Program Progress Performance Report for University Transportation Research Centers (PPPR #6)

Prepared for the Research and Innovative Technology Administration (RITA);
U.S. Department of Transportation (US DOT)

Grant Project Title:

Advanced Operations Focused on Connected Vehicles/Infrastructure (CVI-UTC)

Consortium Members:

Virginia Tech Transportation Institute (VTTI),
University of Virginia (UVA) Center for Transportation Studies, and
Morgan State University (MSU).

Submitted by:
Virginia Tech Transportation Institute
3500 Transportation Research Plaza
Blacksburg, VA 24061

Program Director:
Dr. Thomas Dingus
Director Virginia Tech Transportation Institute
Director National Surface Transportation Safety Center for Excellence
Newport News Shipbuilding Professor of Engineering at Virginia Tech
tdingus@vtti.vt.edu
(540) 231 – 1501

Name of Submitting Official:
Leslie Harwood
Project Associate, CVI-UTC
lharwood@vtti.vt.edu
(540) 231 – 9530
Leslie C. Harwood
Signature

RITA Grant Number: DTRT12-G-UTC20

DUNS: 0031370150000 EIN: 54-6001805

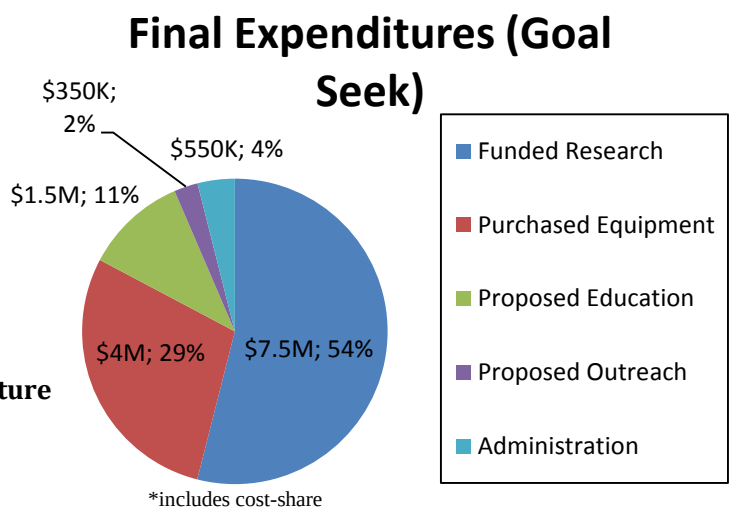
Grant Period: January 2012 – January 2016
Reporting Period End Date: December 2014
Report Frequency: Semi-annual reporting periods
Report Term: July – December 2014

Submission Date: January 30, 2015

Accomplishments

What are the major goals and objectives of the program?

- **Safety**
- **State of Good Repair**
- **Economic Competitiveness**
- **Livable Communities**
- **Environmental Sustainability**
- **All goals though connected vehicles/infrastructure**



*includes cost-share

What was accomplished under these goals?

- **Major activities:**
  - Funded five (5) new research projects
  - Graduated 12 students (5 M.S. and 7 Ph.D.)
  - Placed all 12 graduates in employment post-graduation at private engineering practices or public institutions
  - 62 presentations and publications accepted by national and international transportation conferences and institutions
  - 9 CVI applications developed, improved, or evaluated on CVI-UTC testbeds
  - CVI-UTC research presentations and display planned for 2015 TRB Annual Meeting
  - CVI-UTC Research displayed at 2014 ITS World Congress
  - Completion of grant-sponsored activities toward deployment of the Northern Virginia Connected Vehicle Testbed
  - Developed and participated in the Transportation Undergraduate Research Fellowship (TURF) Program
  - 25 short courses and other professional presentations given, reaching 1,572 students, researchers, and general public
  - 31 underrepresented students supported
  - 2014 CVI-UTC Outstanding Student of the Year Award presented at the 2015 UTC Annual Banquet
  - CVI-UTC research covered by Discovery Channel Canada
  - CVI-UTC research covered by Voice of America
  - Hosted the 3rd Advanced Civil Infrastructure Management Course & 10th Annual Inter-University Symposium on Infrastructure Management
  - Presented at the 2014 Technology Legislative Fair (Maryland)
  - Presented CVI-UTC research at VDOT High School Career Fair in Manassas, VA
  - Motorcycles donated by Motorcycle Safety Foundation for CVI-UTC research
  - Hosted Morgan State Teacher Transportation Institute (Baltimore HS Teachers)
  - Continued data collection and research on the Smart Road and Northern Virginia Connected Vehicle Testbeds
  - Conducted major equipment manufacturer resource meetings with stakeholders
  - Funded UGA and GRA direct tuition and work study
  - Continued website development and updated content
  - Hosted VTTI School Day outreach event (K-12 students, teachers, parents)
  - Demonstrated CVI technologies at the Virginia Science Festival
  - Participated in the Newseum for VTTI Spring Open House and ISE Graduate Students
  - Hosted Pavement Evaluation 2014
  - Demonstrated CVI-UTC research at Blacksburg Community Day 2014

- Specific objectives:

Major Activities:	Safety	State of Good Repair	Economic Competitiveness	Livable Communities	Environmental Sustainability
Funded five (5) new research projects	X	X	X	X	X
Graduated 12 students (5 M.S. and 7 Ph.D.)			X	X	
Placed all 12 graduates in employment post-graduation at private engineering practices or public institutions			X	X	
62 presentations and publications accepted by national and international transportation conferences and institutions	X	X	X	X	X
9 CVI applications developed, improved, or evaluated on CVI-UTC testbeds	X	X	X	X	X
CVI-UTC research presentations and display planned for 2015 TRB Annual Meeting	X	X	X	X	X
CVI-UTC Research displayed at 2014 ITS World Congress	X	X	X	X	X
Completion of grant-sponsored activities toward deployment of the Northern Virginia Connected Vehicle Testbed	X	X	X	X	X
Developed and participated in the Transportation Undergraduate Research Fellowship (TURF) Program	X		X	X	
25 short courses and other professional presentations given, reaching 1,572 students, researchers, and general public	X	X	X	X	X
31 underrepresented students supported			X	X	
2014 CVI-UTC Outstanding Student of the Year Award presented at the 2015 UTC Annual Banquet	X	X	X	X	
CVI-UTC research covered by Discovery Channel Canada	X	X		X	
CVI-UTC research covered by Voice of America	X	X	X	X	X
Hosted the 3rd Advanced Civil Infrastructure Management Course & 10th Annual Inter-University Symposium on Infrastructure Management	X	X	X	X	X
Presented CVI-UTC research at the 2014 Technology Legislative Fair (Maryland)	X	X	X	X	X
Presented CVI-UTC research at the VDOT High School Career Fair in Manassas, VA	X			X	
Motorcycles donated by Motorcycle Safety Foundation for CVI-UTC research	X			X	X
Hosted Morgan State Teacher Transportation Institute (Baltimore HS Teachers)	X		X	X	
Continued data collection and research on the Smart Road and Northern Virginia Connected Vehicle Testbeds	X	X	X	X	X
Conducted major equipment manufacturer resource meetings with stakeholders	X		X	X	
Funded UGA and GRA direct tuition and work study	X		X	X	
Continued website development and updated content	X	X	X	X	X
Hosted VTTI School Day outreach event (K-12 students, teachers, parents)	X			X	
Demonstrated CVI technologies at the Virginia Science Festival	X			X	
Participated in the Newseum for VTTI Spring Open House and ISE Graduate Students	X			X	
Hosted Pavement Evaluation 2014	X	X	X	X	X
Demonstrated CVI-UTC research at Blacksburg Community Day 2014	X			X	

- Significant results, including major findings, developments, conclusions (+ and -):

  Two final reports submitted for approval:

- **Infrastructure Pavement Assessment & Management Applications Enabled by the Connected Vehicles Environment – Proof-of-Concept, S. Katicha (VTTI), H. Zeng (UVA), H. Park (UVA), B. Smith (UVA) and G. Flintsch (VTTI), submitted December 2014.**
- **Connected Vehicle Enabled Freeway Merge Management – Field Test, B. Smith (UVA), submitted November 2014.**

- **Prototyping and Evaluating a Smartphone Dynamic Message Sign (DMS) Application in the CVI-UTC Test Bed (UVA)**
  - The developed VDMS application has satisfying technical performance in terms of battery life, latency, and location accuracy.
  - Positive attitude among participants (21 total) towards VDMS in terms of both usefulness and satisfaction.
  - Most participants (80.95 percent) perceived that VDMS is a safer way to receive information; most (66.67 percent) felt more comfortable receiving information from the VDMS compared to a DMS.
- **Developing Connected-vehicle Freeway Speed Harmonization Algorithms (VTTI)**
  - When the algorithm was applied, the speed of the equipped vehicles decreased gradually to restrict the arrival rates at the downstream bottleneck and mitigate traffic congestion.
  - With increased market penetration rates of the equipped vehicles, the discharge flow rate of the bottleneck was greater, the traffic stream delay was reduced, and vehicle emissions and fuel consumption levels were reduced.
- **An Innovative "Intelligent" Awareness System for Roadway Workers using Dedicated Short-range Communications (VTTI)**
  - The proposed approach is 91 percent accurate in alerting the worker and vehicle of crash and near-crash risks.
  - Accurate warnings may be provided five to six seconds before any potential crash, allowing time for mitigating solutions.
- **Field Testing of Eco-speed Control using Vehicle-to-infrastructure Communication (VTTI)**
  - Fuel consumption of vehicles increased as the demand in the network grew with a more drastic increase beyond the peak volume.
  - Savings in fuel consumption were highest at 25 percent and 150 percent of the peak volume, with savings in the 13 to 30 percent range.
  - Savings in emissions followed the fuel consumption closely and includes carbon monoxide, hydrocarbon, carbon dioxide, and nitrogen oxide emissions.
  - Percentage change in delay was considerably different than that of energy or emissions (i.e., in the order of 38 to 65 percent).
  - Average fuel consumption for an individual vehicle increased gradually for lower penetration rates and had a decline for penetration rates of more than 75 percent.
  - Analysis of total delay incurred by an average vehicle showed a significant decrease for penetration rates beyond 75 percent.
  - Stopped delay reduced to 10 to 50 percent when the penetration rate was increased from 0 to 100 percent with the highest reduction for the lowest volume.
- **Safety and Human Factors of Adaptive Stop/Yield Signs Using Connected Vehicle Infrastructure (VTTI)**
  - A stop made in compliance with an adaptable stop sign had a compliance level of 62.11 percent compared to a stop made at a traditional stop sign (12.44 percent compliance).
  - There was no significant difference in compliance level with the adaptive stop/yield sign based on age and gender.

- Mean glance durations and frequencies decreased rapidly with increased driver experience with the in-vehicle system.
- The mean eyes-off-road time and number of glances to the in-vehicle device when functioning normally are comparable to that of checking the speedometer (Dingus et al.*).
  *Dingus, Thomas A.; Klauer, Sheila G. (2008). The Relative Risks of Secondary Task Induced Driver Distraction SAE Technical Paper Series. Detroit, Michigan.

- **Intersection Management using In-vehicle Speed Advisory/Adaptation (VTTI)**
  - iCACC has the ability to model any type of intersection control and accepts the following inputs: approach volumes, intersection characteristics, weather conditions, vehicle specifications, and the percentage of equipped vehicles at the intersection.
  - iCACC optimizes all levels of automation, from legacy vehicles to fully autonomous vehicles. (Video may be found at: http://bit.ly/ iCACC).
  - The iCACC system logic was compared to conventional intersection control in terms of delay and fuel consumed on a per-vehicle basis for different traffic demand cases (16 cases); simulation results showed significant savings by using the iCACC tool compared to other conventional controls (signal, stop-sign, and/or roundabout) for the same demand level.
- **Connected Motorcycle Crash Warning Systems (VTTI)**
  - Helmet speakers featuring audio warnings: Attracts the riders' attention immediately. The participants could not miss the warning even if being distracted. Conveys urgency and directionality well.
  - Haptic wristbands: Unique physical warning that is different from sound or light. Attracts the riders' attention immediately. The participants could not miss the warning even if being distracted. Conveys directionality well.
  - LED strips placed on helmet visor: Attracts drivers' attention but is not obtrusive due to location (i.e., in periphery vision field). The participants could not miss the warning even if being distracted. Conveys urgency and directionality well. Works well during daytime.
  - Combination of all three warning methods and LED strips placed on mirrors: Attracts riders' attention immediately. Participants cannot miss the warnings even if being distracted.
- **Infrastructure Pavement Assessment and Management Applications Enabled by the Connected Vehicles Environment Research Program – Phase 1: Proof-of-Concept (VTTI)**
  - Proposed method can correctly identify between 80 and 93 percent of deficient pavement sections.
  - Transportation agencies should consider using this low-cost application for pavement condition network screening to identify locations where repairs are needed.
  - Application can serve as a surrogate pavement roughness assessment method for local transportation agencies.
- **Connected Vehicle Enabled Freeway Merge Management – Field Test (UVA)**
  - Data indicate that driver compliance rate is greater when a large- or medium-sized gap is available for a lane change; the lowest compliance rate was observed for a small gap size scenario.
  - In most cases, no significant differences in compliance rates between male and female participants were found.
  - More drivers followed a direct advisory message that advised a lane change compared to a message that indirectly stimulated a lane change through speed control.
- **Measuring User Acceptance of and Willingness-to-pay for CVI Technology (Morgan State)**
  - Participants generally accept selected connected-vehicle technologies.
  - Results to date indicate that price will be the main factor in deciding to purchase a connected-vehicle technology, and safety benefits are most appealing to drivers.
  - Comparisons of willingness-to-pay with several socioeconomic variables found that drivers between the ages of 40 and 49, African-Americans, those with less than a bachelor's degree, and a higher budget for vehicle purchase are positively related to willingness-to-pay.

        - Early adopters or innovators of connected-vehicle technologies are willing to pay more for such systems.
- **Key outcomes or other achievements:**
    - Completing grant-supported development of the Northern Virginia Connected Vehicle Testbed and funding five new research projects totaling $749,469 have been our two major outcomes/achievements during this reporting period.
- **Discussion of stated goals not met:**
    - There were some delays in the completion of the Northern Virginia Connected Vehicle Testbed NoVA which ultimately delayed research efforts of some CVI-UTC projects; however, we anticipate completion of all research projects by end of grant funding period. We also had intended to complete the Northern Virginia Connected Vehicle Testbed expansion (towards Gainesville) during this period, however given the current research demands and time constraints of the grant funding, the CVI-UTC was unable to meet this goal during this period. However, we still have continued support of our consortium partner VDOT/VCTIR, and fully trust that these activities will be completed this year.

What opportunities for training and professional development has the program provided?

- **Short Courses:**
    - 3rd Advanced Civil Infrastructure Management Course & 10th Annual Inter-University Symposium on Infrastructure Management (June 16-27, 2014)
- **Research Presentations:**
  These are research presentations from the CVI-UTC that were completed this academic fall semester (2014) and/or accepted/planned for presentation in the upcoming months (during the 2015 academic spring semester).
    - Agent-Based Simulation of Eco-Speed Controlled Vehicles at Signalized Intersections (Kamalanathsharma/Rakha)
    - Safety and Human Factors of Adaptable Stop Displays Using Connected Vehicle Infrastructure (Noble)
    - Development of an on-demand roadway-lighting system (Palmer/Gibbons)
    - Feasibility of GPS-based Warning System for Roadside Workers (Forsyth/Bowman)
    - Identifying Deficient Pavement Sections using an Improved Acceleration-based Metric (Zeng/Park/Smith)
    - Investigating Drivers' Response to Merge Management Advisory Messages in Connected Vehicle Environment (Hayat/Park/Smith)
    - Agent-Based Modeling Approach to Predict Experienced Travel Times (Chen/Rakha)
    - Examining the Effectiveness of In-Vehicle Auditory Public Traffic Information Compared with Roadside Dynamic Message Signs (Ma/Smith/Fontaine)
    - Data-driven Particle Filter for Multi-step Look-ahead Travel Time Prediction (Chen/Rakha)
    - Intelligent Transit Signal Priority Considering Bus Progression (Hu/Park/Lee)
    - Measuring User Preference and Willingness-to-pay for Connected Vehicle Technologies: The Analysis of the Adaptive Choice-Based Conjoint Survey (Shin/Callow/Dadvar/Lee/Farkas)
    - The Role of Technology in Motorcycle and Moped Safety (Viray/Doerzaph)
    - Predicting Red-light Running Violations at Signalized Intersections using Machine Learning Techniques (Jahangiri/Rhaka/Dingus)
    - Distributed Learning: An Application to Transportation Mode Identification (Jahangiri/Rhaka)
    - Transportation Mode Recognition using Smartphone Sensor Data (Jahangiri/Rhaka)
    - Integrated Corridor Management (ICM) Evaluation Framework – Rigorous Exploration of Potential ICM Benefits (Asare/Smith)
    - Estimation of the Safety Effect of Pavement Condition on Rural Two-Lane Highways (Zeng/Fontaine/Smith)
    - Utilization of Smartphone Sensor Data to Develop Detection and Prevention Models in Transportation (Jahangiri/Rhaka)

- Simulation Testing of Connected Vehicle Applications in a Cloud-based Traffic Simulation Environment (Kamalanathsharma/Rakha)
- Transit Signal Priority with Connected Vehicle Technology (Hu/Park/Parkany)
- Intersection Management of Autonomous Vehicles using an Agent-based Passenger Priority Framework (Zohdy/Rhaka)
- Connected Vehicle Enabled Freeway Merge Assistance System Field Test: Preliminary Results of Driver Compliance to Advisory (Hayat/Park/Smith)
- Developing a Support Vector Machine Classifier for Transportation Mode Identification by Using Mobile Phone Sensor Data (Jahangiri/Rakha)
- Agent-Based Simulation of Eco-Speed Controlled Vehicles at Signalized Intersections (Kamalanathsharma/Rakha)
- Enhancing Roundabout Operations via Vehicle Connectivity (Zohdy/Rakha)
- Development of an Advisory Response Model for A Connected Vehicle Enabled Freeway Merge Assistance System: Interim Status (Hayat/Park/Smith)
- Women's acceptance of and willingness-to-pay for connected vehicles (Farkas/Shin/Lee/Callow/Dadvar)
- Fuel-Optimal Vehicle Throttle Control: Model Logic and Preliminary Testing (Kamalanathsharma/Rakha)
- Modeling Driver Perceptions of Travel Conditions in an In-Situ Route Choice Experiment in Real-World Conditions (Tawfik/Rakha)
- Dynamic Travel Time Prediction using Pattern Recognition (Chen/Rakha/McGhee)
- Public Perception on Increasing Use of Technology in Automobiles: Survey Findings (Kamalanathsharma/Zohdy)
- Use of probe vehicles to measure road ride quality (Katicha/Flintsch/Fuentes)
- Using Driver Eye Glance Behavior to Determine Safety Implications of Adaptive In-vehicle Stop Displays (Sykes/Doerzaph)
- An Evaluation of the AMES Profiler with Ro-Line Laser Sensor for the Measurement of Pavement Profile (St. Louis/Flintsch)
- The Connected Car Evolution (Doerzaph)
- Highway Safety Manual Calibration and Surrogate Safety Assessment Modeling (Park)
- Safety and Human Factors of Adaptable Stop Displays Using Connected Vehicle Infrastructure (Noble)
- Evaluation of Connected Motorcycle Crash Warning Interfaces (Song/McLaughlin/Doerzaph)

- **Other educational programming completed this reporting period includes:**
  - Morgan State Teacher Transportation Institute for Baltimore-area high school teachers
  - VTTI School Days Outreach (K-12 students, teachers, parents)
  - VDOT High School Career Fair in Manassas, VA
  - Transportation Undergraduate Research Fellowship (TURF) Program
  - CVI-UTC Research Displayed at ITS World Congress in Detroit, MI
  - Discovery Channel Canada coverage of CVI-UTC research
  - Voice of America coverage of CVI-UTC research
  - 2014 Technology Legislative Fair (Maryland)
  - Virginia Science Festival Connected Vehicle Demonstration
  - Newseum for VTTI Spring Open House and ISE Graduate Students
  - Pavement Evaluation 2014
  - Blacksburg Community Day 2014

Because this is the last two years (2014-16) of the CVI-UTC under the FY2012 grant funding period, we will continue to look for outreach opportunities, but in general, will continue with those activities already underway.

How have the results been disseminated? If so, in what ways?

- Our main source of dissemination has been through virtual sources, such as our UTC website, the TRB database, and social media outlets. We have also utilized invitations to speak at conferences, conference presentations, and general attendance in professional conferences and networking events hosted by consortium universities or large scale industry events to disseminate research results to a professional audience. Some major special events we have taken part of is that our research made international news, with Discovery Channel Canada and Voice of America news outlets covered our major research and applications. We were also particularly good in technology transfer via presentations and publications (62 total).

What do you plan to do during the next reporting period to accomplish the goal's end objectives?

- Currently we are fulfilling our research goals by funding five new projects totaling $749,469 which will utilize the Northern Virginia Connected Vehicle Testbed. We are also fulfilling our education goals by funding outreach activities and using the resources at each of the consortium universities to attract students and transportation professionals. Another outreach goal will be accomplished within the CVI-UTC in 2015 at the 2015 TRB Annual Meeting in Washington, D.C. and our major CVI-UTC booth, showcase, and demonstrations – this is our next major national outreach goal.

Products

What has the program produced?

- **Short Courses:**
  - 3rd Advanced Civil Infrastructure Management Course & 10th Annual Inter-University Symposium on Infrastructure Management (June 16-27, 2014)
- **Research Presentations:**
  These are research presentations from the CVI-UTC that were completed this academic fall semester (2014) and/or accepted/planned for presentation in the upcoming months (during the 2015 academic spring semester).
  - Agent-Based Simulation of Eco-Speed Controlled Vehicles at Signalized Intersections (Kamalanathsharma/Rakha)
  - Safety and Human Factors of Adaptable Stop Displays Using Connected Vehicle Infrastructure (Noble)
  - Development of an on-demand roadway-lighting system (Palmer/Gibbons)
  - Feasibility of GPS-based Warning System for Roadside Workers (Forsyth/Bowman)
  - Identifying Deficient Pavement Sections using an Improved Acceleration-based Metric (Zeng/Park/Smith)
  - Investigating Drivers' Response to Merge Management Advisory Messages in Connected Vehicle Environment (Hayat/Park/Smith)
  - Agent-Based Modeling Approach to Predict Experienced Travel Times (Chen/Rakha)
  - Examining the Effectiveness of In-Vehicle Auditory Public Traffic Information Compared with Roadside Dynamic Message Signs (Ma/Smith/Fontaine)
  - Data-driven Particle Filter for Multi-step Look-ahead Travel Time Prediction (Chen/Rakha)
  - Intelligent Transit Signal Priority Considering Bus Progression (Hu/Park/Lee)
  - Measuring User Preference and Willingness-to-pay for Connected Vehicle Technologies: The Analysis of the Adaptive Choice-Based Conjoint Survey (Shin/Callow/Dadvar/Lee/Farkas)
  - The Role of Technology in Motorcycle and Moped Safety (Viray/Doerzaph)
  - Predicting Red-light Running Violations at Signalized Intersections using Machine Learning Techniques (Jahangiri/Rhaka/Dingus)
  - Distributed Learning: An Application to Transportation Mode Identification (Jahangiri/Rhaka)
  - Transportation Mode Recognition using Smartphone Sensor Data (Jahangiri/Rhaka)
  - Integrated Corridor Management (ICM) Evaluation Framework – Rigorous Exploration of Potential ICM Benefits (Asare/Smith)

- Estimation of the Safety Effect of Pavement Condition on Rural Two-Lane Highways (Zeng/Fontaine/Smith)
- Utilization of Smartphone Sensor Data to Develop Detection and Prevention Models in Transportation (Jahangiri/Rhaka)
- Simulation Testing of Connected Vehicle Applications in a Cloud-based Traffic Simulation Environment (Kamalanathsharma/Rakha)
- Transit Signal Priority with Connected Vehicle Technology (Hu/Park/Parkany)
- Intersection Management of Autonomous Vehicles using an Agent-based Passenger Priority Framework (Zohdy/Rhaka)
- Connected Vehicle Enabled Freeway Merge Assistance System Field Test: Preliminary Results of Driver Compliance to Advisory (Hayat/Park/Smith)
- Developing a Support Vector Machine Classifier for Transportation Mode Identification by Using Mobile Phone Sensor Data (Jahangiri/Rakha)
- Agent-Based Simulation of Eco-Speed Controlled Vehicles at Signalized Intersections (Kamalanathsharma/Rakha)
- Enhancing Roundabout Operations via Vehicle Connectivity (Zohdy/Rakha)
- Development of an Advisory Response Model for A Connected Vehicle Enabled Freeway Merge Assistance System: Interim Status (Hayat/Park/Smith)
- Women's acceptance of and willingness-to-pay for connected vehicles (Farkas/Shin/Lee/Callow/Dadvar)
- Fuel-Optimal Vehicle Throttle Control: Model Logic and Preliminary Testing (Kamalanathsharma/Rakha)
- Modeling Driver Perceptions of Travel Conditions in an In-Situ Route Choice Experiment in Real-World Conditions (Tawfik/Rakha)
- Dynamic Travel Time Prediction using Pattern Recognition (Chen/Rakha/McGhee)
- Public Perception on Increasing Use of Technology in Automobiles: Survey Findings (Kamalanathsharma/Zohdy)
- Use of probe vehicles to measure road ride quality (Katicha/Flintsch/Fuentes)
- Using Driver Eye Glance Behavior to Determine Safety Implications of Adaptive In-vehicle Stop Displays (Sykes/Doerzaph)
- An Evaluation of the AMES Profiler with Ro-Line Laser Sensor for the Measurement of Pavement Profile (St. Louis/Flintsch)
- The Connected Car Evolution (Doerzaph)
- Highway Safety Manual Calibration and Surrogate Safety Assessment Modeling (Park)
- Safety and Human Factors of Adaptable Stop Displays Using Connected Vehicle Infrastructure (Noble)
- Evaluation of Connected Motorcycle Crash Warning Interfaces (Song/McLaughlin/Doerzaph)

- **Publications:**
  - One route or the other? (Van Essen)
  - Safety, Operational, and Energy Impacts of In-vehicle Adaptive Stop Displays Using Connected Vehicle Technology (Noble)
  - Development and Testing of The iCACC Intersection Controller For Automated Vehicles (Zohdy)
  - Leveraging Connected Vehicle Technology and Telematics to Enhance Vehicle Fuel Efficiency in the Vicinity of Signalized Intersections (Kamalanathshama/Rhaka)
  - Application of Maximum Entropy Sampling Design to Traveler Information System Data Quality Evaluations (Richardson/Smith)
  - Integrated Corridor Management (ICM) Evaluation Framework – Rigorous Exploration of Potential ICM Benefits (Asare/Smith)
  - Estimation of the Safety Effect of Pavement Condition on Rural Two-Lane Highways (Zeng/Fontaine/Smith)
  - Microscopic Estimation of Arterial Vehicle Positions in a Low Penetration Rate Connected Vehicle Environment (Goodall/Smith/Park)

- Microscopic Estimation of Freeway Vehicle Positions from the Behavior of Connected Vehicles (Goodall/Smith/Park)
- Coordinated Transit Signal Priority Supporting Transit Progression Under Connected Vehicle Technology (Hu/Park/Lee)
- Development and Evaluation of an Enhanced Surrogate Safety Assessment Framework (So/Dedes/Park/HosseinyAlamdary/Gerjner-Brzezinska)
- Classification Modeling Approach for Vehicle Dynamics Model-Integrated Traffic Simulation Assessing Surrogate Safety (So/Park/Yun)
- Development and Validation of a Vehicle Dynamics-Integrated Traffic Safety Simulation Environment for Enhanced Surrogate Safety Measures (So/Park/Wolfe/Dedes)
- Calibrating Communications Simulator for Connected Vehicles Application (Su/Lee/Park)
- Intersection Management via Vehicle Connectivity: The iCACC System Concept (Zohdy/Rakha)
- Agent-Based Simulation of Eco-Speed Controlled Vehicles at Signalized Intersections (Kamalanathsharma/Rakha)
- Can We Model Driver Perceptions? An In-Situ Experiment in Real-World Conditions (Tawfik/Rakha)
- Eco-Cooperative Adaptive Cruise Control: Modeling, Testing and Evaluation (Kamalanathsharma)
- Enhancing Roundabout Operations via Vehicle Connectivity (Zohdy/Rakha)
- Real-time travel time prediction using particle filtering with a non-explicit state transition model (Chen/Rakha)
- Real-time Traffic State Prediction: Modeling and Applications (Chen)
- Driver behavior under dynamic traffic advisory information (Hayat/Park/Smith)
- The Interaction between Consumer Knowledge and Gender on Willingness-to-pay for Innovative Safety Features in a New Vehicle (Callow)

- Websites; other Internet (http://www.connectedvehicleinfrastructure-utc.org)
- Technologies, techniques: Many research projects are currently underway and several have completed experimental activities which designed, developed, improved or evaluated CVI applications. The CVI applications that were developed during the reporting period include adaptive stop/yield in-vehicle signage, adaptive overhead lighting system, a mobile application for transit users and providers, an eco-speed control application, emergency vehicle message communication prototype, prototype merge-management application, vehicle-based approach to measure roughness, connected work zone vest, and in-vehicle dynamic signage system.
- Inventions, patent applications, licenses: Nothing to report
- Other: the Northern Virginia Connected Vehicle and Virginia Smart Road Test Beds.

Have other collaborators or contacts been involved? (Can be "nothing to report", if so.) Yes.

- Collaborations with others within the lead or partner universities, especially interdepartmental or interdisciplinary collaborations: Brian Smith (UVA) and Gerardo Flintsch (VTTI) Research: "Infrastructure Pavement Assessment and Management Applications Enabled by the Connected Vehicles Environment Research Program - Phase I: Proof-of-Concept" (CONTINUING); Young Jae Lee (Morgan State) and Kathleen Hancock and Hesham Rakha (VT) Research: "Connected Vehicle-Infrastructure Application Development for Addressing Safety and Congestion Issues Related to Public Transportation, Pedestrians, and Bicyclists" (CONTINUING); Byungkyu (Brian) Park and Jia Hu (UVA) and Young Jae Lee (Morgan State) Research: "Next Generation Transit signal Priority with Connected Vehicle Technology" (CONTINUING).
- Collaborations or contact with others outside the UTC: Brian Smith (UVA) collaborated with members of the Connected Vehicles Pooled Fund Study; Gerardo Flintsch (VTTI) and University of Delaware, Georgia Institute of Technology, Purdue University, University of Iowa, Texas A&M University, and Virginia Tech for the 3rd Advanced Civil Infrastructure Management Course & 10th Annual Inter-University Symposium on Infrastructure Management; general CVI-UTC collaborations regarding testbed development and research projects with Savari,

Cohda, and Arada; Robert Kluger (UVA) and FHWA on "Infrastructure Safety Assessment Using Connected Vehicle Data".

- Collaborations or contacts with others outside of the United States or with an international organization: countries of collaborations or contacts: Brian Park (UVA) collaborated with the Global Research Laboratory at Daegu-Gyeongbook Institute of Technology on a project which focused on the efficiency and safety of the cyber physical system for transportation (i.e., Connected Vehicles); VTTI signed a cooperative agreement with the French Institute of Science and Technology for Transport, Development, and Networks (IFSTTAR); Hesham Rakha (VTTI) collaborated with University of Lyon in France and the University of Twente in the Netherlands on multiple research projects and a CVI-UTC proposal.

Impact

What is the impact of the program?

- The biggest impact of this report is the completion and showcase of the testbeds, the connected motorcycle fleet and the connected vehicle enhancements through CVI-UTC technology and installation and collaboration with institutions and companies like Savari and Iteris and VDOT. Additional important impacts have been funding new applied research which will take place on the Northern Virginia Connected Vehicle Testbed; it allows the testbed to be put to practical use and influence statewide transportation operations. The secondary impacts from the UTC program are our ability to complete outreach, education and workforce development programming within and between the consortium universities, and interest from outside groups, and seeking outside collaboration and participation. Final reports are beginning to come out and have groundbreaking research on CVI applications which will inform both industry and government on the upcoming large-scale Connected Vehicle deployments.

How has it contributed to transportation education, research and technology transfer?

- Results of the research are continuing to be disseminated through national and international journals and publications, conferences, and through outreach and educational events, facilitating technology transfer to students, researchers, and the general public. In addition, multiple graduate student theses and dissertations have been or are expected to be published during this period and in the coming months as a result of CVI-UTC research. Through these avenues, it is expected that CVI-UTC will be used extensively to inform emerging connected vehicle deployments.

How has the program provided opportunities for research and teaching in transportation and related disciplines?

- During this reporting period, we funded five new research projects with applied research on the Northern Virginia Connected Vehicle Testbed. All currently-funded research teams have been reporting on past research funded in 2012-present.

How has the program improved the performance, skills, or attitudes of members of underrepresented groups that will improve their access to or retention in transportation research, teaching, or other related professions?

- Morgan State's participation in our UTC has been able to majorly affect underrepresented groups through their research projects and outreach and education opportunities. By inner-consortium research work with Morgan State, this has allowed UVA and VTTI to participate in influencing underrepresented groups. Morgan State also directly offers programs for Baltimore-area high school students and teachers, which include underrepresented populations, and has allowed UTC research to directly affect future generations of potential engineers and human factors professionals.
- In addition, the CVI-UTC funds many females and other individuals from other underrepresented groups across all consortium universities, many of which have a lead role in research projects. The CVI-UTC has sought to provide opportunities for members of underrepresented groups to gain experience in transportation through research projects.

How has the program developed and disseminated new educational materials or provided scholarships?

- The following students worked on and were educated under the grant:
  - **Kayla Sykes** (UGA, VTTI) Working on Adaptive Stop/Yield and Connected Motorcycle Projects under the direction of Dr. Zachary Doerzaph
  - **A. Nicklow** (UGA, VTTI) Working on Connected-vehicle Applications for Adaptive Lighting under the direction of Dr. Ron Gibbons.
  - **M. Goldammer** (UGA, VTTI) Working on Connected-vehicle Applications for Adaptive Lighting under the direction of Dr. Ron Gibbons.
  - **D. Anthony** (UGA, VTTI) Working on Connected-vehicle Applications for Adaptive Lighting under the direction of Dr. Ron Gibbons.
  - **Annabel St. Louis** (UGA, VTTI) Working on "Infrastructure Pavement Assessment" with Dr. Gerardo Flintsch.
  - **Mohamad Raseem Farook** (GRA, VTTI) Working on "Connected Motorcycle Crash Warning Interfaces" and Adaptive Stop/Yield and Connected Motorcycle Projects under the direction of Dr. Shane McLaughlin and Dr. Zachary Doerzaph.
  - **Shalini Sankaranarayanan** (GRA, VT) Working on Connected Vehicle-Infrastructure Application Development for Addressing Safety and Congestion Issues Related to Public Transportation under the direction of Dr. Kathleen Hancock.
  - **Huanghui Zeng** (GRA, UVA) Working on "Connected Vehicle Enabled Freeway Merge Management - Field Test" under the direction of Dr. Brian L. Smith.
  - **M. Tanveer Hayat** (GRA, UVA) Working on "Connected Vehicle Enabled Freeway Merge Management - Field Test" under the direction of Dr. Brian L. Smith.
  - **Kristen P. Hines** (GRA, VT) Working on "Innovative "Intelligent" Awareness System for Roadway Workers Using Dedicated Short-Range Communications" under the direction of Darrell Bowman (VTTI) and Dr. Tom Martin (VT).
  - **Jason B. Forsyth** (GRA, VT) Working on "Innovative "Intelligent" Awareness System for Roadway Workers Using Dedicated Short-Range Communications" under the direction of Darrell Bowman (VTTI) and Dr. Tom Martin (VT).
  - **Raj Kishore Kamalanathsharma** (GRA, VTTI) tuition and work study funded through the CVI-UTC grant, works at VTTI, studies Civil Engineering at Virginia Tech and advised by Dr. Hesham Rakha.
  - **Mariska van Essen** (GRA, VTTI) tuition and work study funded through the CVI-UTC grant, works at VTTI, studies Civil Engineering at Virginia Tech and advised by Dr. Hesham Rakha.
  - **Hao Chen** (GRA, VTTI) tuition and work study funded through the CVI-UTC grant, works at VTTI, studies Civil Engineering at Virginia Tech and advised by Dr. Hesham Rakha.
  - **Karim Fadhloun** (GRA, VTTI) tuition and work study funded through the CVI-UTC grant, works at VTTI, studies Civil Engineering at Virginia Tech and advised by Dr. Hesham Rakha.
  - **Abdallah Hassan** (GRA, VTTI) tuition and work study funded through the CVI-UTC grant, works at VTTI, studies Civil Engineering at Virginia Tech and advised by Dr. Hesham Rakha.
  - **Peng Su** (GRA, UVA) tuition and work study funded through the CVI-UTC grant and advised by Dr. Brian Park.
  - **Jia Hu** (GRA, UVA) tuition and work study funded through the CVI-UTC grant and advised by Dr. Brian Park.
  - **Arash Jahangiri** (GRA, VTTI) tuition and work study funded through the CVI-UTC grant, works at VTTI, studies Civil Engineering at Virginia Tech and advised by Dr. Tom Dingus.
  - **Arnab Gupta** (GRA, VTTI) Working on "Connected Vehicle System Performance" under the direction of Dr. Zachary Doerzaph.
  - **Reginald Viray** (GRA, VTTI) Working on "Connected Vehicle System Performance" under the direction of Dr. Zachary Doerzaph.

- **Seyedehsan Dadvar** (GRA, Morgan State) tuition and work study funded through the CVI-UTC grant and advised by Dr. Young-Jae Lee.
- **Kaveh Bakhsh Kelarestaghi** (GRA, Morgan State) tuition and work study funded through the CVI-UTC grant and advised by Dr. Young-Jae Lee.
- **Robert Kluger** (GRA, UVA) Working on "Infrastructure Safety Assessment Using Connected Vehicle Data" under the direction of Dr. Brian L. Smith.
- **Jiaqi Ma** (GRA, UVA) tuition and work study funded through the CVI-UTC grant and advised by Dr. Brian Smith.
- **David Recht** (GRA, UVA) tuition and work study funded through the CVI-UTC grant and advised by Dr. Brian Smith.
- **Sampson Asare** (GRA, UVA) tuition and work study funded through the CVI-UTC grant and advised by Dr. Brian Smith.
- **Roma Bhatkoti** (GRA, VT) tuition and work study funded through the CVI-UTC grant and advised by Dr. Pamela Murray-Tuite.
- **Naser Hdieb** (GRA, VT) tuition and work study funded through the CVI-UTC grant and advised by Dr. Pamela Murray-Tuite.
- **Aphisit Phoowarawutthipanich** (GRA, VT) tuition and work study funded through the CVI-UTC grant and advised by Dr. Pamela Murray-Tuite.
- **Kelly Donoughe** (GRA, VT) Working on "Reducing School Bus/Light-Vehicle Conflicts Through Connected Vehicle Communications" under the direction of Darrell Bowman (VTTI).
- **Alex Noble** (GRA, VTTI) Working on "Safety and Human Factors of Adaptive Stop/Yield Signs Using Connected-Vehicle Infrastructure" as a PI with Dr. Tom Dingus.
- **Abhijit Sarkar** (GRA, VTTI) Working on "Safety and Human Factors of Adaptive Stop/Yield Signs Using Connected-Vehicle Infrastructure" under the direction of Dr. Tom Dingus.

How has the program provided exposure to transportation, science and technology for practitioners, teachers, young people, or other members of the project?

- The major education and outreach events that effected exposure of the CVI-UTC technology and research has been: the summer transportation institute sponsored by Morgan State for High School students, and the teacher transpiration institute sponsored by Morgan State for High School teachers, the annual VTTI Open House and School Days event with a special partnership with the Institute for Creativity Arts and Technology in Blacksburg, VA, the UVA Transportation Training Academy and the start of their web series on new transportation and connected vehicle technology. We have worked really hard at our educational and outreach events to make practical application and exposure to students and teachers this past year.
- Major Outreach Events During This Past Reporting Period:
  - Morgan State Teacher Transportation Institute for Baltimore-area high school teachers
  - VTTI School Days Outreach (K-12 students, teachers, parents)
  - VDOT High School Career Fair in Manassas, VA
  - Transportation Undergraduate Research Fellowship (TURF) Program
  - CVI-UTC Research Displayed at ITS World Congress in Detroit, MI
  - Discovery Channel Canada coverage of CVI-UTC research
  - Voice of America coverage of CVI-UTC research
  - 2014 Technology Legislative Fair (Maryland)
  - Virginia Science Festival Connected Vehicle Demonstration
  - Newseum for VTTI Spring Open House and ISE Graduate Students
  - Pavement Evaluation 2014
  - Blacksburg Community Day 2014

Has the grant money or research impacted physical resources at the university, institutional resources or information resources level?

- The grant money has absolutely been instrumental in developing and installing the highly instrumented test beds in Northern Virginia and Southwest Virginia as well as our connected vehicle and connected motorcycle fleets which we use to perform research and collect data. Without the UTC funding, it would be unlikely that these projects could have been completed with the velocity that they have been propelled. It has offered the consortium universities opportunities for research that would not have been possible this year without the grant. Also, the grant funding has allowed educational and outreach programs to continue at consortium universities that would not have been possible otherwise.

Describe ways in which the program made an impact, or is likely to make an impact, on commercial technology or public use.

- Because our UTC has been fortunate enough to work closely with automotive, technology, and wireless communication professionals through assembling our advisory board with these types of professionals, how closely our consortium university leaders works with these professionals, and through our test bed installations – we believe that this allows our UTC a unique opportunity not only to have this commercial technology and public use influence on the direction of our research goals, but also an opportunity to do work that is directly practically applicable and has a great deal of potential for commercial marketing and public use, probably a lot faster than the majority of university research may have an impact on the commercially viable aspects of transportation. We also anticipate that as our research progresses, particular physical artifacts like connected school buses, work zone safety vests, or adaptive stop yield displays in cars, have the potential for commercial technology and public use – just to name a few projects that are working towards immediate practical safety applications.

Describe how results from the program made an impact, or are likely to make an impact, beyond the bounds of science, engineering, and the academic world.

- The CVI-UTC is likely to make an impact beyond STEM or academia because the CVI-UTC encourages safety, affordability, and practicality for every transportation consumer in America. As a result of the research the CVI-UTC is completing, the outreach and education opportunities, and the technical development of CVI technology, applications are being currently tested in a real-world environment on the Northern Virginia Connected Vehicle Test Bed. The CVI-UTC has the advantage of working in a very practical field – transportation and human factors – the goal of which is to use CVI technology to positively affect all drivers; this could even be said to be making a current impact via the Northern Virginia Connected Vehicle Testbed, where millions of drivers utilize I-66 on a daily basis and have been exposed to the UTC research in that manner.

Changes/Problems

- Changes in approach and reasons for change.
  - We funded five additional research projects during this reporting period, which are taking place on the Northern Virginia Connected Vehicle Testbed. Our previous 18 projects have been taking place in Southwest Virginia on the Virginia Smart Road Testbed where CVI tech can be evaluated and proven in a test-track environment before being deployed on public roads.
- Actual or anticipated problems or delays and actions or plans to resolve them.
  - The major anticipated delay is testbed expansion completion, which may occur concurrently while the newly funded research is being completed on the Northern Virginia Connected Vehicle Testbed.
- Changes that have a significant impact on expenditures: Nothing to report.
- Significant changes in use or care of animals, human subjects, and biohazards: Nothing to report.

Outputs

- Research projects awarded:

Research Projects:	Safety	State of Good Repair	Economic Competitiveness	Livable Communities	Environmental Sustainability
Safety and Human Factors of Adaptive Stop/Yield Signs Using Connected Vehicle Infrastructure	X	X	X	X	X
Connected Vehicle Applications for Adaptive Overhead Lighting	X	X	X	X	X
Intersection Management Using In-Vehicle Speed Advisory/Adaptation	X		X		X
Field Testing of Eco-Speed Control Using V2I Communication	X		X		X
An Innovative "Intelligent" Awareness System for Work Zone Workers Using Dedicated Short-Range Communications	X	X		X	
Emergency Vehicle to Vehicle Communication	X			X	
Connected Vehicle Enabled Freeway Merge Management - Field Test	X				
Infrastructure Safety Assessment Using Connected Vehicle Data	X	X	X	X	X
Infrastructure Pavement Assessment and Management Applications Enabled by the Connected Vehicle Environment Research Program - Phase I: Proof-of-Concept	X	X	X	X	X
Connected Vehicle-Infrastructure Application Development for Addressing Safety and Congestion Issues Related to Public Transportation, Pedestrians, and Bicyclists	X	X	X	X	X
Connected Motorcycle Crash Warning Interfaces	X				
Connected Motorcycle System Performance	X				
Developing and Evaluating a Smartphone Application Aimed at Reducing Crashes Involving Bicyclists	X			X	
Developing Connected Vehicle Freeway Speed Harmonization Algorithms	X		X		X
Reducing Bus/Light-Vehicle Conflicts Through Connected Vehicle Communication	X			X	
Next Generation Transit Signal Priority with Connected Vehicle Technology	X		X		X
Prototyping and Evaluating Smart Phone Dynamic Message Sign Application in the CVI-UTC Testbed	X	X	X	X	X
Measuring User Acceptance of and Willingness to Pay for CVI Technology	X	X	X	X	X
A Connected Vehicle-Enabled Virtual Dynamic Message Sign System Demonstration and Evaluation on the Virginia Connected Vehicle Testbed	X	X	X	X	X
Connected Vehicle Virginia Test Bed System Performance	X	X	X	X	
Vehicle Based BSM Generator for Accelerating Deployment	X	X	X	X	
Effect of In-Vehicle ATDM on Traffic Management, Distraction, and Desirability	X	X	X	X	X
Field Demonstration of Cumulative Travel-time Responsive Intersection Control Algorithm under Connected Vehicle Technology	X		X		X

- **Short Courses:**
  - 3rd Advanced Civil Infrastructure Management Course & 10th Annual Inter-University Symposium on Infrastructure Management (June 16-27, 2014)
- **Research Presentations:**
  These are research presentations from the CVI-UTC that were completed this academic fall semester (2014) and/or accepted/planned for presentation in the upcoming months (during the 2015 academic spring semester).
  - Safety and Human Factors of Adaptable Stop Displays Using Connected Vehicle Infrastructure (Noble)
  - Development of an on-demand roadway-lighting system (Palmer/Gibbons)
  - Feasibility of GPS-based Warning System for Roadside Workers (Forsyth/Bowman)
  - Identifying Deficient Pavement Sections using an Improved Acceleration-based Metric (Zeng/Park/Smith)

- Investigating Drivers' Response to Merge Management Advisory Messages in Connected Vehicle Environment (Hayat/Park/Smith)
- Examining the Effectiveness of In-Vehicle Auditory Public Traffic Information Compared with Roadside Dynamic Message Signs (Ma/Smith/Fontaine)
- Intelligent Transit Signal Priority Considering Bus Progression (Hu/Park/Lee)
- Measuring User Preference and Willingness-to-pay for Connected Vehicle Technologies: The Analysis of the Adaptive Choice-Based Conjoint Survey (Shin/Callow/Dadvar/Lee/Farkas)
- The Role of Technology in Motorcycle and Moped Safety (Viray/Doerzaph)
- Predicting Red-light Running Violations at Signalized Intersections using Machine Learning Techniques (Jahangiri/Rhaka/Dingus)
- Distributed Learning: An Application to Transportation Mode Identification (Jahangiri/Rhaka)
- Transportation Mode Recognition using Smartphone Sensor Data (Jahangiri/Rhaka)
- Integrated Corridor Management (ICM) Evaluation Framework – Rigorous Exploration of Potential ICM Benefits (Asare/Smith)
- Estimation of the Safety Effect of Pavement Condition on Rural Two-Lane Highways (Zeng/Fontaine/Smith)
- Utilization of Smartphone Sensor Data to Develop Detection and Prevention Models in Transportation (Jahangiri/Rhaka)
- Simulation Testing of Connected Vehicle Applications in a Cloud-based Traffic Simulation Environment (Kamalanathsharma/Rakha)
- Transit Signal Priority with Connected Vehicle Technology (Hu/Park/Parkany)Intersection Management of Autonomous Vehicles using an Agent-based Passenger Priority Framework (Zohdy/Rhaka)
- Connected Vehicle Enabled Freeway Merge Assistance System Field Test: Preliminary Results of Driver Compliance to Advisory (Hayat/Park/Smith)
- Developing a Support Vector Machine Classifier for Transportation Mode Identification by Using Mobile Phone Sensor Data (Jahangiri/Rakha)
- Agent-Based Simulation of Eco-Speed Controlled Vehicles at Signalized Intersections (Kamalanathsharma/Rakha)
- Enhancing Roundabout Operations via Vehicle Connectivity (Zohdy/Rakha)
- Development of an Advisory Response Model for A Connected Vehicle Enabled Freeway Merge Assistance System: Interim Status (Hayat/Park/Smith)
- Women's acceptance of and willingness-to-pay for connected vehicles (Farkas/Shin/Lee/Callow/Dadvar)
- Fuel-Optimal Vehicle Throttle Control: Model Logic and Preliminary Testing (Kamalanathsharma/Rakha)
- Modeling Driver Perceptions of Travel Conditions in an In-Situ Route Choice Experiment in Real-World Conditions (Tawfik/Rakha)
- Dynamic Travel Time Prediction using Pattern Recognition (Chen/Rakha/McGhee)
- Public Perception on Increasing Use of Technology in Automobiles: Survey Findings (Kamalanathsharma/Zohdy)
- Use of probe vehicles to measure road ride quality (Katicha/Flintsch/Fuentes)
- Using Driver Eye Glance Behavior to Determine Safety Implications of Adaptive In-vehicle Stop Displays (Sykes/Doerzaph)
- An Evaluation of the AMES Profiler with Ro-Line Laser Sensor for the Measurement of Pavement Profile (St. Louis/Flintsch)
- The Connected Car Evolution (Doerzaph)
- Highway Safety Manual Calibration and Surrogate Safety Assessment Modeling (Park)
- Safety and Human Factors of Adaptable Stop Displays Using Connected Vehicle Infrastructure (Noble)
- Evaluation of Connected Motorcycle Crash Warning Interfaces (Song/McLaughlin/Doerzaph)

- **Publications:**

- Safety, Operational, and Energy Impacts of In-vehicle Adaptive Stop Displays Using Connected Vehicle Technology (Noble)
- Development and Testing of The iCACC Intersection Controller For Automated Vehicles (Zohdy)
- Leveraging Connected Vehicle Technology and Telematics to Enhance Vehicle Fuel Efficiency in the Vicinity of Signalized Intersections (Kamalanathshama/Rhaka)
- Application of Maximum Entropy Sampling Design to Traveler Information System Data Quality Evaluations (Richardson/Smith)
- Integrated Corridor Management (ICM) Evaluation Framework – Rigorous Exploration of Potential ICM Benefits (Asare/Smith)
- Estimation of the Safety Effect of Pavement Condition on Rural Two-Lane Highways (Zeng/Fontaine/Smith)
- Microscopic Estimation of Arterial Vehicle Positions in a Low Penetration Rate Connected Vehicle Environment (Goodall/Smith/Park)
- Microscopic Estimation of Freeway Vehicle Positions from the Behavior of Connected Vehicles (Goodall/Smith/Park)
- Coordinated Transit Signal Priority Supporting Transit Progression Under Connected Vehicle Technology (Hu/Park/Lee)
- Development and Evaluation of an Enhanced Surrogate Safety Assessment Framework (So/Dedes/Park/HosseinyAlamdary/Gerjner-Brzezinska)
- Classification Modeling Approach for Vehicle Dynamics Model-Integrated Traffic Simulation Assessing Surrogate Safety (So/Park/Yun)
- Development and Validation of a Vehicle Dynamics-Integrated Traffic Safety Simulation Environment for Enhanced Surrogate Safety Measures (So/Park/Wolfe/Dedes)
- Calibrating Communications Simulator for Connected Vehicles Application (Su/Lee/Park)
- Intersection Management via Vehicle Connectivity: The iCACC System Concept (Zohdy/Rakha)
- Agent-Based Simulation of Eco-Speed Controlled Vehicles at Signalized Intersections (Kamalanathsharma/Rakha)
- Can We Model Driver Perceptions? An In-Situ Experiment in Real-World Conditions (Tawfik/Rakha)
- Simulation Testing of Connected Vehicle Applications in a Cloud-based Traffic Simulation Environment (Kamalanathsharma/Rakha)
- Developing a Support Vector Machine Classifier for Transportation Mode Identification by Using Mobile Phone Sensor Data (Jahangiri/Rakha)
- Modeling Driver Perceptions of Travel Conditions in an In-Situ Route Choice Experiment in Real-World Conditions (Tawfik/Rakha)
- Eco-Cooperative Adaptive Cruise Control: Modeling, Testing and Evaluation (Kamalanathsharma)
- Enhancing Roundabout Operations via Vehicle Connectivity (Zohdy/Rakha)
- Real-time travel time prediction using particle filtering with a non-explicit state transition model (Chen/Rakha)
- Real-time Traffic State Prediction: Modeling and Applications (Chen)
- Driver behavior under dynamic traffic advisory information (Hayat/Park/Smith)
- The Interaction between Consumer Knowledge and Gender on Willingness-to-pay for Innovative Safety Features in a New Vehicle (Callow)

- Websites: (http://www.connectedvehicleinfrastructure-utc.org)
- Technologies or technology assessments; databases, software or models: Many research projects are currently underway and several have completed experimental activities which designed, developed, improved or evaluated CVI applications. The CVI applications that were developed during the reporting period include adaptive stop/yield in-vehicle signage, adaptive overhead lighting system, a mobile application for transit users and providers, an eco-speed control application, emergency vehicle message communication prototype,

prototype merge-management application, vehicle-based approach to measure roughness, connected work zone vest, and in-vehicle dynamic signage system.

- Outreach activities:
  - Morgan State Teacher Transportation Institute for Baltimore-area high school teachers
  - VTTI School Days Outreach (K-12 students, teachers, parents)
  - VDOT High School Career Fair in Manassas, VA
  - Transportation Undergraduate Research Fellowship (TURF) Program
  - CVI-UTC Research Displayed at ITS World Congress in Detroit, MI
  - Discovery Channel Canada coverage of CVI-UTC research
  - Voice of America coverage of CVI-UTC research
  - 2014 Technology Legislative Fair (Maryland)
  - Virginia Science Festival Connected Vehicle Demonstration
  - Newseum for VTTI Spring Open House and ISE Graduate Students
  - Pavement Evaluation 2014
  - Blacksburg Community Day 2014
- Courses and workshops; patents filed or issues, licenses: Nothing to report

Outcomes:

	Increased understanding and awareness of transportation issues:	Improved body of knowledge:	Improved processes, techniques and skills in addressing transportation issues:	Enlarged pool of trained transportation professionals:	Greater adoption of new technology:
Funded five (5) new research projects	X	X	X	X	X
Graduated 12 students (5 M.S. and 7 Ph.D.)	X	X	X	X	X
Placed all 12 graduates in employment post-graduation at private engineering practices or public institutions	X	X	X	X	X
62 presentations and publications accepted by national and international transportation conferences and institutions	X	X	X	X	X
9 CVI applications developed, improved, or evaluated on CVI-UTC testbeds	X	X	X	X	X
CVI-UTC research presentations and display planned for 2015 TRB Annual Meeting	X	X	X	X	X
CVI-UTC Research displayed at 2014 ITS World Congress	X	X	X	X	X
Completion of grant-sponsored activities toward deployment of the Northern Virginia Connected Vehicle Testbed	X	X	X	X	X
Developed and participated in the Transportation Undergraduate Research Fellowship (TURF) Program					X
25 short courses and other professional presentations given, reaching 1,572 students, researchers, and general public	X	X	X	X	X
31 underrepresented students supported	X	X	X	X	X
2014 CVI-UTC Outstanding Student of the Year Award presented at the 2015 UTC Annual Banquet	X	X	X	X	X
CVI-UTC research covered by Discovery Channel Canada	X	X	X	X	X
CVI-UTC research covered by Voice of America	X	X	X	X	X
Hosted the 3rd Advanced Civil Infrastructure Management Course & 10th Annual Inter-University Symposium on Infrastructure Management	X	X	X	X	X

	Increased understanding and awareness of transportation issues:	Improved body of knowledge:	Improved processes, techniques and skills in addressing transportation issues:	Enlarged pool of trained transportation professionals:	Greater adoption of new technology:
Presented CVI-UTC research at the 2014 Technology Legislative Fair (Maryland)	X	X	X	X	X
Presented CVI-UTC research at the VDOT High School Career Fair in Manassas, VA	X	X	X	X	X
Motorcycles donated by Motorcycle Safety Foundation for CVI-UTC research	X	X	X	X	X
Hosted Morgan State Teacher Transportation Institute (Baltimore HS Teachers)			X	X	X
Continued data collection and research on the Smart Road and Northern Virginia Connected Vehicle Testbeds	X	X		X	X
Conducted major equipment manufacturer resource meetings with stakeholders	X	X	X		X
Funded UGA and GRA direct tuition and work study	X		X	X	
Continued website development and updated content		X		X	
Hosted VTTI School Day outreach event (K-12 students, teachers, parents)			X		
Demonstrated CVI technologies at the Virginia Science Festival	X			X	X
Participated in the Newseum for VTTI Spring Open House and ISE Graduate Students	X	X	X	X	X
Hosted Pavement Evaluation 2014	X	X	X	X	X
Demonstrated CVI-UTC research at Blacksburg Community Day 2014	X	X	X	X	X
Funded five (5) new research projects	X	X	X	X	X

Impacts:

	Safer driver behavior:	Increased travel time reliability:	Increased intermodal transportation operations:	Reduction in carbon and other harmful emissions from transportation sources:
Funded five (5) new research projects	X	X		X
Graduated 12 students (5 M.S. and 7 Ph.D.)	X	X	X	X
Placed all 12 graduates in employment post-graduation at private engineering practices or public institutions	X	X	X	X
62 presentations and publications accepted by national and international transportation conferences and institutions	X	X	X	X
9 CVI applications developed, improved, or evaluated on CVI-UTC testbeds	X	X	X	X
CVI-UTC research presentations and display planned for 2015 TRB Annual Meeting	X		X	
CVI-UTC Research displayed at 2014 ITS World Congress	X		X	
Completion of grant-sponsored activities toward deployment of the Northern Virginia Connected Vehicle Testbed	X		X	
Developed and participated in the Transportation Undergraduate Research Fellowship (TURF) Program	X	X	X	X
25 short courses and other professional presentations given, reaching 1,572 students, researchers, and general public	X		X	
31 underrepresented students supported	X	X	X	X
2014 CVI-UTC Outstanding Student of the Year Award presented at the 2015 UTC Annual Banquet	X	X	X	X
CVI-UTC research covered by Discovery Channel Canada	X	X	X	X
CVI-UTC research covered by Voice of America	X			

	Safer driver behavior:	Increased travel time reliability:	Increased intermodal transportation operations:	Reduction in carbon and other harmful emissions from transportation sources:
Hosted the 3rd Advanced Civil Infrastructure Management Course & 10th Annual Inter-University Symposium on Infrastructure Management	**X**			
Presented CVI-UTC research at the 2014 Technology Legislative Fair (Maryland)	**X**	**X**	**X**	**X**
Presented CVI-UTC research at the VDOT High School Career Fair in Manassas, VA	**X**	**X**	**X**	**X**
Motorcycles donated by Motorcycle Safety Foundation for CVI-UTC research	**X**			
Hosted Morgan State Teacher Transportation Institute (Baltimore HS Teachers)	**X**		**X**	
Continued data collection and research on the Smart Road and Northern Virginia Connected Vehicle Testbeds	**X**		**X**	
Conducted major equipment manufacturer resource meetings with stakeholders	**X**	**X**	**X**	**X**
Funded UGA and GRA direct tuition and work study	**X**	**X**	**X**	**X**
Continued website development and updated content	**X**			
Hosted VTTI School Day outreach event (K-12 students, teachers, parents)	**X**			**X**
Demonstrated CVI technologies at the Virginia Science Festival	**X**		**X**	
Participated in the Newseum for VTTI Spring Open House and ISE Graduate Students	**X**			
Hosted Pavement Evaluation 2014	**X**	**X**	**X**	**X**
Demonstrated CVI-UTC research at Blacksburg Community Day 2014	**X**	**X**	**X**	**X**
Funded five (5) new research projects	**X**			

Special Reporting Requirements

If there are any special reporting requirements specified in the award terms and conditions (not applicable for CVI-UTC).