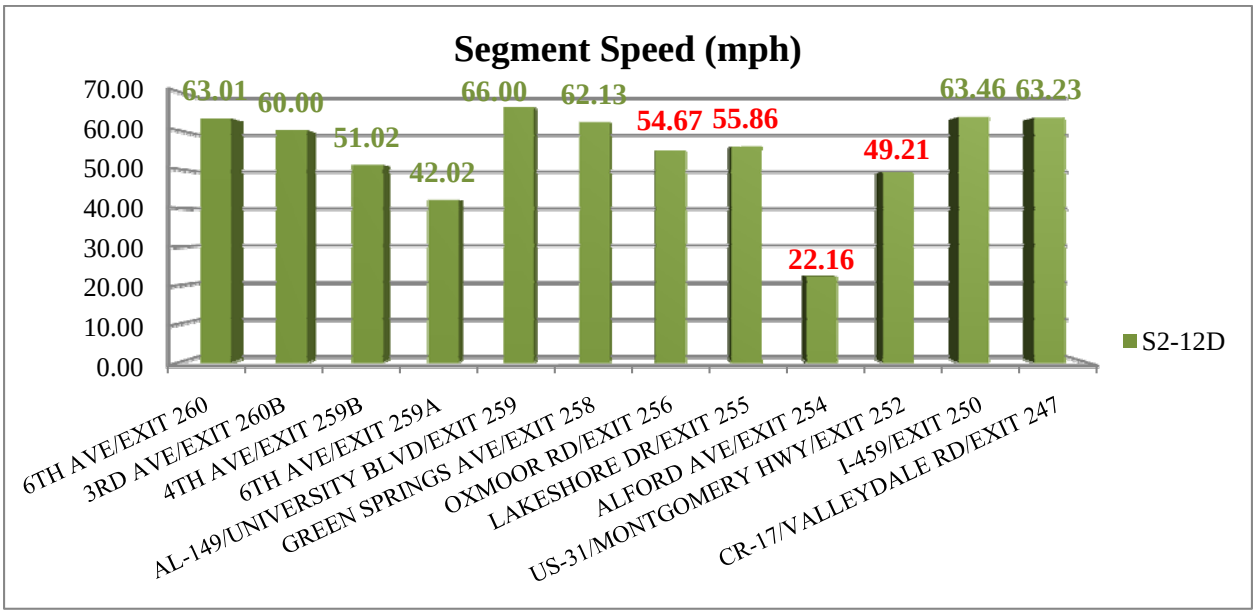


S2-11D 15-min Segment Speeds (Exit 255 –Exit252)

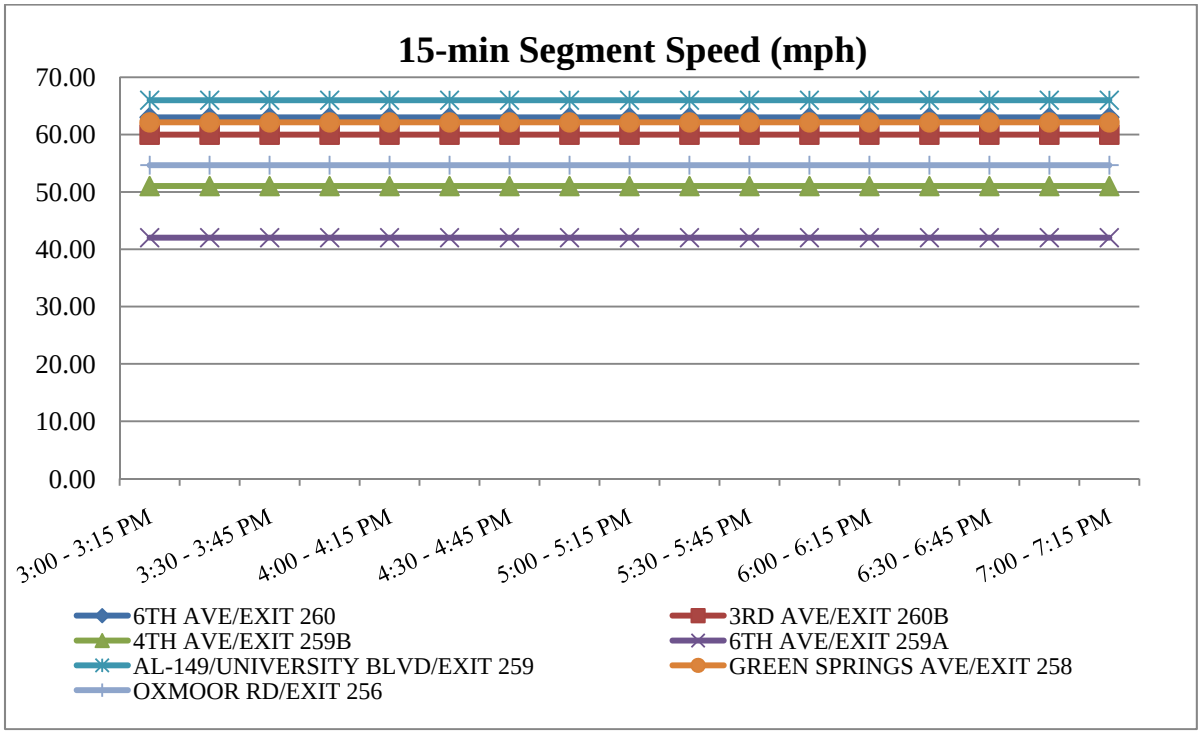


S2-11D 15-min Segment Speeds (Exit 250 –Exit247)

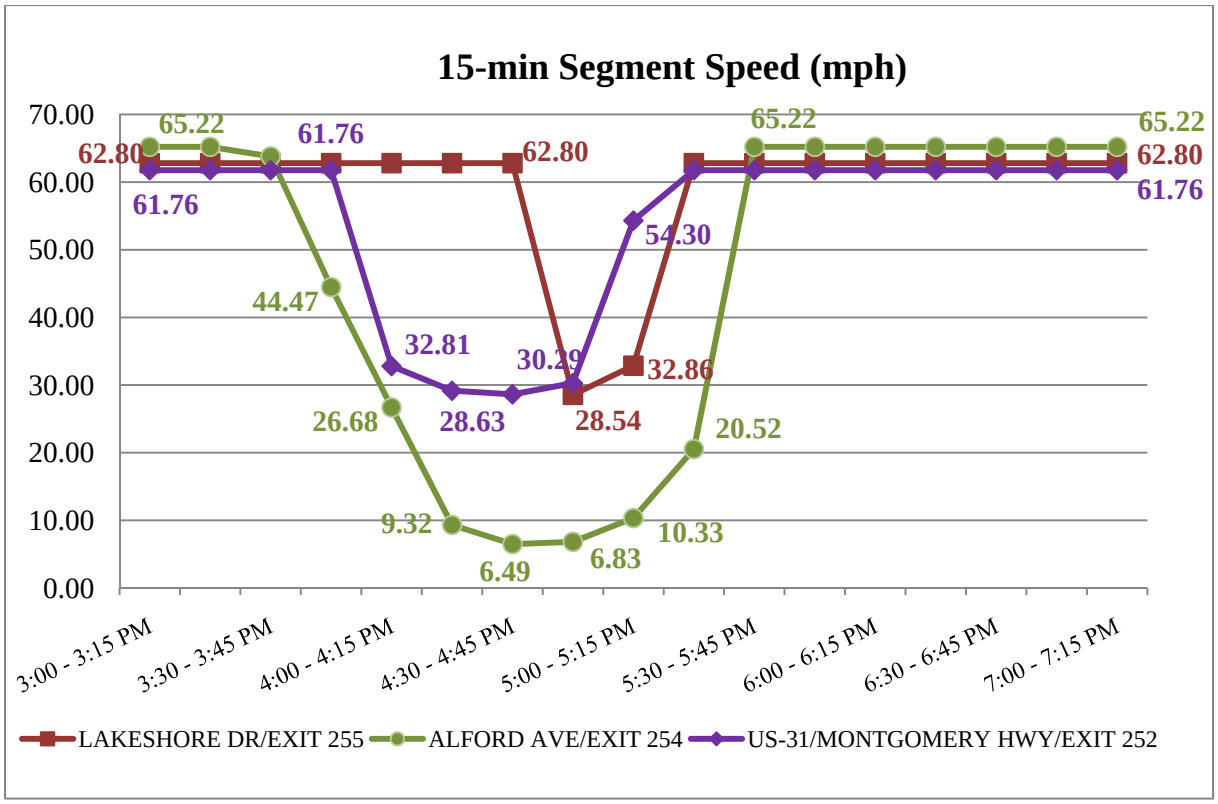
One-Hour Two-Lane Closure (S2-12D)



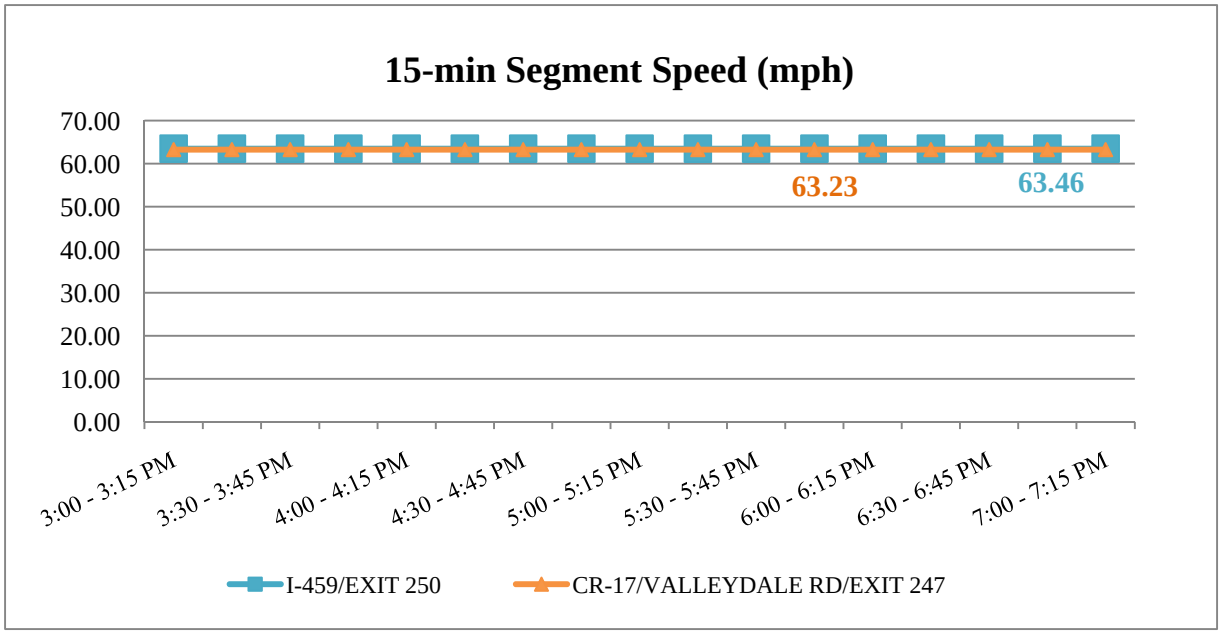
Segment Speeds in S2-12D Scenario



S2-12D 15-min Segment Speeds (Exit 260 –Exit256)

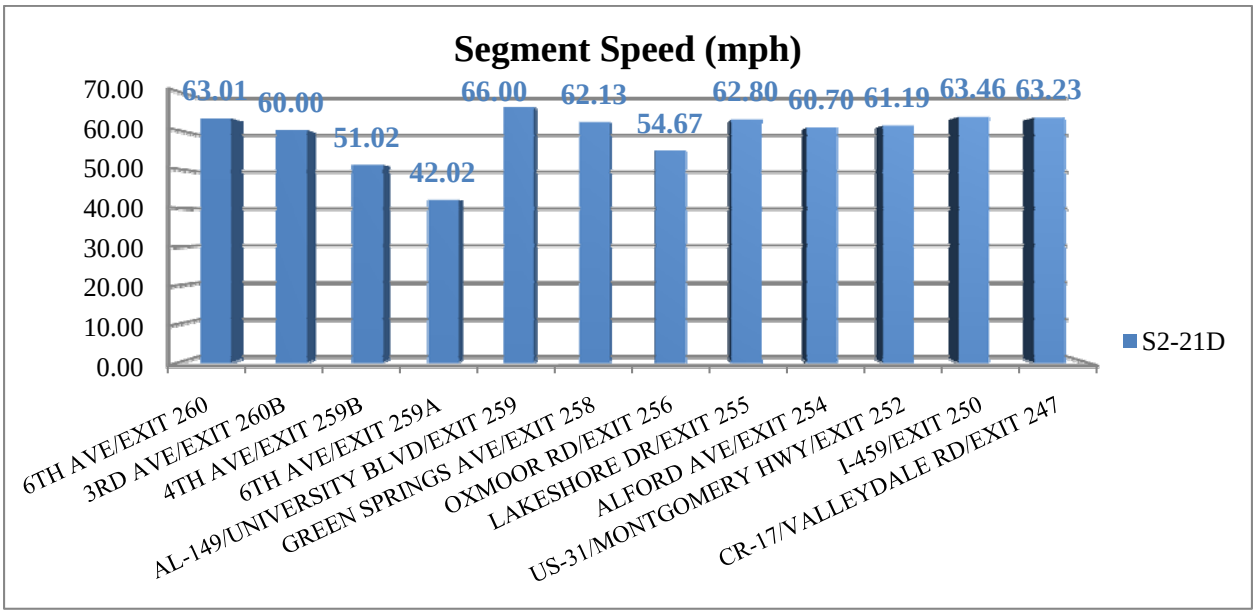


S2-12D 15-min Segment Speeds (Exit 255 –Exit252)

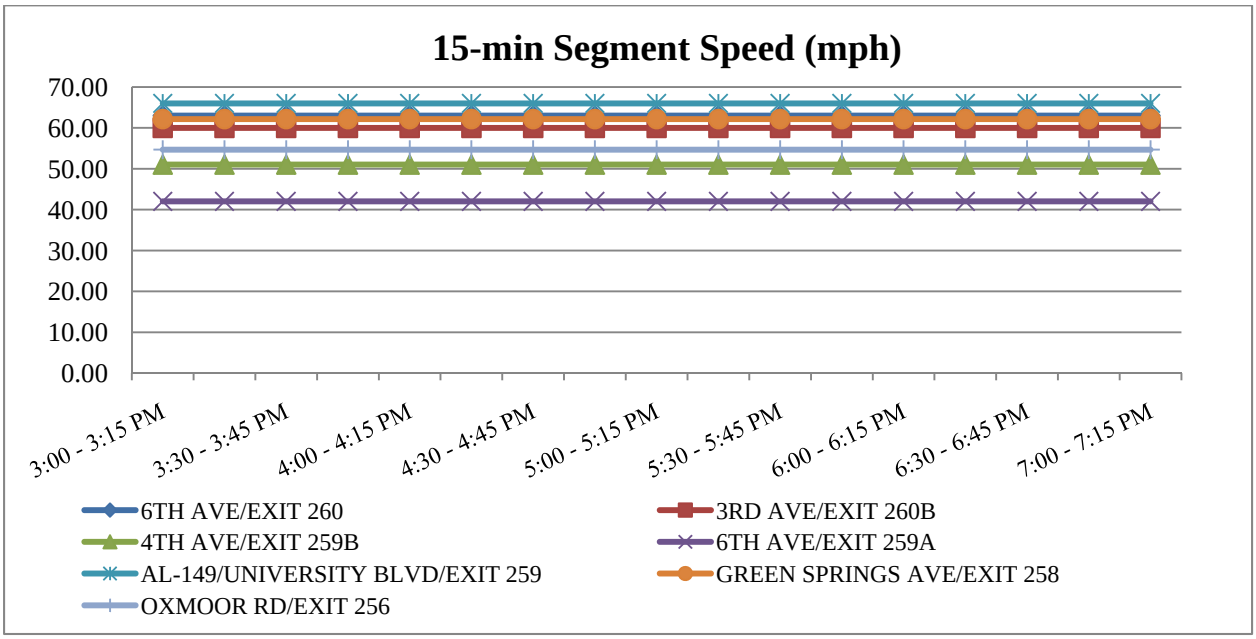


S2-12D 15-min Segment Speeds (Exit 250 –Exit247)

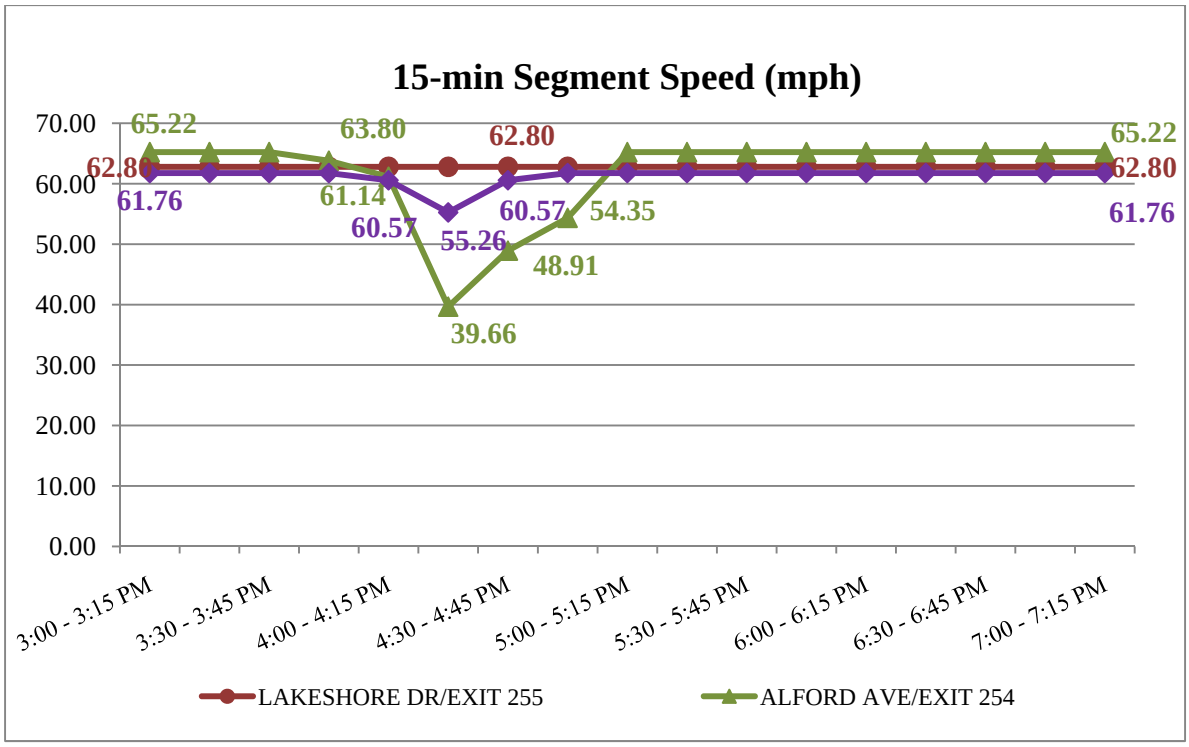
Two-Hour One-Lane Closure (S2-21D)



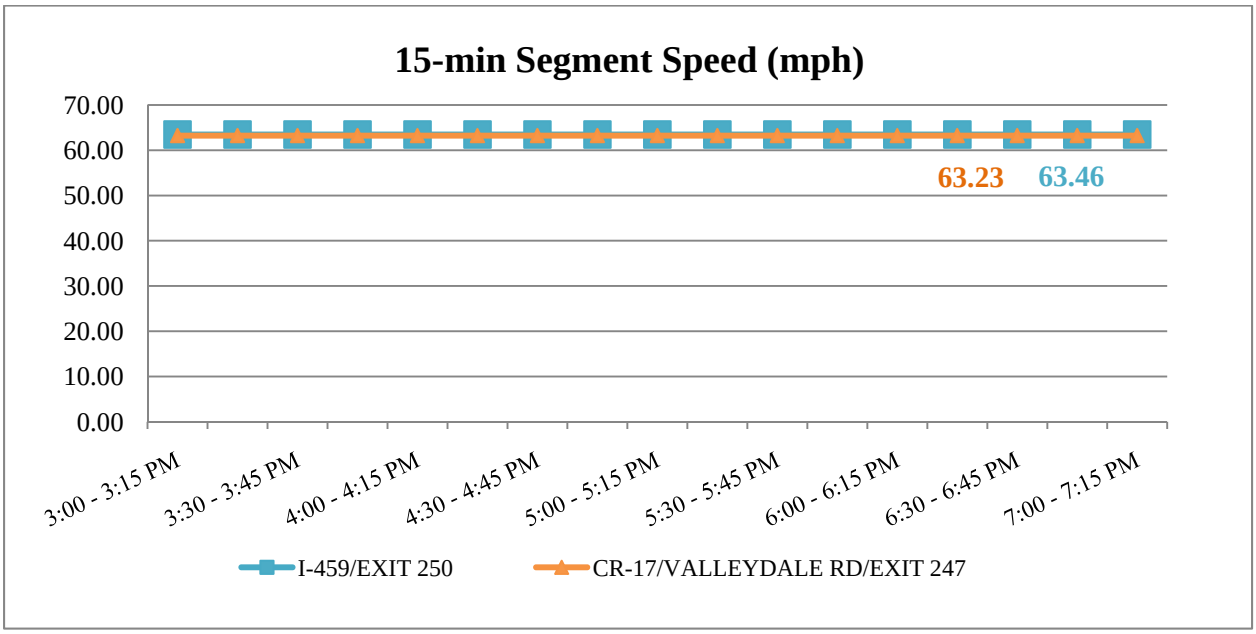
Segment Speeds in S2-21D Scenario



S2-21D 15-min Segment Speeds (Exit 260 –Exit256)

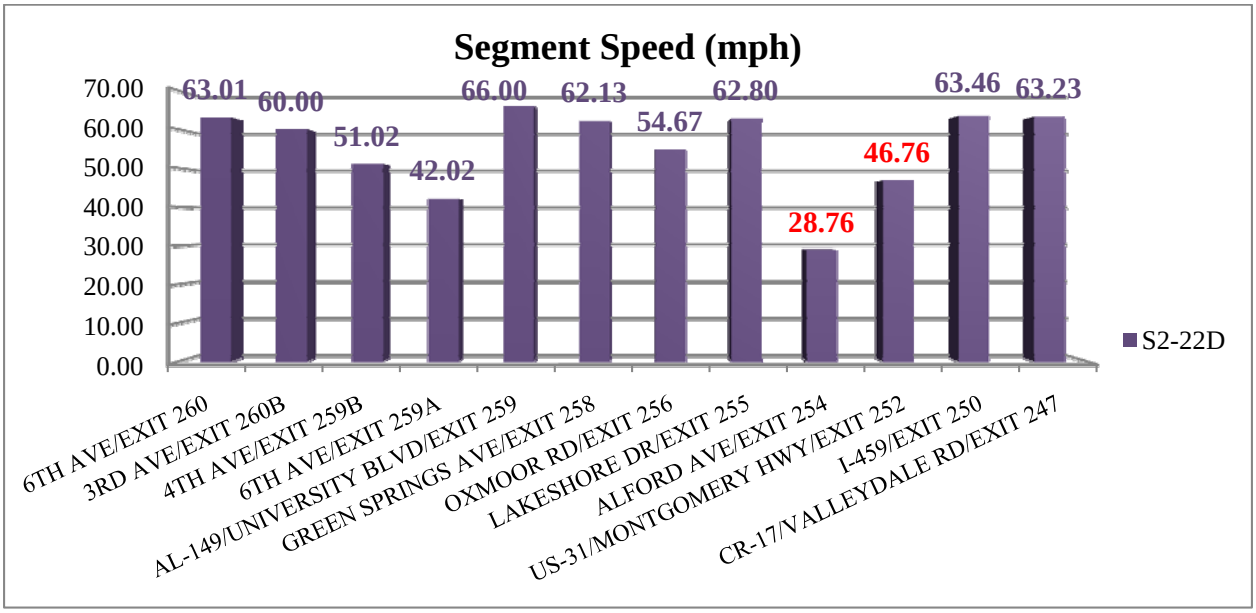


S2-21D 15-min Segment Speeds (Exit 255 –Exit252)

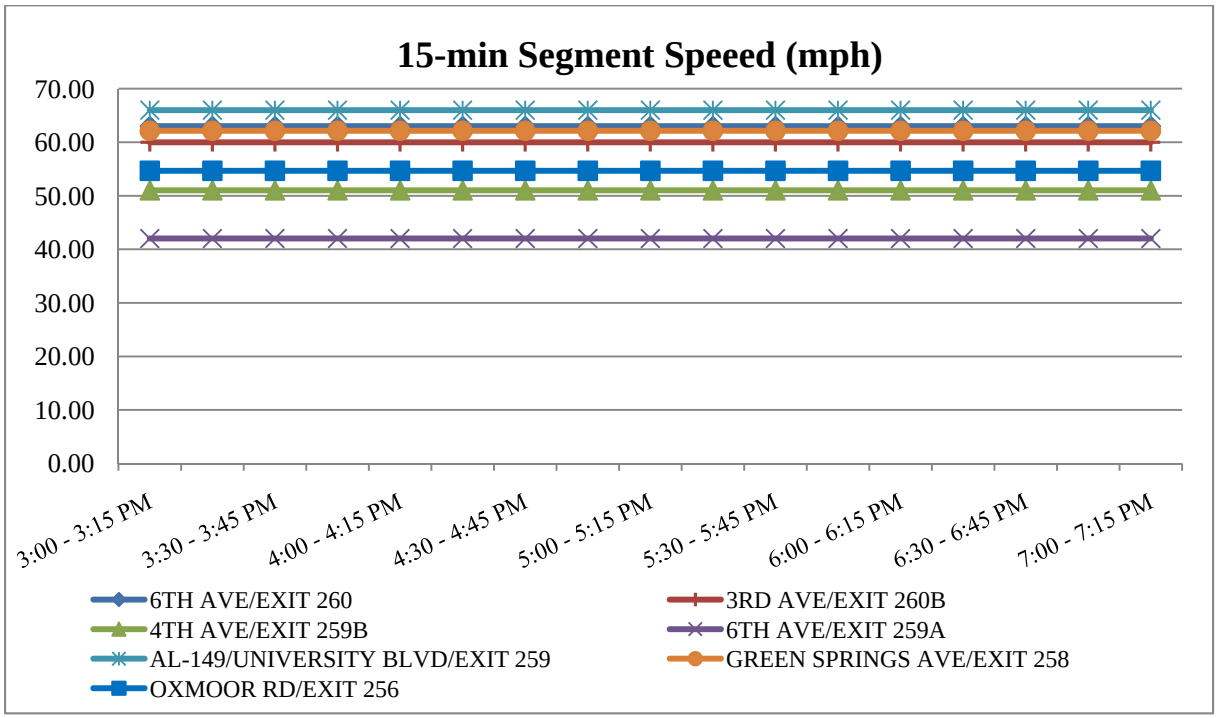


S2-21D 15-min Segment Speeds (Exit 250 –Exit247)

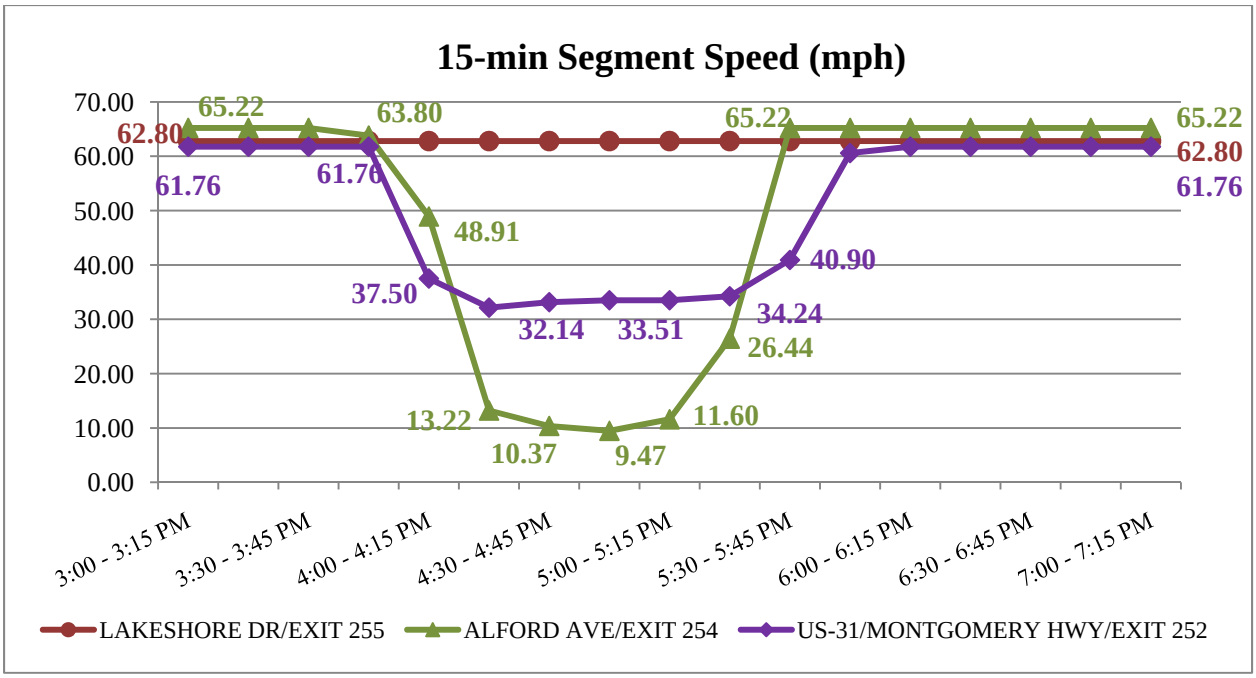
Two-Hour Two-Lane Closure (S2-22D)



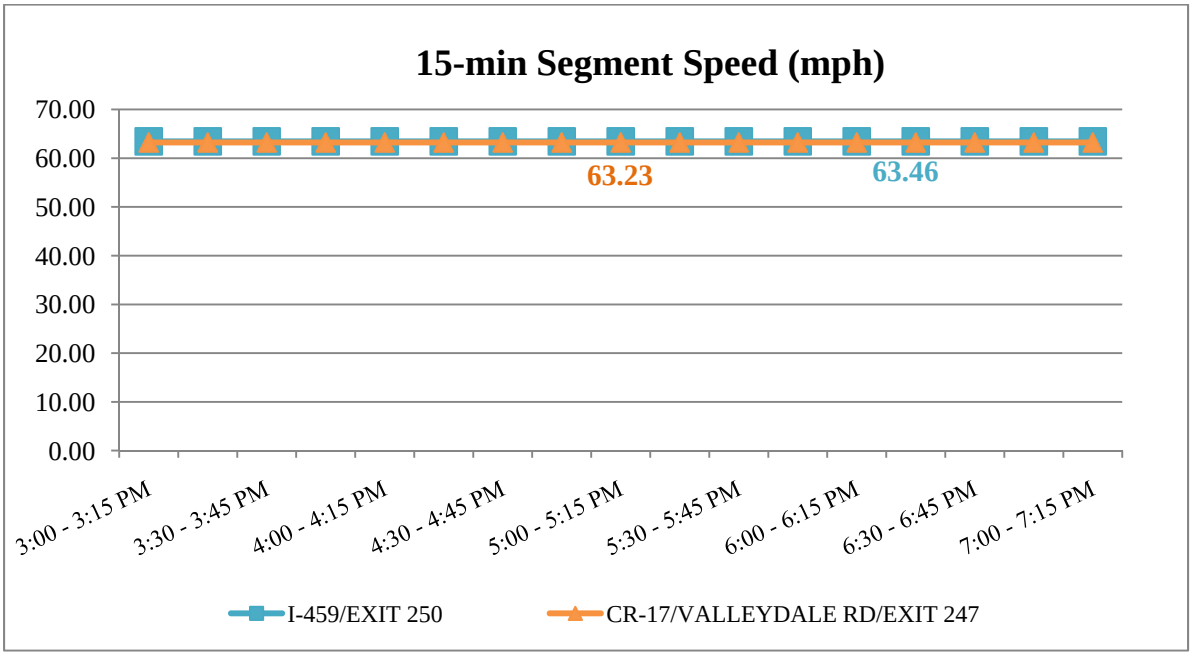
Segment Speeds in S2-22D Scenario



S2-22D 15-min Segment Speeds (Exit 260 –Exit256)

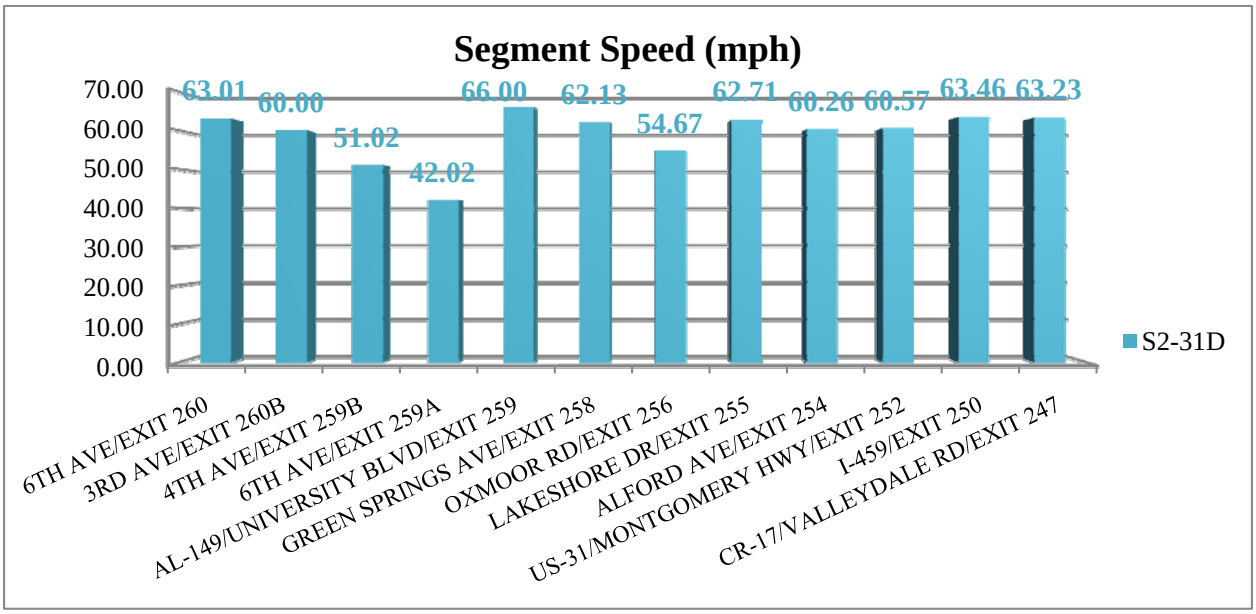


S2-22D 15-min Segment Speeds (Exit 255 –Exit252)

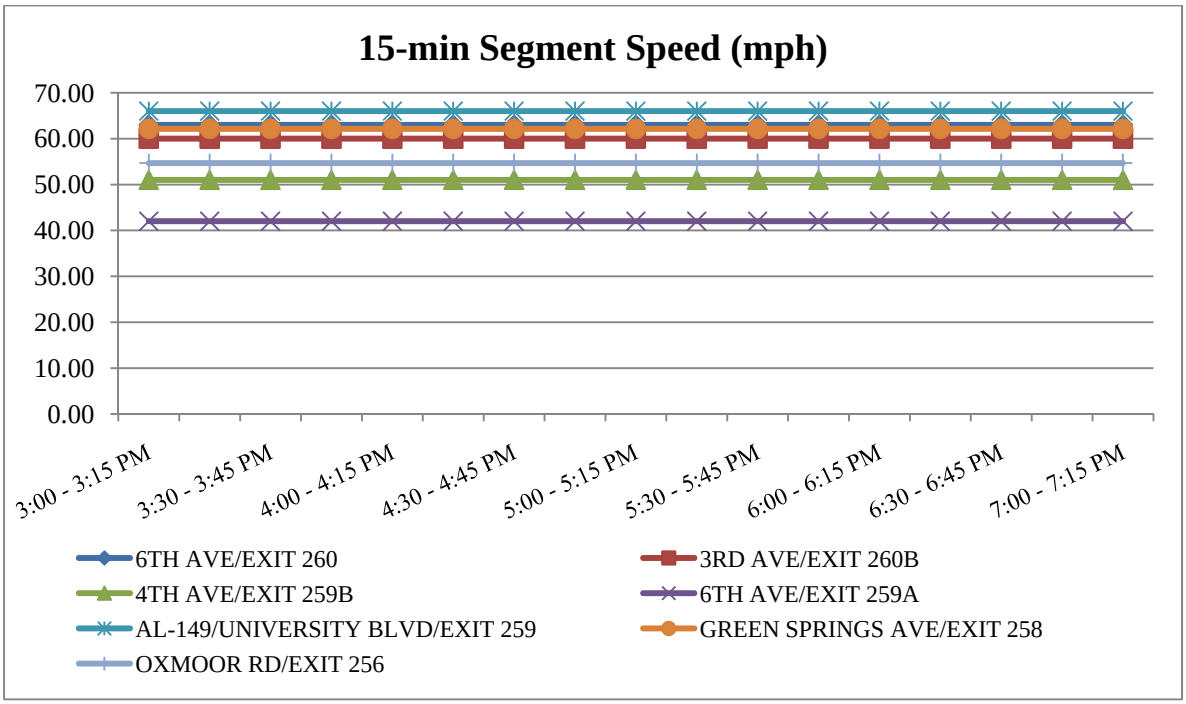


S2-22D 15-min Segment Speeds (Exit 250 –Exit247)

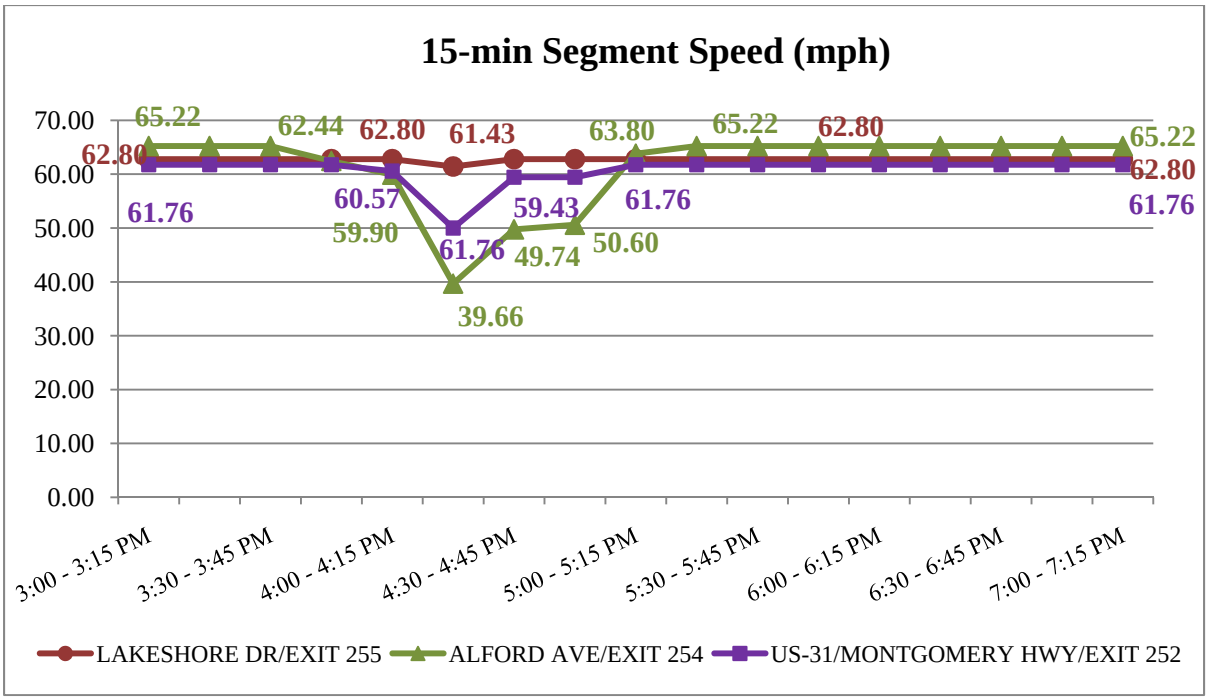
Three-Hour One-Lane Closure (S2-31D)



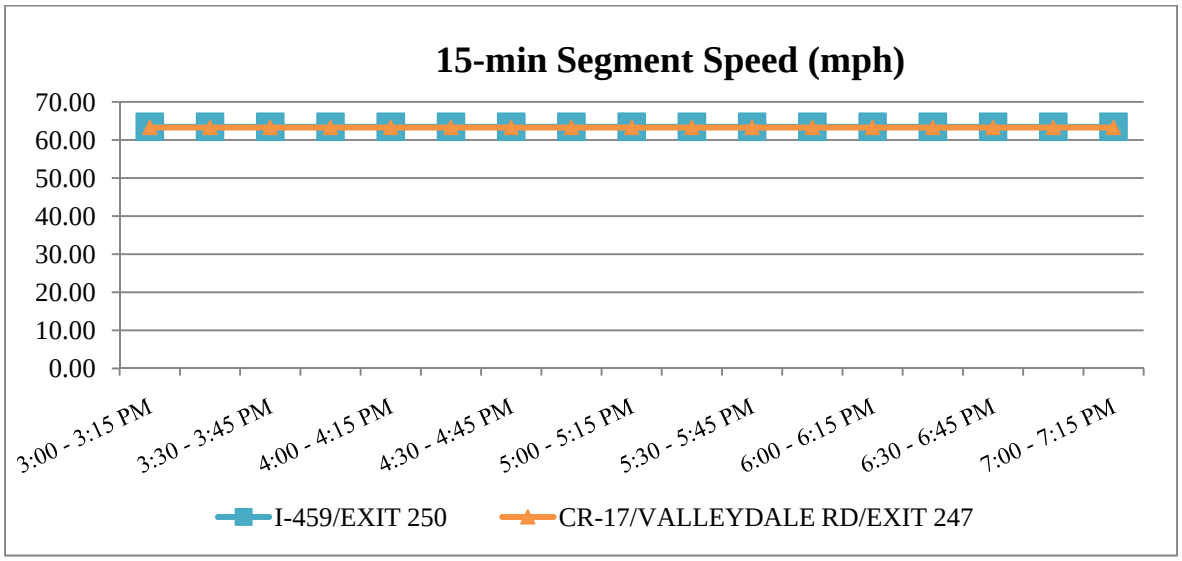
Segment Speeds in S2-31D Scenario



S2-31D 15-min Segment Speeds (Exit 260 –Exit256)

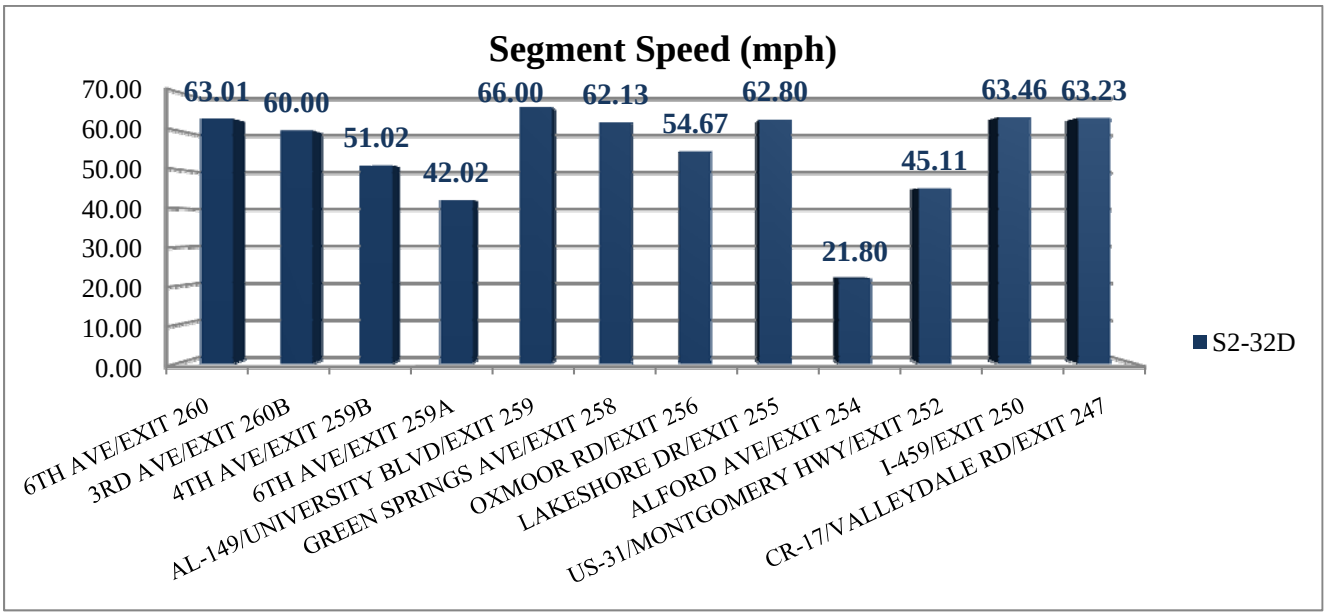


S2-31D 15-min Segment Speeds (Exit 255 –Exit252)

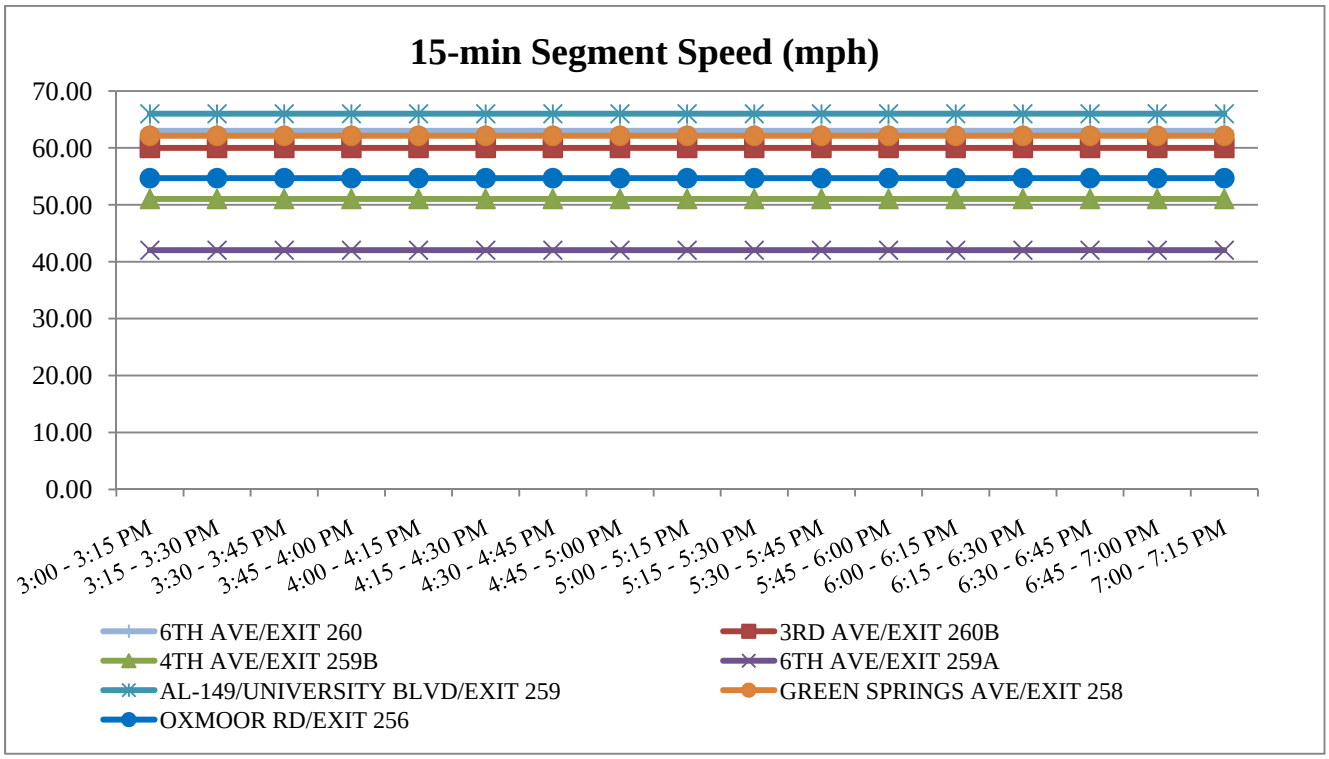


S2-31D 15-min Segment Speeds (Exit 250 –Exit 247)

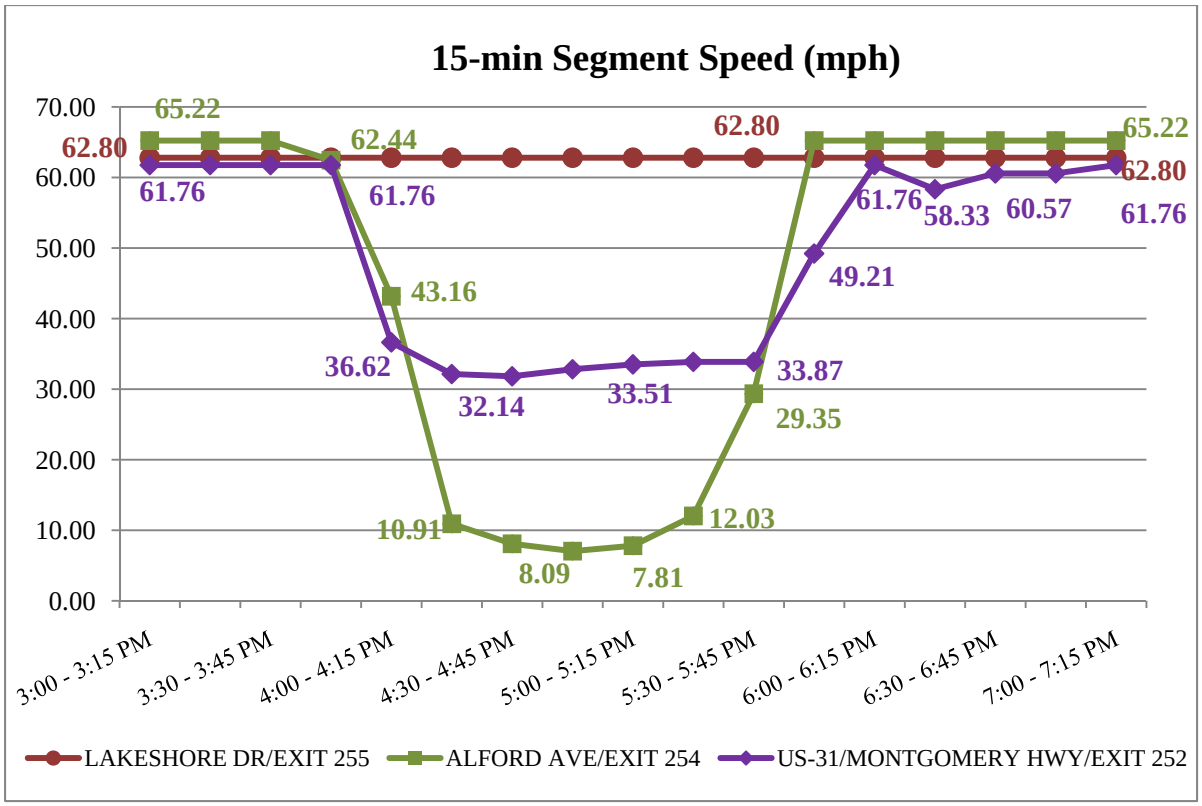
Three-Hour Two-Lane Closure (S2-32D)



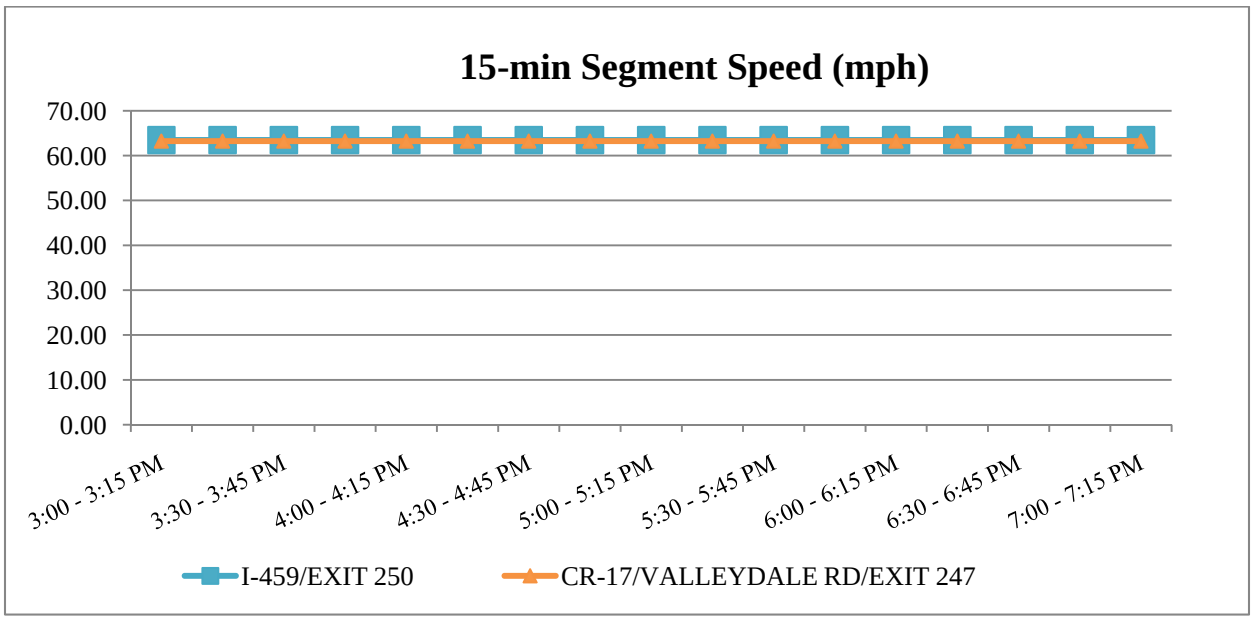
Segment Speeds in S2-32D Scenario



S2-32D 15-min Segment Speeds (Exit 260 –Exit256)



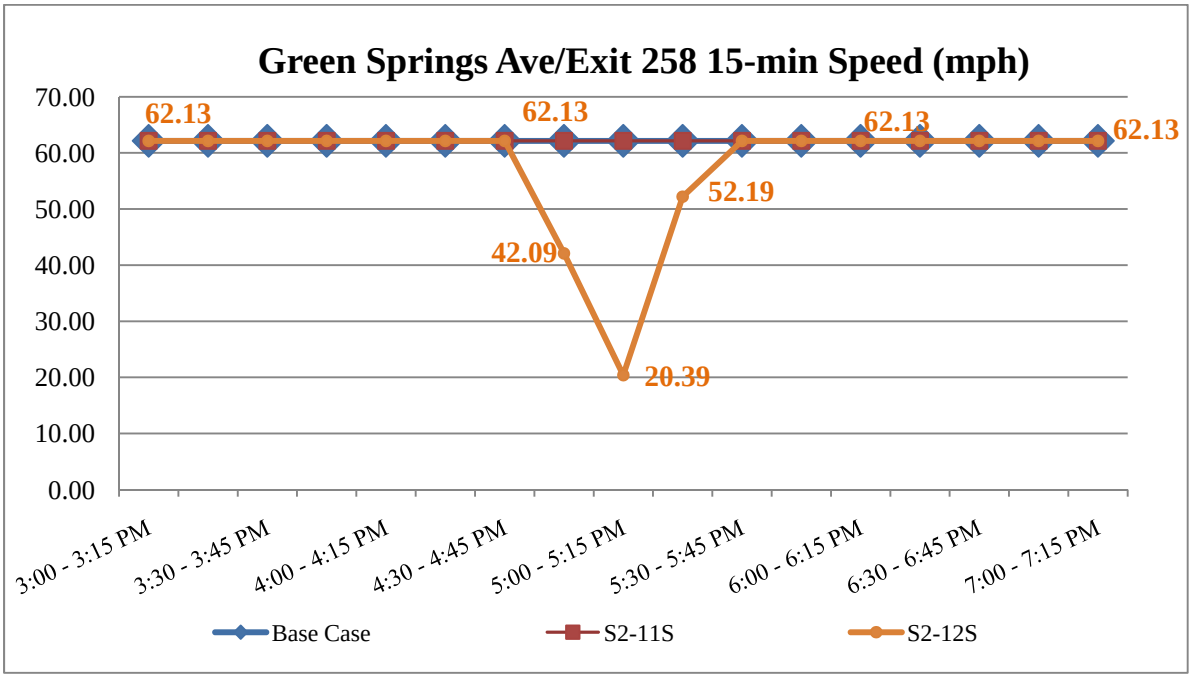
S2-32D 15-min Segment Speeds (Exit 255 –Exit252)



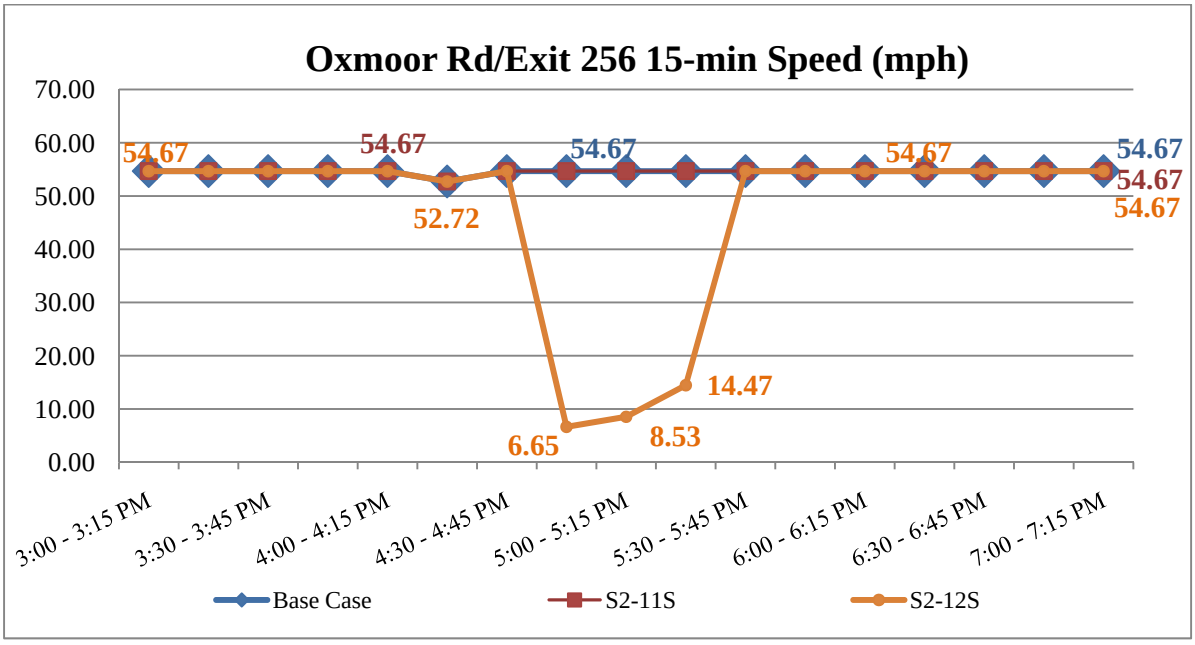
S2-32D 15-min Segment Speeds (Exit 250 –Exit 247)

Comparison of Results from Study Scenarios

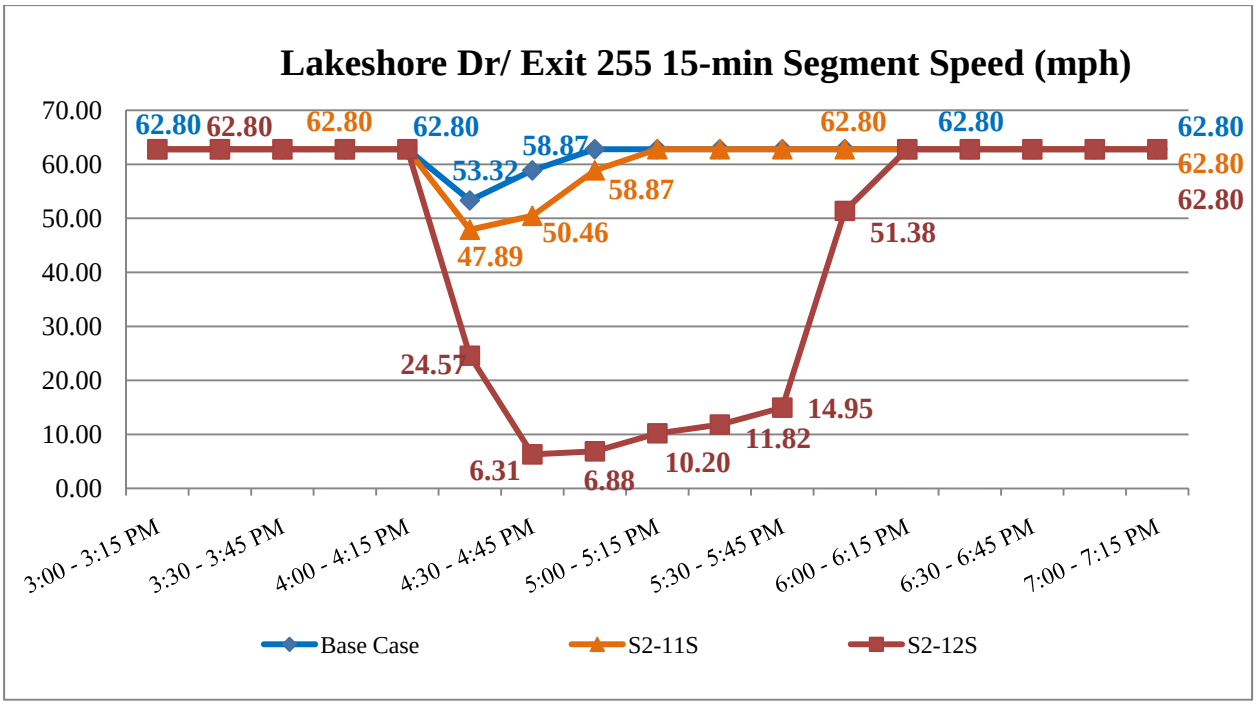
Comparison of Base Case, S2-11S and S2-12S



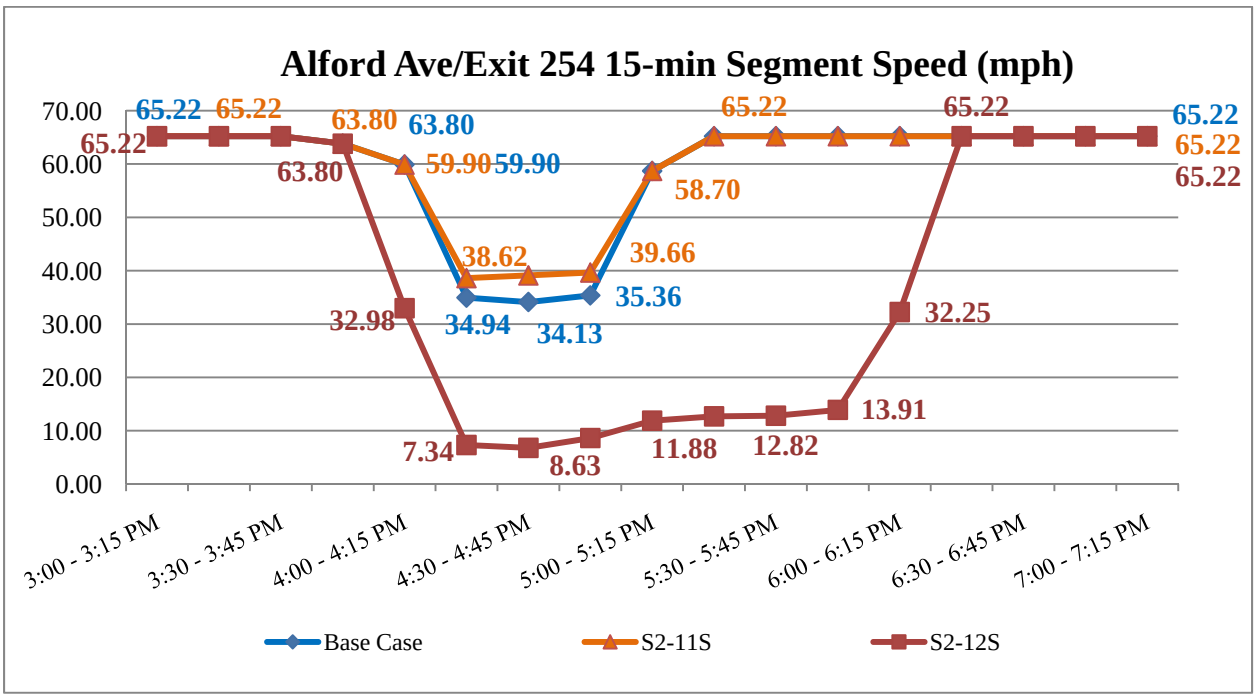
Comparison of Base Case, S2-11S and S2-12S: Green Springs Ave/Exit 258



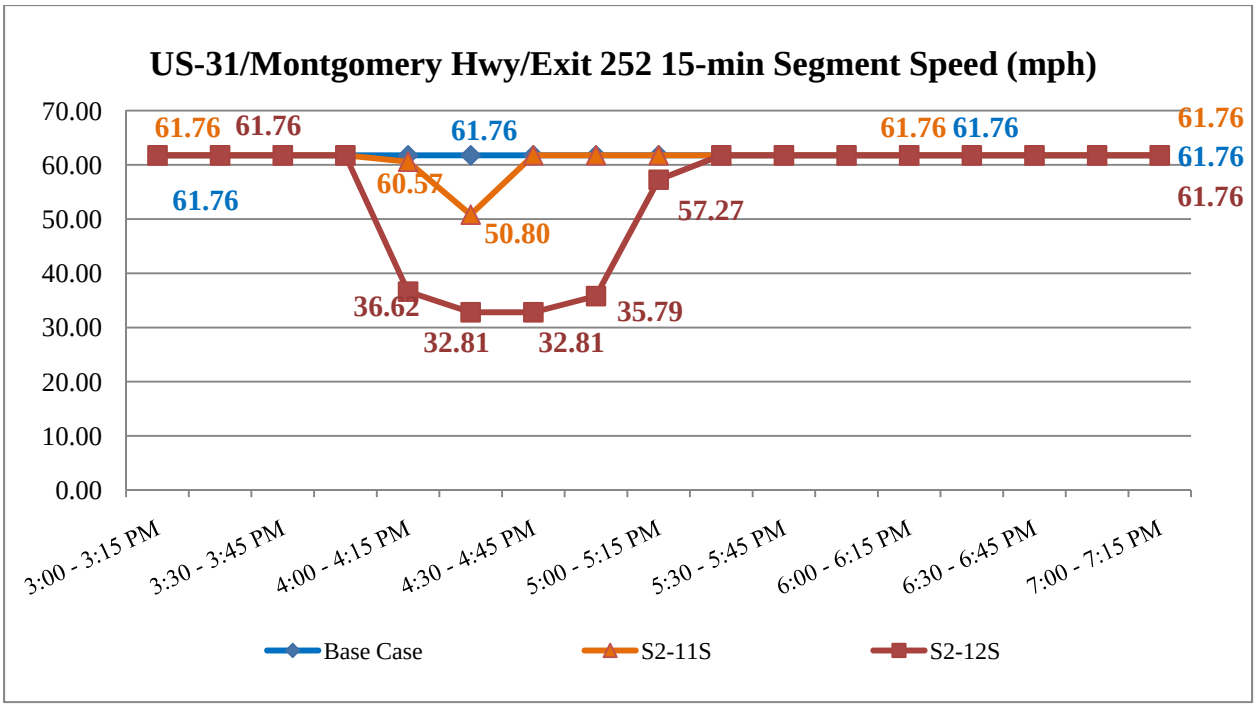
Comparison of Base Case, S2-11S and S2-12S: Oxmoor Rd/Exit 256



Comparison of Base Case, S2-11S and S2-12S: Lakeshore Dr/Exit 255

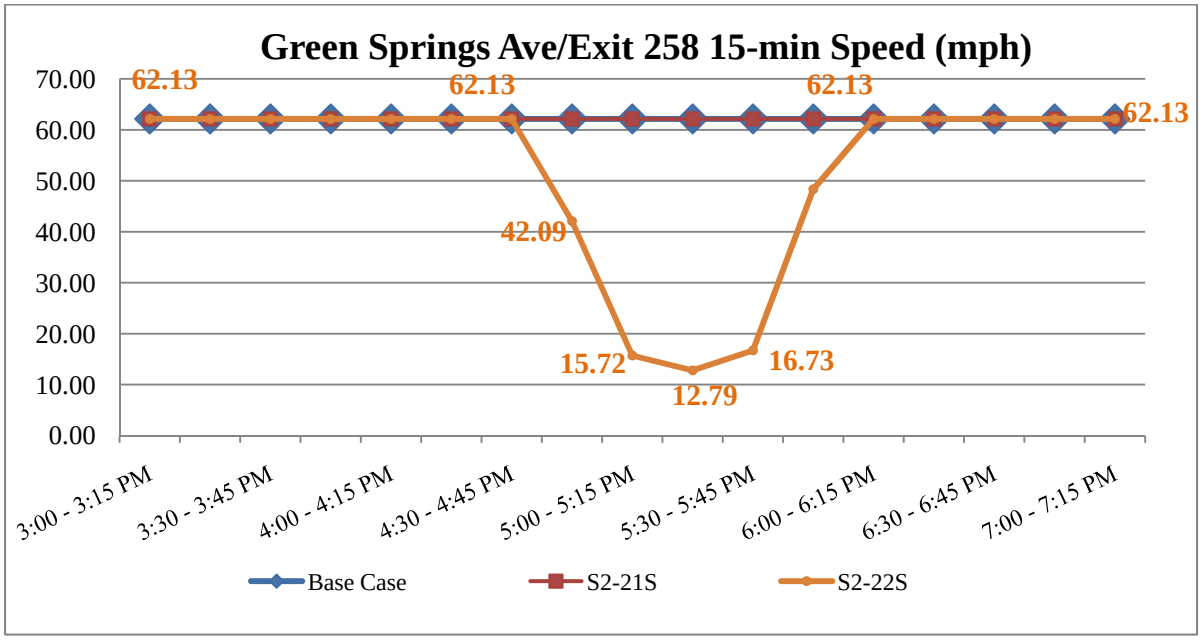


Comparison of Base Case, S2-11S and S2-12S: Alford Ave/Exit 254

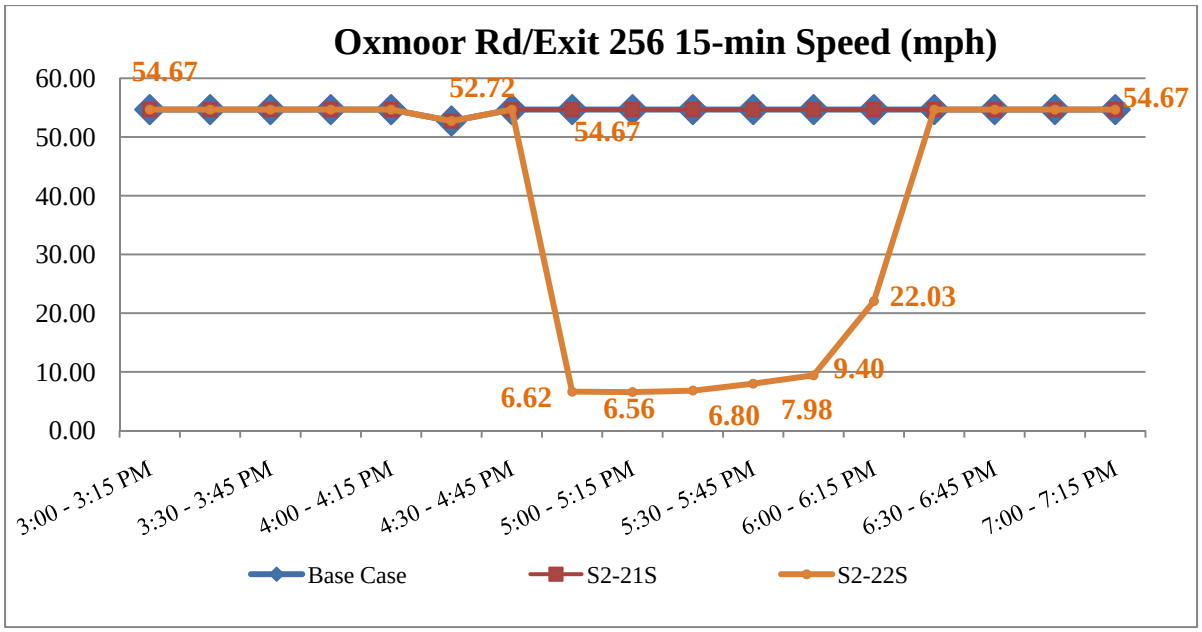


Comparison of Base Case, S2-11S and S2-12S: US-31/Exit 252

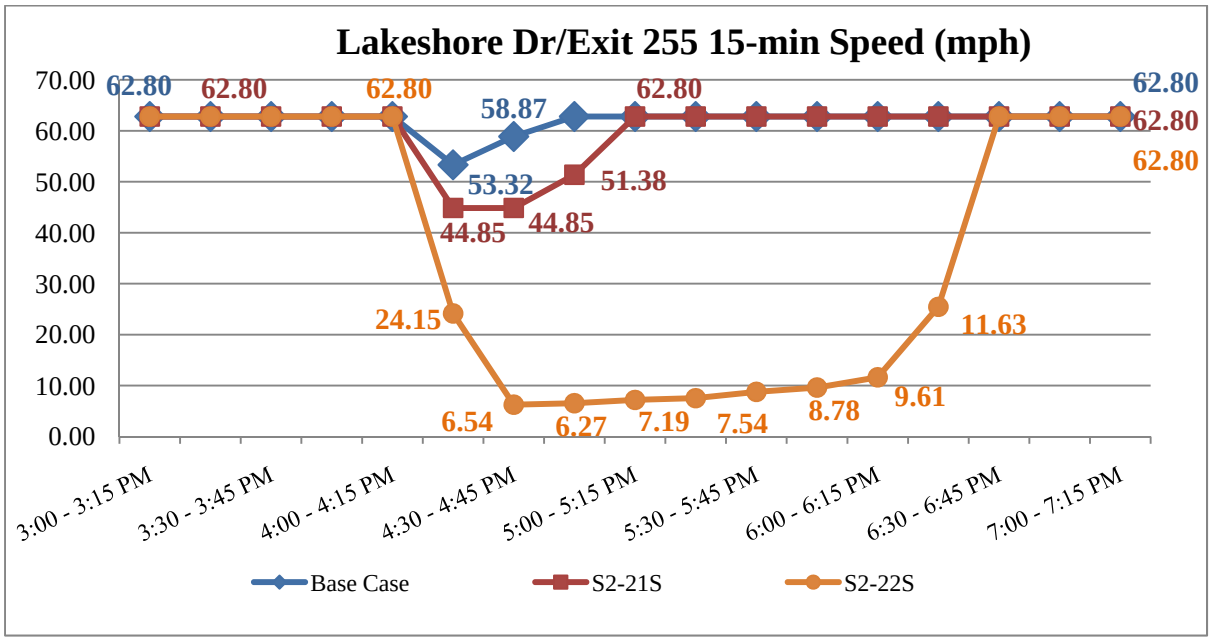
Comparison of Base Case, S2-21S and S2-22S



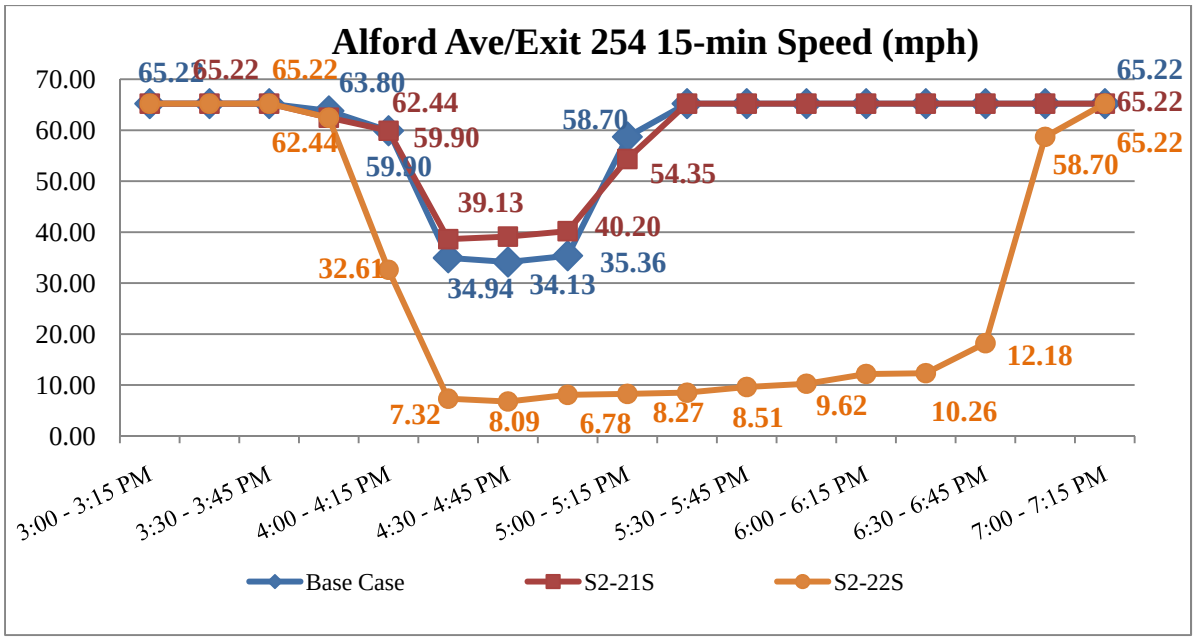
Comparison of Base Case, S2-21S and S2-22S: Green Springs Ave/Exit 258



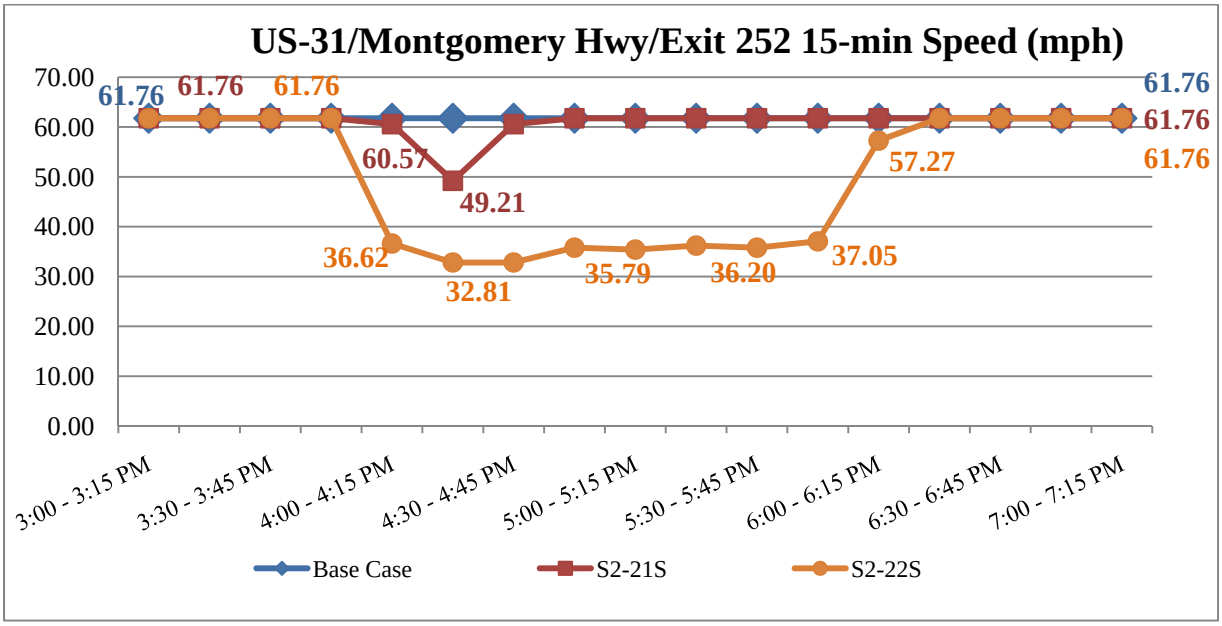
Comparison of Base Case, S2-21S and S2-22S: Oxmoor Rd/Exit 256



Comparison of Base Case, S2-21S and S2-22S: Lakeshore Dr/Exit 255

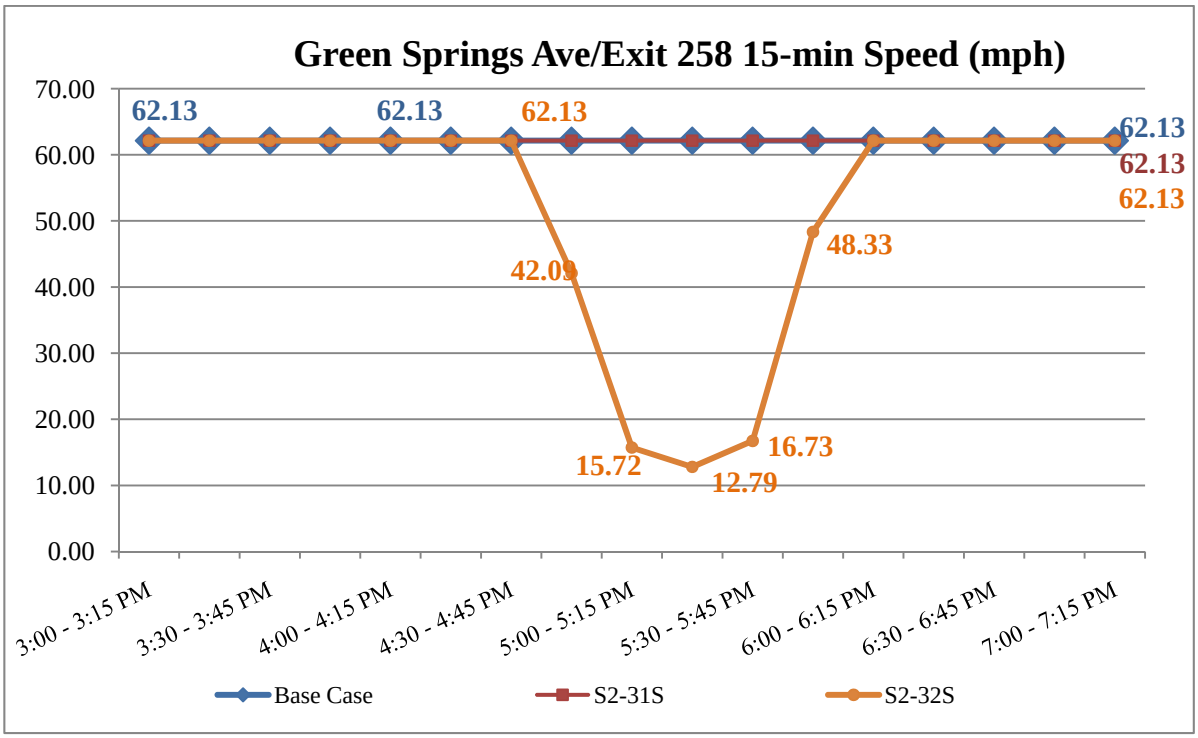


Comparison of Base Case, S2-21S and S2-22S: Alford Ave/Exit 254

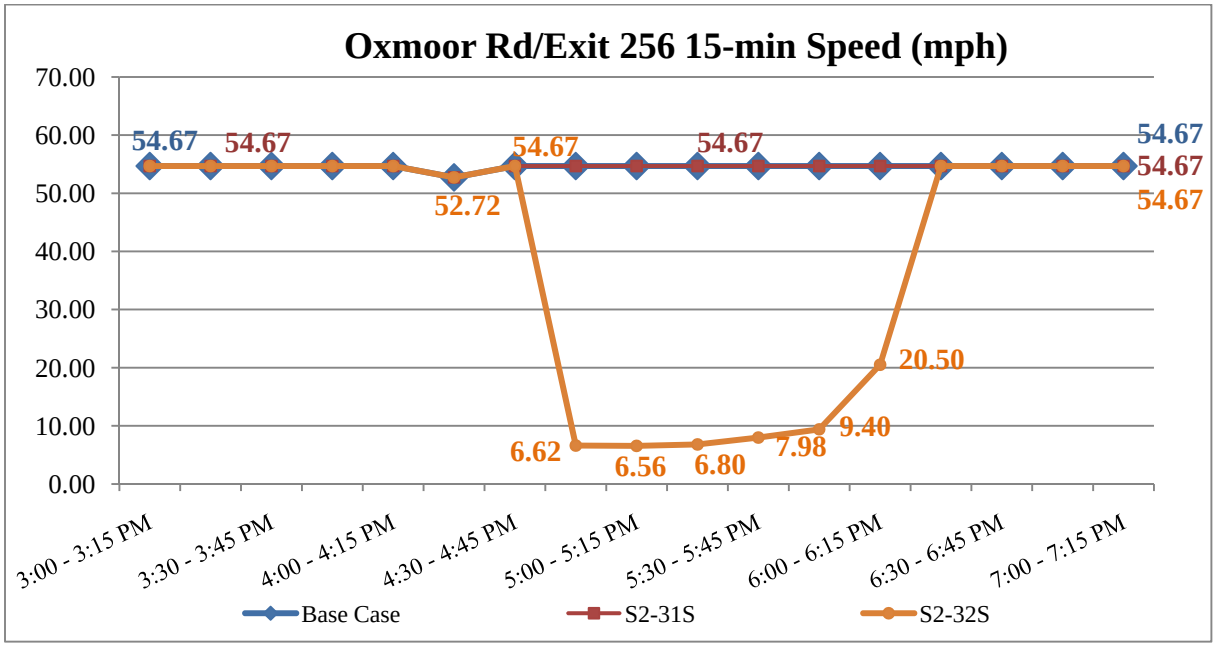


Comparison of Base Case, S2-21S and S2-22S: US-31/Exit 252

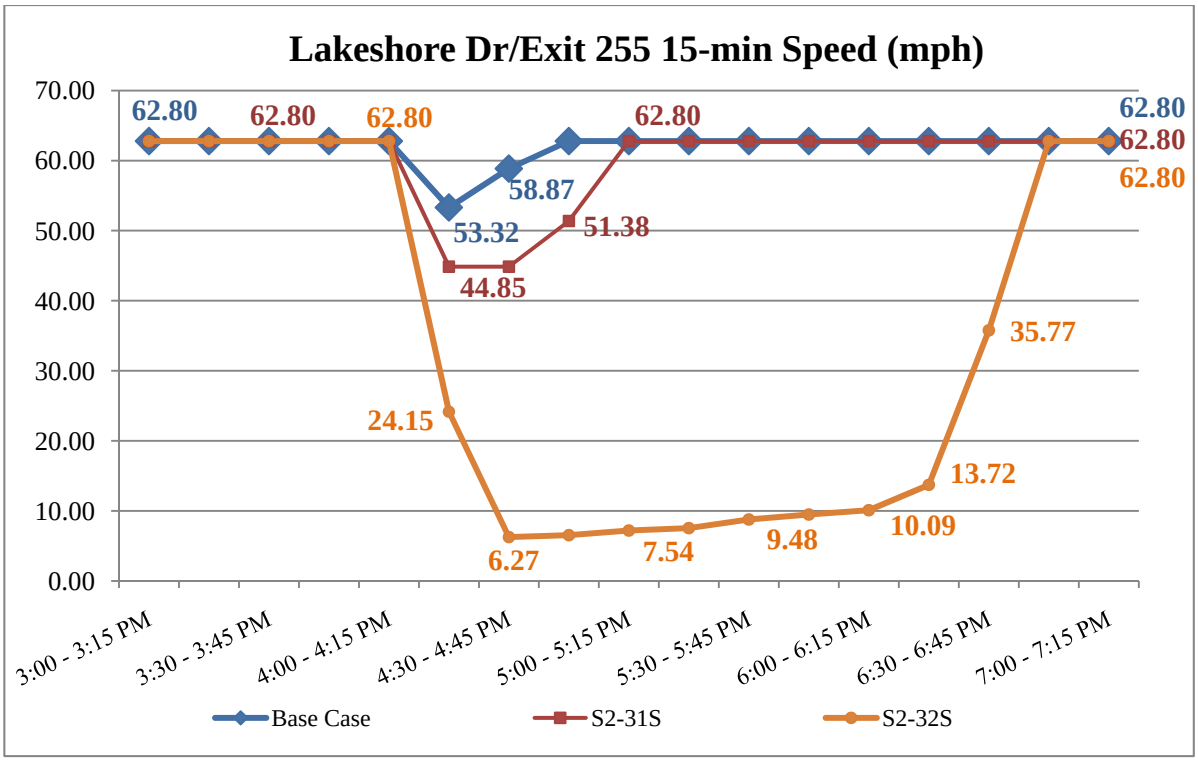
Comparison of Base Case, S2-31S and S2-32S



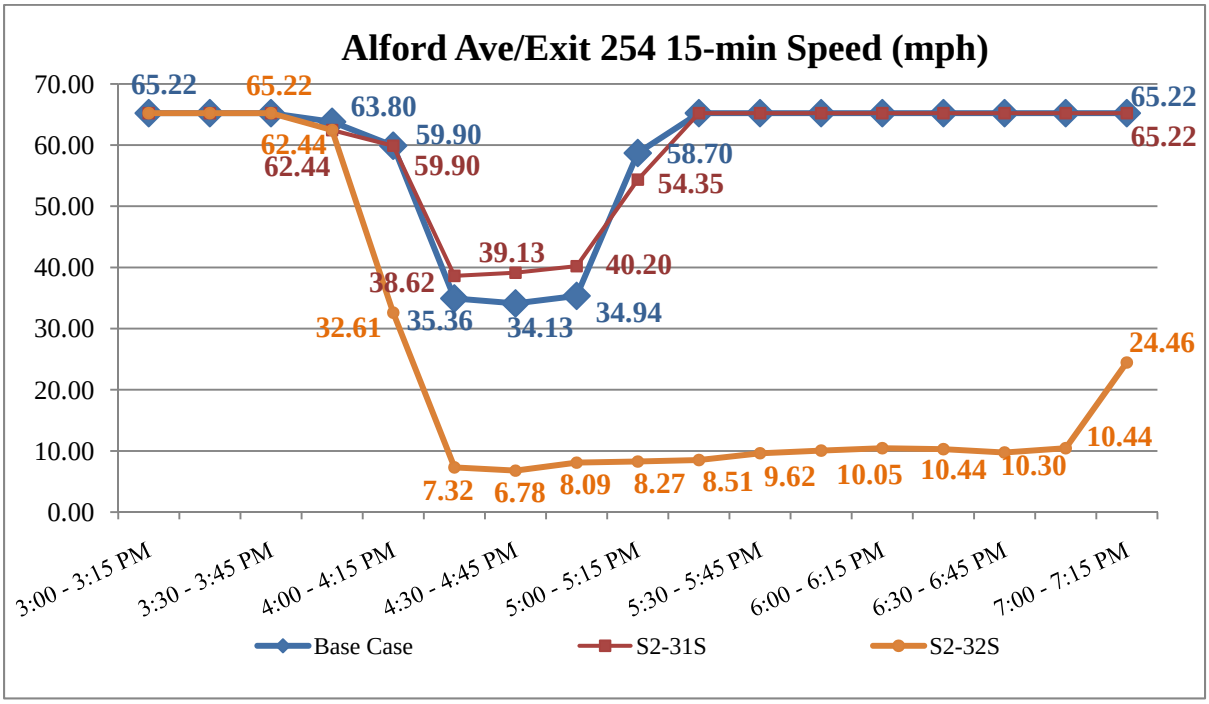
Comparison of Base Case, S2-31S and S2-32S: Green Springs Ave/Exit 258



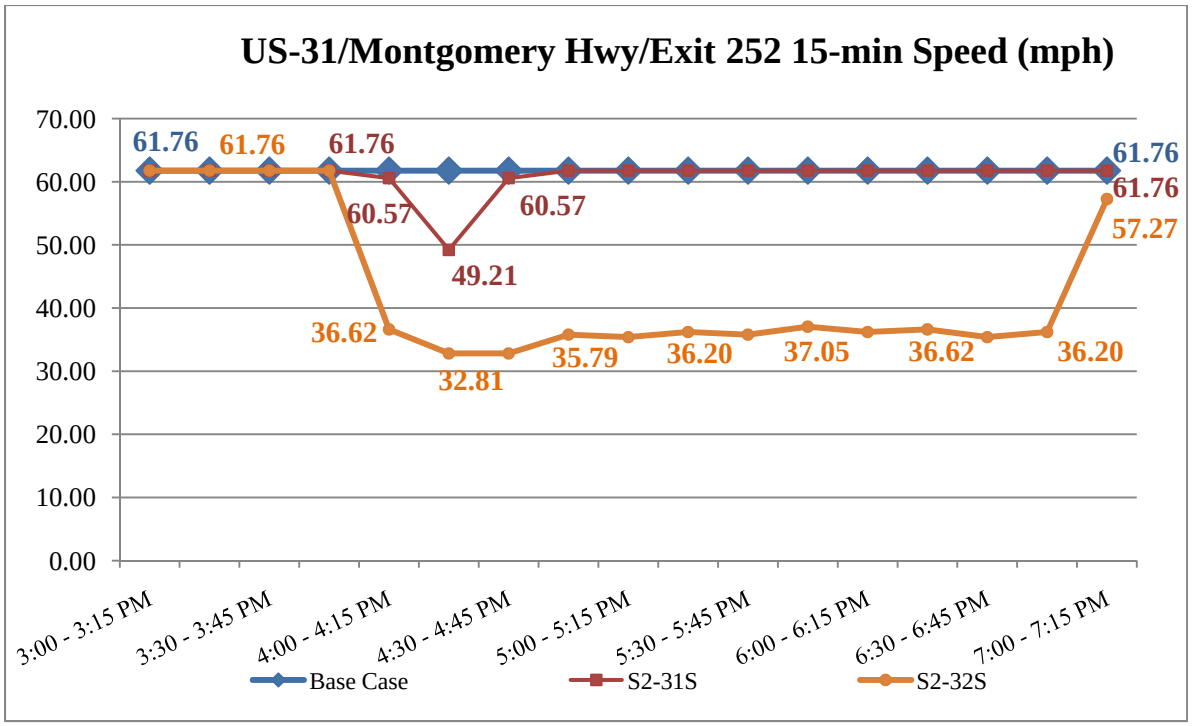
Comparison of Scenarios Base Case, S2-31S and S2-32S: Oxmoor Rd/Exit 256



Comparison of Base Case, S2-31S and S2-32S: Lakeshore Dr/Exit 255

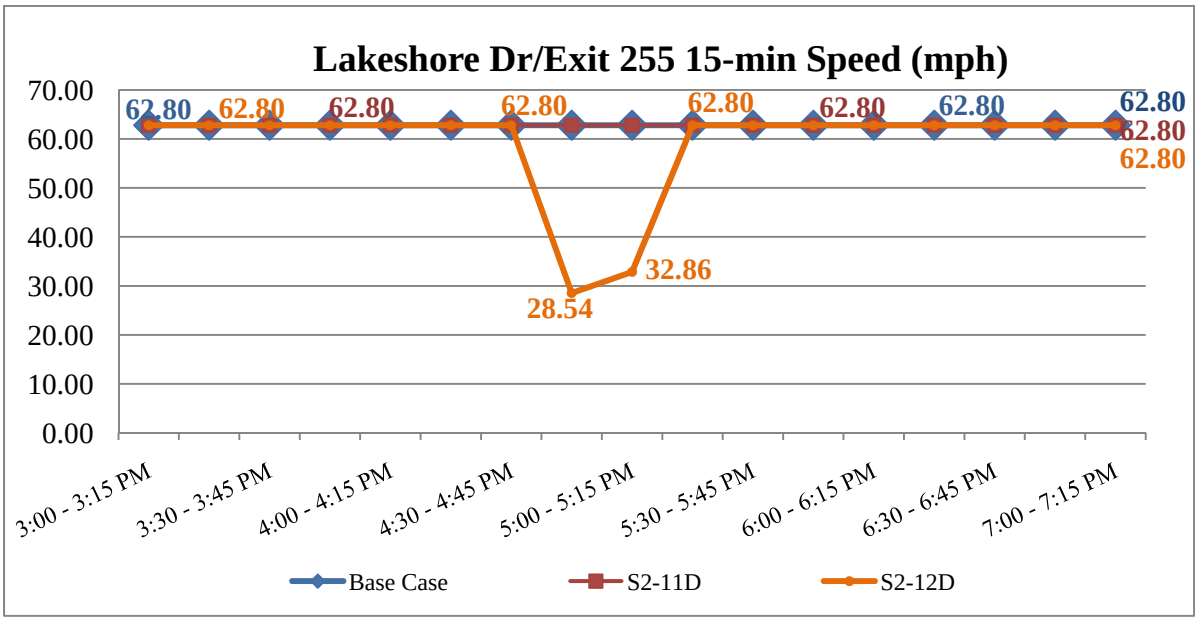


Comparison of Base Case, S2-31S and S2-32S: Alford Ave/Exit 254

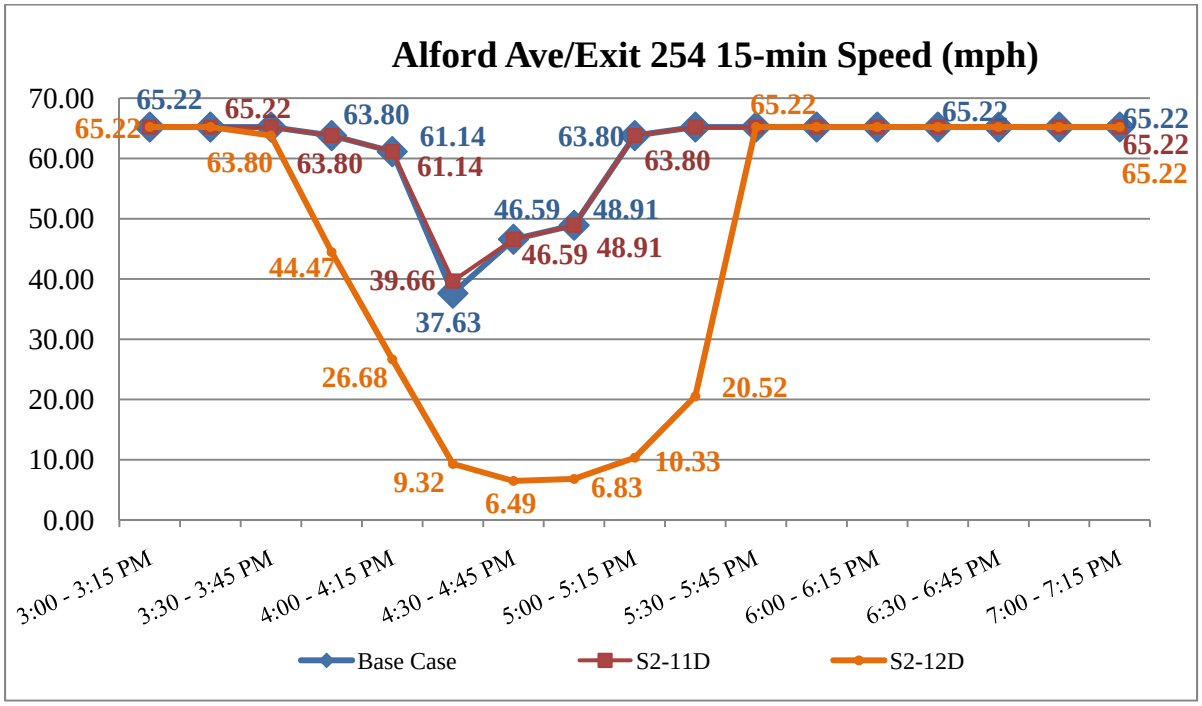


Comparison of Base Case, S2-31S and S2-32S: US-31/Exit 252

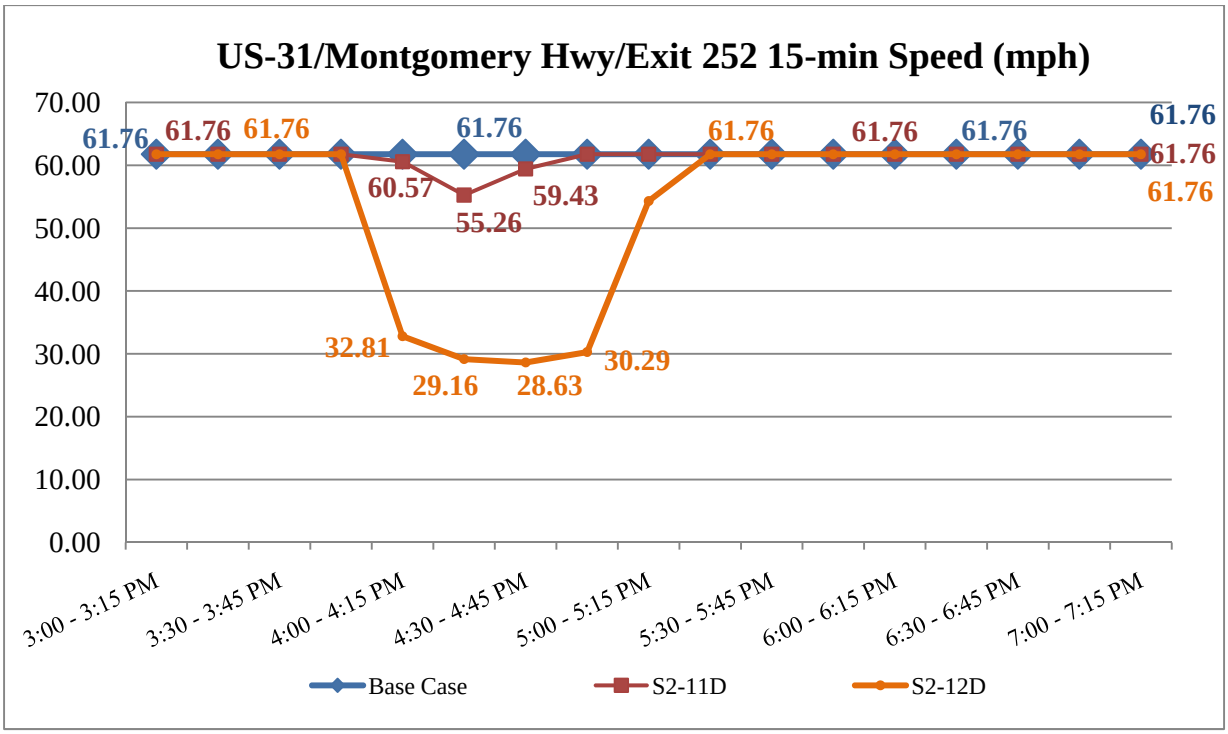
Comparison of Base Case, S2-11D and S2-12D



Comparison of Base Case, S2-11D and S2-12D: Lakeshore Dr/Exit 255

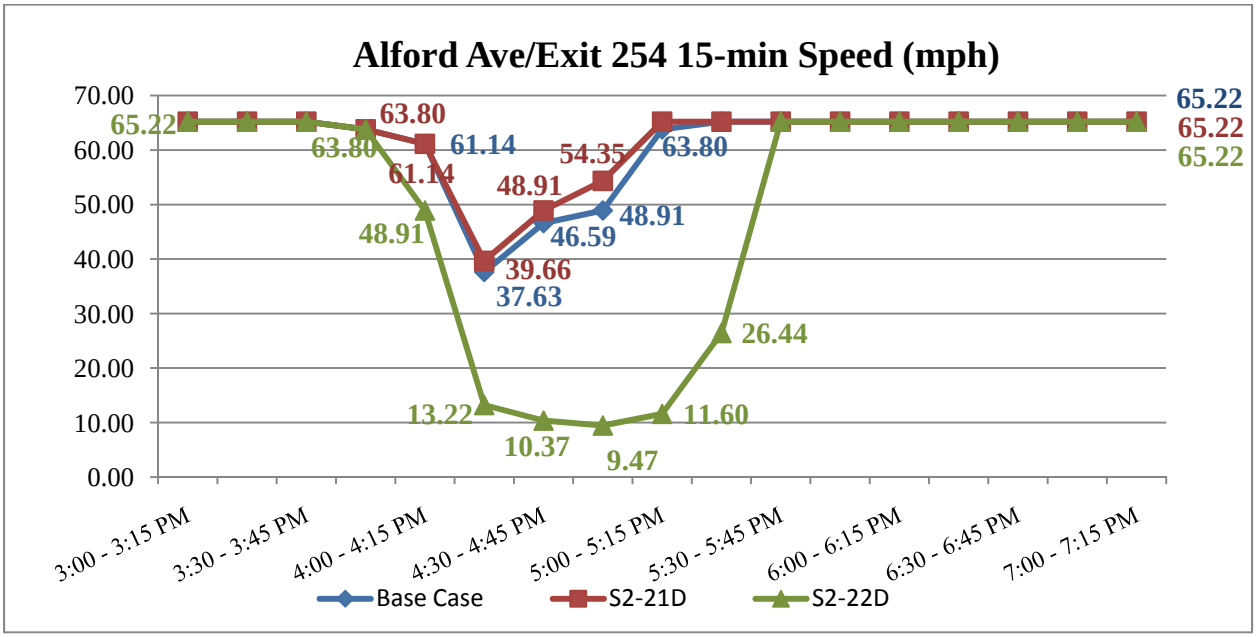


Comparison of Base Case, S2-11D and S2-12D: Alford Ave/Exit 254

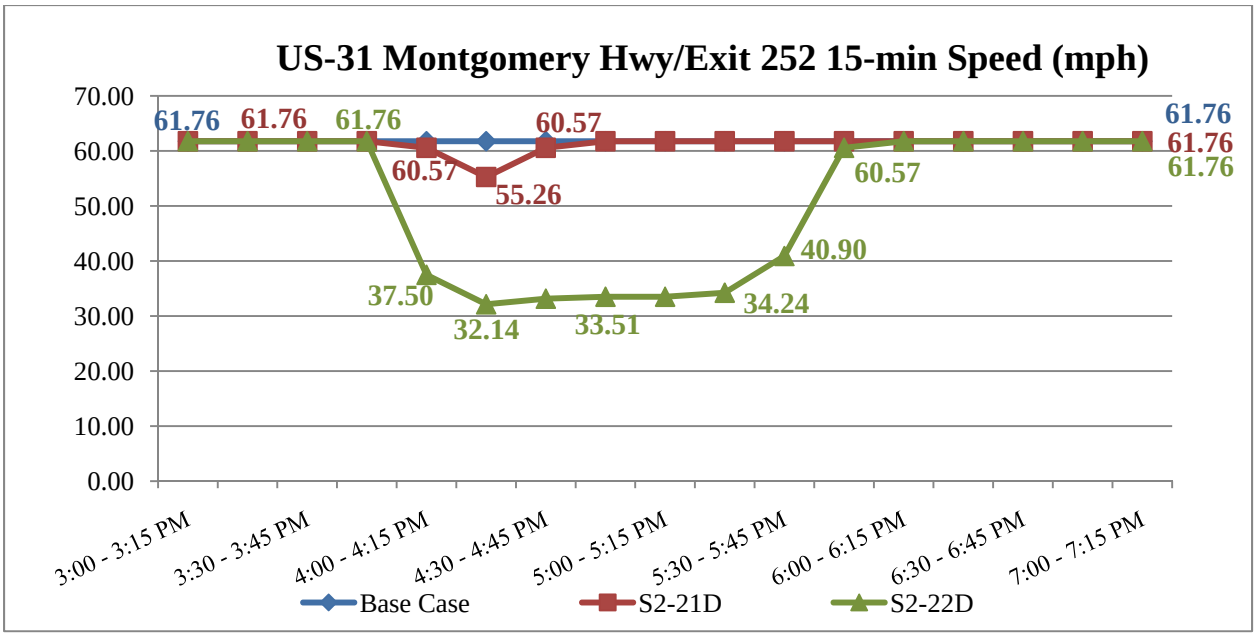


Comparison of Base Case, S2-11D and S2-12D: US-31/Exit 252

Comparison of Scenarios Base Case, S2-21D and S2-22D

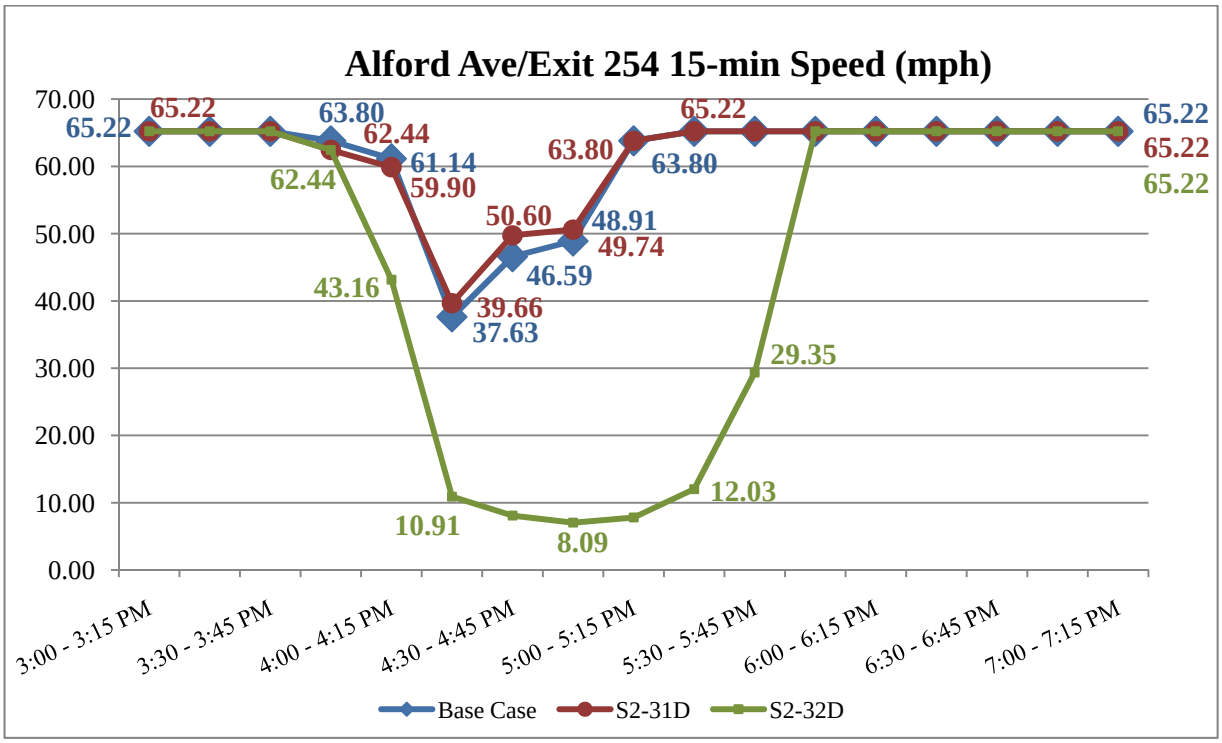


Comparison of Base Case, S2-21D and S2-22D: Alford Ave/Exit 254

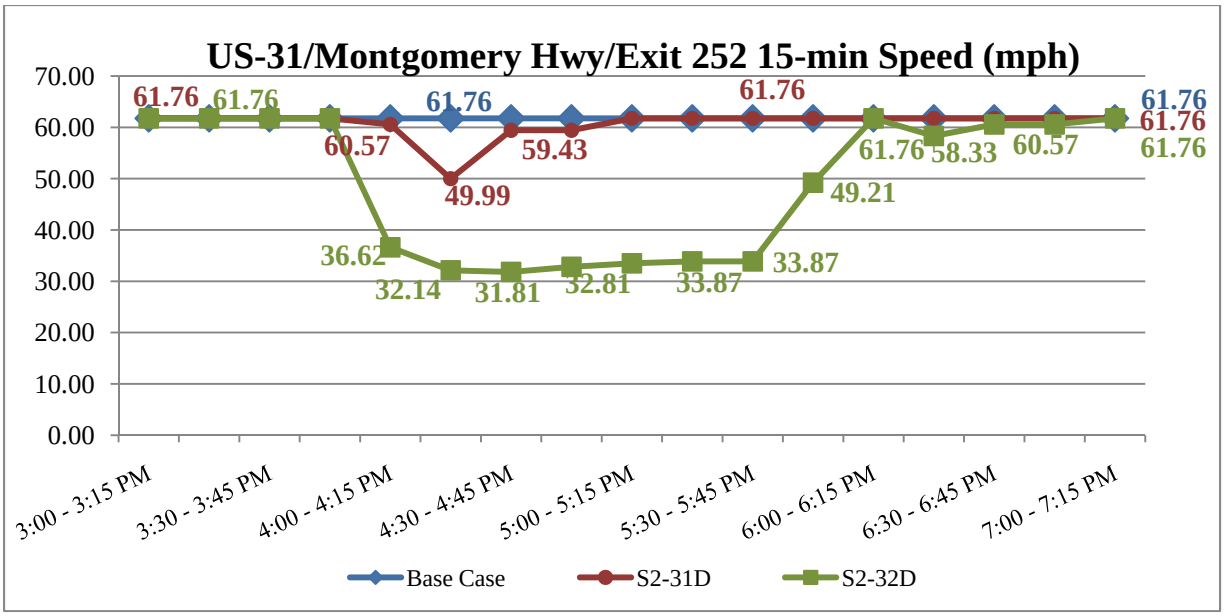


Comparison of Base Case, S2-21D and S2-22D: US-31/Exit 252

Comparison of Scenarios Base Case, S2-31D and S2-32D

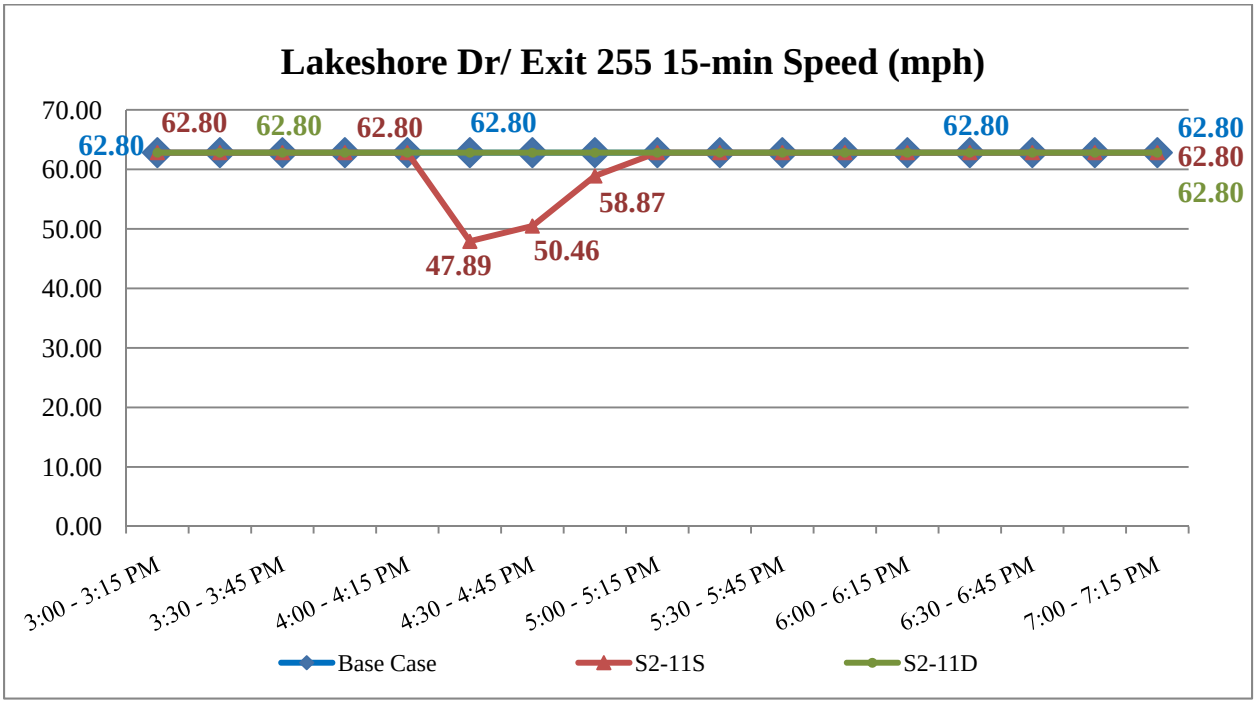


Comparison of Scenarios Base Case, S2-31D and S2-32D: Alford Ave/Exit 254

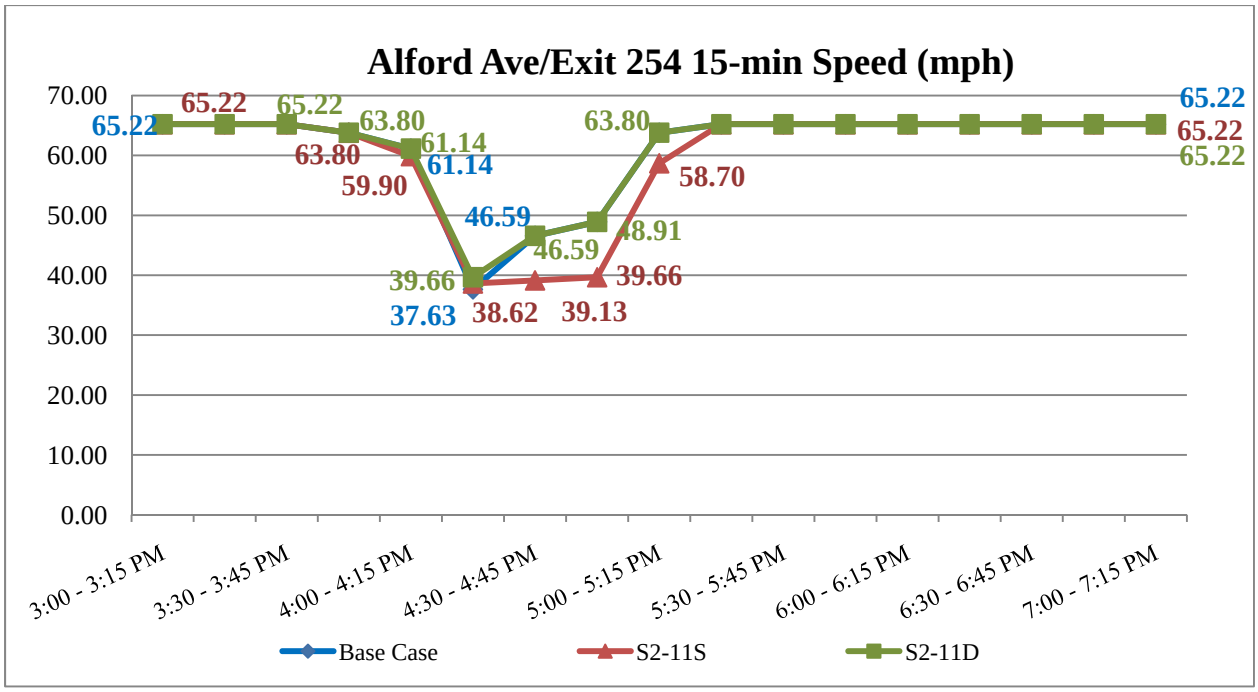


Comparison of Base Case, S2-31D and S2-32D: US-31/Exit 252

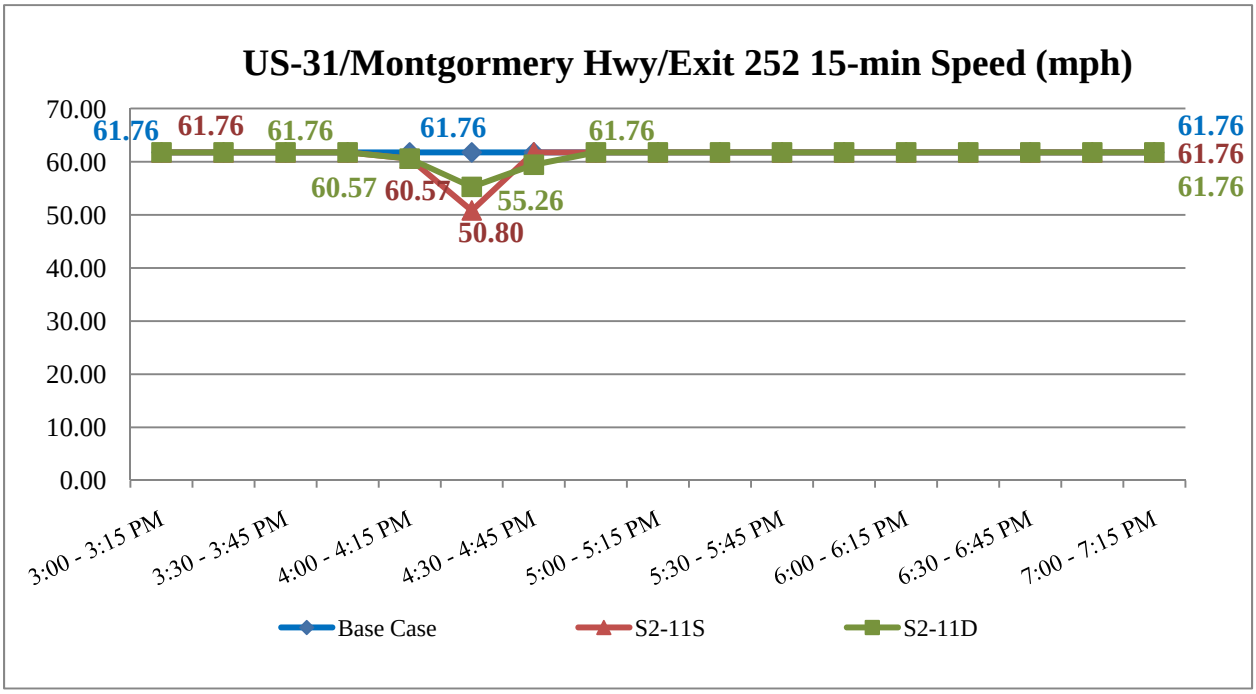
Comparison of Base Case, S2-11S and S2-11D



Comparison of Base Case, S2-11S and S2-11D: Lakeshore Dr/Exit 255

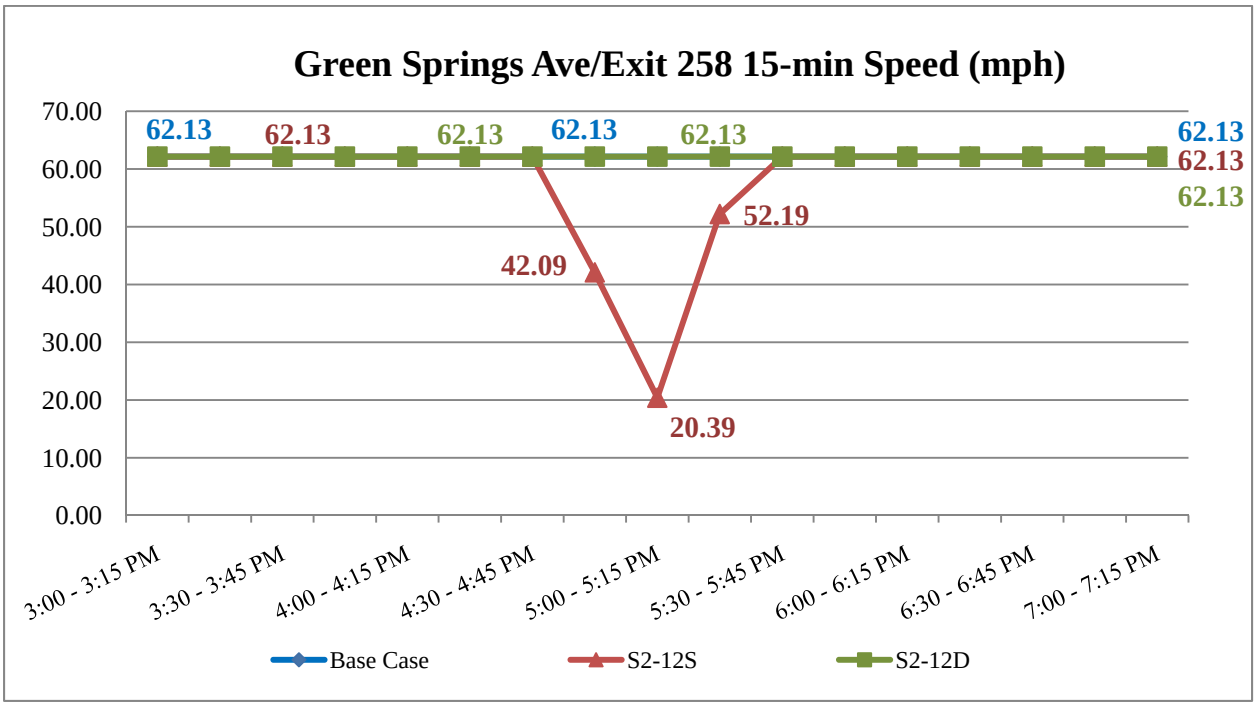


Comparison of Base Case, S2-11S and S2-11D: Alford Ave/Exit 254

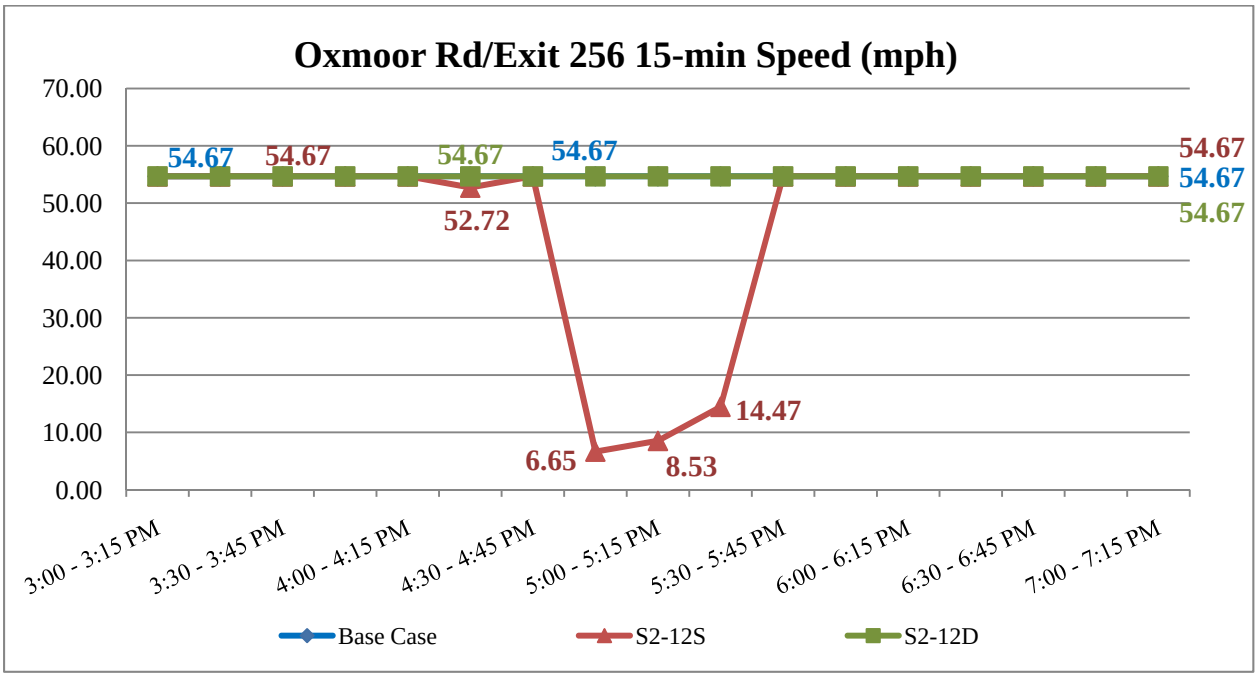


Comparison of Base Case, S2-11S and S2-11D: US-31/Exit 252

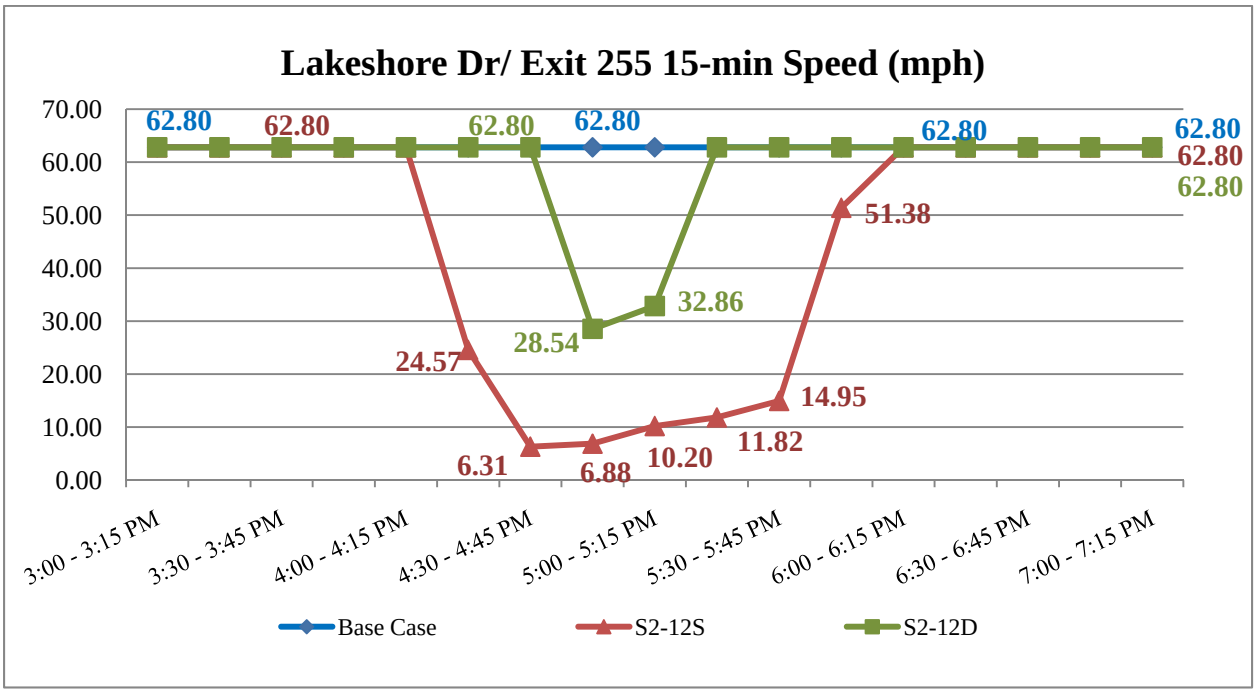
Comparison of Base Case, S2-12S and S2-12D



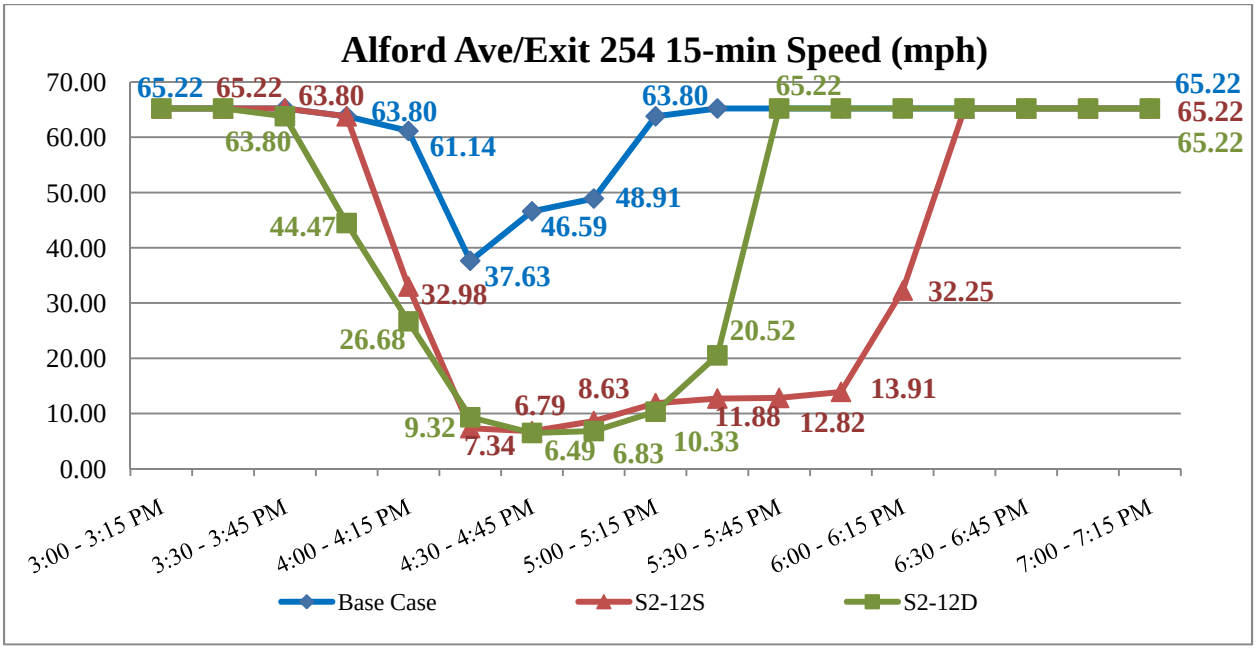
Comparison of Base Case, S2-12S and S2-12D: Green Springs Ave/Exit 258



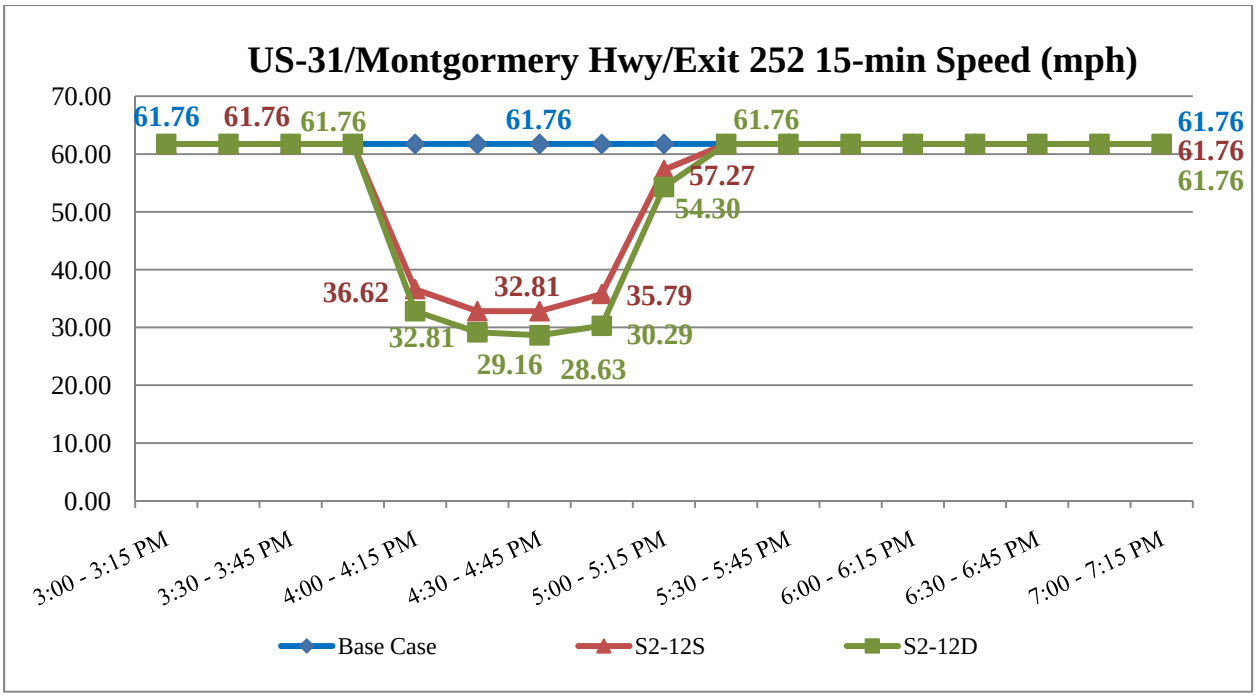
Comparison of Base Case, S2-12S and S2-12D: Oxmoor Rd/Exit 256



Comparison of Base Case, S2-12S and S2-12D: Lakeshore Dr/Exit 255

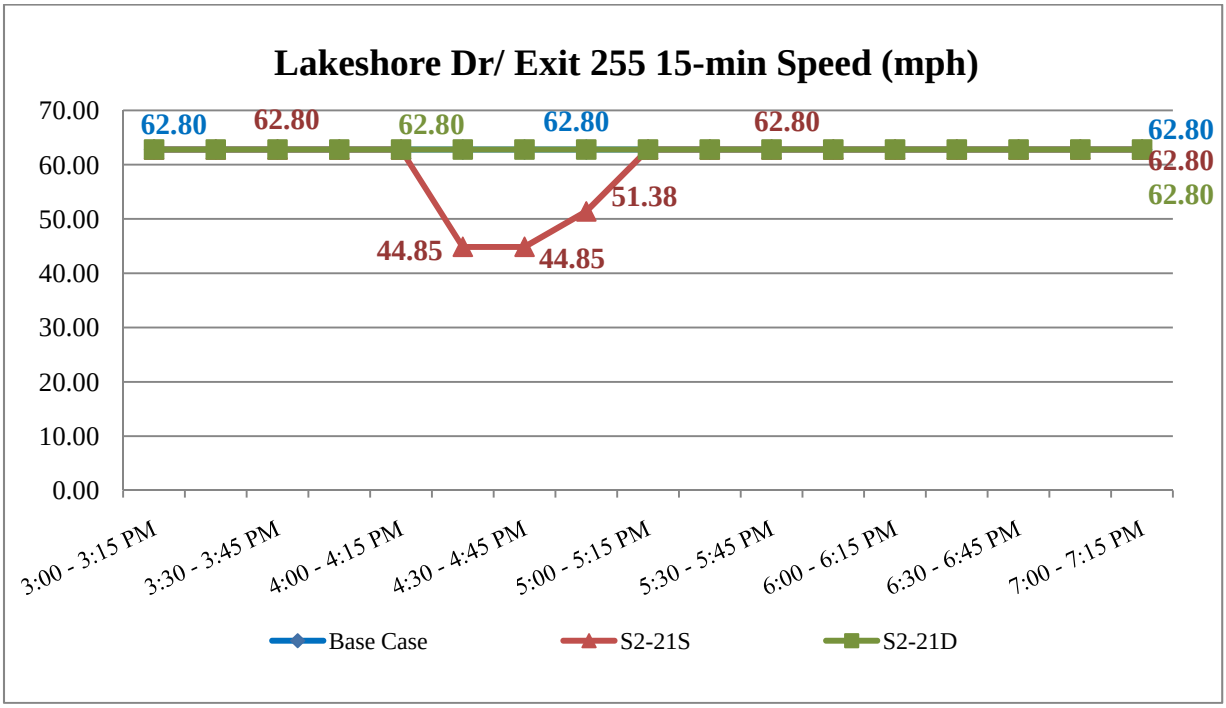


Comparison of Base Case, S2-12S and S2-12D: Alford Ave/Exit 254

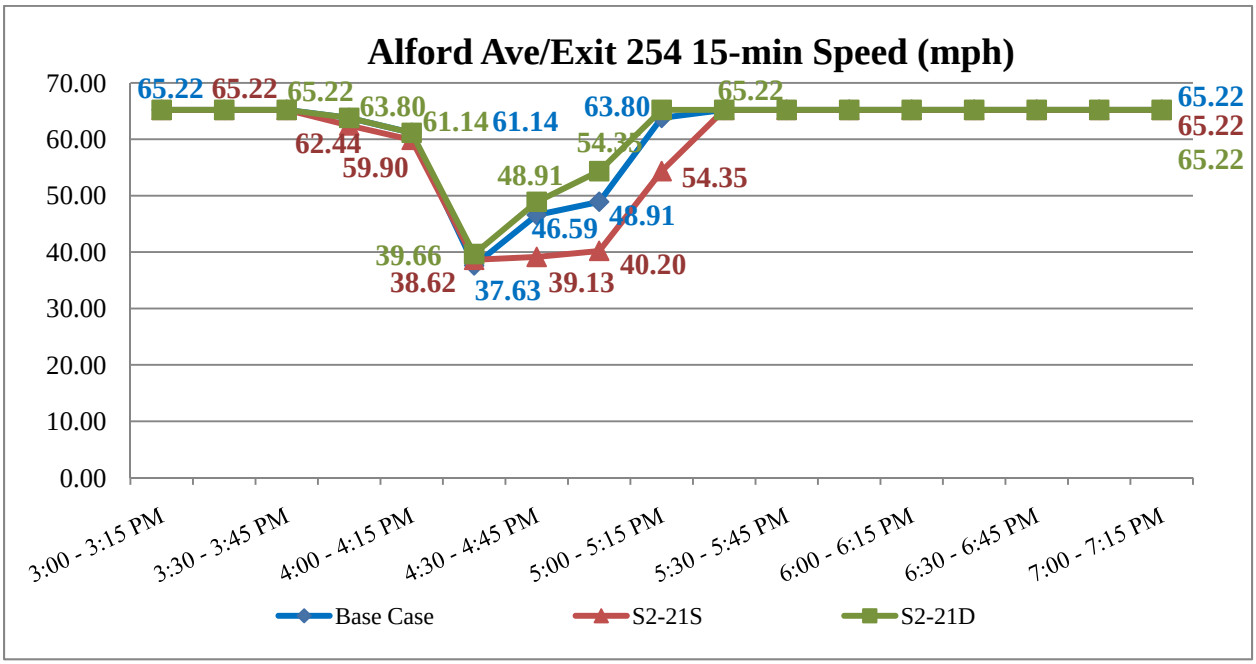


Comparison of Base Case, S2-12S and S2-12D: US-31/Exit 252

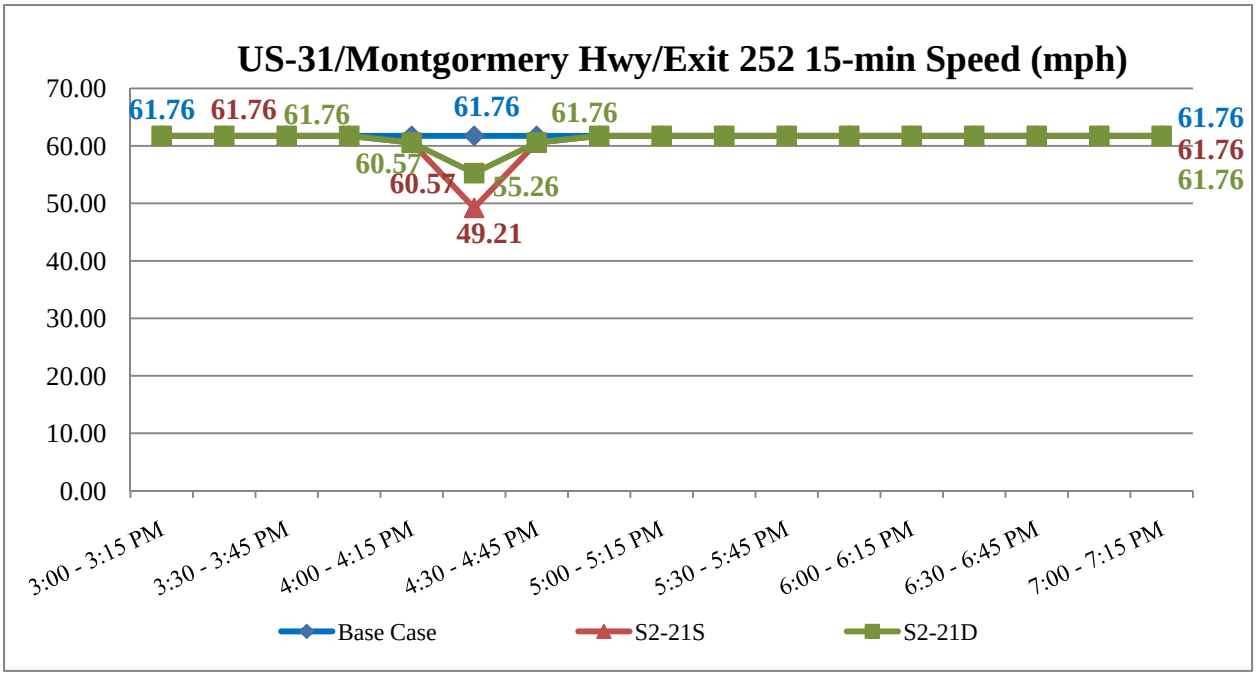
Comparison of Base Case, S2-21S and S2-21D



Comparison of Base Case, S2-21S and S2-21D: Lakeshore Dr/Exit 255

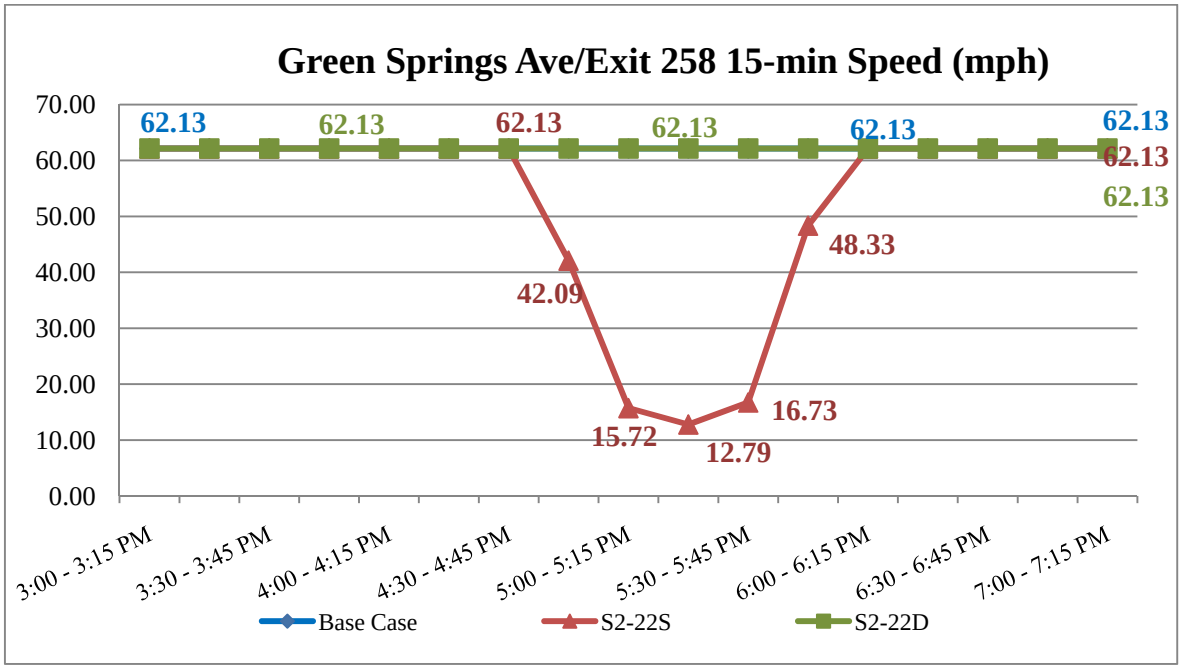


Comparison of Base Case, S2-21S and S2-21D: Alford Ave/Exit 254

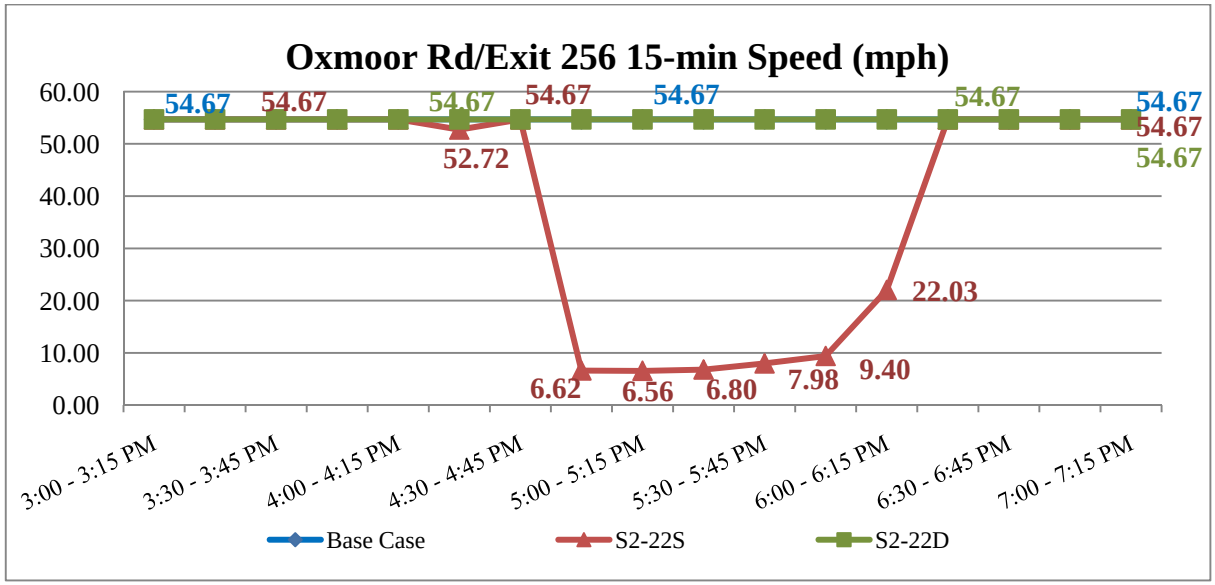


Comparison of Base Case, S2-21S and S2-21D: US-31/Exit 252

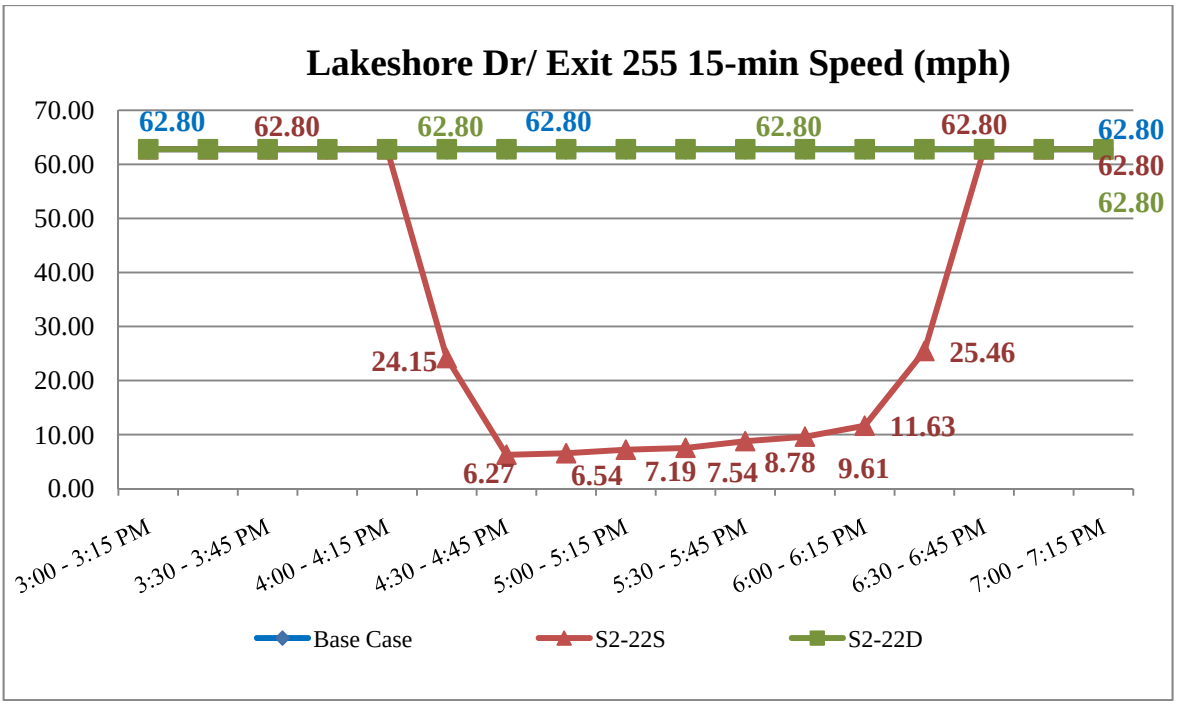
Comparison of Base Case, S2-22S and S2-22D



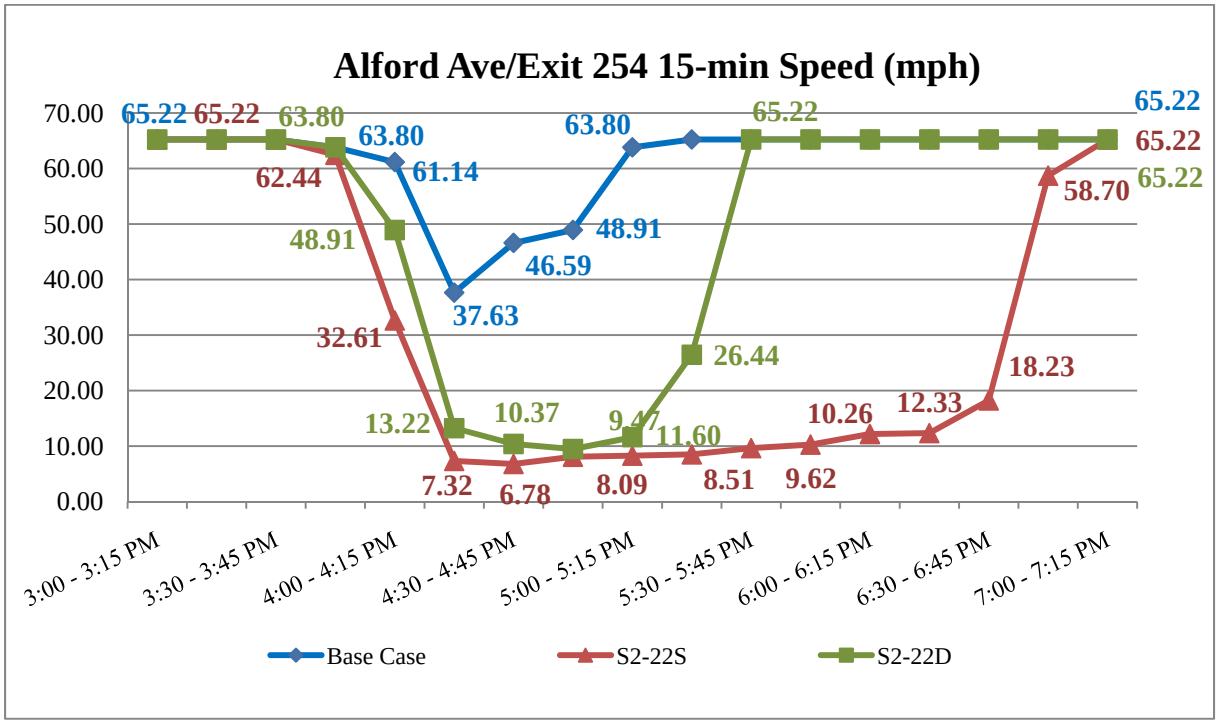
Comparison of Base Case, S2-22S and S2-22D: Green Springs Ave/Exit 258



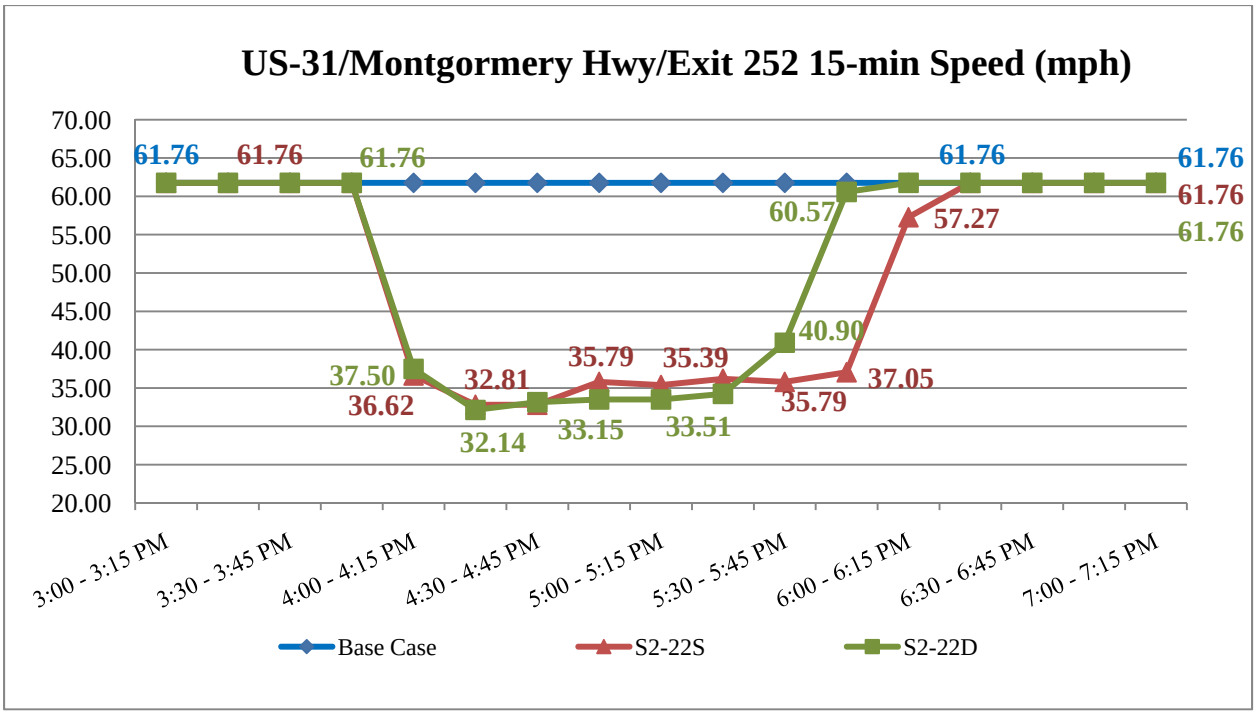
Comparison of Base Case, S2-22S and S2-22D: Oxmoor Rd/Exit 256



Comparison of Base Case, S2-22S and S2-22D: Lakeshore Dr/Exit 255

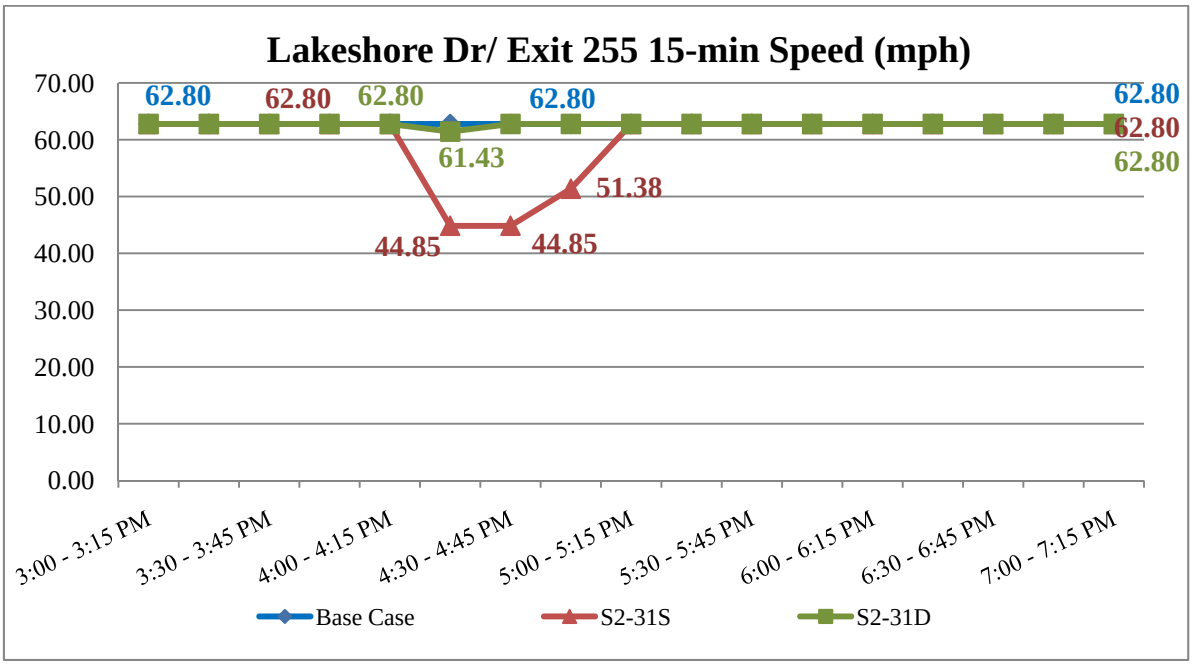


Comparison of Base Case, S2-22S and S2-22D: Alford Ave/Exit 254

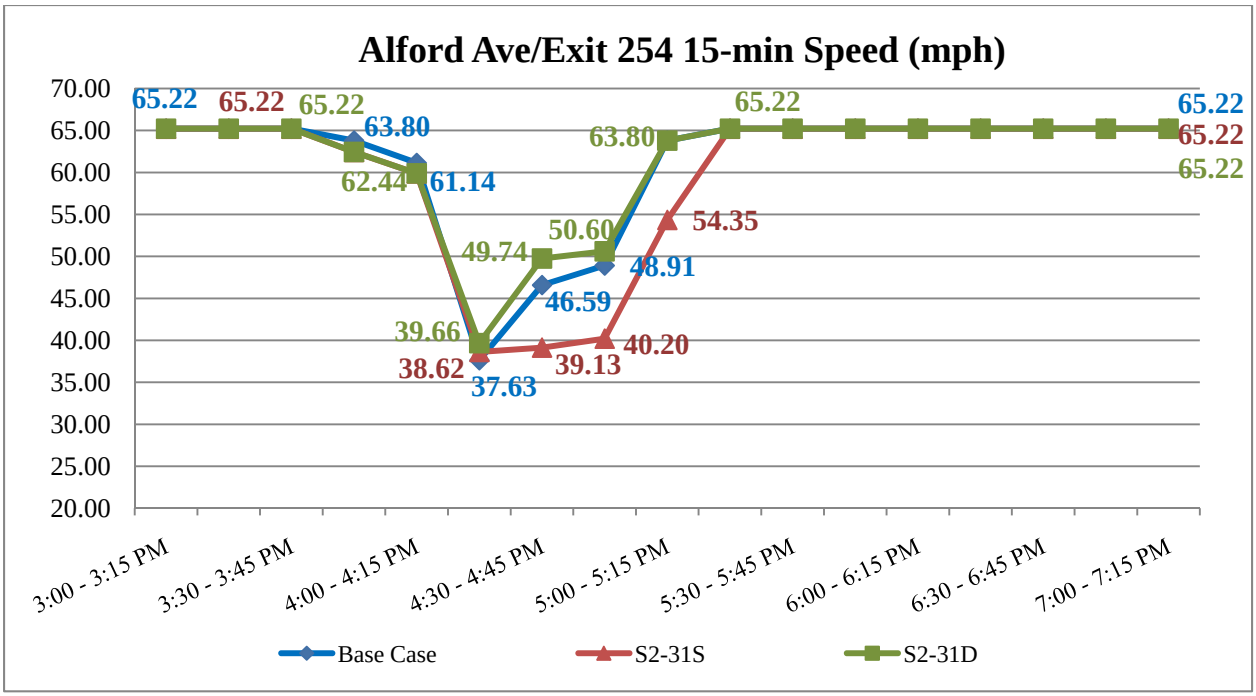


Comparison of Base Case, S2-22S and S2-22D: US-31/Exit 252

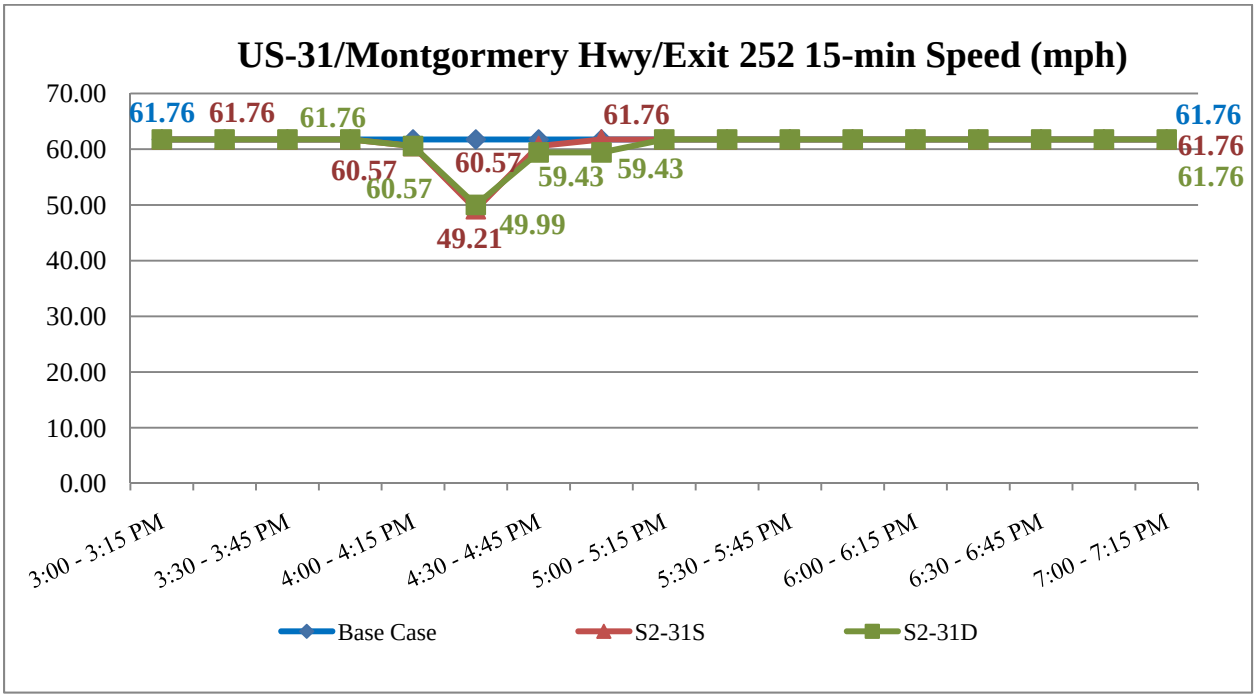
Comparison of Base Case, S2-31S and S2-31D



Comparison of Base Case, S2-31S and S2-31D: Lakeshore Dr/Exit 255

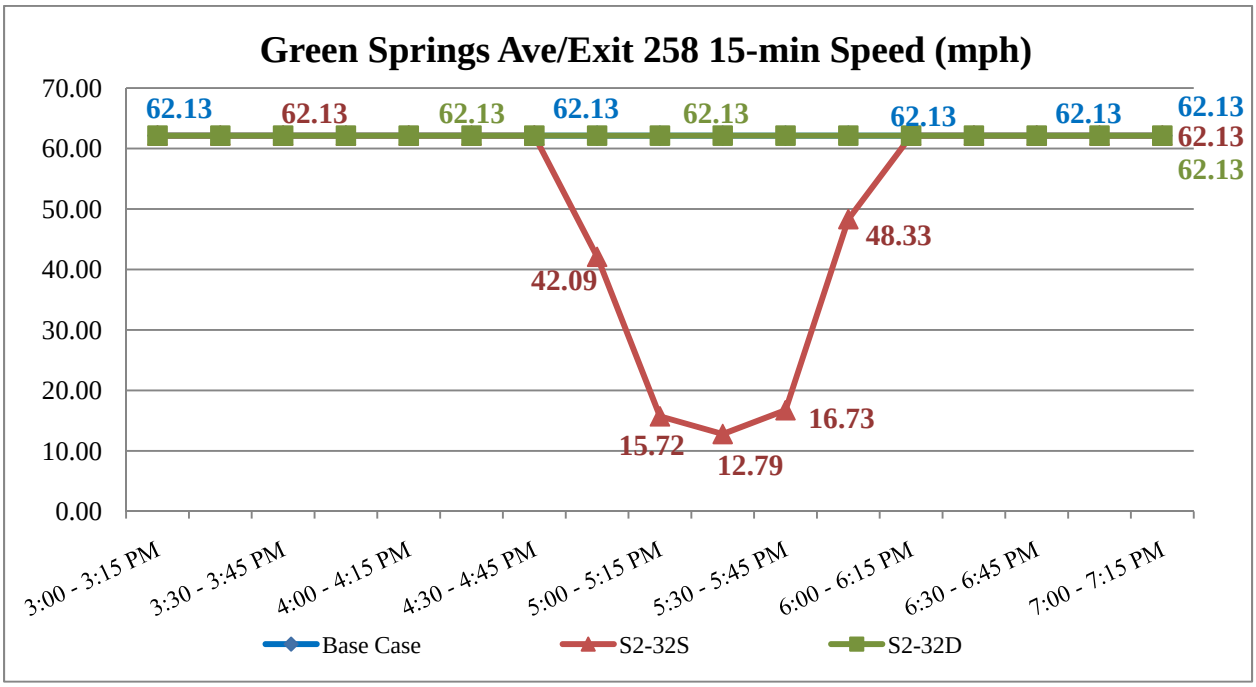


Comparison of Base Case, S2-31S and S2-31D: Alford Ave/Exit 254

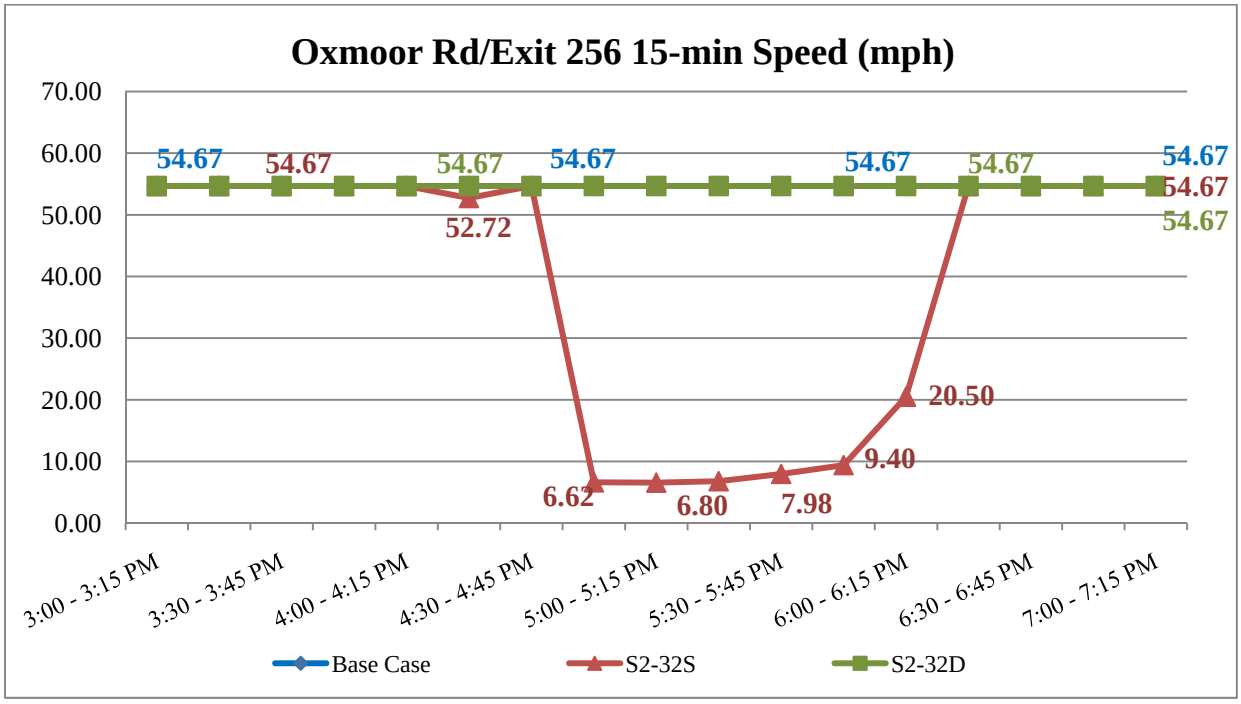


Comparison of Base Case, S2-31S and S2-31D: US-31/Exit 252

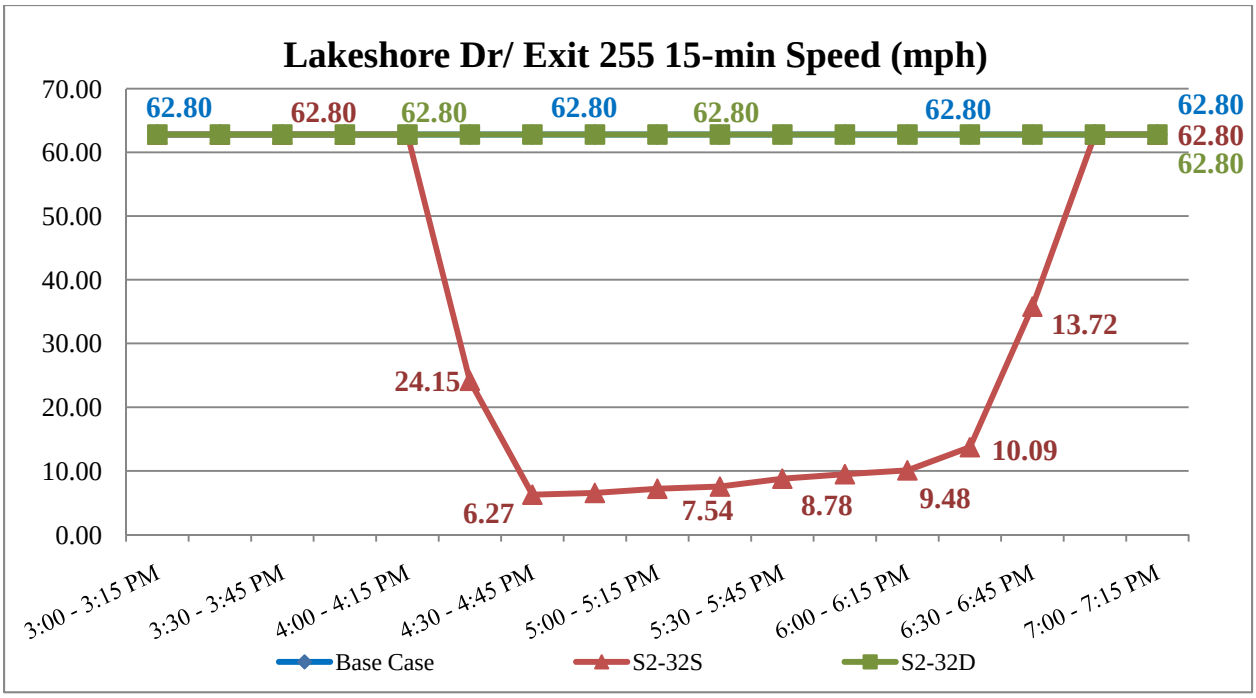
Comparison of Base Case, S2-32S and S2-32D



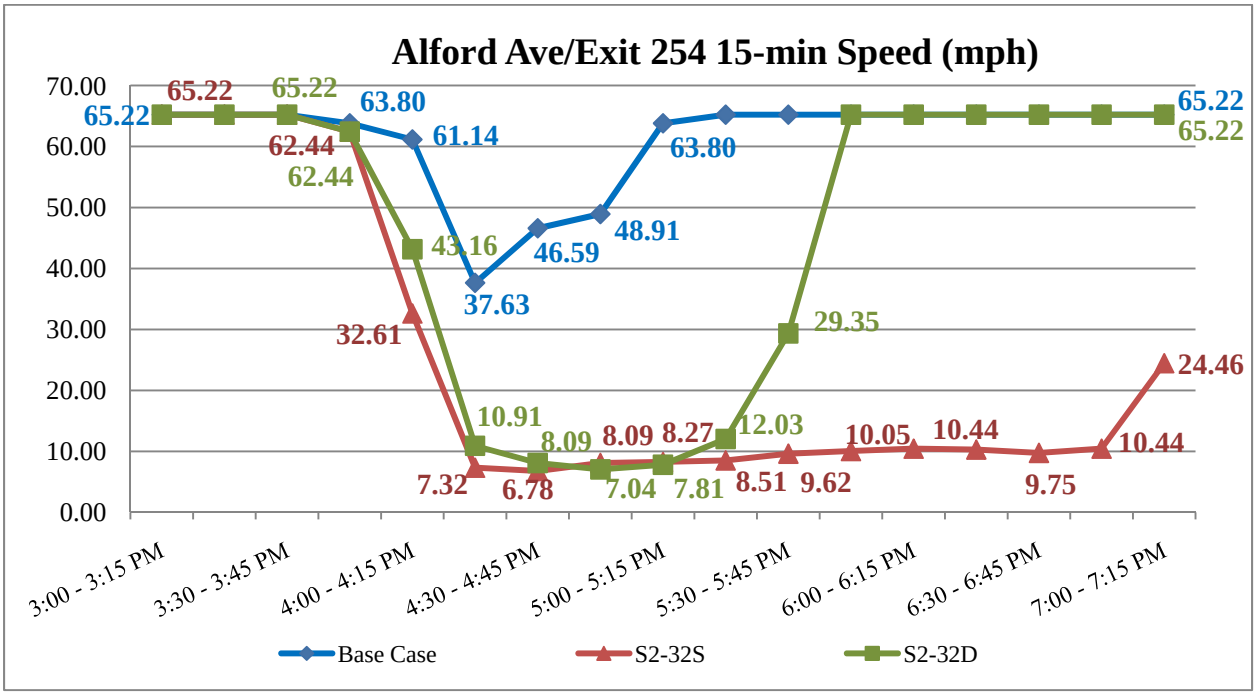
Comparison of Base Case, S2-32S and S2-32D: Green Springs Ave/Exit 258



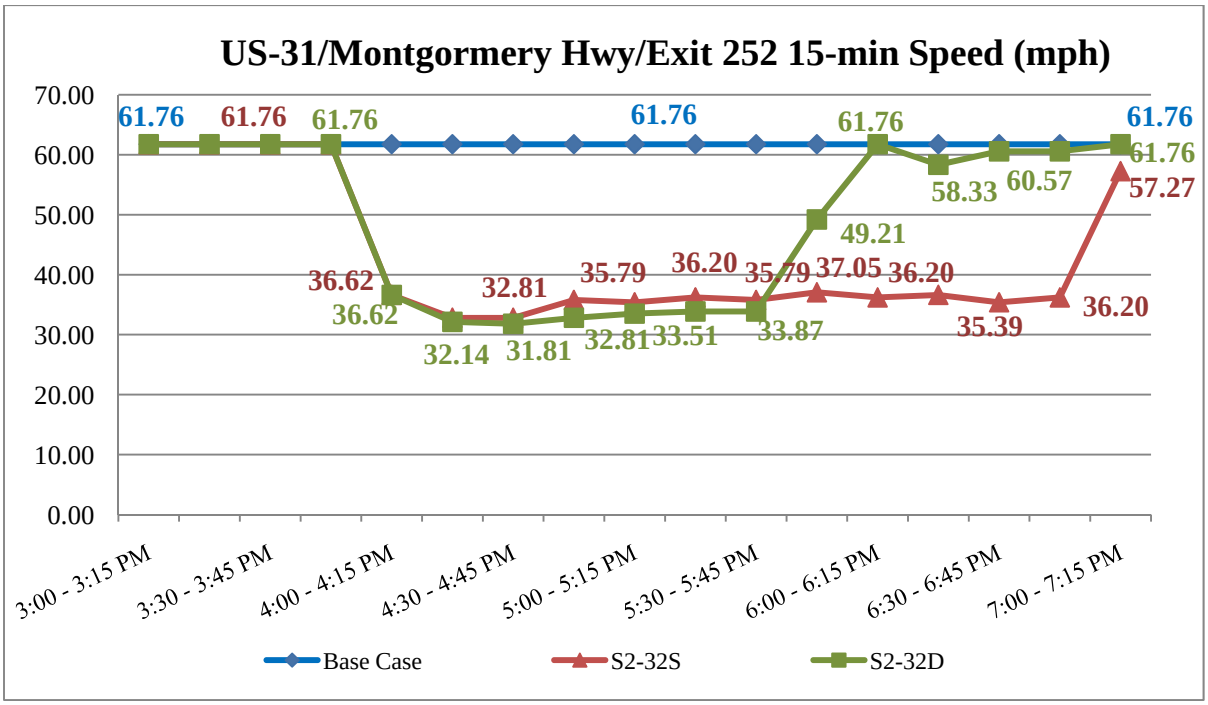
Comparison of Base Case, S2-32S and S2-32D: Oxmoor Rd/Exit 256



Comparison of Base Case, S2-32S and S2-32D: Lakeshore Dr/Exit 255



Comparison of Base Case, S2-32S and S2-32D: Alford Ave/Exit 254



Comparison of Base Case, S2-32S and S2-32D: US-31/Exit 252

Domain 2
Project 5

Development and Testing of a Decision Suport Tool for Optimization of EMS Response Time

Development and Testing of a Decision Support Tool for Optimization of EMS Response Time

Final Report

UAB UTC Domain 2: Development of a Dynamic Traffic Assignment and Simulation Model for Incident and Emergency Management Applications in the Birmingham Region (Aim 5)

Prepared By:

Sharif Melouk, Ph.D. and **Burcu Keskin**, Ph.D.
Department of Information Systems, Statistics, and Management Science
The University of Alabama

Prepared for:

The UAB University Transportation Center
Birmingham, Alabama
DTRT06-G-0048

UAB UTC

August 2011

DRAFT

1. Report No. FHWA/CA/OR	**2. Government Accession No.**	**3. Recipient Catalog No.**
4 Title and Subtitle Title: Development of a Dynamic Traffic Assignment and Simulation Model for Incident and Emergency Management Applications in the Birmingham Region Subtitle: Development and Testing of a Decision Support Tool for Optimization of EMS Response Time		**5 Report Date** August 2011 **6 Performing Organization Code**
7. Author(s) Sharif H. Melouk and Burcu B. Keskin		**8 Performing Organization Report No.**
9 Performing Organization Name and Address The University of Alabama 361 Stadium Dr. 300 Alston Hall Tuscaloosa, AL 35487		**10 Work Unit No. (TRAIS)** **11 Contract or Grant No.**
12 Sponsoring Agency Name and Address UAB University Transportation Center 1530 3rd Avenue South Birmingham, AL 35294-2041		**13 Type of Report and Period Covered** **14 Sponsoring Agency Code**
15 Supplementary Notes		

16 Abstract

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 respond in a timely fashion. In this research effort, we develop an optimization-based planning tool to investigate the allocation of emergency responders so as to reduce response time. Experimentation is performed on several scenarios, and managerial insights are gleaned.

17 Key Words emergency response, resource allocation, optimization		**18 Distribution Statement** No restrictions.	
19 **Security Classification (of this report)** Unclassified	20 **Security Classification (of this page)** Unclassified	**21 No. of pages**	**22 Price**

Contents

Contents iii
List of Tables iv
List of Figures iv
Abstract v

1. Introduction 1
    1.1 Problem Definition 1
    1.2 Objectives 1

2. Methodology 1
    2.1 Notation 1
    2.2 Model 1: Total Response Time Minimization 2
    2.3 Model 2: First Responder Arrival Time Minimization 3
    2.4 Model 3: Maximum Response Time Minimization 4

3. Experimentation 5
    3.1 Experimental Setup 5
    3.2 Experimentation Results and Discussion 7
    3.3 Benefits 10

List of Tables

Number Page
Table 1. Experimentation Parameters 5
Table 2. Incident Type and Response 6
Table 3. Travel Time Expressions 7
Table 4. Model 3 vs. Model 1 (Response Time) 8
Table 5. Model 1 vs. Model 2 (First Responder Time) 8
Table 6. Model 3 vs. Model 2 (First Responder Time) 8
Table 7. Model 1 vs. Model 3 (Full Response Time) 9
Table 8. Responder Utilization by Sub-region 10

List of Figures

Number Page
Figure 1. Percentage of Incidents per One-hour Period 6
Figure 2. Percentage of Incidents per One-hour Period based on Time Period Duration 7

Abstract

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 respond in a timely fashion. In this research effort, we develop an optimization-based planning tool to investigate the allocation of emergency responders so as to reduce response time. Experimentation is performed on several scenarios, and managerial insights are gleaned.

Keywords: Emergency response, resource allocation, optimization

1. INTRODUCTION

1.1 Problem Definition

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 respond in a timely fashion. However, an informal survey of emergency response agencies in the Birmingham, Alabama area found that traffic conditions are typically not considered when dispatching a response unit. Thus, in this research effort, we develop a support decision tool to manage the dispatch of emergency responders to the site of traffic network incidents.

1.2 Objectives

To aid emergency dispatchers and decision-makers, we construct a decision support tool using optimization techniques. Specifically, our goals are to:

- mathematically formulate a network disruption problem,
- develop three distinct optimization models, and
- perform experimentation to compare model versions and different network settings.

We develop three different model versions as emergency responders may approach disruptive events with differing objectives.

2. METHODOLOGY

In this section, we present the notation and formulation for the three mathematical models developed. The models are referred to as:

- Model 1: Total Travel Minimization
- Model 2: First Responder Arrival Time Minimization
- Model 3: Maximum Response Time Minimization

All of these models ensure that all of the incidents are serviced with the appropriate level of response. These models also take into account the response capabilities of the response locations. In general, these models help determine the optimum staffing and response capacity at established responder locations.

2.1 Notation

The common notation for all of these three models follows.

Sets and Indices:

$\mathcal{I}$: Set of responder locations, $\mathcal{I} = \{i : 1, \ldots, I\}$, $\mathcal{I} = \mathcal{RL}$, where $\mathcal{RL}$ is the set of responder locations.

$\mathcal{J}$: Set of incident locations, $\mathcal{J} = \{j : 1, \ldots, J\}$.

$\mathcal{D}$: Set of days, $\mathcal{D} = \{d : 1, \ldots, 7\}$.

$\mathcal{P}$: Set of time periods, $\mathcal{P} = \{p : 1, \ldots, 24\}$.

Problem Parameters:

t_{ijdp} : Travel time between responder location i and incident location j on day d during time period p, $i \in \mathcal{I}$, $j \in \mathcal{J}$, $d \in \mathcal{D}$, and $p \in \mathcal{P}$.

e_{jdp} : Expected number of responders required at incident location j on day d during time period p, $j \in \mathcal{J}$, $d \in \mathcal{D}$, and $p \in \mathcal{P}$.

c_{id} : Maximum number of available responders at responder location i on day d $i \in \mathcal{I}$ and $d \in \mathcal{D}$.

l_{ij} : Number of periods required for a responder to return to response location i from incident location j, $i \in \mathcal{I}$ and $j \in \mathcal{J}$.

Decision Variables:

X_{ijdp} : Number of responders assigned from location i to incident j on day d during time period p, $i \in \mathscr{I}$, $j \in \mathscr{J}$, $d \in \mathscr{D}$, and $p \in \mathscr{P}$.

U_{idp} : Number of responder units available at responder location i on day d at the end of time period p, $i \in \mathscr{I}$, $d \in \mathscr{D}$, and $p \in \mathscr{P}$.

A_{jdp} : Response time of the first responder to incident j on day d during time period p, $j \in \mathscr{J}$, $d \in \mathscr{D}$, and $p \in \mathscr{P}$.

Z_{jdp} : Maximum response time to incident j on day d during time period p, $j \in \mathscr{J}$, $d \in \mathscr{D}$, and $p \in \mathscr{P}$.

2.2 Model 1: Total Response Time Minimization

The objective of Model 1 is to minimize the total response time from responder locations to incident sites. The formulation follows:

$$\text{Minimize} \sum_{i \in \mathcal{I}} \sum_{j \in \mathcal{J}} \sum_{d \in \mathcal{D}} \sum_{p \in \mathcal{P}} t_{ijdp} \, X_{ijdp} \qquad \text{(Model-1)}$$

Subject to:

Set 1: Capacity Limitations

$$\sum_{j \in \mathcal{J}} X_{ijdp} \leq U_{idp}, \qquad \forall i \in \mathcal{I}, \forall d \in \mathcal{D}, \text{and } \forall p \in \mathcal{P}. \quad (1)$$

$$U_{idp} \leq c_{id}, \qquad \forall i \in \mathcal{I}, \forall d \in \mathcal{D}, \text{and } \forall p \in \mathcal{P}. \quad (2)$$

Set 2: Incident Assignment

$$\sum_{i \in \mathcal{I}} X_{ijdp} = e_{jdp}, \qquad \forall j \in \mathcal{J}, \forall d \in \mathcal{D}, \text{ and } \forall p \in \mathcal{P}. \quad (3)$$

Set 3: Resource Balance

$$U_{idp} = U_{i,d,p-1} + \sum_{j \in \mathcal{J}} X_{i,j,d,p-L_{ij}} - \sum_{j \in \mathcal{J}} X_{i,j,d,p-1}, \qquad \forall i \in \mathcal{I}, \forall d \in \mathcal{D}, \text{ and } \forall p \in \mathcal{P}. \quad (4)$$

$$U_{id0} = c_{id}, \qquad \forall i \in \mathcal{I} \text{ and } \forall d \in \mathcal{D}. \quad (5)$$

Set 4: Integrality Constraints

$$X_{ijdp}, U_{idp} \in \mathbb{Z}^+, \qquad \forall i \in \mathcal{I}, \forall j \in \mathcal{J}, \forall d \in \mathcal{D}, \text{ and } \forall p \in \mathcal{P}. \quad (6)$$

In this formulation, constraint set 1 ensures the availability of responders at the response locations. For this purpose, the number of responders sent to all incidents cannot exceed the number of available responders at any time period or day (constraint 1). Additionally, the number of available responders cannot exceed the maximum capacity at a response location (constraint 2). Constraint set 2 ensures that

all of the incidents are served. Constraint set 3 ensures the resource balance at the response locations. That is, constraint 4 tracks the number of available responders at the response locations at each time interval and period. This constraint for this formulation links different periods together. Finally, constraint set 4 restricts the decision variables to positive integers.

2.3 Model 2: First Responder Arrival Time Minimization

This model aims to minimize the first responder travel time to all incidents. A Big-M formulation is used for this model so that responder locations not utilized do not influence the minimization. In addition to the notation defined in Model 1, we define a new variable to capture the utilization of a particular response location, independent of the number of the units being sent from that location. In particular,

Defining new decision variables, for all $i \in \mathscr{I}$, $j \in \mathscr{J}$, $d \in \mathscr{D}$, and $p \in \mathscr{P}$

$$Y_{ijdp} = \begin{cases} 1, & \text{if } X_{ijdp} > 0. \\ 0, & \text{otherwise.} \end{cases} \qquad A_{jdp} = \begin{cases} \min_i\{t_{ijdp} Y_{ijdp}\}, & \text{if } Y_{ijdp} = 1. \\ M, & \text{otherwise.} \end{cases}$$

The formulation for Model 2 follows:

$$\textbf{Minimize} \sum_{j \in \mathscr{J}} \sum_{d \in \mathscr{D}} \sum_{p \in \mathscr{P}} A_{jdp}$$

Subject to:

Set 1: Capacity Limitations

$$\sum_{j \in \mathcal{J}} X_{ijdp} \leq U_{idp}, \qquad \forall i \in \mathcal{I}, \forall d \in \mathcal{D}, \text{and } \forall p \in \mathcal{P}. \quad (1)$$

$$U_{idp} \leq c_{id}, \qquad \forall i \in \mathcal{I}, \forall d \in \mathcal{D}, \text{and } \forall p \in \mathcal{P}. \quad (2)$$

Set 2: Incident Assignment

$$\sum_{i \in \mathcal{I}} X_{ijdp} = e_{jdp}, \qquad \forall j \in \mathcal{J}, \forall d \in \mathcal{D}, \text{ and } \forall p \in \mathcal{P}. \quad (3)$$

Set 3: Resource Balance

$$U_{idp} = U_{i,d,p-1} + \sum_{j \in \mathcal{J}} X_{i,j,d,p-L_{ij}} - \sum_{j \in \mathcal{J}} X_{i,j,d,p-1}, \qquad \forall i \in \mathcal{I}, \forall d \in \mathcal{D}, \text{ and } \forall p \in \mathcal{P}. \quad (4)$$

$$U_{id0} = c_{id}, \qquad \forall i \in \mathcal{I} \text{ and } \forall d \in \mathcal{D}. \quad (5)$$

Set 4: Integrality Constraints

$$X_{ijdp}, U_{idp} \in \mathbb{Z}^+, \qquad \forall i \in \mathcal{I}, \forall j \in \mathcal{J}, \forall d \in \mathcal{D}, \text{ and } \forall p \in \mathcal{P}. \quad (6)$$

Set 5: Responder Assignment

$$X_{ijdp} \leq M\, Y_{ijdp}, \qquad \forall i \in \mathcal{I}, \forall j \in \mathcal{J}, \forall d \in \mathcal{D}, \text{ and } \forall p \in \mathcal{P}. \quad (7)$$

Set 6: Binary Constraints

$$Y_{ijdp} \in \{0, 1\}, \qquad \forall i \in \mathcal{I}, \forall j \in \mathcal{J}, \forall d \in \mathcal{D}, \text{ and } \forall p \in \mathcal{P}. \quad (8)$$

In this formulation, constraint set 5 tracks the utilization of a response location. That is, constraint 7 essentially defines the new variable Y_{ijdp} based on the utilization of a particular response location i that

is responding to incident j. This is a Big-M type of formulation where the big M number is set to e_{jdp}, $\forall j \in \mathrm{J}, \forall d \in \mathrm{D}, and \forall p \in \mathrm{P}$. Finally, constraint set 6 states that the new decision variables are binary.

2.4 Model 3: Maximum Response Time Minimization

This model aims to ensure the total full service time is minimized for all of the incidents. That is, in a situation where multiple response units are required at an incident, we aim to minimize the maximum response time among all of these responders. This model builds on the first two models (i.e., Model 1 and Model 2) with the addition of a new decision variable, Z_{jdp}, where

$$Z_{jdp} = \max_{i \in \mathcal{I}} \{ t_{ijdp} \, Y_{ijdp} \},$$

for all $j \in \mathrm{J}$, $d \in \mathrm{D}$, and $p \in \mathrm{P}$. This new variable captures the maximum time of all responders that are assigned to an incident.

The formulation for Model 3 follows:

$$\text{Minimize} \sum_{j \in \mathcal{J}} \sum_{d \in \mathcal{D}} \sum_{p \in \mathcal{P}} Z_{jdp} \qquad \text{(Model-3)}$$

Subject to:

Set 1: Capacity Limitations

$$\sum_{j \in \mathcal{J}} X_{ijdp} \leq U_{idp}, \qquad \forall i \in \mathcal{I}, \forall d \in \mathcal{D}, \text{and } \forall p \in \mathcal{P}. \quad (1)$$

$$U_{idp} \leq c_{id}, \qquad \forall i \in \mathcal{I}, \forall d \in \mathcal{D}, \text{and } \forall p \in \mathcal{P}. \quad (2)$$

Set 2: Incident Assignment

$$\sum_{i \in \mathcal{I}} X_{ijdp} = e_{jdp}, \qquad \forall j \in \mathcal{J}, \forall d \in \mathcal{D}, \text{ and } \forall p \in \mathcal{P}. \quad (3)$$

Set 3: Resource Balance

$$U_{idp} = U_{i,d,p-1} + \sum_{j \in \mathcal{J}} X_{i,j,d,p-L_{ij}} - \sum_{j \in \mathcal{J}} X_{i,j,d,p-1}, \qquad \forall i \in \mathcal{I}, \forall d \in \mathcal{D}, \text{ and } \forall p \in \mathcal{P}. \quad (4)$$

$$U_{id0} = c_{id}, \qquad \forall i \in \mathcal{I} \text{ and } \forall d \in \mathcal{D}. \quad (5)$$

Set 4: Integrality Constraints

$$X_{ijdp}, U_{idp} \in \mathbb{Z}^{+}, \qquad \forall i \in \mathcal{I}, \forall j \in \mathcal{J}, \forall d \in \mathcal{D}, \text{ and } \forall p \in \mathcal{P}. \quad (6)$$

Set 5: Responder Assignment

$$X_{ijdp} \leq M \, Y_{ijdp}, \qquad \forall i \in \mathcal{I}, \forall j \in \mathcal{J}, \forall d \in \mathcal{D}, \text{ and } \forall p \in \mathcal{P}. \quad (7)$$

Set 6: Binary Constraints

$$Y_{ijdp} \in \{0, 1\}, \qquad \forall i \in \mathcal{I}, \forall j \in \mathcal{J}, \forall d \in \mathcal{D}, \text{ and } \forall p \in \mathcal{P}. \quad (8)$$

Set 7: Variable Definition

$$Z_{jdp} \geq t_{ijdp}\, Y_{ijdp}, \qquad \forall i \in \mathcal{I}, \forall j \in \mathcal{J}, \forall d \in \mathcal{D}, \text{ and } \forall p \in \mathcal{P}. \quad (9)$$

Set 8: Variable Bounds

$$Z_{jdp} \in \mathbb{R}^{+}, \qquad \forall j \in \mathcal{J}, \forall d \in \mathcal{D}, \text{ and } \forall p \in \mathcal{P}. \quad (10)$$

In this formulation, constraint set 7 ensures that the new variable Z_{jdp} obtains the maximum response time among all of the responders. That is, constraint 9 defines the new variable Z_{jdp}. Finally, constraint set 8 states the bounds of the new decision variables.

3. EXPERIMENTATION

3.1 Experimental Setup

To test the models and solution approach, we create a test region resembling the Birmingham area, which mainly consists of Jefferson and Shelby counties. The area is divided into 20 sub-regions and each sub-region is further divided into 20 zones (i.e., total of 400 zones). The centroid of each zone corresponds to a possible incident and/or responder location.

The list of parameters used in the experiments follows in Table 1.

Table 1. Experimentation Parameters

Parameter	Value
Number of responder locations	5, 10, 20
Number of incident location	5, 10, 20, 40
Number of time periods	8, 12, 16
Responder locations	Uniform (level 1) Centrally distributed (level 2)
Incident locations	Uniform (level 1) Centrally distributed (level 2)
Incident severity	Low (based on historical data) High (elevated)
Response location capacity	Low (1 or 2 units per responder location) High (1, 2, or 3 units per responder location)

We use two different distributions to calculate capacity in each responder location. When capacity is low, there is a 67% chance a responder location has only one responder vehicle and a 33% chance it has two responder vehicles. If the capacity is high, there is a 25% chance a responder location has one responder vehicle, a 50% chance that it has two responder vehicles, and a 25% chance that it has three responder vehicles.

With the parameters defined, we create a total of 5760 data sets. To track each data set, we use a run code. For example, a run code of IN5_ID1_IS1_RL5_RC1_RD1_Pe16 represents a situation where there are five incidents (IN5), incidents are distributed in the region uniformly (ID1), incident severity is based on historical data (IS1), five responder locations (RL5) exist, one or two EMS units exist in each responder location (RC1), responder locations are distributed in the region uniformly (RD1), and incidents happen in a 16-hour period (Pe16).

Incident severity determines the number of responders dispatched to an incident. Table 2 shows the type of incidents and the corresponding number of dispatched responder vehicles.

Table 2. Incident Type and Response

Type	Response
Fatality	3 vehicles
Injury	2 vehicles
Property damage	1 vehicle

To generate incidents over a time period, we use historical data. Figure 1 shows the percentage of incidents occurring based on one-hour intervals from historical data.

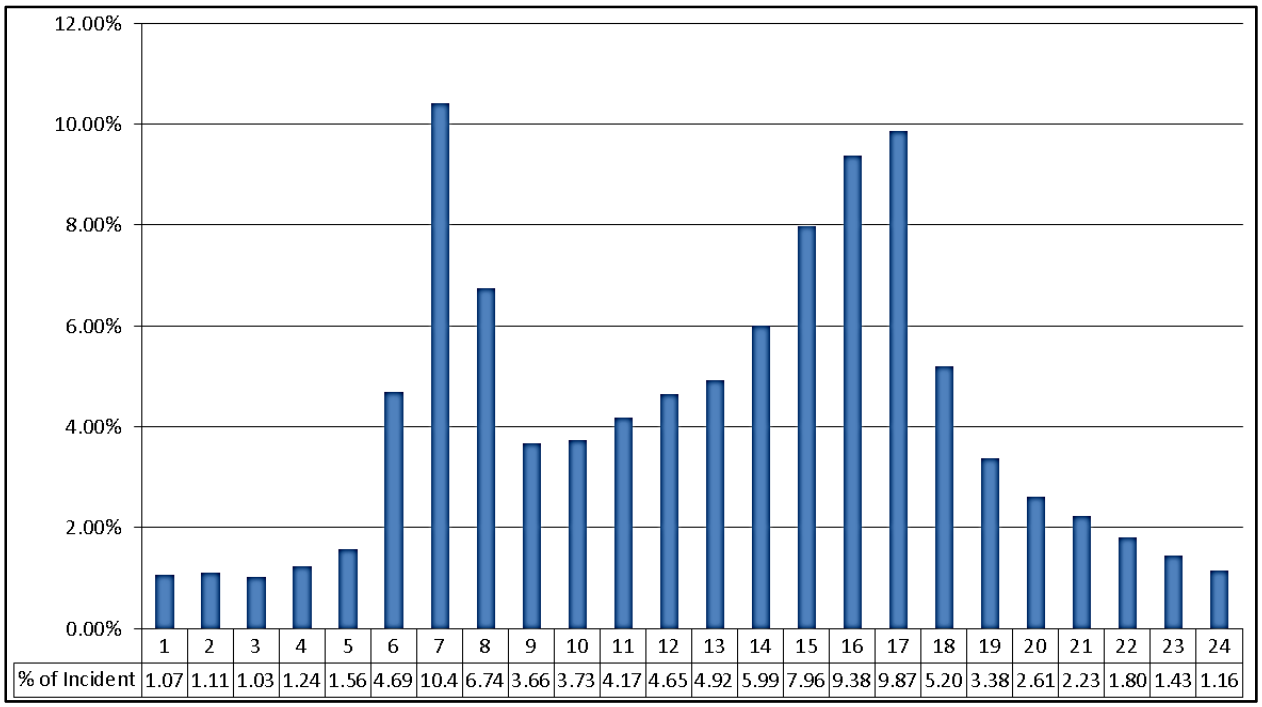


Figure 1. Percentage of Incidents per One-hour Period

Specifically for the time periods investigated (i.e., 8, 12, and 16-hour time periods), Figure 2 displays the incident percentages.

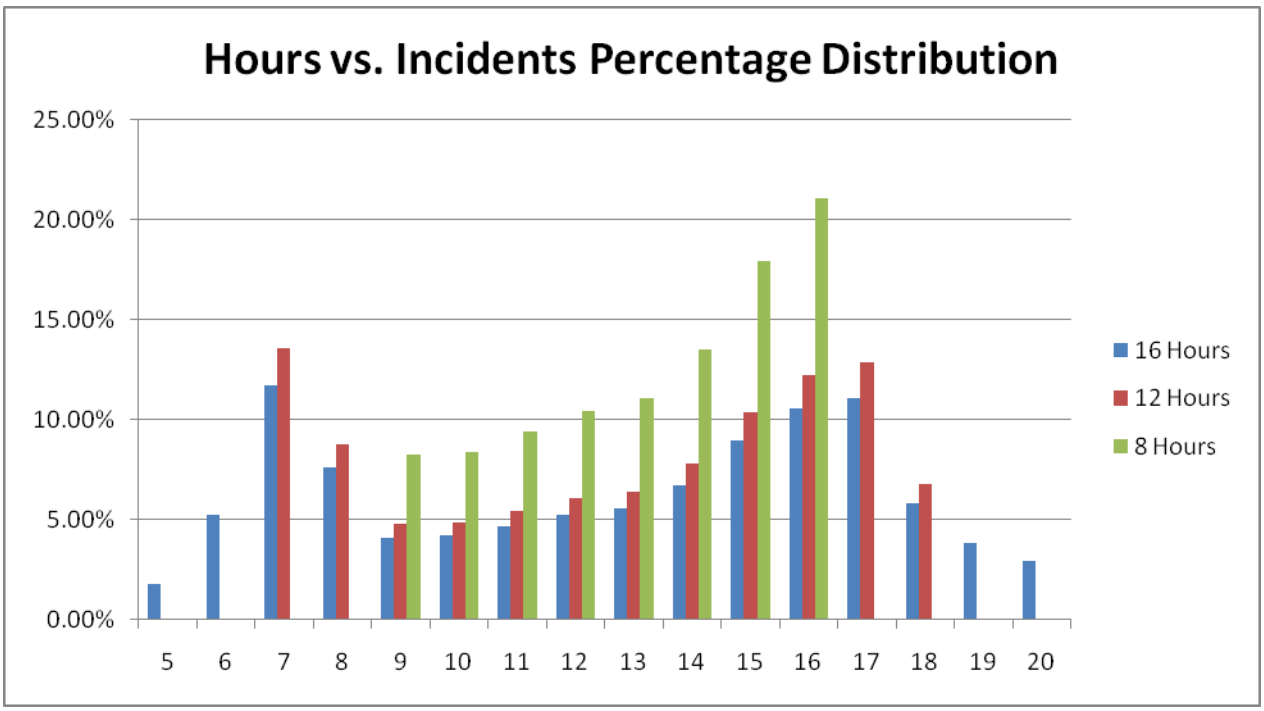


Figure 2. Percentage of Incidents per One-hour Period based on Time Period Duration

Travel time within the same zone consists of both fixed and random time components. Travel time between zones has an additional component that involves a randomly generated value and the straight line distance between the two zones. Table 3 displays the expressions for the travel time components.

Table 3. Travel Time Expressions

	Fixed Time	Random Time (within zone)	Random Time (between zones)
Travel Time within Same Zone	3 minutes	-LN(1-RAND()) * 2	
Travel Time between Zones	3 minutes	-LN(1-RAND()) * 2	-LN(1-RAND()) * 2 *straight line distance

In the random time expressions, "RAND()" refers to a randomly generated value using a Uniform(0,1) distribution. To account for rush hour traffic periods, we increase the appropriate travel times using a congestion factor. During 7AM to 8AM and 4PM to 6PM, the congestion factor is 1.50. During 6AM to 7AM, 8AM to 9AM, 2PM to 4PM, and 6PM to 7PM, the congestion factor is 1.25.

3.2 Experimentation Results and Discussion

<u>Total Response Time Comparison</u>

Table 4 shows the comparison between Model 1 and Model 3. In Model 1, the objective is to minimize the total response time, while model 3 attempts to minimize the maximum response time that an incident location is "fully serviced".

Table 4. Model 3 vs. Model 1 (Response Time)

	Severity		
No. Periods	Low	High	Avg.
16	0.837	2.459	1.607
12	1.066	2.425	1.707
8	0.677	2.234	1.399
Overall Avg.	0.864	2.379	1.577

*Difference reported in minutes

The first column represents the number of time periods under investigation. The second and third columns report the difference in average response time between Model 3 and Model 1 when incident severity levels are low or high, respectively. The fourth column shows the average difference for a given time period. For example, for a 16-hour period when severity is low, average total response time from Model 3 is 1.607 minutes higher than that of Model 1. It is clear that Model 1 outperforms Model 3 when the goal is minimizing total response time. Also, severity level greatly impacts total response time differences. In the high severity cases, the gap between the two models increases which illustrates the usefulness of Model 1 in this type of situation.

First Response Time Comparisons

Tables 5 and 6 display the comparisons of Model 2 to Model 1 and Model 3, respectively, where the goal is to minimize first responder time to incident locations.

Table 5. Model 1 vs. Model 2 (First Responder Time)

	Severity		
No. Periods	Low	High	Avg.
16	1.444	2.204	1.805
12	1.515	1.962	1.726
8	1.111	2.017	1.531
Overall Avg.	1.357	2.061	1.687

*Difference reported in minutes

Table 6. Model 3 vs. Model 2 (First Responder Time)

	Severity		
No. Periods	Low	High	Avg.
16	2.027	3.388	2.673
12	2.336	3.433	2.854
8	1.980	3.133	2.515
Overall Avg.	2.157	3.381	2.735

*Difference reported in minutes

On average, Model 2 offers a lower average first response time (about 1.687 minutes) when compared to Model 1. The difference is more pronounced between Model 2 and Model 3 (about 2.735 minutes). These results are not surprising given that Model 2 is specifically designed to handle first response minimization. Again, a severity level has a significant impact on the average difference between first

responder times which underscores that Model 2 is preferable when first response has increased importance.

Full Response Time Comparison

Table 7 displays the comparison of Model 3 to Model 1, where the goal is to minimize the full response time to incident locations.

Table 7. Model 1 vs. Model 3 (Full Response Time)

	Severity		
No. Periods	Low	High	Avg.
16	0.431	0.969	0.686
12	0.411	0.946	0.663
8	0.492	0.919	0.690
Overall Avg.	0.429	0.954	0.677

*Difference reported in minutes

Model 3 outperforms Model 1, as expected, but the gains are not as significant as was observed in the previous comparisons. However, in the high severity case, the average improvement with Model 3 is approximately one minute. This gain is still significant since the comparison is related to emergency response.

Sub-region Examination

In addition to examining response time, we look at the utilization of all response units measured as the percentage of responder units dispatched from each sub-region. Table 8 displays the responder unit utilization, across all model versions, for the 20 sub-regions created for the experimentation.

Table 8. Responder Utilization by Sub-region

Sub-region	Model 1	Model 2	Model 3	Avg.
S1	2.75%	2.72%	2.73%	2.74%
S2	5.25%	5.50%	5.62%	5.46%
S3	5.10%	4.93%	4.93%	4.99%
S4	4.85%	4.87%	4.85%	4.86%
S5	3.13%	3.10%	3.07%	3.10%
S6	3.33%	3.04%	3.24%	3.20%
S7	6.29%	6.47%	6.35%	6.37%
S8	7.92%	7.83%	7.81%	7.85%
S9	6.70%	6.96%	7.06%	6.90%
S10	4.72%	4.77%	4.78%	4.76%
S11	3.80%	3.78%	3.93%	3.84%
S12	5.31%	5.42%	5.05%	5.26%
S13	7.34%	7.58%	7.16%	7.36%
S14	7.53%	7.45%	7.79%	7.59%
S15	4.47%	4.39%	4.35%	4.40%
S16	3.92%	3.80%	3.76%	3.83%
S17	4.19%	4.03%	4.16%	4.12%
S18	5.71%	5.83%	5.71%	5.75%
S19	4.16%	4.20%	4.08%	4.15%
S20	3.51%	3.31%	3.57%	3.46%

The highlighted sub-regions represent the top five utilized sub-regions.

3.3 Benefits

This type of analysis is valuable as it provides emergency response management with insight on the proper capacity and allocation of its resources to react to various network incident scenarios. As additional capital becomes available, this type of information provides a guide for the expansion and placement of additional resources.

Domain 2
Project 6

The Role Tranist in Safe Evacuation of Special Need Populations in Emergencies and Disasters

The Role of Transit in Safe Evacuation of the Special Need Populations in Emergencies and Disasters

Final Report

UAB UTC Domain 2: Development of a Dynamic Traffic Assignment and Simulation Model for Incident and Emergency Management Applications in the Birmingham Region (Aim 6)

Prepared By:

Virginia Sisiopiku, PhD, Ozge Cavusoglu, MSCE, and Andrew Sullivan, MSCE
Department of Civil, Construction, and Environmental Engineering
University of Alabama at Birmingham

Natalia Ruiz Juri, PhD
Network Modeling Center, The University of Texas at Austin

Kyriacos Mouskos, PhD
City College of New York

Curtis Barrett
Vista Transportation Group, VTG, Inc.

Prepared for:

The UAB University Transportation Center

Birmingham, Alabama

DTRT06-G-0048

UAB UTC

October 2011

1. Report No. FHWA/CA/OR	**2. Government Accession No.**	**3. Recipient Catalog No.**
4 Title and Subtitle The Role of Transit in Safe Evacuation of the Special Need Populations in Emergencies and Disasters UAB UTC Domain 2:, Evaluation of Incident, and Emergency Management Options in the Birmingham Region, Aim 5		**5 Report Date** October 2011 **6 Performing Organization Code**
7. Author(s) Virginia P. Sisiopiku, Ozge Cavusoglu, Andrew J. Sullivan, Natalia Ruiz Juri, Kyriacos Mouskos, and Curtis Barrett,		**8. Performing Organization Report No.**
9 Performing Organization Name and Address University of Alabama at Birmingham 1075 13th Street South Birmingham, AL 35294-4554		**10 Work Unit No. (TRAIS)** **11 Contract or Grant No.**
12 Sponsoring Agency Name and Address UAB University Transportation Center 1530 3rd Avenue South Birmingham, AL 35294-2041		**13 Type of Report and Period Covered** **14 Sponsoring Agency Code**
15 Supplementary Notes		

16 Abstract

During evacuations, the needs of transit-depended and carless populations require special attention and add to the complexity of evacuation logistics. The objective of this work is to examine the role of transit in the evacuation of carless populations as part of a comprehensive evacuation plan. For this purpose a case study is presented describing the development of a large scale simulation/optimization model of the Birmingham, AL region that considers evacuation of carless populations with transit in an event of flooding. Flooding analysis can be useful in evaluating various alternatives to evacuate people, identifying alternative routes based on historical experience of flooded areas, and optimal assignment of rescue personnel and optimization of their routes. The report first provides a synthesis of the state of practice in carless evacuation using transit. Then the study methodology is presented and details are offered on model development, study scenarios modeled and related assumptions. Study scenarios consider vehicle evacuation from the affected area with and without evacuation of carless populations to nearby shelters using transit assets. Consideration is given to the fact that some network links would not be accessible due to the flooding and thus lane closures are considered in the study scenarios to increase the realism of the model. The report demonstrates the opportunities and requirements related to the use of transit for local emergency evacuations in order to best serve the needs and interests of carless populations and the public at large.

17 Key Words Carless Population Evacuation, Transit, Emergency Management, VISTA Simulation and Optimization Platform		**18 Distribution Statement** No restrictions.	
19 Security Classification (of this report) Unclassified	**20 Security Classification (of this page)** Unclassified	**21 No. of pages** 44 + ix	**22 Price**

TABLE OF CONTENTS

LIST OF FIGURES VII
LIST OF TABLES VIII
ABSTRACT IX
1. INTRODUCTION 1
1.1. Study Objectives 1
2. LITERATURE REVIEW 2
2.1. Transportation in Emergency Evacuations 2
2.1.1. Factors Affecting Transportation in Emergency Evacuations 4
2.1.2. Traffic Managements Tools in Emergency Evacuations 9
2.2. Vulnerable Population Concept 11
2.1.3. Challenges of Associated with Vulnerable Populations Evacuations 12
2.3. Transit's Role in Vulnerable Population Evacuations 13
2.4. Modeling Options for Vulnerable Population Evacuation 18
3. METHODOLOGY 21
3.1. Study Approach 21
3.1. Development of Simulation Model for the Evacuation due to Flooding Case Study 21
3.2. Study Site 25
3.3. Evacuation Study Simulation Scenarios 26
2.1.4. Transit Routes Considered 29
3.4. Evacuation Demand Preparation 30
3.6.1. Vehicle Demand during Evacuation 31
3.6.2. Demand for Evacuation using Transit 32
4. STUDY RESULTS 35
4.1. Evacuation Study Scenario Results 35
4.1.1. Network-wide Results 35
4.1.2. BJCTA Bus Routes Results 36
4.1.3. Transit Evacuation Logistics Results 37
5. SUMMARY AND CONCLUSIONS 39
REFERENCES 41

LIST OF FIGURES

FIGURE 2-1 Response in Advance- Versus No-Notice Incident 2

FIGURE 2-2 Scopes of Incident and Level of Responses 3

FIGURE 2-3 Localized Incident Responses 4

FIGURE 2-4 Hazard Scale vs. Evacuation Warning Time Relationship 5

FIGURE 2-5 Phased Evacuation Map 7

FIGURE 2-6 Four-quadrant Map Showing Willingness and Ability to Evacuate 8

FIGURE 2-7: Transit-dependent residents during the evacuation of New Orleans for Hurricane Katrina 14

FIGURE 3-1 Transit Service Area of Jefferson County in ArcGIS Model 22

FIGURE 3-2 Birmingham Emergency Shelters in ArcGIS Model 23

FIGURE 3-3 Existing Bus Service Area in the Jefferson County 23

FIGURE 3-4 Birmingham Shelters in VISTA Model 24

FIGURE 3-5 Zero Car Population in the Birmingham Area in ArcGIS Model 24

FIGURE 3-6 Village Creek Impact Area in ArcGIS Model 25

FIGURE 3-7 Evacuation Area within the Village Creek Impact Area 26

FIGURE 3-8 Zero Car Population in the Evacuation Area in ArcGIS Model 27

FIGURE 3-10 Evacuation Area and Evacuation Origins in ArcGIS Model 32

FIGURE 3-11 Evacuation Bus Routes in VISTA (Scenario 3) 34

LIST OF TABLES

TABLE 2-1 Evacuee Mode Choice 8

TABLE 2-2 Traffic Management Strategies..... 10

TABLE 2-3 Potential Vulnerable Populations in Emergency Evacuations..... 11

TABLE 2-4 Public Transportation Focus in Evacuations 16

TABLE 3-1 Road Closures- Evacuation Scenarios 28

TABLE 3-2 Evacuation Bus Routes 29

TABLE 3-3 Existing Bus Routes..... 29

TABLE 3-4 Existing BJCTA Bus Schedule 30

TABLE 3-5 Outbound BJCTA Bus Routes in Scenario 3..... 30

TABLE 3-6 Evacuation Demand using Bus Routes..... 33

TABLE 3-7 Evacuation Bus Schedule in Scenario 3 33

TABLE 4-1 Network-wide Results from Evacuation Scenarios 35

TABLE 4-2 Comparison of Average Travel Times (min) for BJCTA Bus Routes 36

TABLE 4-3 Comparison of Average Speeds (mph) for Outbound BJCTA Bus Routes..... 36

TABLE 4-4 Comparison of Average Travel Times (min) for Outbound and Inbound BJCTA Bus Routes in Scenario 3 38

TABLE 4-5 Number of Buses Required in Scenario 3 Evacuation..... 38

ABSTRACT

During evacuations, the needs of transit-depended and carless populations require special attention and add to the complexity of evacuation logistics. The objective of this work is to examine the role of transit in the evacuation of carless populations as part of a comprehensive evacuation plan. For this purpose a case study is presented describing the development of a large scale simulation/optimization model of the Birmingham, AL region that considers evacuation of carless populations with transit in an event of flooding. Flooding analysis can be useful in evaluating various alternatives to evacuate people, identifying alternative routes based on historical experience of flooded areas, and optimal assignment of rescue personnel and optimization of their routes.

The report first provides a synthesis of the state of practice in carless evacuation using transit. Then the study methodology is presented and details are offered on model development, study scenarios modeled and related assumptions. Study scenarios consider vehicle evacuation from the affected area with and without evacuation of carless populations to nearby shelters using transit assets. Consideration is given to the fact that some network links would not be accessible due to the flooding and thus lane closures are considered in the study scenarios to increase the realism of the model.

The report demonstrates the opportunities and requirements related to the use of transit for local emergency evacuations in order to best serve the needs and interests of carless populations and the public at large.

Keywords: Carless Population Evacuation, Transit, Emergency Management, VISTA Simulation and Optimization Platform, Village Creek, Alabama.

1. INTRODUCTION

Natural or man-made extreme events require collectively carrying people out of the threat's way. Lessons learned from the 2005 evacuation of New Orleans due to Hurricane Katrina revealed the importance of preparedness in order to address the transportation needs of vulnerable populations in an effective and timely manner. Vulnerable populations are considered those who live with disabilities, the elderly, carless and transit-dependent, and low English proficiency individuals. During evacuations, the aforementioned populations require special resources as their special needs mostly make them unable to evacuate by themselves. It has been estimated that 36% of those who did not evacuate during Hurricane Katrina did not have cars (KFF, 2005).

While carrying emergency responders and equipment to the affected area, the transportation system should move people to safe locations including shelters and medical facilities, in the most efficient way feasible (FHWA, 2004). Utilizing transit resources is considered an effective way in evacuating threatened people especially in areas were the number of carless and transit dependent populations is high. Moreover, the role of transit in evacuation is critical when infrastructure failure occurs due to the emergency. For example, following the 9/11 attack on the World Trade Center, 1.2 million workers and residents of Lower Manhattan were carried out of the danger zone by transit while employees and equipment were sent to the affected area to support the emergency responders during the morning rush hour (TRB, 2008). This success story highlights the great potential of carefully planned and well coordinated evacuations utilizing transit assets toward preventing injury and loss of life in an event of major emergencies.

1.1.Study Objectives

The objective of this study is to examine the role of transit in the evacuation of carless populations due to flooding as part of a comprehensive evacuation plan in the Birmingham, AL region. A case study is used to demonstrate the feasibility of employing transit buses for safe evacuation of transit-dependent populations in the Village Creek area in anticipation of a flooding event. The study determines the geographical distribution of transit-dependent people in need for evacuation, estimates transit resources requirements for evacuation of over 5,000 potentially stranded residents, proposes a staggered evacuation plan for evacuation of affected people, and tests the impacts of the evacuation of network performance with and without transit evacuation consideration.

2. LITERATURE REVIEW

2.1. Transportation in Emergency Evacuations

A variety of different circumstances may require a planned or emergency evacuation. Evacuation is needed when the existing or predicted conditions at certain locations are not safe, and requires people to be moved to safer locations, away from the potential hazard. Examples include evacuation of a block of office buildings because of a water-main break, evacuation of a neighborhood because of a river flood or forest fire, or evacuation of an entire city due to an earthquake or hurricane (Zimmerman et al., 2007).

Emergencies can be divided into two categories in terms of origin, i.e. human-caused or natural. Human-caused events can be intentional or unintentional. For example, a terrorist attack is an intentional human-caused event whereas a chemical explosion is an unintentional one. Natural hazards such as hurricanes, floods, earthquakes, wildfires, and tornados often require evacuations. Some of these events are predictable and thus provide advance notice (such as hurricanes) and others are sudden, no-notice events (Wolshon, 2009). As illustrated in Figure 2-1, no-notice incidents require rapid response, real-time communications capability, and redundant systems. On the contrary, advance-notice incidents allow for advanced evacuation planning, which is a key ingredient to a successful execution of any evacuation plan (Zimmerman et al., 2007).

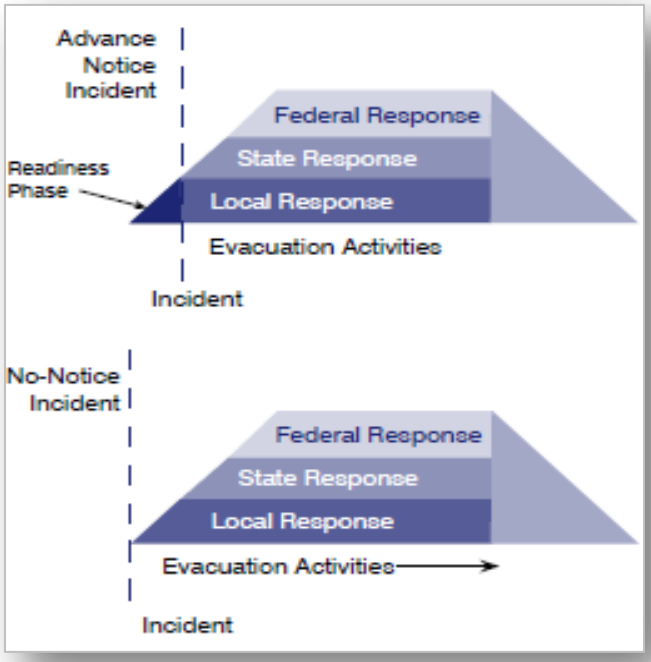


FIGURE 2-1 Response in Advance- Versus No-Notice Incident (Zimmerman et al., 2007)

It is well recognized that evacuation events may vary in type, magnitude, and impact but they all require preparedness, effective resource mobilization, coordination among agencies and communication with the public. The role of transportation in evacuation and emergency response is vital. Transportation systems provide the means and the facilities required for evacuation of populations in an event of an emergency while simultaneously serving the needs of emergency responders who need to access the affected areas (FHWA, 2004). Transportation agencies are also charged with the implementation of plans and actions that facilitates the evacuation such as implementing contra-flow operations plans, waiving fees on bridges and transit, adjusting the timing of traffic signals on key routes etc (Zimmerman et al., 2007). Traffic management strategies in support of evacuation need to be defined carefully by taking into consideration many factors including the characteristics of the emergency, its impact area, the potential compromise of portions of the transportation infrastructure, the behavioral characteristics of evacuees and the limits of available resources.

It should be noted that as the scope of the emergency incidents becomes larger (Figure 2-2), the response to the incidents increases in complexity. As illustrated in Figure 2-3, localized incidents are easily cleared out without the need for evacuation. On the other hand, for emergencies that require evacuation action, the requirements for command structure, communication systems, and coordination capabilities between agencies also increase (Zimmerman et al., 2007).

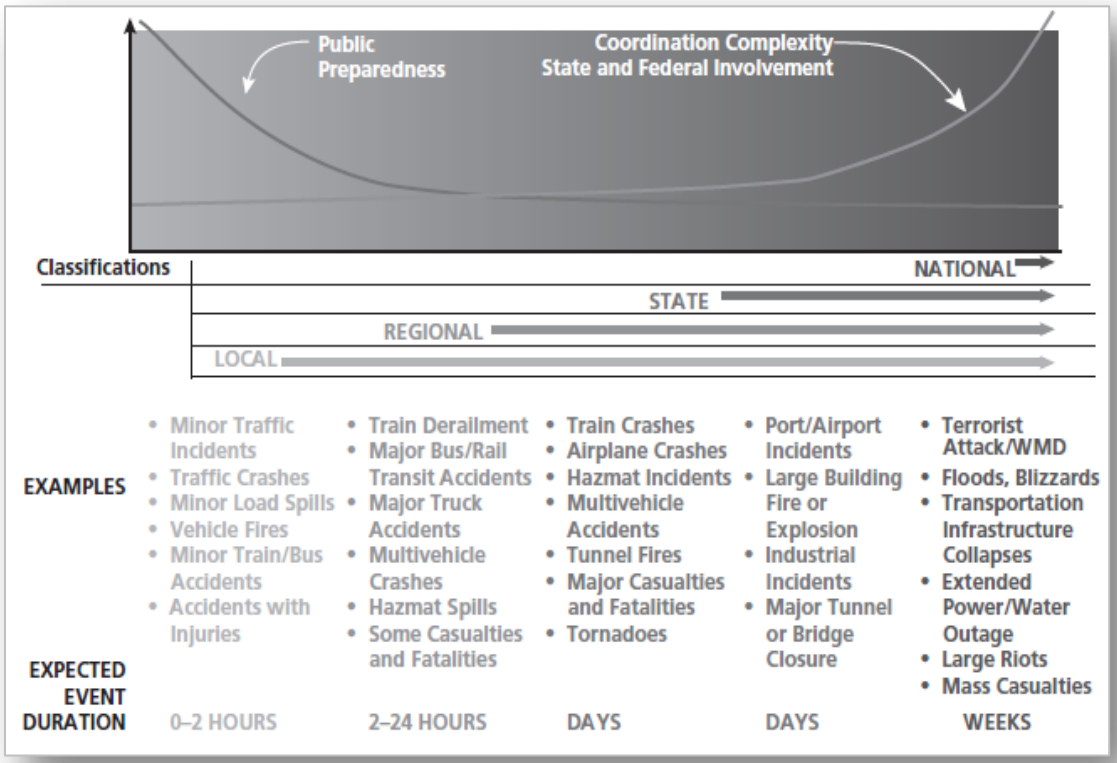


FIGURE 2-2 Scopes of Incident and Level of Responses (TRB, 2008)

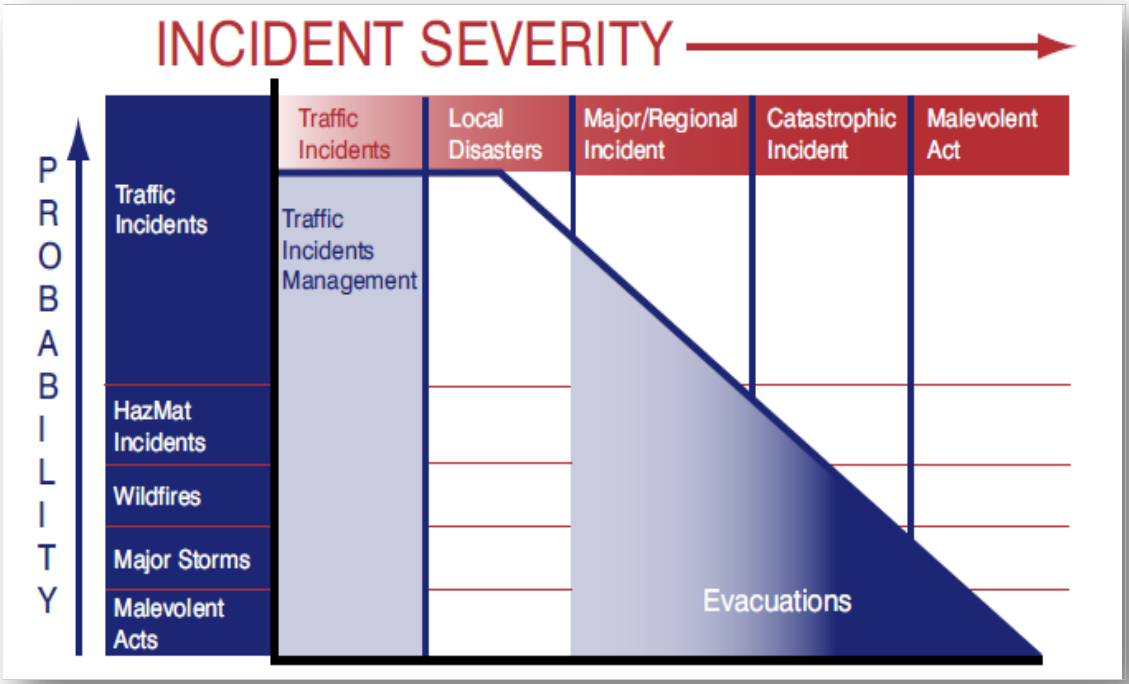


FIGURE 2-3 Localized Incident Responses (Zimmerman et al., 2007)

2.1.1. Factors Affecting Transportation in Emergency Evacuations

The role of transportation in emergency evacuations clearly depends on the type of emergency. Still, there are geographical, behavioral, technological and other factors that affect the role of transportation in evacuations. Such factors are addressed briefly in the following paragraphs.

2.1.1.1. Characteristics of the Emergency

The type, magnitude, time of occurrence and duration of the emergency play an important role in the ability of the transportation system to accommodate the needs of an emergency evacuation.

Contrary to the case of no-notice incidents, the available warning time in advance-notice incidents gives transportation and emergency management officials the chance of implementing evacuation traffic management strategies, namely contraflow operations, phased evacuation plans, and movement of structures, signals, and gates (Wolshon, 2009).

Detailed evacuation plans need to be developed in advance to maximize efficiency and support decision making during the actual event of evacuation. Evacuation routes should be predefined and potential bottlenecks, barriers, and scheduled work zones along the evacuation routes should be noted. Other issues should also be addressed in the planning phase such as capacity restrictions, expected evacuation demand, communication requirements, vulnerable population evacuation etc (Wilson-Goure et al., 2006a).

Even if the evacuation plans are ready, some uncertainties still remain, such as making the evacuation decisions on time (TRB, 2008) since the direction and the development of hazard can change over short periods of time. Moreover, the scope of an evacuation order should be wide enough to protect as many people as possible but not so large that it places critical evacuation demands on the transportation grid and impacts the economic balance of the area. Figure 2-4 shows how warning time, and the impact area change for various types of disasters (Wolshon, 2009).

Hazards Potentially Requiring Evacuation		
Man-Made Events		**Natural Events**
Terrorist Attack	General Advanced Warning Time and Potential Impact Area Both Increase	Earthquake
Chemical Release		Volcanic Eruption
Nuclear Power Plant Accident		Tornado
Dam Failure		Tsunami
		Wildfire
		Flood
		Hurricane

FIGURE 2-4 Hazard Scale vs. Evacuation Warning Time Relationship (Wolshon, 2009)

The timing and duration of the evacuation also affect transportation systems operations. As expected, during peak hours the demand on the transportation network in urban setting is high and even small demand increases can quickly create gridlock situations. When feasible, spreading the demand over space and time is typically a better strategy. Staggering evacuation orders (aka phased evacuations) are found to maximize public safety and evacuation efficiency. Planning evacuations in phases allows the most endangered population to be moved out first from the threatened area and to pass through the higher population areas before the roads get clogged.

Figure 2-5 shows the map of phased evacuation developed by the Louisiana State Police and Department of Transportation and Development (LaDOTD) for coastal Louisiana. Early phases of the evacuation focus on populations facing higher risk and provide flexibility on the routing. As the evacuation progresses disaster comes closer more residents are called to evacuate but and eventually lane reversing takes place to accommodate contra-flow operations along with some road closure and forced rerouting (Wolshon, 2009).

The duration of the evacuation event does not only affect transportation network performance but it becomes important when the evacuation planning depends on transit systems since the shift arrangements, work restrictions, and part-time operators can affect the availability of transit drivers. It should not be overlooked that when the length of evacuation times increases, the need for refueling and maintenance of transit vehicles will also increase (TRB, 2008).

2.1.1.2. Geographical Characteristics

In the event of an evacuation, transportation facilities are required to accommodate large numbers of users who need to travel over a short period of time outside of harm's way. When emergencies are localized and existing transportation facilities have enough reserve capacity to accommodate the evacuation demand an orderly evacuation can be successfully realized. In the event of a regional evacuation, however, capacity bottlenecks become inevitable, which can compromise the ability of a transportation network to serve the evacuating traffic at a reasonable level of service. For example during Hurricane Rita in 2005 when more than 3 million people took the Harrison County roads in an attempt to evacuate, massive traffic jams resulted that that compromised traffic operations for more than 24 hours (TRB, 2008). To make things worse, people from coastal areas in Galveston and Houston who had the priority to be evacuated due to high flooding risk moved toward Houston only to find that the transportation network was already paralyzed from the excess number of vehicles that tried evacuating the Houston metropolitan area (TRB, 2008).

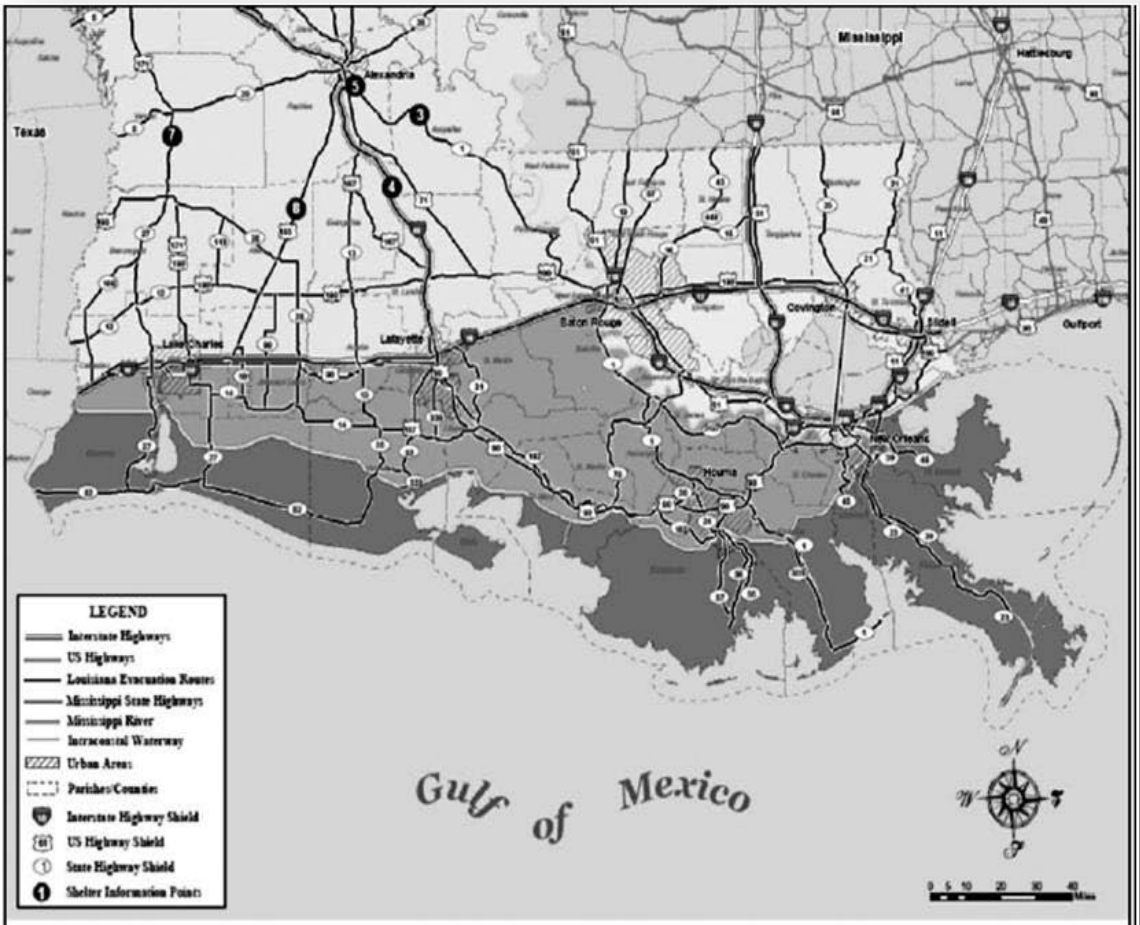
Another issue is the spatial concentration of the transit-dependent population in the urban area, which often incapacitates the usage of the transit service in case of an emergency (TRB, 2008). Lastly, political boundaries of the threatened area have an influence on the role of transportation, especially in regional emergency evacuations due to jurisdictional complexities. Thus, a multijurisdictional or multistate coordination is needed between emergency management agencies and transportation professionals for a successful evacuation (TRB, 2008).

2.1.1.3. Behavioral Characteristics

Lessons learned from earlier evacuations highlight the importance of the behavioral characteristics of evacuating populations in evacuation plans. For example, thousands of New Orleans residents did not evacuate during the Hurricane Katrina. Some of these people did not have the means to evacuate and others chose not to evacuate in order to take care of their home and property, pet, or a friend or relative who was not able to be safely evacuated.

Studies show that the transportation-based characteristics of evacuees differ but can be categorized into general groups according to their travel behaviors, needs, and travel mode availability. One method of categorizing them is their ability and willingness to evacuate. The four-quadrant map in Figure 2-6 illustrates the relationship between willingness and ability to evacuate on an x-y axis graph, where the x-axis and the y-axis represent willingness and ability respectively (Wolshon, 2009).

Quadrant I consists of self-evacuators who are able and willing to evacuate and constitute the majority of U.S. residents. Evacuation plans for this group generally focus on highway management strategies. Quadrants II and III consist of those who are unwilling to evacuate, regardless of their ability to do so. People willing but not able to evacuate, also known as vulnerable populations, are illustrated in Quadrant IV. Their ability to evacuate varies widely based on their individual needs (Wolshon, 2009). Availability of transit evacuation options increases the likelihood of evacuation of individuals in this group,



Phased Evacuation

During a threat of a hurricane, a phased evacuation will be based on geographic location and time in which tropical storm winds are forecasted to reach the affected areas.

Phase I - 50 Hours before onset of tropical storm winds. Includes areas south of the Intracoastal Waterway. These areas are outside any levee protection system and are vulnerable to Category 1 and 2 storms. These areas are depicted in RED on the Evacuation Map. During Phase I there are no route restrictions.

Phase II - 40 Hours before onset of tropical storm winds. Includes areas south of the Mississippi River which are levee protected but remain vulnerable to Category 2 or higher storms. These areas are depicted in ORANGE on the Evacuation Map. During Phase II there are no route restrictions.

Phase III - 30 Hours before onset of tropical storm winds. Includes areas on the East Bank of the Mississippi River in the New Orleans Metropolitan Area which are within the levee protection system but remain vulnerable to a slow-moving Category 3 or any Category 4 or 5 storm. These areas are depicted in YELLOW on the Evacuation Map. During Phase III, certain routes will be directed and the Contraflow Plan implemented.

Phased evacuation procedures are for traffic management purposes only. Consult your local Office of Emergency Preparedness Director for further evacuation information.

FIGURE 2-5 Phased Evacuation Map (Wolshon, 2009)

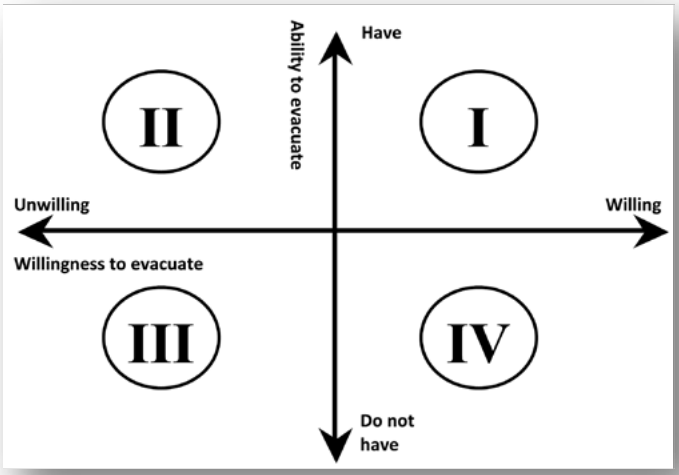


FIGURE 2-6 **Four-quadrant Map Showing Willingness and Ability to Evacuate (Wolshon, 2009)**

Evacuees can also be categorized solely based on their access to any kind of transportation. This can be used to predict the clearance time from the danger zone and arrival time to the destination based on a defined departure time. Table 2-1 shows the mode choices of evacuees based on their ability and willingness to evacuate (Wolshon, 2009).

TABLE 2-1 Evacuee Mode Choice (Wolshon, 2009)

Evacuee Group	Access to Personal Transportation	Utilization of Public Transit Buses	Utilization of Private or other form of 'provided' transportation
1-Self Evacuators	Yes	No	No
2-Able-bodied non-self-evacuators	No	Yes	No
3-Dependent non-self-evacuators	No	No	Yes

The self-evacuators do not need any special arrangements in reaching a transportation mode. Hence, they are the most convenient group to model in an evacuation modeling study. People who do not have access to personal transportation and do not need any special form of assistance are considered in the second group. Zero-vehicle households, elderly and self-help disable people are considered in this group as long as they have the ability to walk to evacuation boarding locations as well as between possible transportation modes. This group is in need of evacuation using transit or some other form of transportation provided service. The third group consists of those special needs individuals who need assistance to reach to transit pick-up locations or require specially equipped vehicles for transportation (Wolshon, 2009).

There are some major challenges in determining the number of people who need help in evacuations, locating them, identifying their special needs, communicating with them, and transporting them to safe locations in case of an emergency. Even if detail data is collected about these populations, keeping the collected data up-to-date is another issue to take into account (TRB, 2008).

2.1.1.4. Available Technology and Other Resources

The availability of technology support, organizational arrangements and required funding resources can also impact the efficiency of orderly evacuations. For example, availability of Intelligent Transportation Systems (ITS) can greatly assist in emergency evacuations by providing real time information on traffic conditions and allowing the communication of traffic management centers with the infrastructure and the evacuees as well as linking them to emergency operations centers during an evacuation. However, to date such systems are not widely available and thus their consideration is very limited in most of the existing emergency plans in the U.S. (Wilson-Goure et al., 2006a).

2.1.1.5. Communication Requirements

Evacuation-related information communications should be established for all three phases of an evacuation: before, during, and after. Prior to an evacuation, public information and outreach campaigns should be developed to help potential evacuees become aware of procedures and prepare for a probable evacuation. During the course of an evacuation it is of critical importance to gather accurate on-time traffic information including traffic flow rates and speeds, lane closures, hazard conditions, incidents, and the availability of alternative routes. Communication is used to convey information to potential evacuees on the need for evacuation and provide details on when to leave and where to go. Media broadcasts, loudspeakers, changeable message signs, cell phones and other wireless technologies can be used to disseminate evacuation orders and relevant traveler information (Wilson-Goure et al., 2006a). Lastly, after an evacuation, evacuees should be informed about when and how to return to their places of origin (Wolshon, 2009).

Moreover, communication should be established not only between authorities and the public, but also between and within the agencies (Wolshon, 2009). In recent evacuations, communication difficulties compromised the ability of authorities to respond effectively to emergencies and confirmed that interoperability of emergency communications should be improved in the future. Furthermore, communication with populations in need for evacuation (e.g., careless and transit-dependent individuals) and those requiring special assistance (e.g., disabled) is both critical and challenging issues that require additional attention.

2.1.2. Traffic Managements Tools in Emergency Evacuations

Traffic management strategies may be implemented at proper locations to improve traffic flow and minimize congestion in the event of an evacuation. Options include implementing contra-flow operations, imposing vehicle restrictions , adjusting the timing of traffic signals, coordination of traffic signals, waiving tolls on bridges, closing highway on-ramps and off-ramps in key locations (Zimmerman et al., 2007, and Wilson-Goure et al., 2006a). In determining the best possible options for implementation, one should consider the unique characteristics of the emergency itself, the availability of technologies and required resources, and the characteristics of the transportation network around the threatened area. Table 2-2 summarizes traffic management strategies that can be used in case of an emergency (Zimmerman et al., 2007).

TABLE 2-2 Traffic Management Strategies (Zimmerman et al., 2007)

TACTIC	DESCRIPTION
No changes to normal roadway operations	No implementation of any specialized traffic management tactics.
Phased releases of outbound vehicles through timed control of major parking centers	Coordinated release of parking facilities would theoretically reduce congestion on evacuation routes. To accomplish implementation of this tactic, parking facilities would be inventoried and categorized according to size, location, or other relevant factors. A phased release protocol would be developed that would provide for gradual release of privately owned vehicles from downtown parking facilities. This would theoretically modulate vehicular congestion on designated evacuation routes.
Reduction of outbound vehicles through closure of major parking centers (i.e., forcing car owners to evacuate via walking transit)	Long-term closure of major parking facilities during an evacuation event would reduce the number of vehicles on evacuation routes and thus would theoretically improve travel times on these routes during an evacuation.
Closure of inbound lanes on selected roads and highways	Closure of inbound lanes on highways utilized for evacuation routes would prevent motorists on these routes from entering the city while the evacuation is underway.
Closure of outbound off-ramps on limited access roads and highways	Closure of outbound off-ramps on highways utilized for evacuation routes would keep evacuees on these routes until they reached planned evacuation destinations.
Closure of outbound on-ramps on limited access roads and highways	This tactic would involve closure of outbound on-ramps on designated evacuation routes to reduce congestion on these roadways due to traffic originating at intermediate locations between evacuation origins and destinations.
Limited contra flow on selected limited-access roads and highways (e.g., one lane for bus convoys, etc.)	Limited contra flow on selected roads is a tactic by which one or more lanes of highway are reversed to accommodate an increased flow of traffic in one direction. Contra flow has been implemented as a component of hurricane evacuation planning in certain southern and southeastern states, but is not a common feature of many disaster evacuation plans because of the need for a long lead time prior to the evacuation event during which the contra flow can be established.
Unlimited contra flow on selected limited access roads and highways with all normally inbound lanes used for outbound traffic	An unlimited contra flow tactic would include redirection of all lanes of a designated evacuation route to accommodate rapid evacuation from a city or region. This is a tactic that lends itself primarily to limited access roadways.
Limited/unlimited contra flow on selected unlimited-access arterials	Temporary closure of inbound travel lanes on selected unlimited-access arterial roadways (such as parkways and boulevards) allows outbound traffic to utilize these lanes during an evacuation.
Traffic control points	Traffic control points are locations along designated evacuation routes which are staffed by emergency management personnel and utilized to maintain a greater degree of evacuation management. Traffic control points can enhance the efficiency of an evacuation, reduce public confusion during an evacuation, and allow increased operational flexibility during an evacuation.
Segregation of pedestrian and vehicle traffic	Certain urban roadways would be designated for use by pedestrians. This would provide separation between vehicles and pedestrians during an evacuation, thus reducing confusion and increasing the efficiency of evacuation from densely populated areas.

2.2. Vulnerable Population Concept

Literature review shows that there are multiple definitions of vulnerable populations within the evacuation context. At first, the definition referred solely to populations with needs for medical assistance. In time, other groups were added to the definition, including the elderly and the mentally or physically disabled (Turner et al., 2010). Today, the term is used to define the populations who are not able to evacuate on their own and need additional assistance in case of an emergency (Zhao et al., 2010) including people who may lack access to a private vehicle or who choose not to drive during an evacuation or even those who are not proficient enough in the English language to understand and execute evacuation orders (TRB, 2008).

The Federal Highway Administration (FHWA) confirms that there is not a universally accepted definition for vulnerable population (Houston et al., 2009). For instance, the carless or transit-depended population is a special needs group in cities where the transit service is limited such as the Birmingham region. However, in large cities such as New York or Washington DC, transit dependency may not be considered as a "special need" because transit services are extensive and frequency and coverage is plentiful (FEMA, 2008). While the United States General Accounting Office (GAO) defines such population as "transportation-disadvantaged" (GAO, 2003), FEMA states that "*Individuals in need of additional response assistance may include those who have disabilities; who live in institutionalized settings; who are elderly; who are children; who are from diverse cultures; who have limited English proficiency; or who are non-English speaking; or who are transportation disadvantaged"* (FEMA, 2008).

It can be seen that the vulnerable population definition varies from across agencies, states and regions (Turner et al., 2010). Populations that may need assistance during evacuations are highlighted in Figure 2-3 (Quigley, 2006; Turner et al., 2010; Zhao et al., 2010; Houston et al., 2009 and ADPH, 2007).

TABLE 2-3 Potential Vulnerable Populations in Emergency Evacuations

• People with disabilities o Living with physical impairment o Deaf/hard of hearing o Blind/low vision o Living with mental illness	• Elderly population
	• Carless and transit-dependent population
	• Low English proficiency/non-English speaking populations
• People living with developmental/cognitive disabilities	• People in prisons
	• Tourists
• People in hospitals (including families of patients and hospital staff)	• Poor/homeless populations
	• People with service animals and household pets

2.1.3. Challenges of Associated with Vulnerable Populations Evacuations

Vulnerable populations present challenges during emergency evacuations because of their spatial concentration throughout an urban area and the difficulty of estimating their group sizes and needs (Turner et al., 2010). A survey conducted by Harvard University in 2007 found that many of the low-income households had difficulties evacuating. The income information can be used as an indicator to locate the special needs population in a region, since income is correlated to the other indicators such as race, age, vehicle ownership rates etc (Zhao et al., 2010). In addition to demographic statistics, land-use information including locations of hospitals and care centers can be used to identify the locations of special needs populations using GIS software (Wolshon, 2009). Non-English speaking populations can also be located using demographic data.

A recent study by the Federal Transit Administration (FTA) used Geographic Information Systems (GIS) and data from the 2000 census to map the locations of linguistically-isolated households and individuals with medical, physical, or mental challenges (Zhao et al., 2010). Even though locating the vulnerable population residencies is feasible, confirming their actual location at the time of evacuation as well as identifying their specific level of transportation needs may remain a big obstacle (Renne et al., 2008). In some cases, they may have unique needs and require the assistance of specially-trained staff and specific equipment (TRB, 2008). Therefore, matching the needs of evacuees with the available transportation resources becomes a critical point in effective evacuations (TRB, 2008). In some cases, transportation is not an option for evacuees, including those who are too frail to move or to be transported in any vehicle. Therefore, sheltering-in-place can be considered as an alternative.

Due to the wide range of transportation needs of vulnerable populations, some of their evacuation characteristics need to be evaluated. These include willingness in evacuation, ability to evacuate, walking speeds, transit loading times, and space requirements on public transit vehicles (Wolshon, 2009). In some regions, voluntary registries were developed to collect information on the evacuee characteristics mentioned above to determine the unique transportation needs of vulnerable populations during evacuations (TRB, 2008). However, most registries are incomplete because of the reluctance of individuals to sign up or because of lack of awareness of the registry (Turner et al., 2010). In some urban areas, community emergency response teams are established to train neighborhood leaders to inform the public and identify the socio-demographic features of the special needs populations as well as the whole community (TRB, 2008). A study done in Northern New Jersey found that the trip generation rates of special needs populations would be higher if the resources are made available for them to evacuate (Deka and Carnegie, 2010).

Even if detailed information about special needs population is gathered, keeping these registries up to date, especially in big cities, is a real problem which requires high-cost solutions (Turner et al., 2010). Therefore, New York City has adopted a new approach. In the event of a major incident, special needs populations are encouraged to dial a 311 citywide number to arrange their own transport. Los Angeles intended to create a database with the information gathered from special needs-related social service agencies, but the project stalled because of funding considerations (TRB, 2008).

Effective communication with vulnerable populations may pose additional challenges. For instance, half of Tampa residents did not know their evacuation zone, although it was repeated continuously using all kind of communication tools. According to 2007 census data, people with severe disabilities earn $12,800 annually, which is almost half of what people without disability make. Therefore, it should not be surprising that most low-income disabled people live in slum areas with insufficient infrastructures such as telephone and internet service, or public transportation (Renne et al., 2008), a fact that adds to the difficulty of communication during evacuations. Hence, it is important to establish in advance reliable mechanisms to communicate with these special needs populations (TRB, 2008). An Americans with Disabilities Act (ADA) guide prepared by the Civil Rights Division Disability Rights Section, of the U.S. Department of Justice, provides information on how to reach vulnerable populations. The guide suggests using a combination of warning methods including telephone calls, auto-dialed TTY (teletypewriter) messages, text messaging, e-mails, and even direct door-to-door contact with pre-registered individuals (ADA, 2008).

Another important issue is the willingness of people to evacuate during mandatory evacuations. Studies confirm that people with special needs are more likely to leave their house if they are convinced that the emergency shelter will sufficiently meet their needs. Studies on earlier evacuations show that people who decide not to evacuate mostly think they are safer staying in their home. In some cases people decide not to evacuate to take care of a friend or a relative who is not able to be self-evacuated (Wolshon, 2009). In a survey conducted in Florida after Hurricane Frances, nearly half of the special needs households said that having a person with special needs affected their evacuation decision (Zhao et al., 2010). Evacuees may decide not to leave for other reasons, such as a desire to protect their homes or to take care of pets. Some people who are low income, elderly, uneducated or recent immigrants may not want to evacuate because they do not trust the government (Wolshon, 2009) as was the case with many of the vulnerable populations of New Orleans who decided not to evacuate during Katrina.

On the other hand, people who had a prior evacuation experience were more willing to evacuate (TRB, 2008). Also, informing evacuees in advance about the evacuation process increases their willingness to evacuate. Therefore, city officials and emergency agencies should demonstrate the advantages of evacuation and arrange visits to emergency shelters in advance to increase the public's confidence in the evacuation process and thus the compliance with evacuation orders during emergencies (Houston et al., 2009).

2.3. Transit's Role in Vulnerable Population Evacuations

The painful lessons learned from the 2005 evacuation of New Orleans due to the hurricane Katrina show the clear need for better handling of vulnerable population evacuation in the future. It is a fact that over one third of those who did not evacuate during Hurricane Katrina were carless, thus depended on assistance in order to be evacuated. Another 24,000 patients, staff, and families of patients were left behind in twenty-two hospitals as no plans for their safe evacuation were in place. In addition, only 79% of nursing homes were not evacuated with gruesome consequences (Quigley, 2006).

Even when emergency evacuation plans are available, execution of those plans may be challenging. For example, New Orleans had an emergency plan that relied on transit to carry up to 200,000 to safety. However, the plan failed mostly because of the lack of communication between agencies and the insufficient number of drivers and equipment available (TRB, 2008). It is recognized that the vulnerable population of New Orleans had more difficulty being evacuated than the rest of the population and suffered greater losses as a result (Wendell, 2006). Figure 2-8 shows the misery of transit-dependent populations in New Orleans during evacuation for Hurricane Katrina. This tragedy revealed that, in future evacuations, transportation needs of vulnerable populations should be well evaluated and carefully addressed in advance (Renne et al., 2008) in order to ensure that the people in need get the appropriate resources at the proper times to ensure their safety and wellbeing (Balog et al., 2005).

FIGURE 2-7: Transit-dependent residents during the evacuation of New Orleans for Hurricane Katrina (Source: Businessweek, AP Photo/Dave Martin)

Recent history also shares many examples showcasing the effectiveness of well planned and executed transit evacuations. In Houston, for instance, in advance of Hurricane Rita landfall, transit systems were used effectively during an evacuation (Wendell, 2006). The Metropolitan Transit Authority of Harris County (METRO) assisted in evacuating the transit-dependent population in advance of the hurricane as well as carried fuel to emergency responders and distributed bottled water to the motorists who were stuck in traffic on freeways (TRB, 2008). In

another case study, following the September 11 attack on the World Trade Center, 1.2 million workers and residents of Lower Manhattan were carried out of the danger zone by transit while employees and equipment were sent to the affected area to support the emergency responders during the morning rush hour. Meanwhile, when the federal government was shut down after the strike on the Pentagon, the road network became overloaded and Metrorail was used in the Washington, DC area, evacuating hundreds of thousands people from Washington and Northern Virginia in a few hours. These events show that transit systems can play a crucial role in mass evacuation of threatened people, including transit dependent populations. Such role is often defined by the distinct features of evacuation events. Table 2-4 summarizes the likely focus of public transportation during natural disaster, security-related and non-security related evacuations (Balog et al., 2005).

Another factor that plays an important role in the ability of public transit to transport special needs populations in emergencies is the dispersion of vulnerable populations throughout the geographical region of service. Matching the origins and needs of evacuees with available transportation resources is critical in effective evacuations of carless and other populations in need. Connectivity of transit modes at certain locations can increase the effective use of transit systems in evacuations. Especially when rail systems are connected to other transit services, large numbers of evacuees can be transported fast to safe destinations. In any event some arrangements should be done to accommodate evacuation logistics such as shifting drivers and equipment to predefined areas or designing "pick up" points to gather and carry the special needs population to safe destinations (TRB, 2008; Turner et al., 2010). The capacity, condition and size of the transit fleet should be considered as well. If transit coverage is limited, as in many small and medium US cities and towns, the ability of existing public transportation agencies to evacuate persons in need may be limited, and plans should be made in advance for use of additional resources such as school buses, shuttles, rented motor coach buses etc to supplement existing resources. Good coordination among vehicle providers of transit and/or contracted services, and careful fleet management and route scheduling can guarantee proper deployment of drivers and equipment and thus are the cornerstones of successful evacuation of populations in need (Wendell, 2006).

But even when transit evacuation is planned carefully and communications and logistics issues are taken care of, still human factors issues play a major role in effective emergency evacuations of the population as a whole, and the vulnerable population in particular. For example, regular users of public transportation systems are more knowledgeable of how to access the transit system in case of an emergency and more likely to utilize the service than non users. Also, pre-event education and training as well as personal experiences from prior evacuations play a role in the willingness of people to evacuate, especially when they depend on transportation and/or medical assistance. Thus a great need exists to perform behavioral analysis as part of evacuation preparedness studies to analyze the behavior of people in emergency risk conditions (Mei, 2002). Such studies can help determining how many people will evacuate, when they will leave, where they will come from, where they will go to, and what modes they will select to make the trip. The inputs gathered from behavioral analysis are used in transportation analysis along with the evacuation transportation network characteristics and inputs from the vulnerability analysis to calculate the clearance time of an area (Wolshon, 2009).

TABLE 2-4 Public Transportation Focus in Evacuations (Balog et al., 2005)

EVACUATION CATEGORY	EXAMPLES	AFFECTED GEOGRAPHIC LOCATION	PUBLIC TRANSPORTATION FOCUS
Evacuation, with Some Warning, for Natural Disasters ONLY	Hurricane, flooding, wildfires	Potentially very large, perhaps, thousands of square miles	Those segments of the community who rely on public transportation for mobility; special needs populations; and emergency response personnel who need to reach particular locations or require specialized equipment or support.
Evacuation for Security Threat ONLY	Credible threat leads community to evacuate downtown commercial district or special event	Potentially smaller geographic area, but perhaps highly populated	Using existing transportation infrastructure to quickly and effectively initiate rush hour levels of service away from threatened area. This service returns commuters to their cars and homes, and will also deliver those users, who opt to leave their cars in the city, to a designated area for pick-up, or to a shelter to wait until such time as the threat passes.
Evacuation after No-Notice Event, NOT Security-Related	Hazardous materials accident, gas leak/explosion, winter storm that disrupts electricity	Depends on the event, could range from a single accident site to a densely populated urban center	Supporting the immediate transportation needs of the affected victims and emergency responders; supporting wide scale and rapid implementation of a major urban evacuation (if necessary).
Evacuation after No-Notice Event, Security-Related	On-going threat/adverse conditions force evacuation of urban center after bombing or chemical agent release	Depends on the event, could range from a single building to a city block, to a densely populated urban center	Coordinating with local, state and federal security assessments and intelligence, transportation systems will attempt to provide rush hour service levels to return commuters. In addition, transportation operators, vehicles, and resources will support emergency responders, providing transportation to and from the event scene, and supporting immediate responder needs for specialized equipment and personnel.

It should be noted that evacuation plans must consider transportation network capacity restrictions and should account for evacuating passenger vehicles as well as transit buses if they are involved in evacuation (Wendell, 2006). Otherwise, excessive vehicle demand will create large scale congestion and large amounts of evacuating vehicles including transit buses could be trapped in traffic, as was the case in Houston during the Hurricane Rita evacuation (Zhao et al., 2010; Renne et al., 2008). When transit services can substitute passenger vehicle transportation, the equilibrium mode-split between vehicular traffic and transit would assist in minimizing the total vehicle-travel time for all users (Abdelgawad et al., 2010).

As the case with all emergency evacuations, when transit and other transportation resources are used to evacuate populations in need, transportation professionals need to be in collaboration with emergency managers, law enforcement, first responder agencies, local and state government, and transit providers to address the problems encountered with during major emergencies (TRB, 2008). Thus, transit operators need to be involved actively in emergency plan preparations with broad understanding of their capabilities and limitations and help build more

effective evacuation plans especially for vulnerable populations (Balog et al., 2005). Moreover, transit agency representatives also need to be the part of the command structure in emergency responses.

2.3.1. Vulnerable Population Evacuations Using Transit

In the past, vulnerable populations have been successfully evacuated in several emergencies using transit. While the circumstances may differ from case-to-case some main themes emerge that can be used to guide future attempts to evacuation populations in need using public transit and similar resources.

2.3.1.1. The 9/11 Terrorist Attacks

Right after the attack on the World Trade Center in the morning of 9/11/01, the New York Metropolitan Transportation Authority and New Jersey Transit began shuttling passengers out of Lower Manhattan and rushed emergency workers, buses, and equipment to the World Trade Center site to support emergency responders. 1.2 million people were successfully carried out from the hot zone with Metro (TRB, 2008). It has been reported that, buses were also used to carry incident victims without any attention to fares or routes. Moreover, New York Police Department's Harbor Unit ferried 5,000 people to New Jersey and Staten Island. According to the Port Authority, 160,000 people evacuated New York City on New York Waterway ferries, and 250,000 to 300,000 left by other water transportation, which included Coast Guard vessels and other privately operated dining boats and even tug boats (Wilson-Goure et al., 2006a). In a similar fashion, in Washington, D.C., following the terrorists strike on the Pentagon Metrorail evacuate several hundred thousand people from Washington and Northern Virginia within a few hours (TRB, 2008) providing great relief to the heavily loaded transportation network.

2.3.1.2. Hazardous Material Fire

On October 5, 2006 a fire at a hazardous waste facility in Apex, North Carolina caused the evacuation of over 17,000 people. The evacuation was staged, and very clear geographical demarcation areas were communicated to the public. Initial instructions to the public were to shelter in place followed by an evacuation order issued a short time later. Emergency management personnel estimated that a large shadow evacuation contributed more than 30,000 additional people to the evacuation. Emergency management officials stated that only a small number of people chose not to evacuate the area (Jones et al., 2008). The town's "Reverse 9-1-1 System" was activated as part of the notification and warning. This system sends prerecorded messages from the 9-1-1 center to threatened neighborhoods to provide emergency information such as evacuation or shelter-in-place instructions. Apex police officers began warning people downwind of the facility and went door-to-door to inform people that they needed to leave (USFA, 2008). Among others, 103 nursing home patients from a singular nursing home evacuated with seventeen ambulances, wheelchair vans, and two transit buses in about 3.5 hrs. To accommodate transit dependent individuals, Raleigh city buses were used to evacuate those who needed transportation. This activity was implemented in an ad hoc manner and was conducted successfully, although few people utilized the available resources (Jones et al., 2008).

In January 2005, it has been reported that an explosion and a fire occurred at the Teris LLC facility in El Dorado, Arkansas that soon grew out of control. Approximately half an hour after the incident a mandatory evacuation was ordered. The evacuation took approximately 2 hours for the nursing homes and another 2 hours for the other El Dorado residents. An estimated 500 El Dorado citizens were evacuated overnight. A county jail facility which is approximately 400 yards from the incident site was also evacuated and 170 prisoners were transported with six school buses to safe locations (Wilson-Goure et al., 2006b).

2.3.1.3. Wildfires Evacuations

Beginning on October 21, 2003 and continuing through November 4, 2003, Southern California experienced the largest wild land urban interface fire in the State's history. The fast moving fires consumed 740,000 acres and required over 15,000 fire fighters to support the effort. Over 100,000 people evacuated their homes, and many of these people were from mountainous areas with very limited routes of egress. One of the largest single evacuation efforts was concentrated in San Bernardino County where mountain area residents evacuated after dark in areas without power (Jones et al., 2008). Reports confirm that Bear Valley Community Hospital long-term residents were evacuated during the incident. Some staff was directed to prepare the residents for an evacuation, pack up resident's medical records, 3 days of food and medications, call in additional clinical staff, and contact families. By delegating tasks, the staff focused on the evacuation of patients and not necessarily on the fire situation (Wilson-Goure et al., 2006b).

In 2007, between October 20th and November 9th, another series of wildfires burned across areas of southern California from Los Angeles and San Bernardino Counties in the north down to San Diego. The wildfires necessitated the largest evacuation in California's history, with some estimates of nearly a million people evacuating from the affected regions. The Office of Emergency Services reported that an estimated 1,000 elderly people were carried out through transit buses during 2007 Southern California Wildfires Evacuation in the San Diego area (Jones et al., 2008).

The examples cited above show the vital role that transit systems can play in the evacuation of people located in highly dense areas (such as urban city centers) as well populations in need for transportation during emergencies. Developing evacuation plans in advance that take under consideration evacuation needs, available resources, and best distribution of such resources in order to maximize potential benefits for all users is an essential ingredient for success. In the following paragraphs a case study is presented where such an evacuation plan is developed to assist the evacuation of an area in Birmingham, AL due to flooding and is tested using a traffic simulation model.

2.4. Modeling Options for Vulnerable Population Evacuation

Since the 1980s, macroscopic or mesoscopic simulation models have been developed to model evacuation traffic patterns and estimate network clearance time for areas around nuclear power plants. Examples include NETVAC, MASSVAC and OREMS (Han and Yuan, 2005). In the

1990s evacuation research shifted its emphasis to hurricane evacuation in response to severe hurricanes that hit in this time period (Chiu et al., 2007). Several tools were developed for hurricane evacuation modeling and information sharing, the most notable of which are SLOSH, HURREVAC, HAZUS-MH, CATS/JACE, and ETIS. Details on these models are available in FHWA, 2006.

Most of the above models are generally used to estimate the evacuation clearance time and to develop evacuation plans a priori through trial-and-error processes for different events or scenarios such as good/bad weather conditions, day/night-time evacuations, and different roadway conditions such as contra-flow lanes. These models allow emergency planners to experiment with alternative routes, destinations, traffic control and management, and evacuation participation rates. The "optimal" plan is usually sought through a trial-and-error process, which is usually time consuming and may lead to suboptimal conclusions. The models are static in terms of traffic flow modeling and thus their capability in generating prescriptive decision support is limited. Their inherent limitation rises from the fact that they cannot deal with time varying flows. Static models assume that the traffic conditions across the network remain at a fixed level through the simulation period. But in an emergency evacuation situation, such assumptions may not be valid, and it may take a vehicle longer to get out of the network than that predicted using static assignment techniques (Chiu et al., 2007).

Review of the literature highlights the need to consider dynamic network flow models to address the evacuation problem (Chiu et al., 2007). Dynamic traffic assignment (DTA) can be employed to predict time-dependent link flows and travel times as it takes under consideration time-varying traffic conditions. For this reason DTA results are proven to be more realistic than those from traditional static models, which typically underestimate congestion levels. For example, Andem (2006) compared link flows of evacuation traffic using Static Traffic Assignment (STA) with those obtained from DTA and observed that DTA better matches traffic counts from a hurricane evacuation based on a sample of households in South Carolina (Andem, 2006). Overall, it is generally accepted that DTA offers an inherit advantage when developing dynamic evacuation plans and is an important tool for real-time operations (Han and Yuan, 2005).

DTA is also important to address traffic demand changes related to information provision. Evacuees often change their decisions prior to or during evacuation in response to various traffic management strategies, such as radio/message sign information or contra-flow lanes, improved signal control, etc. Once the traffic management decisions are modified, the traffic "demand" on various evacuation routes is expected to change as well and needs to be captured by the traffic simulators (Zheng et al., 2010). Due to the advantages of DTA models compared to STA counterparts, assessment of the use of traffic simulators with dynamic traffic assignment capabilities in evacuation modeling and planning is therefore of great interest.

It should be noted that DTA models have not been specifically designed for modeling evacuations; however, some research has been conducted to enable such capabilities in a DTA system. In relevant work, Chiu et al. (2007) demonstrate the use of a dynamic traffic flow model for a no-notice mass evacuation. Using the mesoscopic simulation and assignment tool Dynamic Urban Systems in Transportation (DynusT) they evaluate contra-flow and phased evacuation

strategies (Chiu et al., 2007). Lu and Gao (2010) used the TransCAD DTA model to predict the effects on the traffic network operations across a wide area of a no notice evacuation with road closures due to a chemical spill. According to the study, the model assumed that every user had full information about the conditions, resulting in a potential underestimation of traffic congestion. In recent years, the cell transmission model (CTM) has been used as part of the six system-optimal (SO) single-destination dynamic traffic assignment (DTA) method in several evacuation studies to determine the multi-dimensional optimal decisions simultaneously, including evacuees' departure time, destination and route choices (Zheng et al., 2010).

In another evacuation study, a microscopic simulation model PARAMICS was used to implement short-term traffic control strategies during evacuations. The model used dynamic network modeling techniques and adaptive control theory, and consider the traffic network under evacuation conditions as a dynamic system (Liu et al., 2007). DynaMIT-E (DynaMIT for Evacuations) is another DTA model that was used to evaluate the evacuation of Central Business District of the City of Boston. The study results show that DynaMIT-E is capable of predicting short-term congestion successfully, which is beneficial for emergency personnel to efficiently manage the highways during emergencies (Balakrishna et al., 2008).

Evacuation in the event of a major nuclear power plant accident was studied by Han and Fuan (2005) using the VISSIM microscopic simulation tool. The DTA module in VISSIM was utilized to route the drivers based on the network conditions at the time of the accident. The most desirable destination choice for evacuees was modeled instead of defining the destinations based on shortest travel time. Further, an evacuee behavior model was proposed by Chiu et al. (2005) to predict the approximate number of travelers who do not follow the system optimal paths during evacuation. Real-time pre-trip route guidance was also considered in the model as a way to help drivers to avoid incident related congestion (Chiu et al., 2005).

Few simulation studies are currently available that investigate transit-based evacuation in a realistic network scale. In a recent effort, Naghawi and Wolshon (2010) used TheTRansportation ANalysis and SIMulation System (TRANSIMS) traffic simulation system for the analysis of region-wide evacuation process and adapted the TRANSIMS model for the development of a New Orleans transit-based evacuation (Naghawi and Wolshon, 2010). In another effort, Mastrogiannidou et al. (2009) employed the VISTA model in a transit assisted emergency evacuation study in an urban area. The study modeled transit assisted emergency evacuation procedures in high density areas (e.g., urban clusters), or from large and heavily utilized facilities (e.g., transit hubs, malls, hospitals, business centers etc.) to remotely located safe sites utilizing a state-of-the-art traffic micro-simulation software package in integration with emergency evacuation models. In a statistical study done by Deka and Carnegie (2010), it was found that, the automobile-oriented evacuation would not be efficient in cities with high transit-dependent populations. The study concluded that in such cases the efficient use of transit resources such as buses and shuttles is the most critical component of the evacuation.

Overall the literature review confirmed that DTA models are superior to STA ones when modeling evacuation scenarios and identified a few studies that demonstrate the usefulness of DTA models as a management and decision support tool in responding to emergency situations.

3. METHODOLOGY

3.1. Study Approach

This study built on VISTA models developed in Aims 2 and 4 of the UAB UTC Domain 2 project and expanded their scope so as to enable the modeling of evacuation of individuals without vehicles using transit options due to a flooding emergency in Birmingham, Alabama. For this purpose, the prototype regional model of the Birmingham network developed in Aim 2 was expanded to include details about the location of populations in need of assistance in the event of an evacuation (i.e. vulnerable populations). Study scenarios considered evacuation of carless populations from the affected area to nearby shelters using transit assets as well as evacuation of the general public using private vehicles.

Furthermore, existing transit routes servicing the area of interest were added to the model. In addition, new transit routes required for evacuation of carless populations were designed and modeled in VISTA. A detailed transit evacuation plan was developed and incorporated into VISTA including schedule and location of transit pick up points, destination points (i.e. drop off locations), transit vehicle carrying capacity, start and end time of operation, and resource requirements.

As far as the transportation network is concerned, the geographic area affected by the flood was defined and consideration was given to the fact that some network links would not be accessible due to the flooding. Thus road closures were designed in the study scenarios using historical data and were introduced in the VISTA model to realistically represent actual conditions.

As part of the flooding simulation study, modeling of optimum evacuation zones were completed with the simulation tool and an evacuation OD matrix was solved considering evacuation zone demands and the capacity of destinations (shelters). The impact of emergency evacuation due to flooding on traffic operations was measured using selected MOEs such as travel times and traffic volumes during evacuation period. Results from the VISTA runs were used to quantify the impacts of evacuation of carless individual using transit. Detail information about the simulation model development, study site used, and the simulation scenarios considered is presented in the following paragraphs.

3.1. Development of Simulation Model for the Evacuation due to Flooding Case Study

As mentioned in the Aim 2 report, the study network of the Birmingham prototype model was built in VISTA using background geometric and AADT volume data from the TRANPLAN (TRANsportation PLANning) model provided by the Regional Planning Commission of Greater Birmingham (RPCGB).

For the purpose of evacuation due to flooding case study, the Transit Service Area of Jefferson County data were obtained from Birmingham - Jefferson County Transit Authority (BJCTA) and emergency shelters data taken from Jefferson County Emergency Management Agency. Overall, 90 shelters were identified across Jefferson County. The maximum available capacity of the

shelters is 31,629. Among these there are 21 shelters in the evacuation area with a sheltering capacity of 5,785 which are not usable for evacuees in the case study considered. The estimated number of residents that need to be evacuated from the affected area is around 15, 068, thus the available shelters have enough capacity to accommodate the evacuees.

GIS capabilities were employed through the use of ArcGIS software to map relevant information and then incorporate into the VISTA Birmingham prototype model. The GIS technology that has the ability to capture, store, manipulate, query, analyze, and visualize digital data graphically. The maps created in ArcGIS showing existing transit area and emergency shelters in the Jefferson County are illustrated in Figure 3-1 and 3-2 respectively, while their VISTA counterparts can be seen in Figure 3-3 and 3-4.

The ArcGIS tool was also utilized to map the location of the transit dependent population throughout the Jefferson County. This was done by utilizing the relevant U.S. Census data for zero car households available through Census.gov. The ArcGIS map in Figure 3-5 illustrates the geographical distribution of low, medium, and high density zero car households across the study region. The dark blue sections in the map show the highest concentration of carless populations. Such information was used in the case study to define evacuation needs and determine origins, service areas, and evacuation routes of transit vehicles accordingly.

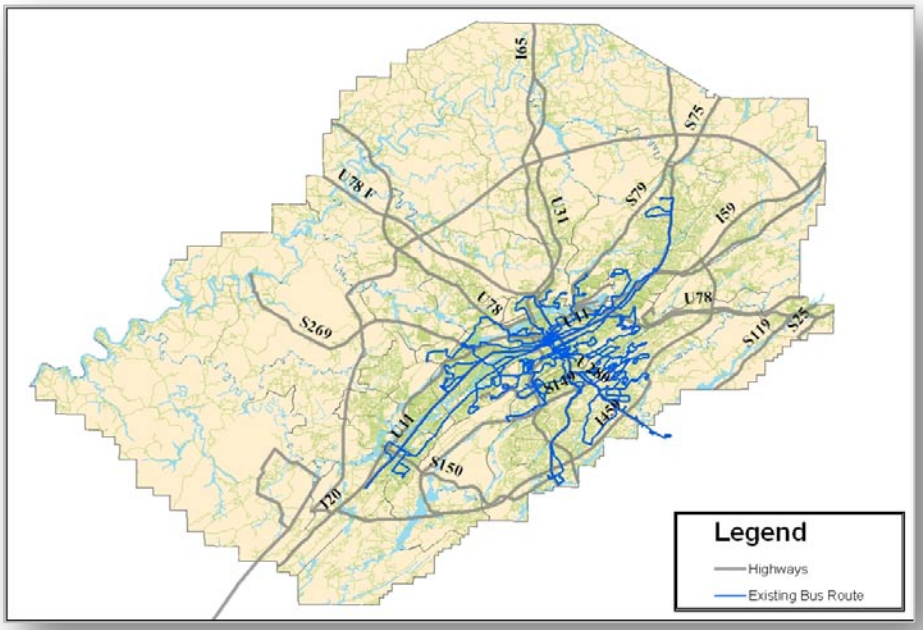


FIGURE 3-1 Transit Service Area of Jefferson County in ArcGIS Model

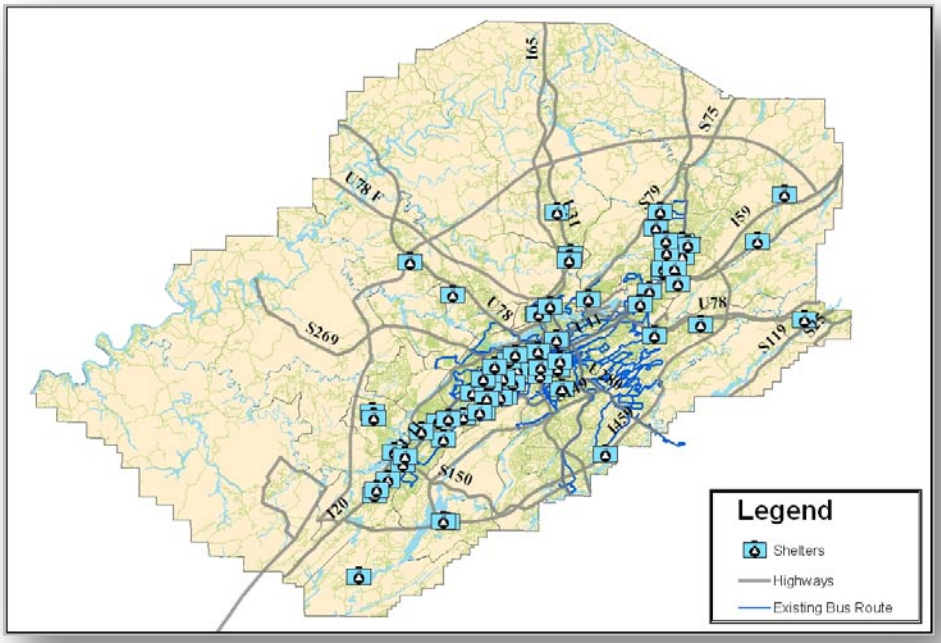


FIGURE 3-2 Birmingham Emergency Shelters in ArcGIS Model

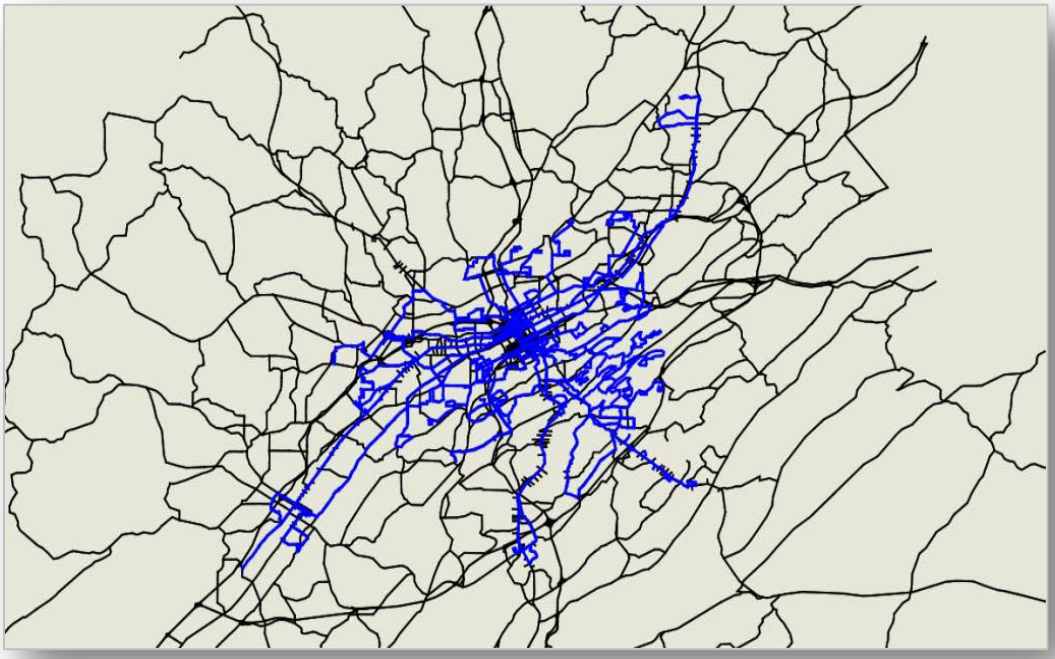


FIGURE 3-3 Existing Bus Service Area in the Jefferson County

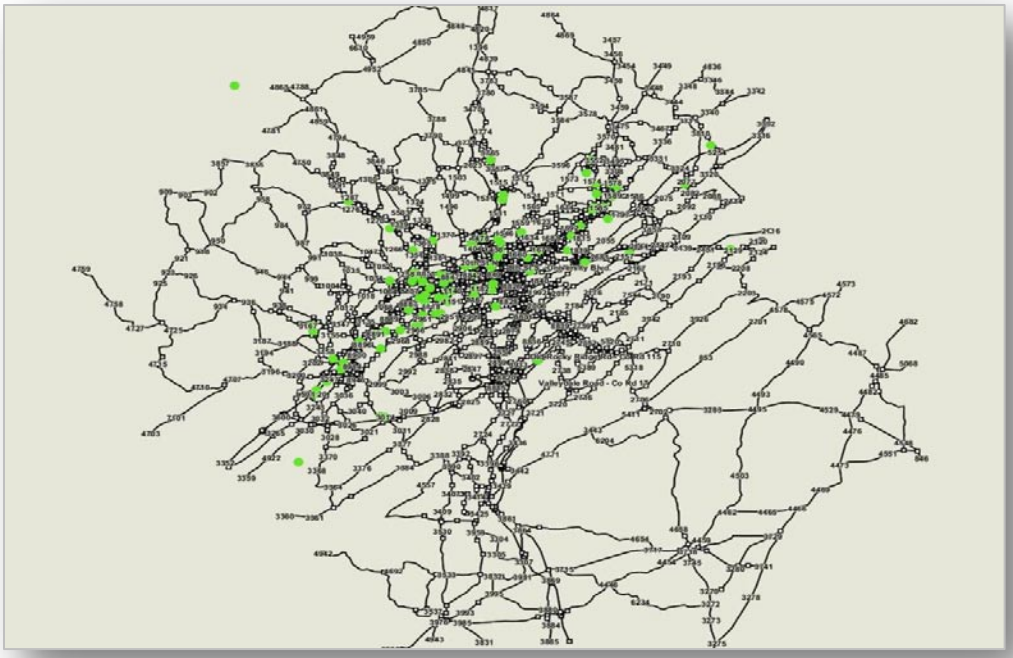


FIGURE 3-4 Birmingham Shelters in VISTA Model

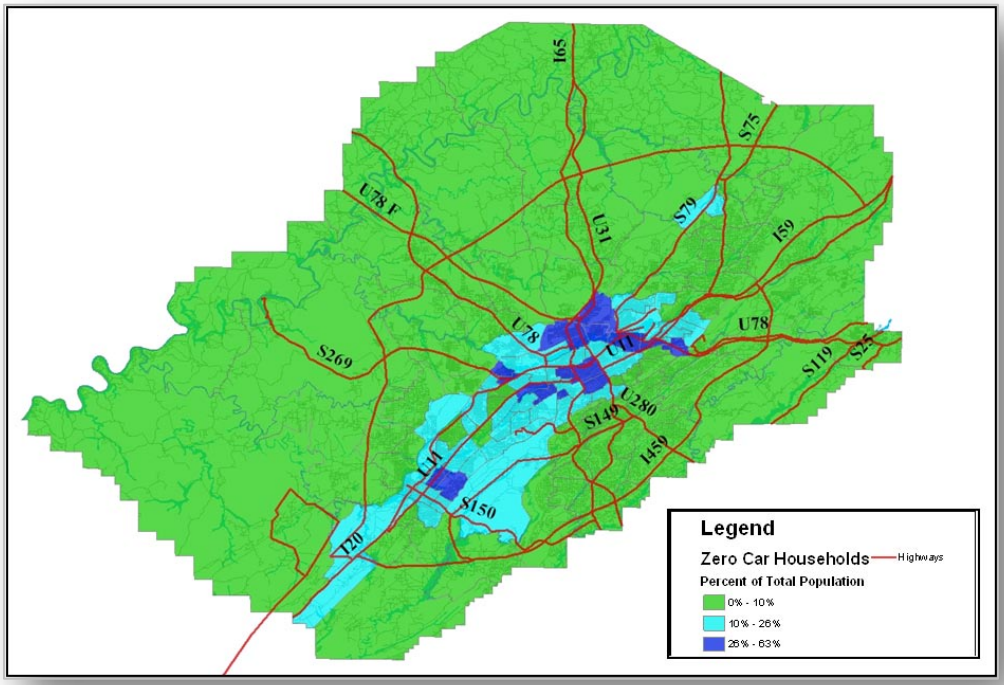


FIGURE 3-5 Zero Car Population in the Birmingham Area in ArcGIS Model

3.2. Study Site

Review of historical flood data from the Birmingham region led to the selection of the floodplain of Village Creek as the study area of interest in the flooding scenario. Village Creek has been flooded more than 20 times in a 20 years period and its chance of inundation in the future remains high. Moreover, the creek is located in a high residential area, where there are more than 5,000 dwellings, 200 commercial/industrial structures and about 100 critical facilities (FEMA, 2007).

Village Creek rises within the northwest part of Birmingham and flows in a southwesterly direction through the city for 12 miles. In this 12-mile stretch, the creek drains an area of approximately 40 square miles. The impact area of Village Creek is shown in Figure 3-6. Historical data show that Village Creek's flood velocities range from 3 to 9 feet per second. The flood duration is usually less than 10 hours, with a flood reaching maximum stage about 2 to 4 hours after an intense rainfall. In some areas flood waters can rise at a rate of 3 feet per hour. During the floods of December 1983, Village Creek rose above its flood stage by 4.8 feet causing the flooding in the Ensley neighborhood of Birmingham and damaged 400-500 homes (FEMA, 2000). Thus this study area is ideal for consideration in a case study scenario looking into evacuation due to flooding. The evacuation area considered in the case study is a sub set of the impact are of Village Creek and is defined in Figure 3-7.

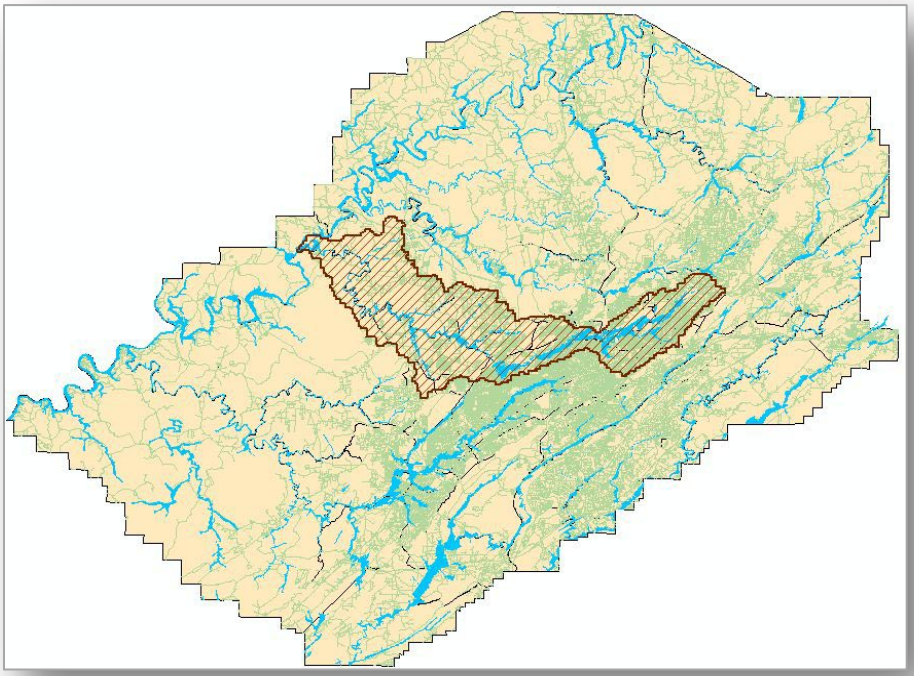


FIGURE 3-6 Village Creek Impact Area in ArcGIS Model

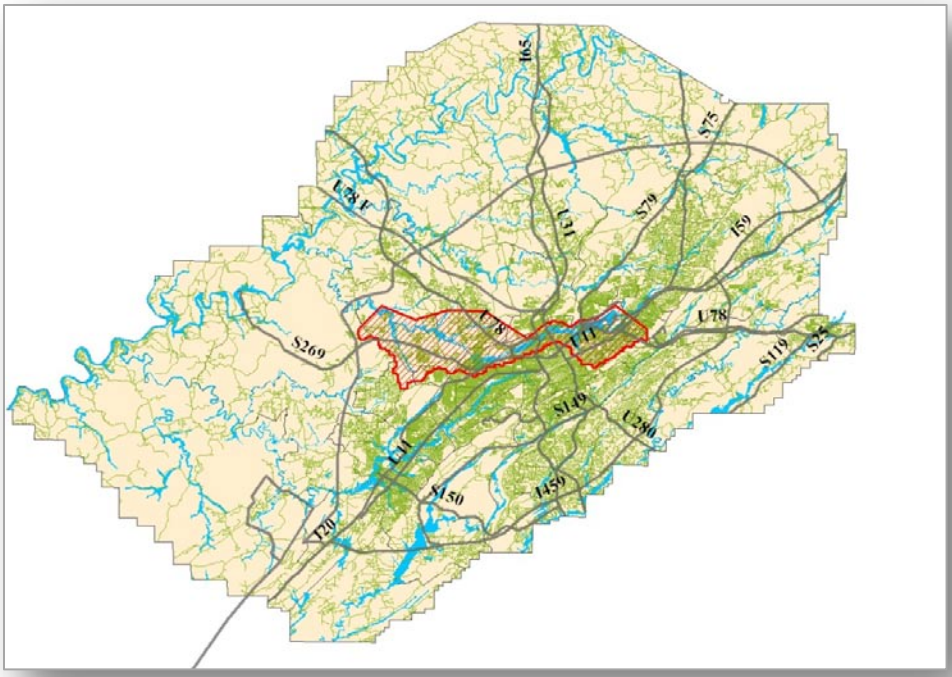


FIGURE 3-7 Evacuation Area within the Village Creek Impact Area

In order to define the locations of zero car households in the impact area of Village Creek, the maps in Figures 3-5 and 3-7 were superimposed using the ArcGIS tool, as illustrated in Figure 3-8. Inspection of Figure 3-8 reveals that a large portion of the flood-prone area serves carless populations who, in the event of an evacuation, would be unable to transport themselves outside of the harm's way. Thus evacuation plans need to be carefully prepared and tested in advance considering the evacuation needs of all area residents, including carless populations in the event of a future flooding situation.

3.3. Evacuation Study Simulation Scenarios

Three scenarios were designed for the Birmingham network to model the evacuation of local residents using personal vehicles as well as possible evacuation of carless individuals to area shelters using transit buses.

Scenario 1 (Base Case) assumed non-evacuation conditions and is used as a baseline for comparisons. The existing bus routes of the area were incorporated into this scenario.

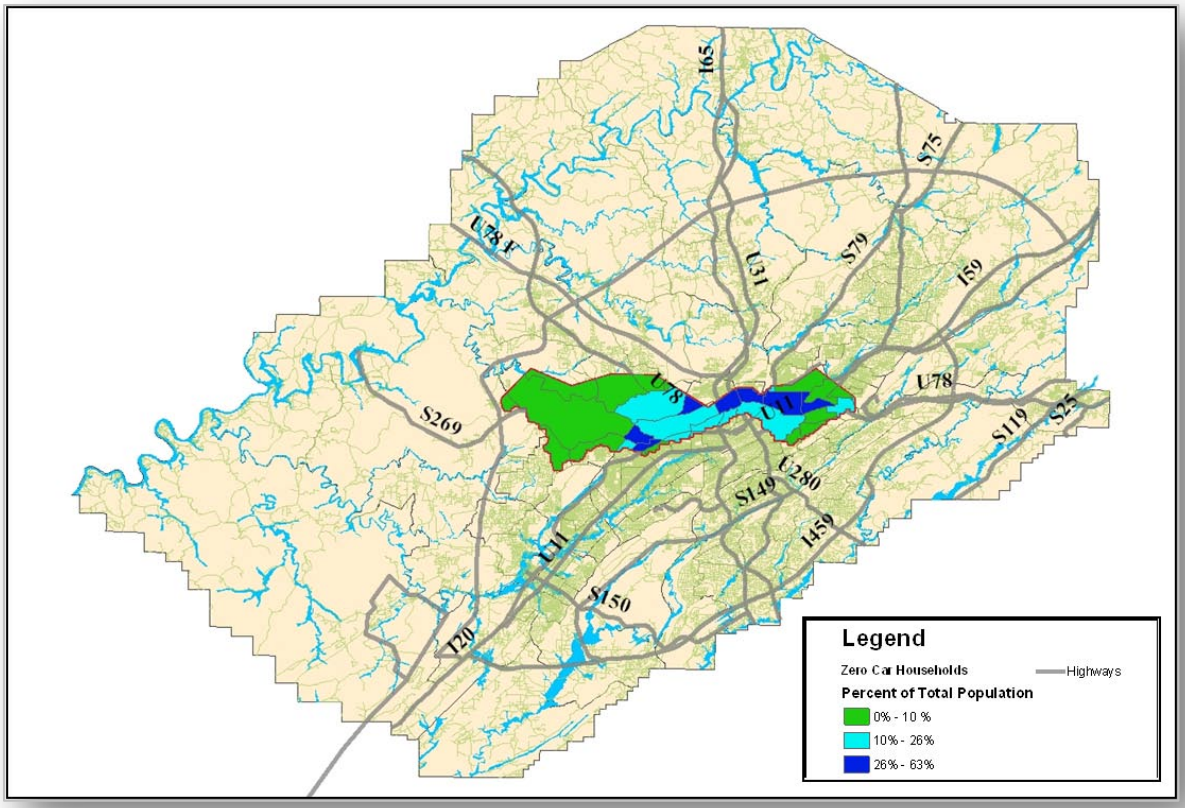


FIGURE 3-8 Zero Car Population in the Evacuation Area in ArcGIS Model

In *Scenario 2* vehicle evacuation was modeled in anticipation of flooding of Village Creek, without any special provisions for carless populations. Those individuals were assumed to either be carried by families and friends or remain stranded as it is often the case if plans for evacuation of persons in need are not in place a priori.

The flood was estimated to start on a Saturday at noon (i.e. 12:00 pm) and pre-evacuation started at 10:00 am and extended to 2:00 pm. Under this scenario, it was assumed that 75% of the population in the impacted area was evacuated before noon while the rest of the population would evacuate between 12:00 pm and 2:00 pm. Furthermore, five road segments were assumed to be closed due to the flooding from noon to 2 pm, resulting in 18 link closures in the VISTA network. Table 3-1 shows the list of road closures and the affected VISTA links. In order to communicate with evacuating public and assist them to select diversion roads due to road closures, 23 variable message signs were placed in the VISTA model at critical locations as shown in Figure 3-8.

Scenario 3 assumed similar traffic and evacuation conditions to those defined in Scenario 2, but in addition to the evacuation of residents using private vehicles, evacuation of carless population also took place using transit from 10:00 am and 12:00 pm. For this purpose, 8 evacuation bus routes were defined in the model as listed in Table 3-2 along with destination shelters.

TABLE 3-1 Road Closures- Evacuation Scenarios

Road Name	Closure ID	Link ID	Link Length	Closure	
				Start Time	Duration (hrs)
Ave I	1	2182	1109	12:00 PM	2
	1	2183	1109	12:00 PM	2
	1	2181	2006	12:00 PM	2
	1	2178	2006	12:00 PM	2
	1	2646	1901	12:00 PM	2
	1	2179	1901	12:00 PM	2
18th St	2	18339	2032	12:00 PM	2
	2	17578	2032	12:00 PM	2
Warrior Rd	4	2269	845	12:00 PM	2
	4	2271	845	12:00 PM	2
Ensley Five Points Rd	5	2273	1796	12:00 PM	2
	5	2591	1796	12:00 PM	2
20th St	6	2652	422	12:00 PM	2
	6	2661	422	12:00 PM	2
	6	11414	369	12:00 PM	2
	6	2653	370	12:00 PM	2
	6	11413	739	12:00 PM	2
	6	2649	739	12:00 PM	2

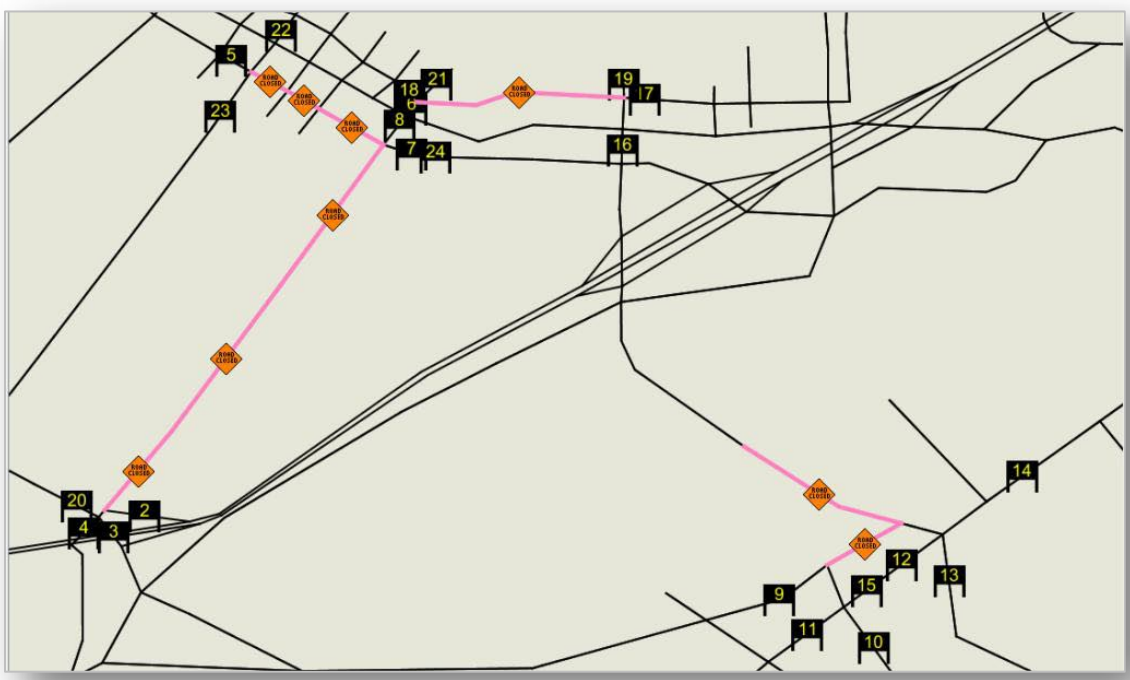


FIGURE 3-8 Road Closures due to Flooding in VISTA Model

TABLE 3-2 Evacuation Bus Routes

BJCTA Route ID	Evacuation Route Name	Destination Shelter Name
Route 5	Pratt/Ensley - Fair Park Arena	Fair Park Arena
Route 17	Oporto Madrid - Boutwell Auditorium	Boutwell Auditorium
Route 22	41st Ave N - Civic Center	Civic Center
Route 23	Shuttlesworth Dr - Civic Center	Civic Center
Route 25	Aviation Ave - Boutwell Auditorium	Boutwell Auditorium
Route 38	Pratt/Ensley - Bartow Arena	Bartow Arena
Route 40	Sayreton - Epic School	Epic Elementary School
Route 40	33rd Ave W - Epic School	Epic Elementary School

2.1.4. Transit Routes Considered

In *Scenarios 1 and 2* the transit schedule remains as usual. Ten bus routes currently operating from the Birmingham Jefferson County Transit Authority (BJCTA) in the study area of interest were modeled into VISTA as seen in Table 3-3. The corresponding bus schedule is displayed in Table 3-4.

In *Scenario 3*, during the evacuation period (from 10:00 am to 2:00 pm) the regular bus schedule was put on hold and replaced by the evacuation transit service schedule. This altered schedule is displayed in Table 3-5. For safety reasons, no transit service was provided during the actual flooding event (i.e., from 12:00 to 2:00 pm) on routes that traversed the evacuation zone namely Routes 5, 17, 22, 23, 25, 38, and 40. It should be also noted that scheduling of transit operations on Routes 31, 42, and 45 remained unaffected as those transit lines are not in the vicinity of the flood impact area.

TABLE 3-3 Existing Bus Routes

BJCTA Route ID	BJCTA Route Name
Route 5	Ensley-Wylam-West Ensley
Route 17	Century Plaza – Eastwood Mall
Route 22	Tarrant City
Route 23	North Birmingham
Route 25	Center Point
Route 31	Highway 31 South
Route 38	Graymont Avenue
Route 40	Fairmont
Route 42	Hollywood/Brookwood Mall
Route 45	Bessemer

TABLE 3-4 Existing BJCTA Bus Schedule

	Outbound			Inbound		
BJCTA Route ID	**Headway (sec)**	**Start Time**	**End Time**	**Headway (sec)**	**Start Time**	**End Time**
Route 5	3,600	5:00 AM	9:00 PM	3,600	4:45 AM	7:45 PM
Route 17	1,800	5:55 AM	9:25 PM	1,800	6:55 AM	8:25 PM
Route 22	4,800	6:30 AM	9:20 PM	4,800	6:00 AM	8:40 PM
Route 23	2,700	5:15 AM	8:15 PM	2,700	5:15 AM	9:00 PM
Route 25	3,600	6:00 AM	9:00 PM	3,600	6:00 AM	8:00 PM
Route 31	1,800	6:00 AM	6:00 PM	1,800	6:45 AM	6:45 PM
Route 38	1,800	6:00 AM	9:00 PM	1,800	5:30 AM	9:00 PM
Route 40	3,600	6:05 AM	9:05 PM	3,600	5:05 AM	8:05 PM
Route 42	3,600	7:00 AM	6:00 PM	3,600	6:20 AM	6:20 PM
Route 45	3,600	5:30 AM	9:30 PM	3,600	5:30 AM	9:30 PM

TABLE 3-5 Outbound BJCTA Bus Routes in Scenario 3

	Period 1			Period 2		
BJCTA Route ID	**Headway (sec)**	**Start Time**	**End Time**	**Headway (sec)**	**Start Time**	**End Time**
Route 5	3,600	5:00 AM	9:55 AM	3,600	2:00 PM	9:00 PM
Route 17	1,800	5:55 AM	9:55 AM	1,800	2:25 PM	9:25 PM
Route 22	4,800	6:30 AM	9:55 AM	4,800	2:30 PM	9:10 PM
Route 23	2,700	5:15 AM	9:55 AM	2,700	2:15 PM	8:15 PM
Route 25	3,600	6:00 AM	9:55 AM	3,600	2:00 PM	9:00 PM
Route 31	1,800	6:00 AM	6:00 PM	1,800	6:00 AM	6:00 PM
Route 38	1,800	6:00 AM	9:55 AM	1,800	2:00 PM	9:00 PM
Route 40	3,600	6:05 AM	9:55 AM	3,600	2:05 PM	9:05 PM
Route 42	3,600	7:00 AM	6:00 PM	3,600	7:00 AM	6:00 PM
Route 45	3,600	5:30 AM	9:30 PM	3,600	5:30 AM	9:30 PM

3.4. Evacuation Demand Preparation

In order to have a robust evacuation model, it is important to estimate the number of potential evacuees as well as their geographical distribution in the evacuation area. Using such information along with information about shelter locations and other potential destinations, origins and destinations of evacuees can be defined.

It should be emphasized that the travel patterns of drivers during evacuations differ greatly from typical travel patterns, thus the OD matrices available for regular transportation planning purposes are not proper to use in evacuation models. For that reason, necessary demand

adjustments for affected zones were made to account for changes in travel patterns during the evacuation and thus a new OD matrix was considered in the Birmingham VISTA model for evacuation scenarios 2 and 3. Moreover, the demand of carless evacuees in the evacuation zone was defined through ArcGIS and census data and was included in the VISTA evacuation model. The following paragraphs describe the details of evacuation demand preparation in the VISTA model.

3.6.1. Vehicle Demand during Evacuation

As stated above, the vehicle demand in the evacuation area needed adjustments to properly reflect evacuation travel patterns. First, the evacuation area was defined in the ArcGIS model using historical inundation data as a subset of the Village Creek flood impact region. The vehicle demand originating inside and outside the evacuation area was then determined as follows:

- The OD pairs starting and ending outside the evacuation area were not changed. In other words, it was assumed that the drivers outside of the evacuation area were not affected from the evacuation.
- No outside vehicles were allowed to enter the evacuation area during evacuation.
- No outside vehicles were allowed to enter the evacuation area during evacuation. Thus the OD pairs starting outside and ending inside the evacuation area during the evacuation period were assumed not taken place at all.
- Vehicles with origins inside the evacuation zones and destinations outside would evacuate to those destinations. There were 36,710 such vehicles evacuating vehicles during the 4-hr evacuation period. Based on the study assumptions, 75% of these vehicles (or 27,532 trips) departed between 10:00 am and 12:00 pm, while the rest (9,718 vehicles) assumed to leave between 12:00 pm and 2:00 pm during which time lane closures became also in effect.
- Vehicles with origins and destinations inside the evacuation zones would have to be rerouted to other destinations, outside the affected area. In the original model, 9,818 trips originated and ended in the affected area. Those vehicles were also evacuated within the 4-hr evacuation period (75% before 12:00 pm and 25% afterwards) and area shelters were defined as their new destinations. The selection of the destination was based on calculation of the shortest travel time from the origin to potential shelter destinations. To do so, a new OD matrix was solved through Excel Solver that considered the location and demand of the origins and the location and capacity of shelters and the results were incorporated to the VISTA model.

Figure 3-9 shows the evacuation area considered in the study and the evacuation origins created in the ArcGIS model.

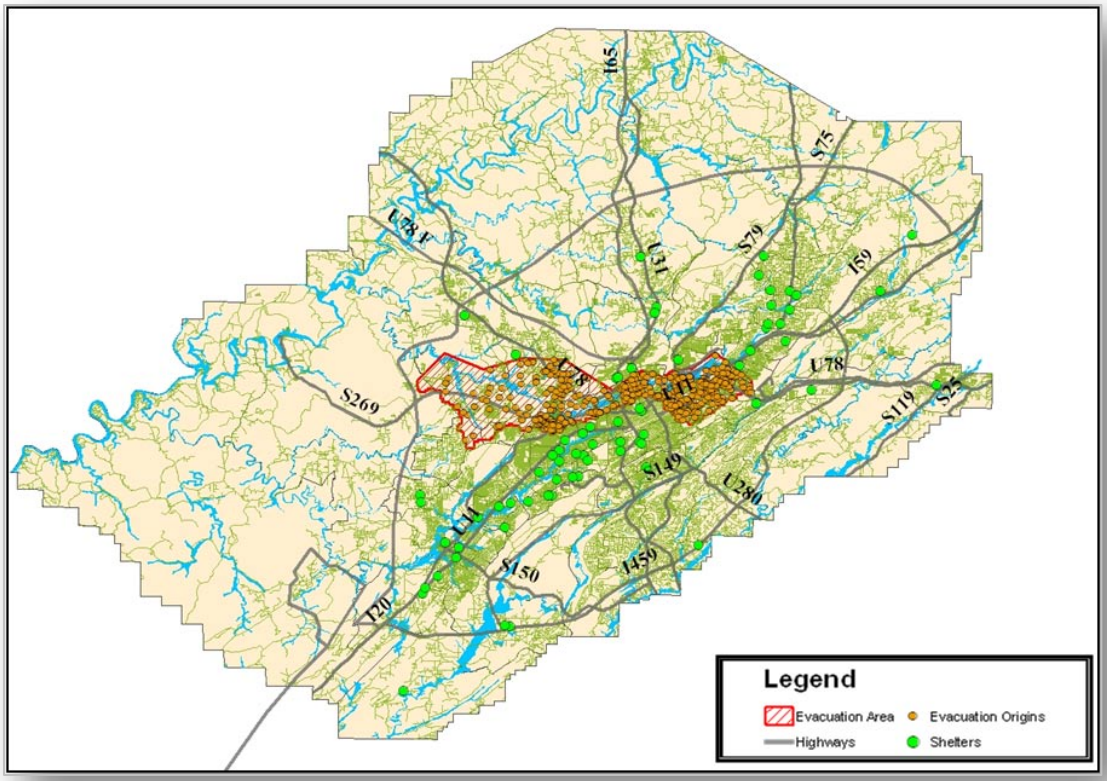


FIGURE 3-9 Evacuation Area and Evacuation Origins in ArcGIS Model

3.6.2. Demand for Evacuation using Transit

In order to define evacuation demand using transit, the size of the carless population in the evacuation area was estimated using Zero Car Households data taken from census.gov. As mentioned before, the locations of zero car households were superimposed to the evacuation area using ArcGIS tool and affected area was used in estimating the carless population demand. The estimated number of carless individuals in the affected area was 6,765 people. It was assumed that 75% of this population would use the transit options to evacuate, thus the demand for transit evacuation in the case study was 5,040.

Eight pick-up locations for loading of transit vehicles were identified based on the spatial distributions of carless populations in the evacuation area. Evacuation bus routes were defined originating from those pick-up locations and terminating to five nearby shelters. Existing bus routes in the Jefferson County were used in defining the evacuation bus routes. The carrying capacity of each bus is 45 people per trip, based on the information provided by BJTCA, and was used to determine the number of trips needed to serve the transit-depended evacuees in Scenario 3. Moreover, consideration of shelter capacities took place when developing the transit evacuation routes and schedule.

The evacuation bus routes and shelters considered can be seen in Table 3-6 whereas Table 3-7 summarizes evacuation bus schedules including bus headways, start time and end time for each evacuation bus route considered. Based on the transit evacuation plan that was developed in this study, the bus routes shown in Figure 3-11 were defined in the VISTA model under Scenario 3.

The results from the simulation analysis of the three scenarios considered as part of the flood evacuation study are presented and discussed next.

TABLE 3-6 Evacuation Demand using Bus Routes

BJCTA Route ID	Evacuation Bus Route		Shelter Capacity	Evacuation Demand	Number of Trips
	Origin	Destination Shelter			
Route 5	Pratt/Ensley	Fair Park Arena	900	900	20
Route 17	Oporto Madrid	Boutwell Auditorium	600	585	13
Route 22	41st Ave N	Civic Center	750	720	16
Route 23	Shuttlesworth Dr	Civic Center	750	720	16
Route 25	Aviation Ave	Boutwell Auditorium	600	585	13
Route 38	Pratt/Ensley	Bartow Arena	370	360	8
Route 40	Sayreton	Epic Elementary School	600	585	13
Route 40	33rd Ave W	Epic Elementary School	600	585	13
			TOTAL	**5,040**	**112**

TABLE 3-7 Evacuation Bus Schedule in Scenario 3

BJCTA Route ID	Evacuation Route Name	Headway (sec)	Start Time	End Time
Route 5	Pratt/Ensley - Fair Park Arena	300	10:20:00 AM	11:55:00 AM
Route 17	Oporto Madrid - Boutwell Auditorium	300	10:30:00 AM	11:30:00 AM
Route 22	41st Ave N - Civic Center	300	10:30:00 AM	11:45:00 AM
Route 23	Shuttlesworth Dr - Civic Center	300	10:30:00 AM	11:45:00 AM
Route 25	Aviation Ave - Boutwell Auditorium	300	10:30:00 AM	11:30:00 AM
Route 38	Pratt/Ensley - Bartow Arena	600	10:00:00 AM	11:10:00 AM
Route 40	Sayreton - Epic School	300	10:30:00 AM	11:30:00 AM
Route 40	33rd Ave W - Epic School	300	10:30:00 AM	11:30:00 AM

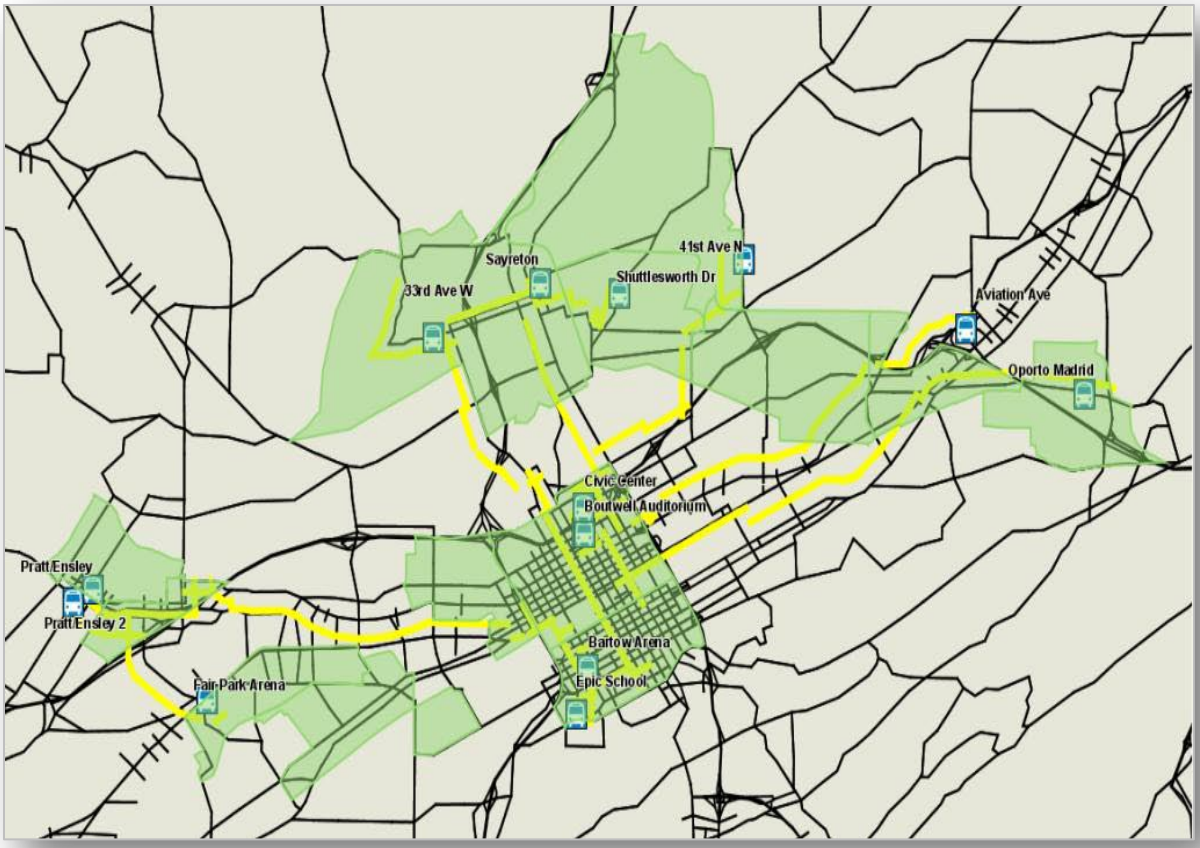


FIGURE 3-10 Evacuation Bus Routes in VISTA (Scenario 3)

4. STUDY RESULTS

4.1. Evacuation Study Scenario Results

4.1.1. Network-wide Results

The VISTA general reports were obtained for the three scenarios considered in the flood evacuation case study and network-wide results were considered to evaluate the impact of evacuation on network operations with and without transit. The summary results for the three scenarios considered (i.e., Scenario 1-normal travel and transit operations; Scenario 2-passenger vehicle evacuation only and normal transit operation; Scenario 3-passenger vehicle and carless evacuation using transit; altered transit schedule) are show in Table 4-1.

TABLE 4-1 Network-wide Results from Evacuation Scenarios

Scenarios	Avg Travel Speed (mph)	Total Delay Time (veh-hours)	Avg Delay Time (min/veh-mile)	Avg Total Time (min/veh-mile)
Scenario 1	38.619	50,910.62	0.236	1.632
Scenario 2	35.483	94,762.55	0.678	2.104
Scenario 3	35.367	98,333.47	0.746	2.181

As expected, under the evacuation order (Scenarios 2 and 3), all network performance measures were affected. More specifically, the average travel speeds were found to be approximately 8% lower than those observed under normal operations (Scenario 1) whereas the total delays nearly doubled. Overall, the average total time (expressed in min/veh-mile) increased by 30% in the evacuation Scenario 2 when compared to normal operations (Scenario 1). These observations confirm that localized events can impact traffic operations far beyond their immediate area of occurrence and thus regional models such as the ones developed in this study are essential in order to study these effects and develop plans to minimize the extend and severity of their undesirable consequences on network performance.

Another important observation from the study findings displayed in Table 4-1 is that the differences in performance measures between Scenarios 2 and 3 appear to be small. More specifically, the additional evacuation of over 5,000 carless people using transit in Scenario 3 had practically no impact on network-wide average speed when compared to Scenario 2. Comparison of Scenarios 2 and 3 results further revealed some incremental changes in total and average delay time were observed, however, those changes were small (in the order of 3-10%) indicating that well planned evacuation of carless population, as in the case study presented in this project, is feasible without compromising the overall network performance.

4.1.2. BJCTA Bus Routes Results

Implementation of evacuation procedures should not only consider its impacts on network operation but also evaluate potential impacts on transit operations in the region as some local residents and users often depend on such service in order to perform their everyday activities.

This study looked closely at the travel times and operating speeds of BJCTA bus routes under the private vehicle evacuation scenario (Scenarios 2) and compared them to their counterparts under normal traffic operations (Scenario 1). The results of these comparisons are summarized in Tables 4-2 and 4-3. Similar comparisons can be performed with results from Scenario 3, however, these comparisons were omitted on purpose since the evacuation bus routes are not identical to the regular bus routes used in Scenarios 1 and 2.

TABLE 4-2 Comparison of Average Travel Times (min) for BJCTA Bus Routes

BJCTA Route ID	Average Travel Times (min)	
	Scenario 1	Scenario 2
Route 5	22.18	22.83
Route 17	23.60	23.60
Route 22	18.67	18.90
Route 23	14.63	14.58
Route 25	39.95	45.88
Route 31	29.50	36.12
Route 38	20.70	35.74
Route 40	19.00	19.00
Route 42	20.80	20.80
Route 45	30.90	32.87

TABLE 4-3 Comparison of Average Speeds (mph) for Outbound BJCTA Bus Routes

BJCTA Route ID	Average Speeds (mph)	
	Scenario 1	Scenario 2
Route 5	30.21	29.38
Route 17	28.50	28.50
Route 22	29.28	28.91
Route 23	29.79	29.88
Route 25	27.33	24.68
Route 31	28.83	27.84
Route 38	26.26	21.63
Route 40	28.75	28.75
Route 42	25.80	25.80
Route 45	31.78	30.54

Consideration of the results displayed in Tables 4-2 and 4-3 reveals the following:

- The evacuation of people in private cars in Scenario 2 impacts operations along certain transit routes within the impact area, specifically Routes 25 and 38. A 15% increase in average travel time was observed in Scenario 2 along bus Route 25 coupled with a 9.7% drop in average speed (from 27.3 mph in Scenario 1 to 24.68 in scenario 2). The impacts of the evacuation where even more pronounced along bus Route where the observed change in average travel time and speed were 73% and 17.7% respectively.
- On the other hand, the performance of several other transit routes within the impact area was minimally affected by the evacuation of private vehicles considered in Scenario 2. Those bus routes are Routes 5, 17, 22, 23, and 40 and their average travel times and average speeds remained unchanged in Scenario 2 compared to Scenario 1.
- As far as routes outside the impacted area are concerned, the performance of Route 31 is also impacted from the evacuation as evidenced by a 22% increase in average travel time in Scenario 2, whereas other routes (namely Routes 42 and 45) did not experience any considerable changes in operating performance. One explanation for this is that certain transit routes may not be close to the affected area but still may be affected from changing traffic demands as a result of the evacuation and the evacuation trip distribution in the transportation network.
- All things considered, the results show that evacuations affect all transportation users, including transit ones. The degree to which the performance of transit routes is affected can be determined a priori through evacuation impacts studies using regional models such as the VISTA Birmingham region prototype model developed and demonstrated in this study. Even when transit resources are not directly involved in the evacuation, knowledge of potential evacuation impacts on transit system operations can help transit authorities develop plans to adjust their schedules in order to minimize potential disruption in service and avoid unnecessary compromises in service quality in the event of an actual evacuation.

4.1.3. Transit Evacuation Logistics Results

Another benefit from performing off-line evacuation impacts analysis is the opportunity to develop and refine the transit evacuation plan. Based on the VISTA results from Scenario 3, outbound and inbound travel times of evacuation transit routes were determined (Table 4-4) and were then used to determine the number of round trips that a bus servicing this route can perform within the evacuation time period. Assuming 5 minutes are required for loading/uploading of passengers at terminal locations, the transit resources required in order to perform the transit evacuation described in Scenario 3 are presented in Table 4-5. Such information can be of great value to the transit and emergency management personnel as they consider resource allocation issues in the event of an emergency. For example, given that the evacuation of 5,000 carless people under the study assumptions requires 47 buses, if the agency cannot allocate those resources other options need to be considered such as starting the evacuation earlier and thus utilizing fewer transit buses or staying within the 2 hr time frame but expand the evacuation transit fleet to include non-transit vehicles (such as motor coaches, shuttle buses etc).

TABLE 4-4 Comparison of Average Travel Times (min) for Outbound and Inbound BJCTA Bus Routes in Scenario 3

BJCTA Route ID	Evacuation Route Name	Avg Travel Times (min)- Scenario 3		
		Outbound	Inbound	Roundtrip
Route 5	Pratt/Ensley - Fair Park Arena	5.94	5.55	11.49
Route 17	Oporto Madrid - Boutwell Auditorium	18.98	18.20	37.18
Route 22	41st Ave N - Civic Center	6.62	5.46	12.08
Route 23	Shuttlesworth Dr - Civic Center	7.77	7.50	15.27
Route 25	Aviation Ave - Boutwell Auditorium	12.93	9.40	22.33
Route 38	Pratt/Ensley - Bartow Arena	17.37	13.33	30.70
Route 40	Sayreton - Epic School	31.33	21.20	52.53
Route 40	33rd Ave W - Epic School	22.00	19.70	41.70

TABLE 4-5 Number of Buses Required in Scenario 3 Evacuation

BJCTA Route ID	Evacuation Route Name	Number of Buses
	Pratt/Ensley - Fair Park Arena	3
Route 5	Oporto Madrid - Boutwell Auditorium	8
Route 17	41st Ave N - Civic Center	3
Route 22	Shuttlesworth Dr - Civic Center	4
Route 23	Aviation Ave - Boutwell Auditorium	5
Route 25	Pratt/Ensley - Bartow Arena	4
Route 38	Sayreton - Epic School	11
Route 40	33rd Ave W - Epic School	9
Route 40	**TOTAL**	**47**

5. SUMMARY AND CONCLUSIONS

In emergencies and disasters the needs of carless populations are often overlooked. Hurricanes in Louisiana, Florida and all along the Gulf Coast revealed how vulnerable these residents are in emergency situations and how important it is to develop a clear understanding of their unique problems and needs and addressing them within the emergency planning process. In doing so, the transit system can play a crucial role in providing resources to accommodate safe and efficient transportation of people that depend on community and public transportation as their primary means of mobility, before, during, and after emergency situations.

The effectiveness of such strategies clearly depends on the knowledge acquired prior to an emergency on transportation needs and available transit assets, and best practices for optimizing the allocation of such assets in order to maximize the efficiency and better serve the needs of the public in the event of an evacuation. This project studied such needs in depth through literature review and traffic modeling and analysis using a simulation and optimization modeling approach.

The literature review pointed out the importance of using dynamic traffic assignment (DTA) when modeling evacuations as it allows for the integration of time-varying traffic conditions as vehicles traverse a network. This inherent capability provides DTA based models an edge over conventional static assignment models, when it comes to estimating the traffic effects over time for given assumptions on travel behavior due to a planned or assumed realization of an evacuation scenario.

The literature search also revealed there are only a handful of studies modeling evacuation using transit assets. This is a complex problem since one needs to determine changes in traffic demands in the affected region under evacuation (i.e., update the OD matrix), consider transit logistics (i.e., develop a detailed transit evacuation plan considering resources limitations, introducing new routes and optimizing resource allocations), as well as infrastructure restrictions (i.e., lane closures, carrying capacity limitations etc) and behavioral issues. This study took these factors under consideration as it developed and tested a comprehensive emergency evacuation scenario in the Birmingham region due to a local flooding event.

The Birmingham case study was used to demonstrate the feasibility of employing transit buses for safe evacuation of transit-dependent populations in the Village Creek area in anticipation of a flooding event. The study determined the geographical distribution of transit-dependent people in need for evacuation, estimates transit resources requirements for evacuation of over 5,000 potentially stranded residents, proposed a comprehensive staggered evacuation plan for evacuation of affected people, and tested the impacts of the evacuation of network performance with and without transit evacuation consideration.

The study analyzed the network-wide impacts of two evacuation scenarios (i.e., one considering private vehicle evacuation only and another considering carless evacuation in conjunction to private vehicle evacuation) and concluded that serving the needs of vulnerable population is

feasible and can have a minimal added effects on network average travel time and speed, when planned and implemented in an efficient manner.

Moreover, the results clearly indicate that the effects of an evacuation process oftentimes extend far beyond the high impact area and may affect traffic network and transit operations outside the immediate area of interest. This underlines the need to develop large scale simulation models that consider not only localized but also regional impacts of evacuation under various scenarios.

Among the contributions of the study was demonstrating the use of VISTA performance measures to: a. assess automobile evacuation impacts on transit operations; b. refine transit evacuation plans and schedules; and c. determine resources needed in order to execute successfully transit evacuation plan.

Overall, the study succeeded in demonstrating the usefulness of the VISTA Birmingham model as a decision support tool for optimizing network performance and logistics during evacuation of users with private vehicles as well as carless populations. Having such a tool in place is essential during emergency response in order to facilitate the efficient movement of all evacuees while capturing the dynamics of emergency conditions both on the demand and the supply side of the transportation system.

REFERENCES

1. Abdelgawad, H., B. Abdulhai and M. Wahba. Optimizing Mass Transit Utilization in Emergency Evacuation of Congested Urban Areas. TRB 89th Annual Meeting Compendium of Papers DVD, Paper # 10-3718. Transportation Research Board of the National Academies, Washington, D.C., 2010.

2. Alabama Department of Public Health (ADPH). Preparing for Special Needs in an Emergency, Tips on How to Prepare Resources to Assist in Planning. Emergency Preparedness Special Needs Booklet. 2007. Retrieved from: http://www.adph.org/riskcommunication/assets/ADPHSpecialNeedsBooklet.pdf

3. American with Disabilities Act (ADA). An ADA Guide for Local Governments: Making Community Emergency Preparedness and Response Programs Accessible to People with Disabilities. The Department of Justice, Information and Technical Assistance on the Americans with Disabilities Act. 2008. Retrieved from: http://www.ada.gov/emergencyprepguide.htm

4. Andem, S.K. A Comparative Analysis of Hurricane Evacuation Traffic Conditions Using Static and Dynamic Traffic Assignments. Master of Science Thesis. The Department of Civil and Environmental Engineering, Louisiana State University, 2006.

5. Balakrishna, R., Y.Wenn, M. B. Akiva and C. Antoniou. Simulation-Based Framework for Transportation Network Management for Emergencies. Transportation Research Record: Journal of the Transportation Research Board. Volume 2041, Transportation Research Board of the National Academies, Washington, D.C., 2008, pp. 80-88.

6. Balog, J.N., A. Boyd, J. Caton, P.N. Bromley, J. B. Strongin, D. Chia and K. Bagdonas. Public Transportation Security: Public Transportation Emergency Mobilization and Emergency Operations Guide. Transit Cooperative Research Program (TCRP) Report 86, Volume 7. Transportation Research Board of the National Academies, Washington DC, 2005.

7. Chiu, Y.C., Korada, P. and P.B. Mirchandani. Dynamic Traffic Management for Evacuation. TRB 84th Annual Meeting Compendium of Papers CD-ROM, Paper # 05-2369. Transportation Research Board of the National Academies, Washington, D.C., 2005.

8. Chiu, Y.C., Zheng, H., Villalobos, J. and B. Gautam. Modeling No-Notice Mass Evacuation Using a Dynamic Traffic Flow Optimization Model. IIE Transactions, Volume 39 (1), 2007, pp 83-94.

9. Deka, D. and Carnegie J.A. Analyzing Evacuation Behavior of Transportation-Disadvantaged Populations in Northern New Jersey. TRB 89th Annual Meeting Compendium of Papers DVD, Paper # 10-1584. Transportation Research Board of the National Academies, Washington, D.C., 2010.

10. Federal Emergency Management Agency (FEMA). Interim Emergency Management Planning Guide for Special Needs Populations. Comprehensive Preparedness Guide 301 (CPG-301). Federal Emergency Management Agency and Department of Homeland Security Office for Civil Rights and Civil Liberties, August 2008.

11. Federal Emergency Management Agency (FEMA). Losses Avoided in Birmingham, Alabama Analysis for 735 Acquisitions on Village Creek. Post-Disaster Economic Evaluation of Hazard Mitigation. Common Effort of Federal Emergency Management Agency (FEMA) Region IV, Atlanta, GA, US Army Corps of Engineers (USACE) Mobile District, AL and City of Birmingham, Birmingham, AL. October, 2000.

12. Federal Emergency Management Agency (FEMA). Public and Private Sector Best Practice Stories for All Activity/Project Types in All States and Territories in Region IV relating to Flooding. Acquisition, Evaluation & Analysis: Acquisition Successes in Birmingham. November, 2007.

13. Federal Highway Administration (FHWA). Emergency Transportation Response Overview. Technical Report of the U.S. Department of Transportation Federal Highway Administration (FHWA) Office of Operations. Report No: FHWA-OP-04-048. April, 2004. Retrieved from: http://www.ops.fhwa.dot.gov/aboutus/one_pagers/emerg_response.pdf

14. Federal Highway Administration (FHWA). Report to Congress on Catastrophic Hurricane Evacuation Plan Evaluation. Common effort of the U.S. Department of Transportation (DOT) and the U.S. Department of Homeland Security (DHS). June, 2006. Retrieved from: http://www.fhwa.dot.gov/reports/hurricanevacuation/rtc_chep_eval.pdf

15. General Accounting Office (GAO). Transportation Disadvantaged Populations: Some Coordination Efforts Among Programs Providing Transportation Services, But Obstacles Persist. A Report to Congressional Requesters. Publication GAO-03-697. United States General Accounting Office, June 2003.

16. Han, L.D. and F, Yuan. Evacuation Modeling and Operations Using Dynamic Traffic Assignment and Most Desirable Destination Approaches. TRB 84th Annual Meeting Compendium of Papers CD-ROM, Paper # 05-2401. Transportation Research Board of the National Academies, Washington, D.C., 2005.

17. Henry J. Kaiser Family Foundation (KFF). Survey of Hurricane Katrina Evacuees. Online document in collaboration with the Washington Post and Harvard University. September, 2005. Retrieved from: http://www.kff.org/newsmedia/upload/7401.pdf

18. Houston, N., A.V. Easton, E.A. Davis, J. Mincin, B.D. Phillips and M. Leckner. Evacuating Populations with Special Needs, Routes to Effective Evacuation Planning Primer Series. Publication FHWA-HOP-06-109. Federal Highway Administration (FHWA), U.S. Department of Transportation. 2009.

19. Jones, J.A., Walton, F., Smith, J.D. and B. Wolshon. Assessment of Emergency Response Planning and Implementation for Large Scale Evacuations. Report of the United States Nuclear Regulatory Commission (U.S.NRC). October 2008.

20. Liu, H. X., J. X. Ban, W. Ma, and P. B. Mirchandani. Model Reference Adaptive Control Framework for Real-Time Traffic Management under Emergency Evacuation. Journal of Urban Planning and Development © ASCE, Volume 133(1), March 2007, pp 43-50.

21. Lu, X. and S. Gao. Using Travel Demand Forecasting Software for Emergency Planning in Small and Medium-Sized Regions. TRB 89th Annual Meeting Compendium of Papers DVD, Paper # 10-1415. Transportation Research Board of the National Academies, Washington, D.C., 2010.

22. Mastrogiannidou, C., Boile, M, Golias, M., Theofanis, S. and A. Ziliaskopoulos. Transit-Assisted Emergency Evacuation of High-Density Clusters in Urban Areas. TRB 88th Annual Meeting Compendium of Papers DVD, Paper # 09-3439. Transportation Research Board of the National Academies, Washington, D.C., 2009.

23. Mei, B. Development of Trip Generation Models of Hurricane Evacuation. MSCE Thesis in the Department of Civil and Environmental Engineering. Louisiana State University, Agriculture and Mechanical College. August 2002.

24. Naghawi, H and B. Wolshon. Transit-Based Emergency Evacuation Simulation Modeling. Journal of Transportation Safety & Security, 2: 2, pp 184-201. June 2010.

25. Quigley, B. Six Months after Katrina: Who Was Left Behind - Then and Now. Online document published on commondreams.org on February, 2006. Retrieved from: http://www.commondreams.org/views06/0221-36.htm

26. Renne, J. L., T. W. Sanchez and T. Litman. National Study on Carless and Special Needs Evacuation Planning: A Literature Review. Publication FTA-LA-26-8001. Federal Transit Administration (FTA), U.S. Department of Transportation, 2008.

27. Transportation Research Board (TRB). The Role of Transit in Emergency Evacuation. TRB Special Report 294. Transportation Research Board of the National Academies, Washington DC, 2008.

28. Turner, D.S., B. Wolshon, S. Islam, W.A. Evans, V.P. Sisiopiku and M.D. Anderson. Issues, Practices, and Needs for Communicating Evacuation Information with Vulnerable Populations. TRB 89th Annual Meeting Compendium of Papers DVD, Paper # 10-3775. Transportation Research Board of the National Academies, Washington, D.C., 2010.

29. U.S. Fire Administration (USFA). Chemical Fire in Apex, North Carolina. U.S. Fire Administration/Technical Report Series. Publication USFA-TR-163. Department of Homeland Security and the U.S. Fire Administration (USFA) Major Fire Investigations Program, 2008. Retrieved from: http://www.usfa.fema.gov/downloads/pdf/publications/tr_163.pdf

30. Wendell, C. Emergency Evacuation Report Card 2006; 25 Urban Areas Could Face Greater Challenges than New Orleans Experienced after Hurricane Katrina. American Highway Users Alliance. Retrieved from: http://www.highways.org/wp-content/uploads/2006/10/Evacuation_Study-FINAL.pdf

31. Wilson-Goure, S., Houston, N. & Easton, A.V. Assessment of State of the Practice and State of the Art in Evacuation Transportation Management. Task Two: Literature Search for Federal Highway Administration (ITS-JPO). McLean, Virginia. 2006a.

32. Wilson-Goure, S., N. Houston and A.V. Easton. Assessment of State of the Practice and State of the Art in Evacuation Transportation Management. Task Three, Technical Memorandum for Federal Highway Administration (ITS-JPO) on Case Studies. Publication FHWA-HOP-08-014. Federal Highway Administration, the *ITS* Joint Program Office (*JPO*), U.S. Department of Transportation, McLean, Virginia. 2006b.

33. Wolshon, B. Transportation's Role in Emergency Evacuation and Reentry: A Synthesis of Highway Practice. National Cooperative Highway Research Program (NCHRP) Synthesis-392. Transportation Research Board of the National Academies, Washington, DC. January, 2009.

34. Zheng, H., Chiu, Y.C., Mirchandani, P.B. and M. Hickman. Modeling of Evacuation and Background Traffic for an Optimal Zone-Based Vehicle Evacuation Strategy. TRB 89th Annual Meeting Compendium of Papers DVD, Paper # 10-3093. Transportation Research Board of the National Academies, Washington, D.C., 2010.

35. Zhao, F., K. Xing, S. Yang, C. Lu and S. Chung. Hurricane Evacuation Planning for Special Needs Populations. Technical Report of the U.S. Department of Transportation Federal Transit Administration (FTA). Report No: FTA-FL-04-7104-2010.04. May, 2010.

36. Zimmerman, C., Brodesky, R. & Karp, J. Using Highways for No-Notice Evacuations: Routes to Effective Evacuation Planning Primer Series. Technical Report of the U.S. Department of Transportation Federal Highway Administration (FHWA). Report No: FHWA-HOP-08-003. Columbus, OH. November, 2007.

Domain 3
Project 1

Distracted Driving in Teens with and without ADHD

Abstract

Objective: To determine the effect cell phone conversation or text messaging has on motor vehicle collision-related injury risk in teens with or without Attention Deficit/Hyperactivity Disorder – Combined Type (ADHD-C) and whether a computerized cognitive intervention improves driving performance of these individuals.

Patients or Other Participants: Teens (average age 17 years) with a diagnosis of ADHD-C (N=22) were matched with typically developing controls (N=21). Participants randomly assigned to the intervention completed 9 hours of training on RoadTour™ over 6 weeks. Four indicators of driving performance were recorded by the simulator: (a) deviation of lane position; (b) reaction time; (c) average driving speed; (d) total number of motor vehicle collisions.

Results: The repeated measures analysis of variance revealed main effects for driving condition on (a) reaction time ($F = 4.23$, $p = 0.02$), (b) motor vehicle collisions ($F = 3.31$, $p = 0.04$), and (c) number of deviations ($F = 21.68$, $p < 0.001$). The repeated measures analysis of variance revealed significant intervention effects for (a) motor vehicle crashes and (b) lane deviations.

Conclusions: Distraction negatively impacts driving performance of novice teenager drivers, regardless of ADHD-C status. Preliminary evidence suggests that the RoadTour™ intervention may be an effective tool for improving driving performance of novice drivers.

What's Known on This Subject

Motor vehicle collisions are the leading cause of mortality among teenagers. Evidence suggests this risk is higher while engaging in cell phone conversations and text messaging because the cognitive, physical and visual demands of these tasks interfere with driving performance.

What This Study Adds

This study is among the first to experimentally examine the potential increased risk cell phone conversations or text messaging introduce for typically developing, teen drivers and their same age peers who have been diagnosed with Attention Deficit/Hyperactivity Disorder – Combined Type.

Introduction

Motor vehicle collisions (MVCs) are the leading cause of mortality among teenagers, accounting for approximately 1 in 3 deaths among persons between the ages of 16 and 19.[1] A number of factors increase MVC crash risk for novice drivers: (a) they may be particularly vulnerable to distraction given their poor behavioral control, (b) they may be less able to anticipate and identify hazards, (c) they may be more willing to take risks,[2] and, (d) they may lack the skill and judgment required to navigate effectively and safely.[3]

Cell phone conversations and text messaging impose certain cognitive, physical and visual demands that interfere with driving performance given the verbal, motor and attention processing required to successfully engage in either task while driving.[4] It is well established in the literature that cell phone use compromises the performance of young adult drivers,[5-8] but few studies have examined cell phone distraction in novice, teen drivers.[9] Given the cognitive, visual, and motor constraints required to drive and compose a text message simultaneously, the effect of text messaging on driving performance may be even more detrimental than the effect of

engaging in a cell phone conversation. Though multitasking is demanding for all drivers, it may greatly increase the risk and severity of MVC-related injury for novice, teen drivers because of their relative inexperience.[10]

Another group shown to be at-risk for poor driving performance are those who have been diagnosed with Attention-Deficit/Hyperactivity Disorder (ADHD). ADHD is a behavior disorder affecting an estimated 3% to 7% of the population, with males overrepresented at a ratio of 3 to 1.[11] Teenagers with the Combined Type of ADHD (ADHD-C) are characterized as having impulsive, hyperactive, and inattentive behavior patterns,[12] as well as deficits in executive functioning.[11] These cognitive and behavioral deficits may be implicated in the driving environment. Studies have shown that teens with ADHD-C are more likely to engage in risky driving, but few studies have experimentally examined the potential increased risk that cell phone conversations or text messaging may introduce for typically developing, novice, teen drivers and their same age peers who have been diagnosed with ADHD-C.[13, 14]

The purpose of the study was to determine the effect(s) of engaging in a cell phone or text messaging conversation had on increased MVC-related injury risk in teens with (and without) ADHD-C. Specifically, this study compared the driving performance of teenagers with a diagnosis of ADHD-C and a matched control sample without ADHD-C operating a virtual driving simulator while (a) engaged in a cell phone conversation, (b) engaged in a text messaging exchange, or (c) undistracted (Specific Aim 1). We hypothesized teens would exhibit riskier driving behavior during the text messaging condition given that it may be more cognitively demanding than a cell phone conversation, and we believed that the impact of distraction would be significantly greater among those with ADHD-C. In addition, we compared the short-term changes in driving performance of teens with and without ADHD-C in a virtual driving simulator

as a function of a cognitive training intervention (Specific Aim 2). We hypothesized that driving performance would significantly improve post-cognitive training intervention for both groups.

Patients and Methods

Participants

This prospective intervention study was conducted at the University of Alabama at Birmingham's Translational Research for Injury Prevention Laboratory® between June 2009 and September 2010. This study was approved by the University of Alabama at Birmingham's Institutional Review Board for the Protection of Human Subjects. Written Informed Consent (parents) and assent (minors) were obtained.

A total of twenty-two, 16- to 18-year-old teenagers with a previous diagnosis of ADHD-C and twenty-one typically developing controls matched on gender, ethnicity, and months of driving experience since receiving permit were recruited. Teenagers with ADHD-C were recruited through local behavioral assessment clinics and from the community. Controls were recruited from the community.

Inclusion criteria for the two groups included those who regularly used a cell phone with text messaging capability and who were willing to use their personal cell phone during each testing session. Participants were required to possess a valid driver's license and to have access to a home computer in which to engage in the cognitive intervention, if randomly assigned to do so. Exclusion criteria for both groups included physical disabilities that precluded their ability to participate fully in any aspect of the experimental protocol.

Because certain comorbidities are common in persons with ADHD-C, participants with comorbidities were not excluded. Those with ADHD-C who were taking physician-prescribed

stimulant medications were not excluded. Instead, they were instructed to forego taking their typical medication dosage during the 12 hours prior to their appointment. This was done for a separate but related study the results of which are not reported herein. However, those who were taking prescribed medications other than stimulants that remain active in the body for up to two weeks were excluded due to their inability to forego taking medication on the day of the session.

Procedure

Tasks were administered to the experimental and control group participants by a team of trained student research assistants who used standardized protocols. Figure 1 depicts participant flow through the study.

[Figure 1]

Session One Activities: Pre-Intervention. Each participant received instruction in the operation and use of the virtual driving simulator during a calibration session prior to actual data collection. Participants drove a standardized scenario without the introduction of a distraction until they achieved stable driving performance to make certain they could demonstrate a minimum standard of proficiency with regard to basic driving tasks.

Participants then engaged in the driving task which consisted of three, five mile driving conditions presented in random order. The three conditions were: (a) no distraction, during which participants anticipated receiving a text message or phone call but received neither, (b) a cell phone conversation, where participants received a cell phone call immediately upon beginning the scenario and subsequently engaged in a naturalistic phone conversation for the

remainder of the scenario, or (c) a text message exchange, wherein participants received a text message immediately upon beginning the scenario and engaged in reading and responding to text messages for the remainder of the scenario. Cell phone and text messaging conditions were structured to mimic a typical, initial conversation between two persons not previously introduced.

Following the first simulator driving session, all participants completed several brief paper-and-pencil questionnaires documenting basic demographic information, cell phone and text messaging use, and driving history/experience. Participants drove in a second simulator driving session after completing the questionnaires to evaluate the effect of medication for those with ADHD-C (results not reported herein). All participants drove twice during the first session to eliminate the possibility of additional practice bias for those with ADHD-C. Subsequently, half the participants were randomly selected to receive a cognitive intervention computer program at the end of the session. Those assigned to the intervention received the computer software and instructions for its use. All participants received monetary compensation for participation.

Cognitive Intervention. Those randomly assigned to the intervention condition were asked to complete a minimum of 9 hours of training on the Posit Science™ subtest RoadTour™. RoadTour™ is training program that consists of 90 minutes of training over a 6 week time period. Compliance was verified and documented when the participant connected to the internet via a central server at Posit Science which logged each training bout.[15]

Session Two Activities: Post-Intervention. Procedures for this session were similar to those in session one (see Figure 1). Before dismissal, study participants were debriefed and received monetary compensation for their participation.

Measures

Driving Simulator. Participants engaged in a computerized driving simulation task to provide a measure of driving performance under specified conditions of interest (STISIM Drive, Systems Technology Inc., Hawthorne, CA). The simulation was displayed on three, 20" LCD computer monitors, providing a 135° field of view (Figure 2). Participants sat within the simulator's passenger compartment which provided a view of the roadway and dashboard instruments, including a speedometer. The vehicle was controlled by moving a steering wheel in a typical driving manner and depressing accelerator and brake pedals accordingly. An on-board stereo sound system provided naturalistic engine sounds, external road noise, and sounds of passing traffic.

[Figure 2]

The driving scenarios featured a two lane, bi-directional road and day-time suburban scenery. Participants were required to navigate through a number of potentially hazardous situations. Speed limits varied within the scenario but remained constant across conditions.

Four indicators of driving performance were electronically recorded by the simulator:

(a) Deviation of lane position

(b) Reaction time

(c) Average driving speed

(d) Total number of motor vehicle collisions

Cognitive Intervention: Speed-of-Processing Intervention (RoadTour™). RoadTour™ is the latest version of the Useful Field of View (UFOV) speed-of-processing intervention designed to improve the efficiency and accuracy of visual information processing and the ability to perform complex visual attention tasks.[16] Users are trained to improve the speed and accuracy with which they identify and locate visual information using a divided attention format.[16] RoadTour™ retains the tasks used in previous efficacy trials with older adults, [16-21] but modifies the delivery platform so that it can be easily self-administered. The UFOV intervention is associated with improvements in everyday functional abilities[17] and driving skills.[18]

Data Analysis

A repeated measures analysis of variance (RM ANOVA) using a mixed model approach estimated the association between distraction condition and driving behaviors. The mixed model approach allowed the analysis to account for factors that could affect driving ability. [22, 23]

A RM ANOVA regression model was used to estimate the effect of a cognitive training intervention on driving performance in a virtual driving simulator. For each measure of driving behavior, separate models were run for each of three distraction conditions. An interaction between intervention and ADHD was used to determine whether the effect of the intervention differed by whether the individual had ADHD. Contrasts were used to produce *p*-value estimates for the comparison of the driving performance variables pre- and post-intervention. *P*-values less than 0.05 were considered significant for all analyses. All analyses were conducted using SAS version 9.2.

Results

Teens averaged 17 years of age with approximately 14% of the sample represented by racial minorities (Table 1). The sample included more males than females, which was expected as more males have a diagnosis of ADHD-C. Teens with ADHD-C exhibited significantly greater levels of childhood ADHD symptom severity than controls.

[Table 1]

Specific Aim One

"To compare the driving performance of teenagers operating a virtual driving simulator while (a) engaged in a cell phone conversation, (b) engaged in a text messaging exchange, or (c) undistracted"

Adjusting for driving period and medication use, significant main effects of condition emerged for three of the four driving behaviors examined. There was a significant main effect of distraction condition on reaction time ($F = 4.23$, $p = 0.02$). Reaction time was significantly longer in the texting period when compared to the cell phone ($\beta = .05$, $p = 0.02$) and the no distraction period ($\beta = .05$, $p = 0.01$). There was no difference in reaction time between the cell phone and no distraction conditions ($\beta = .00$, $p = 0.87$).

[Figure 3]

A significant main effect of condition emerged for number of MVCs ($F = 3.31$, $p = 0.04$), with more occurring during the cell phone condition than during the no distraction period ($\beta = 0.2742$, $p = 0.01$). While the number of crashes was higher for the texting period compared

to the no distraction period, this difference was not significant (β=0.14, p=0.18) nor was the difference between the cell phone and text messaging conditions (β=0.13, p=0.22).

[Figure 4]

A significant effect of condition on the number of deviations was revealed (F = 21.68, $p < 0.001$). This effect was limited to the texting condition compared to the no distraction condition (β = 1.72, p < 0.001) and to the cell phone distraction condition (β = 1.72, p < 0.001).

[Figure 5]

While there was no difference in mean speed among the distraction conditions (F = 0.20, p = 0.82) compared to the no distraction condition, mean speed was lower for both the texting (β = -0.38, p =0.57) and cell phone use (β = -0.35, p = 0.60) conditions.

Specific Aim Two

"To compare short-term changes in driving performance of teens with and without ADHD-C in a virtual driving simulator as a function of a cognitive training intervention"

There was no significant effect of the intervention on the mean number of lane deviations for the cell phone and no distraction driving periods; however, during the texting condition the mean number of lane deviations significantly declined post-intervention for individuals without ADHD (6.52 vs. 2.17, p<0.001) (Table 2). This effect was not present among those with ADHD

(6.91 vs. 5.87, p=0.65). The difference in the effect of the intervention was moderately significant by diagnosis of ADHD (p=0.05).

For the number of MVCs, there was no effect of the intervention during the cell phone distraction period. For the no distraction period, a significant reduction in the number of MVCs was observed among those without ADHD (0.89 vs. 0.18, p=0.0205). During the text messaging distraction period, a significant reduction in MVCs was observed among those with ADHD (1.07 vs. 0.39, p=0.04). No difference in the effect of the intervention between those with and without ADHD was observed, and the number of crashes decreased post-intervention for each model. There was no effect of the cognitive intervention on average speed and reaction time during the driving simulation.

[Table 2]

Discussion

Findings from Specific Aim 1 suggest that distraction negatively impacts driving performance of novice teenage drivers, regardless of ADHD status. This is in contrast to our hypothesis that the negative impact of distraction would be greatest among teens with ADHD-C. Though previous studies have demonstrated that individuals with ADHD exhibit impairments in their general driving performance, [13, 14] these studies have not compared the impact of distraction across individuals with and without ADHD-C in their analyses. Our findings are consistent with the only study to assess the impact of cell phone conversation as a distraction across these two populations,[8] which found that when distracted by cell phone conversations, that under more

challenging driving conditions young adults, ages 17 to 24, with ADHD did not exhibit significantly more detriments in driving than did the young adults without ADHD.

Text messaging did not globally worsen driving performance as indicated by our driving performance measures. Rather, text messaging caused driving performance to deteriorate on two of the four driving performance measures: reaction time and lane deviations. It is not surprising that text messaging would impact these driving performance measures as these are likely sensitive to the amount of time required to take one's eyes off of the road to read, compose, and send a text message. This proposition is consistent with an earlier simulator study which found that time spent with eyes off of the road increased by 400% when engaging in text messaging while driving compared to a non-distracted driving condition.[24] Despite not reaching statistical significance, participants in our series experienced more collisions during the text messaging condition compared to a period of driving when they were not distracted, and inspection of the statistical means suggests that when distracted by either cell phone conversation or text messaging, individuals slowed their driving speed. Reduced driving speed has been interpreted by others as an indicator of impaired driving performance and reduced driver efficiency.[7, 25] It is likely there was insufficient statistical power to detect significant differences on these driving indicators. Despite this, our findings readily confirm that distracted driving, whether in the form of a cell phone conversation or text messaging, negatively impacts driving performance.

Findings from Specific Aim 2 provide preliminary evidence that a cognitive speed of processing intervention may be an effective tool for improving driving performance with novice drivers. The six-week RoadTour™[16] intervention improved driving performance of all participants in our study; however, the pattern of improvement differed across diagnostic groups. Specifically, the frequency of lane deviations in the texting condition and crashes in the non-

distracted condition was reduced post-intervention in novice drivers without ADHD while the number of crashes exhibited by novice drivers with ADHD was reduced in the texting condition post-intervention. This finding is consistent with our hypothesis that the intervention would improve driving performance in both groups.

Every study has limitations, and this study is no exception. Our study examined the driving performance of only forty-three teenagers; a modest sample size especially given that half the participants were further divided by ADHD diagnosis. A virtual driving simulator was used in our study to allow extensive data collection in a safe environment, but no simulator can completely reproduce a real world driving situation. Finally, the self-administered cognitive speed-of-processing intervention includes certain game elements to stimulate the interest of potential users. However, given the advanced technologies to which teenagers are currently exposed in common video games, the training program may still prove ultimately disinteresting to younger study populations.

Conclusion

The present study not only underscores that distracted driving is impairing to all novice drivers, not just those with attention difficulties, but also provides empirical evidence of the positive impact of a cognitive speed-of-processing intervention on improving teen driving performance. A study examining a larger sample size must be conducted if the results can be reliably generalized to the US teen population. Future studies might consider a naturalistic approach so as to observe teen driving during a routine day, as well as the impact of UFOV training, under actual roadway conditions.

Acknowledgements

Special thanks to Translational Research for Injury Prevention Laboratory Research Assistants for data collection and entry. Also, we would like to acknowledge the support and guidance of Dr. Karlene Ball, Dr. Flaura Winston, Dr. Jack Berry, Jeffrey Foster, Uwe Meissner, David Ball, David Benz, and Peter Delahunt through various development stages of this project.

References

1. National Center for Injury Prevention and Control [NCIPC]. *WISQARS™ (Web-based Injury Statistics Query and Reporting System)*. Retrieved April 20, 2009 from www.cdc.gov/ncipc/wisqars.
2. Lee JD. Technology and teen drivers. *J Safety Res*. 2007;38:203-213.
3. McGwin G, Brown DB. Characteristics of traffic crashes among young, middle-aged, and older-drivers. *Accident Anal Prev.* 1999;31:181-198.
4. Charlton SG. Driving while conversing: Cell phones that distract and passengers who react. *Accident Anal Prev.* 2009;41:160-173.
5. Caird JK, Willness CR, Steel P, Scialfa C. A meta-analysis of the effects of cell phones on driver performance. *Accident Anal Prev.* 2008*;40:*1282-1293.
6. Drews FA, Pasupathi M, Strayer DL. Passenger and cell phone conversations in simulated driving. *J Exp Psychol Appl.* 2008;*14:*392-400.
7. Horrey WJ, Wickens CD, Consalus KP. Modeling drivers' visual attention allocation while interacting with in-vehicle technologies. *J Exp Psychol Appl.* 2006;*12:*67-78.
8. Reimer B, Mehler B, D'Ambrosio LA, Fried R. The impact of distractions on young adult drivers with attention deficit hyperactivity disorder (ADHD). *Accident Anal Prev.* 2010;42: 842-851.
9. Shinar D, Tractinsky N, Compton R. Effects of practice, age, and task demands on interference from a phone task while driving. *Accident Anal Prev.* 2005;*37*:315-326.
10. Neyens DM, Boyle LN. The influence of driver distraction on the severity of injuries sustained by teenage drivers and their passengers. *Accident Anal Prev.* 2008;*40:*254-259.
11. Barkley RA. *ADHD and the nature of self-control.* New York: Guilford Press; 1997.
12. American Psychiatric Association. *Diagnostic and statistical manual of mental disorders Fourth Edition.* 1994; Washington, DC: Author.
13. Barkley RA, Guevremont DG, Anastopolous AD, DuPaul GJ, Shelton TL. Driving-related risks and outcomes of attention-deficit/hyperactivity disorder in adolescents and young adults: A 3-5 year follow-up survey. *Pediatrics*. 1993;92:212-218.
14. Barkley RA, Murphy KR, DuPaul GJ, Bush T. Driving in young adults with attention deficit hyperactivity disorder: Knowledge, performance, adverse outcomes, and the role of executive functioning. *J Int Neuropsychol Soc.* 2002; 8: 655-672.
15. Posit Science. Posit science: brain training software. Retrieved July 27, 2011 at http://www.positscience.com/our-products/insight.
16. Ball KK, Berch DB, Helmers KF, Jobe JB, Leveck MD, Marsiske M, Morris JN, Rebok GW, Smith DM, Tennstedt SL, Unverzagt FW, Willis SL, Advanced Cognitive Training for Independent and Vital Elderly Study Group. Effects of cognitive training interventions with older adults: a randomized controlled trial. *JAMA.* 2002;288:2271-2281.
17. Edwards JD, Wadley VG, Vance DE, Wood K, Roenker DL, Ball KK. The impact of speed of processing training on cognitive and everyday performance. *Aging Ment Health.* 2005;9:1-10.
18. Roenker DL, Cissell GM, Ball KK, Wadley VG, Edwards JD. Speed-of-processing and driving simulator training result in improved driving performance. *Human Factors*. 2003;45:218-233.

19. Vance D, Dawson J, Wadley VG, Edwards JE, Roenker DL, Rizzo M, Ball K. The accelerate study: The longitudinal effect of speed of processing training on cognitive performance of older adults. *Rehabil Psychol.* 2007;52:89-96.
20. Wadley VG, Benz R, Ball KK, Roenker DL, Edwards JD, Vance DL. Development and evaluation of home-based speed-of-processing training for older adults. *Arch Phys Med Rehabil.* 2006;87: 757-763.
21. Willis SL, Tennstedt SL, Marsiske M, Ball K, Elias J, Koepke KM, Morris JN, Rebok GW, Unverzagt FW, Stoddard AM, Wright E, for the ACTIVE Study Group. Long- term effects of cognitive training on everyday functional outcomes in older Adults. *JAMA.* 2006;296:2805-2814.
22. Barkley RA. *Defiant Children: A Clinician's Manual for Assessment and Parent Training.* 2nd ed. New York: The Guilford Press; 1997:188-209.
23. Fitzmaurice G, Davidian M, Verbeke G, Molenberghs G. *Longitudinal Data Analysis*. Boca Raton, FL: Chapman and Hall/CRC; 2008.
24. Hosking S, Young K, Regan M. The effects of text messaging on young novice driver performance. Monash University Accident Research Centre, Report No. 246. 2006.
25. Stavrinos D, Garner AA, Franklin CA, Ball KK, Sisiopiku V, Ball D, Fine PR. Impact of distracted driving on traffic flow parameters. 2010; Manuscript under review.

Figures

Figure 1. Participant Flow Through Study

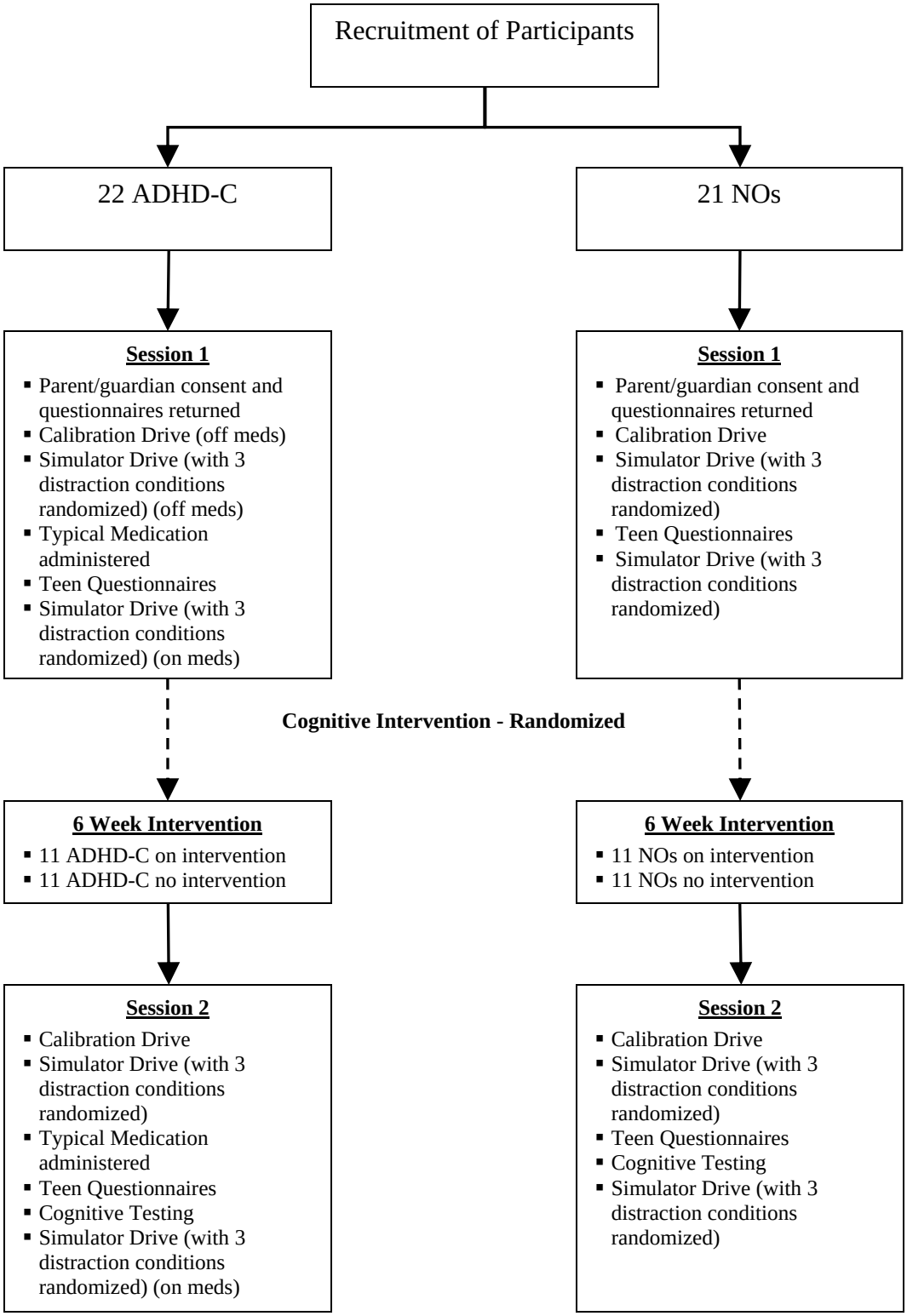
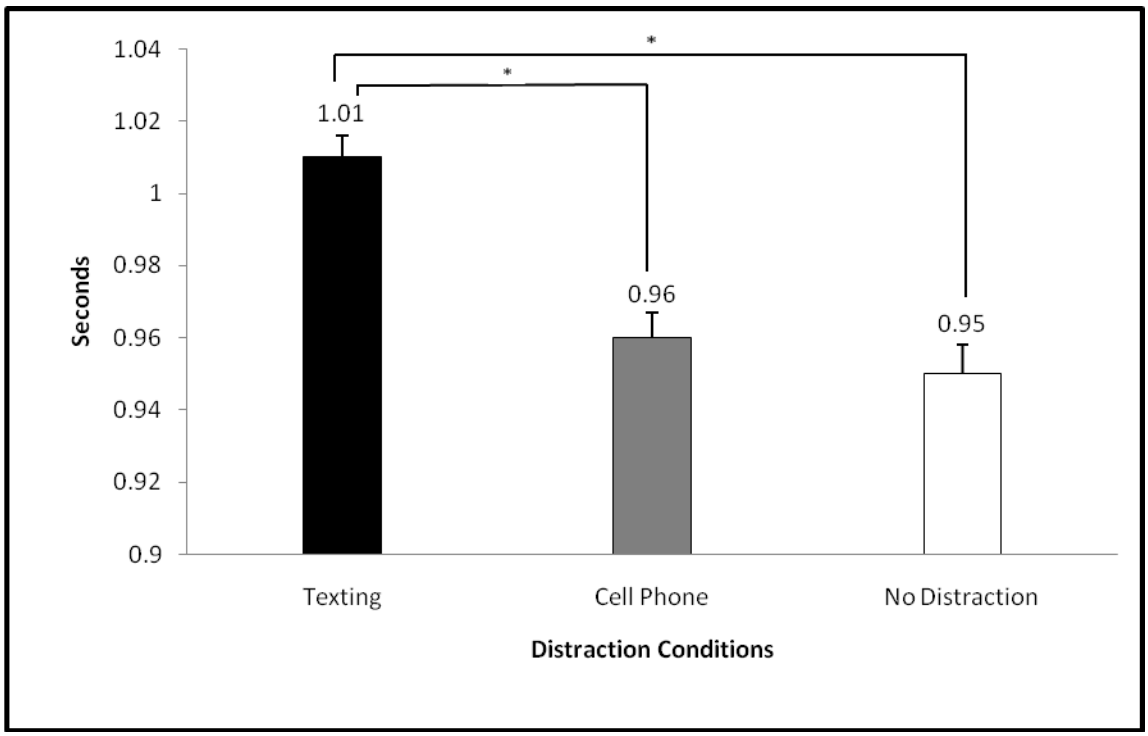


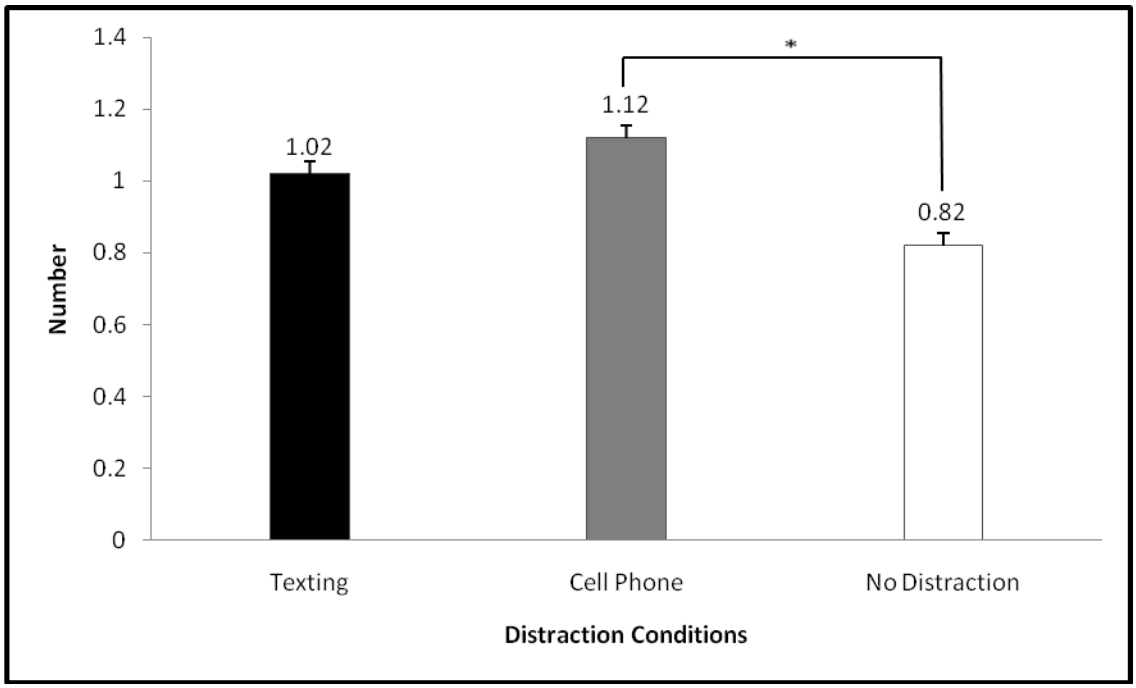
Figure 2. STISIM Driving Simulator

Figure 3. Average Reaction Times Across Distraction Conditions



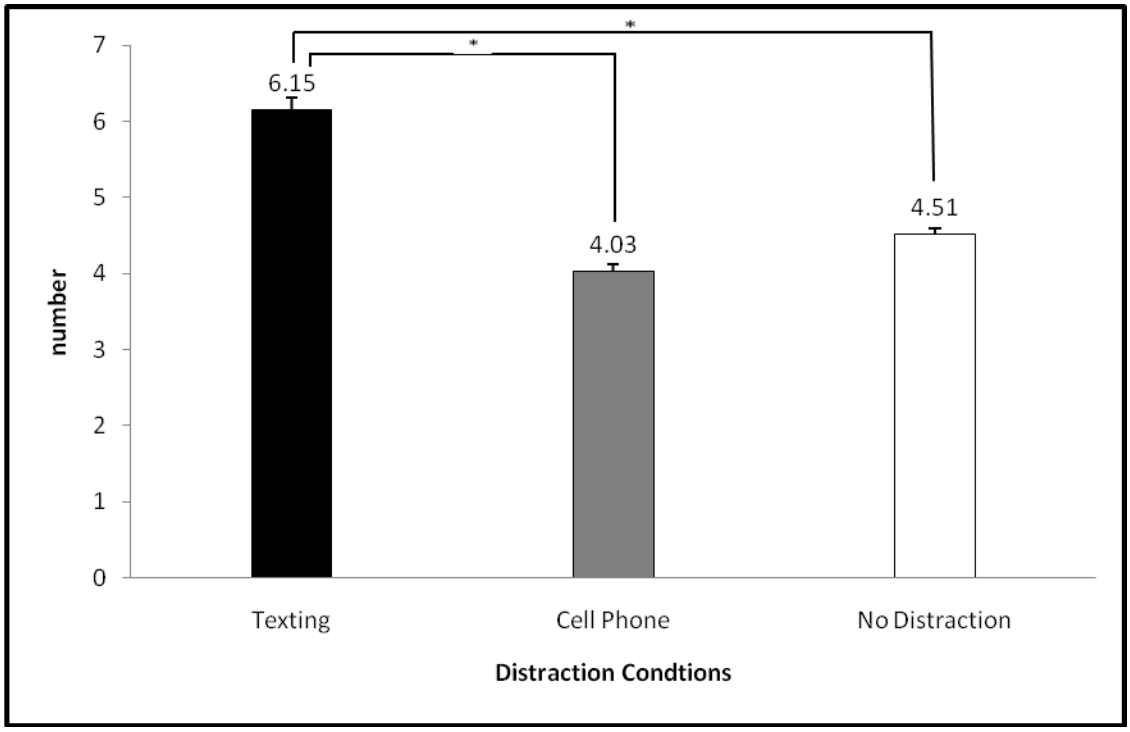
*$p < 0.05$

Figure 4. Average MVCs Across Distraction Conditions



*$p < 0.05$

Figure 5. Average Lane Deviations Across Distraction Conditions



*$p < 0.05$

Tables

Table 1. Demographic Characteristics of Sample by Diagnostic Group

	ADHD-C		Control	
Demographic Characteristic	Mean	SD	Mean	SD
Age (years)	17.07	0.92	17.16	0.94
Childhood ADHD Symptom Severity (total score)	**26.23**	**14.61**	**14.62**	**7.55**
	Frequency	Percent	Frequency	Percent
Gender				
Male	16	72.7	15	76.2
Female	6	23.7	6	23.80
Ethnicity				
Caucasian	19	86.4	18	85.7
Minority	3	13.6	3	14.3

Note. **Bold** indicates $p < 0.05$. ADHD symptoms are teen self-report of childhood behavior (ages 5-12).

Table 2. The effect of a cognitive training intervention on driving performance in a virtual driving simulator by diagnosis of ADHD-C and type of distraction

	No distraction				Texting				Cell-phone			
	Pre	Post	p-value*	p-$value_{int}$*†	Pre	Post	p-value*	p-$value_{int}$*†	Pre	Post	p-value*	p-$value_{int}$*†
Speed												
ADHD+	29.97	29.75	0.14	0.44	30.65	30.20	0.95	0.27	30.32	31.00	0.67	0.88
ADHD-	32.56	34.31	0.35		30.86	33.59	0.20		31.38	32.37	0.50	
Deviations												
ADHD+	5.24	5.48	0.10	0.72	6.91	5.87	0.65	0.05	4.16	5.28	0.14	0.25
ADHD-	3.70	3.58	0.87		6.52	2.17	< 0.001		3.67	3.68	0.99	
Reaction time												
ADHD+	0.97	0.97	0.64	0.87	1.01	1.01	0.91	0.82	0.95	0.95	0.99	0.92
ADHD-	0.91	0.91	0.89		0.99	0.98	0.77		0.95	0.94	0.90	
Crashes												
ADHD+	1.02	0.36	0.07	0.90	1.07	0.39	0.04	0.70	1.20	0.72	0.19	0.57
ADHD-	0.89	0.18	0.02		1.06	0.54	0.08		1.09	0.84	0.37	

* Estimated from repeated measures ANOVA
† p-value for interaction between ADHD and intervention

Domain 3
Project 2

Assessment of Global Positioning System Utilization in Emergency Medical Services

Enhancement of Global Positioning System Utilization in Emergency Medical Services
The purpose of this study is to determine the average cost per mile to operate EMS vehicles and calculate the potential financial impact on EMS service providers by purchase and utilization of GPS navigators based upon the foundation that utilizing GPS navigators in ambulances reduces miles traveled1.

An invitation to participate in the study was developed (see attachment A) and forwarded to Dr. John Campbell at the Alabama Department of Public Health, Office of EMS and Trauma (ADPH/OEMS&T). In turn, Dr. Campbell disseminated the invitation to all Regional EMS Directors via email, who also forwarded the invitation to their respective EMS Service Providers. The invitation included background information, instructions to complete the survey, and a URL to direct participants to the survey tool on-line.

Over a period of approximately 3 months, 26 EMS agencies responded to the survey. Of these, 17 agencies reported they do not keep tabulation of fleet mileage. Of the remaining nine agencies, two were removed for the reason that their fleet consisted primarily of fire trucks, and one was unable to provide the average cost of new vehicles. Numerous attempts to increase the number of survey respondents through contact with Regional EMS Directors and individual EMS Service Providers proved unsuccessful, as most services report they do not track fleet mileage. Using an alternate route, we attempted to obtain the mileage information from ADPH/OEMS&T, as beginning and ending mileages is a required reportable field. However, according to Dr. Campbell services are not recording this information.

Be that as it may, based upon the information received from the remaining six EMS service providers, we are able to produce the following results:

The average cost to operate an ambulance is $1.46 per mile. Under the assumption of a reduction of 1.3 mile per call from the initial study, EMS services would save $1.90 per each call responded to while using GPS navigators ($1.46 X 1.3 miles per call). Applying a $500 purchase price per GPS navigator, we can project savings (per ambulance) on an annual and life expectancy basis (of the GPS Navigator).

PROJECTED SAVINGS Daily Run Volume/Ambulance	Yearly Run Volume/Ambulance	1st year Savings	3-year Savings
1	365	$194	$1,581
2	730	$886	$3,661
3	1,095	$1,581	$5,742
4	1,460	$2,274	$7,822
5	1,825	$2,964	$9,902
6	2,190	$3,661	$11,983
7	2,555	$4,356	$14,064
8	2,920	$5,048	$16,144
9	3,285	$5,742	$18,225
10	3,650	$6,435	$20,305

ASSUMPTIONS: $1.46 per mile to operate an ambulance, 1.3 miles saved per call utilizing GPS navigators, $500 cost of new GPS navigator, three-year useful life of GPS navigator

Applying this methodology to the six survey respondents, we can project the potential financial impact over the GPS Navigators expected three year useful life for these agencies.

RESULTS of AMBULANCE SERVICE: A Total Miles Driven by Fleet	332,543
Number Active Ambulances in Fleet	9 (Type III)
Number Emergency Calls in 2009	6,958
Maintenance & Operating Cost 2009	$216,044
Average cost New Ambulance	$125,000
Avg. Years of Service per Ambulance	4
Calculated	**Results**
Average Annual Mileage per Ambulance	36,949
Annual Call Volume per Ambulance	773 (64 per month)
Annual Maint. & Op. Cost per Ambulance	$24,005
Annualized Value of Ambulance	$25,000
Annual Ambulance Cost	$49,005
Average Cost / Mile to Operate	$1.33
Months to Pay Off GPS unit ($500/unit)	4.5
1st year projected Savings with GPS	$833 / Ambulance $7,497 for Fleet
3-yr projected savings with GPS	$3499 / ambulance $31,490 for Fleet)

Calculations: Average Annual Mileage per Ambulance = Total Miles Driven by Fleet / Number Active Ambulances in Fleet
Annual Call Volume per Ambulance = Number of Emergency Calls in 2009 / Number Active Ambulances in Fleet
Annual Maint. & Op. Cost per Ambulance = Maintenance & Operating Cost 2009 / Number Active Ambulances in Fleet
Annualized Value of Ambulance = (Average cost New Ambulance–20% Residual Value) / Avg. Years of Service per Ambulance
Annual Ambulance Cost = Annual Maint. & Op. Cost per Ambulance + Annualized Value of Ambulance

Average Cost / Mile to Operate = Annual Ambulance Cost / Average Annual Mileage per Ambulance
Months to pay Off GPS unit = $500 / (Monthly Call Volume X Average Cost / Mile to Operate X 1.3 Mile Saved per Call)
1st year projected Savings with GPS = Annual Call Volume per Ambulance X Average Cost / Mile to Operate X 1.3 Mile Saved per Call - $500
3-yr projected savings with GPS = (Annual Call Volume X 3) X Average Cost / Mile to Operate X 1.3 Mile Saved per Call - $500

RESULTS of AMBULANCE SERVICE: B

Total Miles Driven by Fleet	75,000
Number Active Ambulances in Fleet	4 (Type II)
Number Emergency Calls in 2009	214
Maintenance & Operating Cost 2009	$41,000
Average cost New Ambulance	$67,000
Avg. Years of Service per Ambulance	6
Calculated	**Results**
Average Annual Mileage per Ambulance	18,750
Annual Call Volume per Ambulance	54 (4 per Month)
Annual Maint. & Op. Cost per Ambulance	$10,250
Annualized Value of Ambulance	$8,933
Annual Ambulance Cost	$19,183
Average Cost / Mile to Operate	$1.02
Months to Pay Off GPS unit ($500/unit)	84
1st year projected Savings with GPS	($429) / Ambulance ($1,715) for Fleet
3-yr projected savings with GPS	($287) / Ambulance ($1,146) for Fleet

RESULTS of AMBULANCE SERVICE: C

Total Miles Driven by Fleet	70,520
Number Active Ambulances in Fleet	2 (Type III)
Number Emergency Calls in 2009	1,200
Maintenance & Operating Cost 2009	$20,183
Average cost New Ambulance	$100,000
Avg. Years of Service per Ambulance	4
Calculated	**Results**
Average Annual Mileage per Ambulance	35,260
Annual Call Volume per Ambulance	600 (50 per Month)
Annual Maint. & Op. Cost per Ambulance	$10,092
Annualized Value of Ambulance	$20,000
Annual Ambulance Cost	$30,092
Average Cost / Mile to Operate	$0.85
Months to Pay Off GPS unit ($500/unit)	9
1st year projected Savings with GPS	$166 / Ambulance $331 for Fleet
3-yr projected savings with GPS	$1,497 / Ambulance $2,994 for Fleet

RESULTS of AMBULANCE SERVICE: D

Total Miles Driven by Fleet	3,500
Number Active Ambulances in Fleet	1 (Type III)
Number Emergency Calls in 2009	80
Maintenance & Operating Cost 2009	$1,500
Average cost New Ambulance	$100,000
Avg. Years of Service per Ambulance	15
Calculated	**Results**
Average Annual Mileage per Ambulance	3,500
Annual Call Volume per Ambulance	80 (7 per Month)
Annual Maint. & Op. Cost per Ambulance	$1,500
Annualized Value of Ambulance	$5,333
Annual Ambulance Cost	$6,833
Average Cost / Mile to Operate	$1.95
Months to Pay Off GPS unit ($500/unit)	30
1st year projected Savings with GPS	($297) per Ambulance ($297 for Fleet)
3-yr projected savings with GPS	($109) per Ambulance ($109) for Fleet)

RESULTS of AMBULANCE SERVICE: E

Total Miles Driven by Fleet	54,963
Number Active Ambulances in Fleet	3 (Type I)
Number Emergency Calls in 2009	1,416
Maintenance & Operating Cost 2009	$25,915
Average cost New Ambulance	$131,000
Avg. Years of Service per Ambulance	8
Calculated	**Results**
Average Annual Mileage per Ambulance	18,321
Annual Call Volume per Ambulance	472 (39 per Month)
Annual Maint. & Op. Cost per Ambulance	$8,638
Annualized Value of Ambulance	$13,100
Annual Ambulance Cost	$21,738
Average Cost / Mile to Operate	$1.19
Months to Pay Off GPS unit ($500/unit)	8
1st year projected Savings with GPS	$228 per Ambulance $684 for Fleet
3-yr projected savings with GPS	$1,684 per Ambulance $5,052 for Fleet

RESULTS of AMBULANCE SERVICE: F

Total Miles Driven by Fleet	6,800
Number Active Ambulances in Fleet	2 (Type III)
Number Emergency Calls in 2009	933
Maintenance & Operating Cost 2009	$3,000
Average cost New Ambulance	$140,000
Avg. Years of Service per Ambulance	10
Calculated	**Results**
Average Annual Mileage per Ambulance	3,400
Annual Call Volume per Ambulance	467 (39 per Month)
Annual Maint. & Op. Cost per Ambulance	$1,500
Annualized Value of Ambulance	$11,200
Annual Ambulance Cost	$12,700
Average Cost / Mile to Operate	$3.74
Months to Pay Off GPS unit ($500/unit)	3
1st year projected Savings with GPS	$1,765 per Ambulance $3,531 for Fleet
3-yr projected savings with GPS	$6,296 per Ambulance $12,592 for Fleet

As you can see, two of the services would not benefit (financially) from purchasing GPS navigators simply because their run volume is too low. However, the remaining four could see a significant return on investment. After discussing the low number of responses, Dr. Gonzalez feels that more participants are needed before a manuscript will carry enough validity to ensure acceptance/publication by a peer reviewed journal. He feels that 20 services with good data would be ideal, but a minimum of ten would suffice.

1. Gonzalez RP, Cummings GR, Harlan SM, Mulekar MS, Rodning CB. Improving emergency medical service response time with global positioning system navigation. J Trauma. 2009 Nov; 67(5): 899-902
http://www.ncbi.nlm.nih.gov/pubmed/19901646?tool=MedlinePlus

Domain 3

Project 3

Alabama Transportation Database Project

The purpose of this project is to create an online database that unifies Alabama's transportation legislation, funding, and research. The objective is to organize a database that is useful and accessible to state legislators and researchers, as well as the common individual searching for such material on any given internet search engine. Data for Alabama's transportation-related policies, funding, and research exist on the internet. However, these three components are never together on a single website. Furthermore, any one of these components was rarely displayed in a format that was easily located or understood. This database will prove to be a useful instrument to legislators and professionals in transportation, because it will enable them to locate any transportation-related bill in session through any point in the legislative process. This will also allow one to easily locate which proposed bills are implementing aspects of the Strategic High Safety Plan. This database is a unique venture that will span beyond being a complementary tool for transportation safety and will become an essential tool having united Alabama's legislative, financial, and academic efforts in transportation.

Progress to Date

Task 1. Development of the Project Team

A multidisciplinary project team was formed consisting of a post-baccalaureate psychology student, a graduate public health (epidemiology) student, an undergraduate psychology student, and an undergraduate engineering student.

Task 2. Literature Reviews to Identify Existing Organizational Structures

Alabama Legislation Information System Online (ALISON) was identified as the source for state transportation-related legislation. Existing legislation can be found by searching through the Code of Alabama, and pending bills' information can be found within the current session. A history of the proposed bill dated to the most recent activity is given, along with the full text of the proposed bill. A method of storing the data for each transportation-related proposed bill was developed in a data table, so that research assistants can update each bill as changes occur. It was determined that the pending legislation in session will require continual daily monitoring and manual updating. Proposed bills will display if it is relevant to the Strategic Highway Safety Plan.

Alabama's transportation research was located and entered into the database. Project funding, researcher and institution information, and project status are displayed. Completed projects have links to their final report, while ongoing projects have links to their project description.

Task 3. Organization of Data Entry

Using the Transportation Research Board's (TRB) category, committee, and subcommittee labels, an organizational scheme for categorizing Alabama's transportation-related information has been developed. Both existing and proposed legislation, research and funding were organized by these categories to enhance the "searchability" of the data. A user can locate the desired information whether knowing exactly for what he or she is searching or having just a general idea.

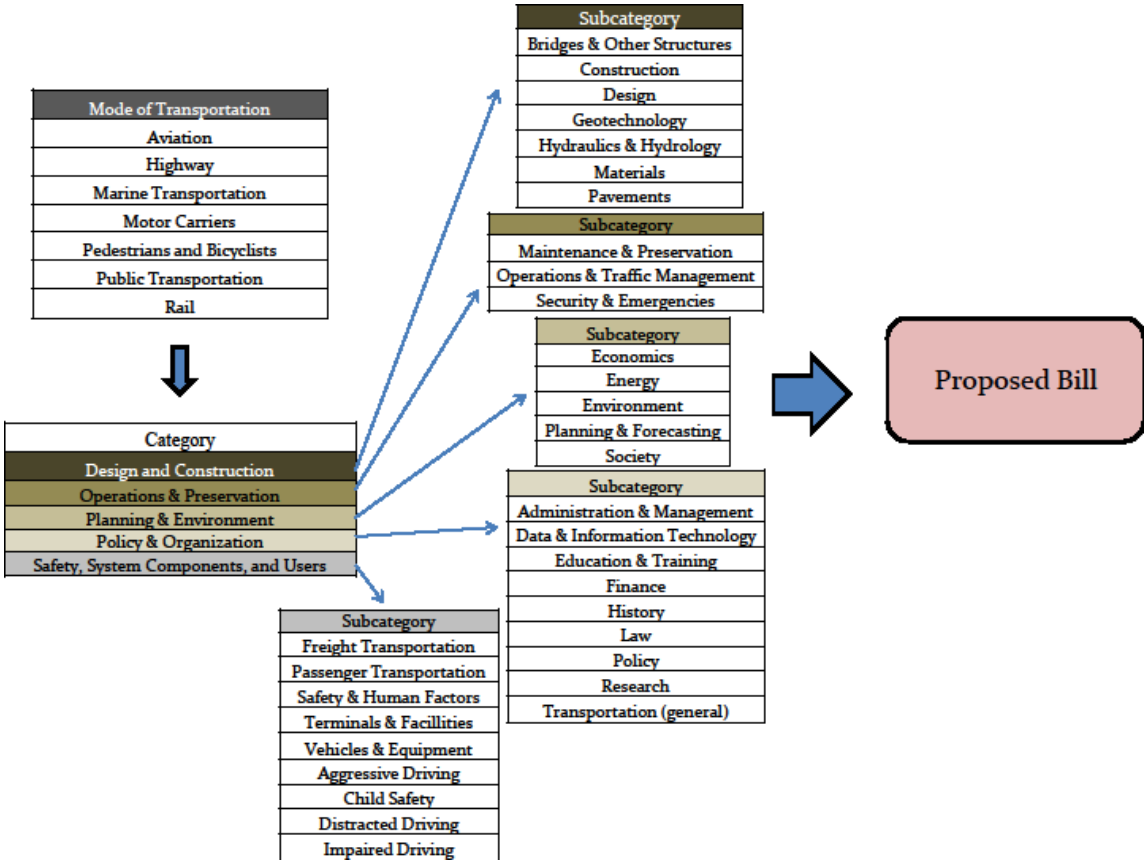
Emphasis was placed on the Highway mode of transportation. Over 1200 entries of transportation-related legislation from the Code of Alabama has been collected, uploaded to the database, and categorized. 189 Project descriptions and final reports from UTCA's list of projects have also been collected as far back as 2004, uploaded to the database, and categorized.

Task 4. Integration of Database into Online Format

A website beta of the database has been developed in the PHP scripting language. The entire Access database current at time of development was uploaded and the project team determined future directions of the website beta.

Future Directions

With the existing legislation entered in the database, focus will shift to expanding the information in the database to further encompass Alabama's transportation research. The proposed transportation-related bills for Alabama's 2012 legislation session will be tracked in the database. Tracking the currently proposed bills will be the highlight of the future online database. The website beta will continue to be developed. The final website will be shown to the director of the Alabama Department of Transportation (ALDOT) and other transportation professionals for further feedback and additional recommendations.



UAB UTC