PROGRAM PROGRESS PERFORMANCE REPORT

Connected Vehicle/Infrastructure University Transportation Center (CVI-UTC)

January 1 to June 30, 2015
Connected Vehicle/Infrastructure University Transportation Center (CVI-UTC)

The mission statement of the Connected Vehicle/Infrastructure University Transportation Center (CVI-UTC) is to conduct research that will advance surface transportation through the application of innovative research and using connected-vehicle and infrastructure technologies to improve safety, state of good repair, economic competitiveness, livable communities, and environmental sustainability.

The goals of the Connected Vehicle/Infrastructure University Transportation Center (CVI-UTC) are:

- 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

Disclaimer

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Program Progress Performance Report for
University Transportation Research Centers (PPPR #7)
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
Morgan State University (MSU)

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DUNS: 0031370150000
EIN: 54-6001805

Grant Period: January 2012 – July 2016
Reporting Period End Date: June 2015
Report Frequency: Semi-annual reporting periods
Report Term: January – June 2015

Submission Date: July 30, 2015
Accomplishments

What are the major goals and objectives of the program?

The goals of the Connected Vehicle/Infrastructure University Transportation Center (CVI-UTC) are:
- 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

Focused on the following strategic goals:
- Safety
- State of Good Repair
- Economic Competitiveness
- Livable Communities
- Environmental Sustainability

What was accomplished under these goals?

During the January 1 to June 30, 2015 reporting period covered by this PPPR, the following was accomplished:

Major activities:
- Research projects: 14 projects ongoing, 2 projects completed and final reports pending, 7 final reports submitted for approval (expected during the next reporting period)
- Funded UGA and GRA direct tuition and work study: 28 students supported during this reporting period (including many underrepresented students)
- Graduated 3 students (1 undergraduate, 2 Ph.D.); all 3 students were placed in employment post-graduation at private engineering practices, public institutions, or continued to pursue a higher degree
- 8 CVI applications developed, improved, or evaluated on CVI-UTC testbeds during this reporting period
- Continued data collection and research on the Smart Road and Northern Virginia Connected Vehicle Testbeds
- 21 presentations and publications accepted by national and international transportation conferences and institutions during this reporting period
- CVI-UTC research displayed at the Transportation Research Board (TRB) 95th Annual Meeting 2015, Jan 10-14, 2015, in Washington DC.
- CVI-UTC research displayed at Society of Automotive Engineers Government Industry Meeting (SAE GIM), Jan 20-22, 2015 Washington, DC.
- CVI-UTC research displayed at Lifesavers Conference, March 15-17 2015, Chicago, IL.
- Hosted and presented CVI-UTC research at VTTI School Day outreach event (K-12 students, teachers, parents), April 2, 2015, Blacksburg, VA.
• Along with TRB, co-hosted the International Conference on Managing Pavement Assets, May 18-21 2015, Washington, DC.
• Hosted and presented CVI-UTC research at Staff Appreciation Day, May 20 2015 Blacksburg VA.
• CVI-UTC research displayed at the Intelligent Transportation Systems of America Annual Meeting, June 2-5, 2015 in Pittsburg, PA.
• 2014 CVI-UTC Outstanding Student of the Year Award presented at the 2015 UTC Annual Banquet at the Transportation Research Board (TRB) 95th Annual Meeting 2015, Jan 10, 2015, in Washington DC.
• Hosted and presented CVI-UTC research at Media Day, June 12, 2015, Blacksburg, VA.
• Hosted and presented CVI-UTC research to many community groups, businesses, and academic groups during multiple tours of the Virginia Smart Road and VTTI facilities
• Continued website development and updated content

Specific objectives:

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<thead>
<tr>
<th>Major Activities:</th>
<th>Safety</th>
<th>State of Good Repair</th>
<th>Economic Competitiveness</th>
<th>Livable Communities</th>
<th>Environmental Sustainability</th>
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<tr>
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Significant results, including major findings, developments, and conclusions:
Seven final reports submitted for approval:
  o Based on the compliance data, it is evident that the highest compliance rates are achieved for large and medium gap size scenarios, with no significant difference of compliance rates between these gap sizes.
  o Though the small gap scenario has resulted in the lowest compliance rates (58%), it implies that some drivers were comfortable following advisories when available gaps were relatively smaller and accept gaps that they would have otherwise rejected. This indicates that the Merge Management Advisories have the potential to improve merging operation even in highly congested condition.
  o A valuable lesson from this study is that it is important to design advisory messages in straightforward way so that drivers can readily understand and with which the desired outcomes are easily achieved.
  o In most cases, no significant differences in compliance rates between male and female participants were found.
  o Older participant drivers (65 years and above) demonstrated statistically significant lower compliance rate when compared with all other age groups.
  o In terms of response time, for both MCA and LCA strategy, we can observe similar trend in the average reaction times across the different gap sizes with comparatively slower response for VSL advisory. Also, as gap size decreased, the average reaction time also increased, this may be due to drivers becoming more cautious about lane changing as the available gap size decreased.

• Safety, Operational, and Energy Impacts of In-Vehicle Adaptive Stop Displays Using Connected Vehicle Technology: A. Noble (VTI), T. Dingus (VTI), Z. Doerzaph (VTI), H. Rahka (VTI), B. Katz (VT); submitted January 2015, revisions pending.
  o The performance of participants using the adaptive stop display indicates no difference in stopping behavior in terms of driver input when compared to a traditional stop sign. However, the increased level of compliance to the stop display is something that should be noted; participants were not missing valuable information and were more willing to stop when using the adaptive stop display.
  o A stop made in compliance with the adaptive stop display had a compliance level of 62.11 percent compared to a stop made at a traditional stop sign (12.44 percent compliance).
  o When participants were presented with the “proceed with caution” display, they exhibited more risk-averse behaviors that were appropriate when responding to situational changes that required higher levels of attention, such as an increase in traffic.
  o Mean glance durations and frequencies decreased rapidly with increased driver experience with the in-vehicle system.
  o 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.
  o Participants were generally able to learn how to use the display quickly.
  o Additionally, the number of glances to the display decreased to about one glance per intersection approach after the first six to eight exposures to the system.
  o Scanning behaviors increased during situations of higher traffic levels, which was a sign that they were not relying totally on the system and still sought information from their surroundings before committing to proceeding through the intersection.
For one intersection with an ADT of 1,950 vehicles per day controlled by adaptive stop display compared to traditional stop signs the savings to society in terms of CO$_2$ emissions is $24,349.14 over 45 years.

**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), G. Flintsch (VTTI); submitted December 2014, revisions pending.

- 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.

**Infrastructure Safety Assessment Using Connected Vehicle Data:** R. Kluger (UVA), B. Smith (UVA); submitted December 2014, revisions pending.

- Utilized naturalistic driving data to classify crash and near-crash events with elements of the Basic Safety Message (BSM).
- Successfully developed a model to detect crashes and near-crashes and also designed a methodology to apply hot spot identification.
- Project findings outline an approach to identify crash hotspots utilizing connected vehicle data, once testbed data is widely available.

**An Innovative “Intelligent” Awareness System for Roadway Workers Using Dedicated Short-Range Communications:** D. Bowman (VTTI), T. Martin (VT); submitted January 2015, revisions pending.

- Approach enables detection of roadside workers in situations where existing solutions may fail due to visual occlusions or environmental conditions.
- Experimental results show that the warning system can distinguish between a near miss, complete miss, and collision with a worker with 91% accuracy.
- Accurate warnings can be provided 5 to 6 seconds before any potential collision, allowing time for mitigating solutions.

**Prototyping and Evaluating a Smartphone Dynamic Message Sign (DMS) Application in the CVI-UTC Test Bed:** B. Smith (UVA), J. Ma (UVA); submitted March 2015, revisions pending.

- 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.

**Connected Motorcycle System Performance:** R. Viray (VTTI), Z. Doerzaph (VT); submitted June 2015, revisions pending.

- Across the various tests, it was quite apparent that rider occlusion and ranges impacts communication performance. In situations where the motorcycle has direct line of sight with the vehicle, a noticeable increase in performance is seen.
- For the dynamic range tests, it was observed that the forward mounted antenna had an overall wider communication range of -300m to +300m in the open sky environment. For the rear mounted antenna, a -300m to +100m in the open sky environment.
- Having a wider overall communication range allows for effective detection of motorcycles in crash avoidance applications. Depending on the specific crash avoidance application,
however, such distances may mean more or less in different configurations. For example, if a vehicle and a motorcycle are approaching each other head on, having a longer communication range in the ahead direction proves more valuable.

Two projects completed:

- **Connected Vehicle Applications for Adaptive Overhead Lighting:** M. Palmer (VTTI), R. Gibbons (VTTI), A. Medina (VTTI); completed June 2015, report pending.
  - Survey results indicate acceptance of the on-demand lighting concept with participants often rating the system to be safe for the speeds they were driving (35 and 55mph).
  - Participants were able to detect pedestrians on the side of the road under the on-demand conditions nearly as well as under the continuous lighting conditions, but the differences were not statistically significant.

- **Connected Motorcycle Crash Warning Interfaces:** M. Song (VTTI), S. McLaughlin (VTTI), Z. Doerzaph (VTTI); completed August 2014, report pending.
  - Connected vehicle technology (CVT) based motorcycle crash warning systems (CWS), through its prototype crash warning interface (CWI) and applications, delivered positive impact on participants’ opinions of having the system on their own motorcycles. Participants believed that a CVT-based CWS and its applications would have benefitted them in the motorcycle crashes they had experienced, had the technology been available.
  - Although the combination of all individual displays was better at catching riders’ attention without confusion, it demanded so much attention that normal riding behavior would be impaired. Double-stimulus is hard to miss, but not too overwhelming, and was preferred by most participants (92.3%).
  - Visor-mounted LED light strips were level with eyes on the visual scanning path into peripheral vision field. Tests suggested that naïve users may look at them when triggered. Moving the strips further apart, deep into the peripheral vision or up to the edge of the visor might discourage riders from looking directly at them and getting distracted.
  - An appropriate level of volume would help present the urgency level and overcome any road noise. The presentation of directional information turned out to be a weak point for simple tones on different channels; using speech in addition to various channels may be a good solution.
  - Uncommon types of warnings, such as haptic alerts that provided physical stimuli, turned out to be effective, and the haptic wristband was ranked highly among all displays. Although the bulky design requires further improvement, the concept is promising. As with visual displays, the haptic design performed well at presenting directional information.
  - Environment could influence the performance of warning interfaces, so it would make sense to develop a smarter CWI by adjusting alerts based on environmental measures.
  - CWS applications overall were less favored by sport riders than cruiser and touring riders, who might put more emphasis on riding comfort and safety. Cruiser and touring riders, who may use an in-helmet headset more often in group riding, preferred the in-helmet headset over other displays, while sport riders showed no preference.

Fourteen research projects currently underway:

- **Emergency Vehicle-to-Vehicle Communication:** P. Murray-Tuite (VT); ongoing.
  - A number of studies involving the reaction times have been conducted for the moment that an object was visible, but the connected vehicle project involves stimuli that were not immediately recognized. For gradual or delayed onset situations, the reactions time from the
first visibility to vehicle response could be over 10 seconds (Gundy, 1992, Moberly and Langham, 2001, Muttart, 2000).

- The first research question is to determine if the reaction times equal 2.5 seconds. The hypotheses to be tested are \( H_0: \mu = 2.5 \) seconds versus \( H_a: \neq 2.5 \). According to STATA, a two-sided t-test the mean is 2.5 is rejected at the 5 percent level with a p-value of 0.001. Further hypothesis testing was performed since the reaction to invisible objects (audio messages) in the connected vehicle was assumed to be greater than 2.5 seconds. A one-tailed t-test that the mean is 2.5 rather than a larger amount is also rejected at the 5 percent level with a p-value of 0.0005.

- Accordingly, reaction times for the connected vehicle have a tendency to rise higher than the normal case. Typically, predictive equations are created by Multiple Stepwise Linear Regression (MSLR) based on the selection of variables and the accuracy of the resulting regression as a predictor. Thus, this leads to another research question which would be to determine if there is a better model for predicting the reaction time.

- With the collected data in the connected vehicle, Support Vector Regression proved better models than MSLR.

- **Field Testing of Eco-speed Control using Vehicle-to-infrastructure Communication**: H. Rahka (VTTI); ongoing.
  - 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.

- **Next-Generation Transit Signal Priority with Connected Vehicle Technology**: B. Park (UVA), J. Hu (UVA), Y. Lee (Morgan State); ongoing.
  - Field evaluation test confirmed that the transit signal priority (TSP) under connected vehicle technology work as expected.
  - A simulation-based study shows that the TSP under Connected Vehicle significantly improves both bus travel time as well as network delay when compared to Conventional TSP and No TSP cases.
  - TSP under connected vehicle developed in this study can handle multiple buses as well as coordination with adjacent intersections.

- **Field Demonstration of Cumulative Travel-time Responsive Intersection Control Algorithm under Connected Vehicle Technology**: B. Park (UVA); ongoing.
  - The cumulative travel-time responsive (CTR) algorithm was enhanced by adopting adaptive Kalman filter (AFK) algorithm that works much better under low market penetration rates of connected vehicles. The AKF seems outperform existing actuated signal control at a lower market penetration rate of 15%.
- Developed hardware in the loop simulation environment featuring actual controller used in the Northern Virginia, CID, and VISSIM microscopic traffic simulator.
- A field testing of the Bluetooth readers indicated that the market penetration rate of the Bluetooth devices was much lower than expected – approximately 10% (compared to some literature indicating about 20%). This might lead to significant disadvantage in the field deployment.

- **Reducing School Bus/Light-Vehicle Conflicts Through Connected Vehicle Communications:** K. Donoughe (VTTI), A. Alden (VTTI); ongoing.
  - Initial analysis of results indicate that the "school bus ahead" alert provided by the on-board HMI was effective at providing an enhanced awareness of school bus loading ahead.

- **Intersection Management using In-vehicle Speed Advisory/Adaptation:** H. Rakha (VTTI), I. Zohdy (VT); ongoing.
  - 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.

- **Developing Connected Vehicle Freeway Speed Harmonization Algorithms:** H. Rakha (VTTI), H. Chen (VTTI), M. Elhenawy (VTTI); ongoing.
  - 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.

- **Measuring User Acceptance of and Willingness-to-pay for CVI Technology:** H. Shin (Morgan State), M. Callow (Morgan State), Y. Lee (Morgan State), A. Farkas (Morgan State); ongoing.
  - 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.

- **Developing and Evaluating a Smartphone Application Aimed at Reducing Crash Involving Bicycles:** A. Jahangiri (VTTI), H. Rakha (VTTI), T. Dingus (VTTI); ongoing.
  - The following results were obtained using only a part of the data. The data collection is still ongoing and the results will be updated after completing the analysis for the entire data.
  - A naturalistic cycling data collection system was conducted that can be used to develop bicycle violation prediction models.
  - The system architecture that embodied cyclist violation prediction models was demonstrated. It was shown how connected vehicle technology can be adopted for different parts to
communicate amongst themselves. Communication between different system entities was shown to have different purposes:

1. Sending required variables for violation prediction models such as bicycle speed, acceleration, and current location.
2. Sending warning to the drivers/riders in potential danger.
3. Sending a “control change” order to change the signal setting.

- In case of signal-controlled intersections, it was found that it is more likely that a cyclist violates a red light when making right turns. Also, the probability of red light violation decreases when there is side traffic at the intersection or when there is traffic in front of the cyclist.
- In case of stop-controlled intersections, the likelihood of violating a stop sign increases when there is no side traffic or when the cyclist is younger.
- Violation prediction models at stop-controlled intersections were developed. The model accuracy of about 94 percent was obtained when the time to intersection for the cyclist was about 2 seconds.

- A Connected Vehicle-Enabled Virtual Dynamic Message Sign System Demonstration and Evaluation on the Virginia Connected Vehicle Testbed: H. Park (UVA), B. Smith (UVA), D. Recht (UVA); ongoing.*
- Human Factors Evaluation of an In-Vehicle Active Traffic and Demand Management (ATDM) System: K. Sykes (VTTI), A. Noble (VTTI), Z. Doerzaph (VTTI); ongoing.*
- Connected Vehicle Virginia Test Bed System Performance: R. Viray (VTTI), Z. Doerzaph (VTTI); ongoing.*
- Vehicle-Based BSM Generator for Accelerating Deployment: R. Viray (VTTI), R. Resendes (VTTI); Z. Doerzaph (VTTI); ongoing.*
- Applications of Connected Vehicle Infrastructure Technologies to Enhance Transit Service Efficiency and Safety: Y. Lee (Morgan State), K. Hancock (VT), H. Rakha (VTTI); ongoing.*

* Note that at the time of reporting, research projects marked with an asterisk had recently initiated research activities and therefore did not have preliminary or final results to report.

**Key outcomes or other achievements:**
The Northern Virginia Connected Vehicle and Virginia Smart Road Test Beds are now completely operational allowing translational research toward deployment to be conducted. All CVI-UTC research activities have either been completed or are currently underway and utilizing the test bed environments. These research projects will aid in the next phase of application development and ultimate deployment of CVI systems in Northern Virginia.

**Discussion of stated goals not met:**
Nothing to report.

**What opportunities for training and professional development has the program provided?**
Educational programming completed this reporting period includes:
- VTTI School Days Outreach (K-12 students, teachers, parents)
- Virginia Tech Staff Appreciation Day
- Media Day in Blacksburg, Virginia
- Presented CVI-UTC research to many community groups, businesses, and academic groups during multiple tours of the Virginia Smart Road and VTTI facilities
Because this is the last year (2015-16) 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 and the TRB database. 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. In addition, a Media Day was hosted in Blacksburg, Virginia which featured CVI-UTC research and applications, and were covered by multiple media outlets including local news channels, Traffic Technology Today, and the U.S. Chamber of Commerce. The CVI-UTC was also particularly good in technology transfer via presentations and publications (21 total) during this reporting period.

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

During the next reporting period, the CVI-UTC will continue ongoing research projects, continue CVI application development, produce final reports, and disseminate research through presentations and publications. The results of these research projects will aid in the deployment of upcoming systems. Our outreach goals will be filled through continued activities which present CVI-UTC research to the public (such as VTTI School Day). In addition, the CVI-UTC is planning a high-level VIP demonstration of CVI-UTC research and applications on the Northern Virginia Test Bed, with invitations being extended to U.S. DOT congressional staff, Virginia Secretary of the Commonwealth, Secretary of Transportation, and other state officials, to experience connected vehicle and automated vehicle capabilities.

**Products**

**What has the program produced?**

- **Research Presentations:**
  The following are research presentations from CVI-UTC research projects that were completed during this reporting period (January 1 – June 30, 2015) and/or accepted/planned for presentation in the upcoming months (noted with *).
  
  
  
  
  
Publications:
The following are publications from CVI-UTC research projects that were completed during this reporting period (January 1 – June 30, 2015) and/or accepted/planned for publication in the upcoming months (noted with *).


**Websites; other Internet:**

CVI-UTC maintains a website to document consortium-related activity (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 the following:

- A Virtual Dynamic Message Sign (VDMS) system was developed by the UVA CTS team, in collaboration with VTTI, which 1) provides audio messages of existing text messages on Dynamic Message Signs (DMSs) to drivers, and also 2) can be used to create additional virtual DMSs for better traffic operations. (CVI-UTC project: A Connected Vehicle-Enabled Virtual Dynamic Message Sign System Demonstration and Evaluation on the Virginia Connected Vehicle Testbed)

- A Transit Signal Priority (TSP) application has been developed and tested on the Virginia Smart Road. (CVI-UTC project: Next Generation Transit Signal Priority with Connected Vehicle Technology)

- A CTR algorithm has been developed and enhanced by adopting an adaptive Kalman filter algorithm. (CVI-UTC project: Field Demonstration of Cumulative Travel-time Responsive Intersection Control Algorithm under Connected Vehicle Technology)

- An application for providing an alert to driver's approaching a loading school bus was developed and evaluated for driver response and overall efficacy. (CVI-UTC project: Reducing School Bus/Light-Vehicle Conflicts Through Connected Vehicle Communications)

- A VDMS smartphone application was developed for the Android platform. (CVI-UTC project: Prototyping and Evaluating a Smart Phone Dynamic Message Sign Application in the CVI-UTC Testbed)

- An application is currently under development which will utilize radar data to populate remote vehicle information for a BSM for transmission over the air. UTC project: Vehicle Based BSM Generator for Accelerating Deployment)

- A naturalistic cycling data collection system was developed that can be used to develop bicycle violation prediction models. (CVI-UTC project: Developing and Evaluating a Smartphone Application Aimed at Reducing Crashes Involving Bicycles)

- A user location-based mobile app and a server program is being developed to request flexible transit service. (CVI-UTC project: Applications of Connected Vehicle Infrastructure Technologies to Enhance Transit Service Efficiency and Safety)

**Inventions, patent applications, licenses:**

Nothing to report
Participants & Collaborating Organizations

Have collaborators or contacts been involved?

- Collaborations with others within the lead or partner universities, especially interdepartmental or interdisciplinary collaborations:
  - “A Connected Vehicle-Enabled Virtual Dynamic Message Sign System Demonstration and Evaluation on the Virginia Connected Vehicle Testbed”: UVA CTS and VTTI
  - “Next Generation Transit Signal Priority with Connected Vehicle Technology”: UVA and Morgan State
  - “Applications of Connected Vehicle Infrastructure Technologies to Enhance Transit Service Efficiency and Safety”: VT and Morgan State

- Collaborations or contact with others outside the UTC:
  - “A Connected Vehicle-Enabled Virtual Dynamic Message Sign System Demonstration and Evaluation on the Virginia Connected Vehicle Testbed”: UVA CTS has been working with the Public Safety Traffic Operation Center (PSTOC) of VDOT. The VDMS system will be demonstrated to the staff of PSTOC and used by the PSTOC operators for an operational testing.
  - “Reducing School Bus/Light-Vehicle Conflicts Through Connected Vehicle Communications”: VTTI collaborated with Leidos (Brian Katz) who contributed resources (loan of a school bus) for completion of the study.
  - “Connected Vehicle Virginia Test Bed System Performance”: VTTI collaborated with Iteris, which provided Intelligent Transportation System networking support services for the test corridor in Northern Virginia.

- Collaborations or contacts with others outside of the United States or with an international organization:
  - “Next Generation Transit Signal Priority with Connected Vehicle Technology”: UVA collaborated with the Cyber Physical System Center at DGIST in South Korea.
  - “Field Demonstration of Cumulative Travel-time Responsive Intersection Control Algorithm under Connected Vehicle Technology”: UVA collaborated with the Cyber Physical System Center at DGIST in South Korea.
  - “Connected Vehicle Virginia Test Bed System Performance”: VTTI collaborated with University Miguel Hernández Miguel Sepulcre Ubiquitous Wireless Communications Research Laboratory Uwicore, Signal Theory and Communications Division.

Impact

What is the impact on the development of the principal discipline(s) of the program?

With the completion of the Northern Virginia and Smart Road test beds, the research being conducted under the CVI-UTC is moving into a translational research phase, where the applications that are being developed to assist travelers and the overall roadway transportation system are moving toward the
ultimate goal of deployment of CVI technologies. This research will have a direct impact on the base of knowledge, theory, and methods used to develop these technologies such that deployment can be realized. In addition, the CVI-UTC is continuing to conduct outreach activities, education and workforce development programming within and between the consortium universities, and seeking outside collaboration and participation toward the goal of CVI technology deployment.

**What is the impact on other disciplines?**
The CVI-UTC has continued to conduct education and outreach activities which increase awareness about CVI technology across multiple disciplines. Major educational outreach events during this reporting period include:
- VTTI School Days Outreach (K-12 students, teachers, parents)
- Virginia Tech Staff Appreciation Day
- Media Day in Blacksburg, Virginia
- Presented CVI-UTC research to many community groups, businesses, and academic groups during multiple tours of the Virginia Smart Road and VTTI facilities

**What is the impact on the development of transportation workforce development?**
During this reporting period, the CVI-UTC supported 28 undergraduate, masters, and Ph.D. level students at the consortium universities. The research projects conducted under the CVI-UTC provided opportunities for the students to conduct research, many toward course projects, theses, and dissertations, and gain valuable knowledge and training in the transportation field toward future employment.

In addition, 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.

Furthermore, 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.

- The following students worked on and were educated under the grant during this reporting period (January 1 – June 30, 2015):
  - **Kayla Sykes** (GRA, VTTI) Working on “Human Factors Evaluation of an In-Vehicle Active Traffic and Demand Management (ATDM) System” as the PI under the direction of Dr. Zachary Doerzaph.
  - **Alex Noble** (GRA, VTTI) Working on “Human Factors Evaluation of an In-Vehicle Active Traffic and Demand Management (ATDM) System” and “Connected Vehicle System Performance” under the direction of Dr. Zachary Doerzaph.
  - **Jen Palacios** (UGA, UVA) Working on “Infrastructure Safety Assessment Using Connected Vehicle Data” under the direction of Dr. Brian Smith.

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.


Rauful Islam (GRA, VT) Working on “Emergency Vehicle-to-Vehicle Communication” under the direction of Dr. Pamela Murray-Tuite and “Applications of Connected Vehicle Infrastructure Technologies to Enhance Transit Service Efficiency and Safety” under the direction of Dr. Kathleen Hancock.


Naser Hdieb (GRA, VT) Working on “Emergency Vehicle-to-Vehicle Communication” under the direction of Dr. Pamela Murray-Tuite and “Applications of Connected Vehicle Infrastructure Technologies to Enhance Transit Service Efficiency and Safety” under the direction of Dr. Kathleen Hancock.

Mohammed Almannaa (GRA, VT) Working on “Field Testing of Eco-Speed Control Using V2I Communication” under the direction of Dr. Hesham Rakha.

Keane Rucker (UGA, UVA) Working on “Connected Vehicle Enabled Freeway Merge Management – Field Test” under the direction of Dr. Brian Smith.


M. Tanveer Hayat (GRA, UVA) Working on “Connected Vehicle Enabled Freeway Merge Management - Field Test” under the direction of Dr. Brian L. Smith.

Seongah Hong (GRA, UVA) Working on “Field Demonstration of Cumulative Travel-time Responsive Intersection Control Algorithm under Connected Vehicle Technology” under the direction of Dr. Brian Park.

Shalini Sankaranarayanan (GRA, VT) Working on “Applications of Connected Vehicle Infrastructure Technologies to Enhance Transit Service Efficiency and Safety” under the direction of Dr. Kathleen Hancock.

Kelly Donoughe (GRA, VT) Working on “Reducing School Bus/Light-Vehicle Conflicts Through Connected Vehicle Communications” under the direction of Andy Alden (VTTI).

Jiaqi Ma (GRA, UVA) Working on “Prototyping and Evaluating a Smart Phone Dynamic Message Sign Application in the CVI-UTC Testbed” under the direction of Dr. Brian Smith.

Arnab Gupta (GRA, VTTI) Working on “Connected Vehicle System Performance” under the direction of Dr. Zachary Doerzaph.

Abhijit Sarkar (GRA, VTTI) Working on “Connected Vehicle Virginia Test Bed System Performance” under the direction of Dr. Zachary Doerzaph.

Ismail Zohdy (GRA, VTTI) Working on “Intersection Management using In-vehicle Speed Advisory/Adaptation” as PI under the direction of Dr. Hesham Rakha.

Abdallah Hassan (GRA, VTTI) Working on “Intersection Management using In-vehicle Speed Advisory/Adaptation” under the direction of Dr. Hesham Rakha.
o Ran Tu (GRA, VTTI) Working on “Developing Connected Vehicle Freeway Speed Harmonization Algorithms” under the direction of Dr. Hesham Rakha.

o Arash Jahangiri (GRA, VTTI) Working on “Developing and Evaluating a Smartphone Application Aimed at Reducing Crashes Involving Bicycles” under the direction of Dr. Hesham Rakha and Dr. Tom Dingus.

o Clayton Thomas (GRA, VTTI) Working on “Applications of Connected Vehicle Infrastructure Technologies to Enhance Transit Service Efficiency and Safety” under the direction of Dr. Kathleen Hancock and Dr. Hesham Rakha.

o Kaveh Bakhsh Kelarestaghi (GRA, VTTI) Working on “Applications of Connected Vehicle Infrastructure Technologies to Enhance Transit Service Efficiency and Safety” under the direction of Dr. Kathleen Hancock and Dr. Hesham Rakha.

What is the impact on physical, institutional, and information resources at the university or other partner institutions?

The grant money has 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. These resources have offered the consortium universities opportunities for research that would not have been possible without this grant. In addition, the grant funding has allowed educational and outreach programs to continue at consortium universities that would not have been possible otherwise.

What is the impact on 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 results from CVI-UTC research will have a translational impact on the future of CVI technologies, being used extensively to inform emerging connected vehicle deployments. The CVI-UTC is laying the groundwork for CVI technology, with the ultimate goal of deploying this technology such that lives may be saved, mobility improved, and positive impacts made on the environment.

What is the impact on society beyond science and technology?

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 have been or 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:

During this reporting period, a capstone project was funded which will take the results of the 23 research projects funded under the CVI-UTC and develop real-world applications which drivers can actually use and
gain benefits from CVI technologies. This project will include a demonstration of the CVI technologies developed to high-level VIPS, as previously described, currently slated to take place during the next reporting period.

**Actual or anticipated problems or delays and actions or plans to resolve them:**
Nothing to report.

**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.

### Additional Information Regarding Products and Impacts

#### Outputs:

**Research projects awarded:**

<table>
<thead>
<tr>
<th>Research Projects</th>
<th>Safety</th>
<th>State of Good Repair</th>
<th>Economic Competitiveness</th>
<th>Livable Communities</th>
<th>Environmental Sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety and Human Factors of Adaptive Stop/Yield Signs Using Connected Vehicle Infrastructure</td>
<td>X</td>
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<td>Connected Vehicle Applications for Adaptive Overhead Lighting</td>
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<td>Field Testing of Eco-Speed Control Using V2I Communication</td>
<td>X</td>
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<td>An Innovative &quot;Intelligent&quot; Awareness System for Work Zone Workers Using Dedicated Short-Range Communications</td>
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<td>Emergency Vehicle to Vehicle Communication</td>
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<td>Connected Vehicle Enabled Freeway Merge Management - Field Test</td>
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<td>Infrastructure Safety Assessment Using Connected Vehicle Data</td>
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<td>Infrastructure Pavement Assessment and Management Applications Enabled by the Connected Vehicle Environment Research Program - Phase I: Proof-of-Concept</td>
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<td>Connected Motorcycle Crash Warning Interfaces</td>
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<tr>
<td>Connected Motorcycle System Performance</td>
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<tr>
<td>Developing and Evaluating a Smartphone Application Aimed at Reducing Crashes Involving Bicyclists</td>
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<tr>
<td>Developing Connected Vehicle Freeway Speed Harmonization Algorithms</td>
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<td>Reducing Bus/Light-Vehicle Conflicts Through Connected Vehicle Communication</td>
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<td>Next Generation Transit Signal Priority with Connected Vehicle Technology</td>
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<td>Prototyping and Evaluating Smart Phone Dynamic Message Sign Application in the CVI-UTC Testbed</td>
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<td>Measuring User Acceptance of and Willingness to Pay for CVI Technology</td>
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### Research Projects:

<table>
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<tr>
<th>Research Project</th>
<th>Safety</th>
<th>State of Good Repair</th>
<th>Economic Competitiveness</th>
<th>Livable Communities</th>
<th>Environmental Sustainability</th>
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<tbody>
<tr>
<td>Connected Vehicle Virginia Test Bed System Performance</td>
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<td>Vehicle Based BSM Generator for Accelerating Deployment</td>
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<td>Effect of In-Vehicle ATDM on Traffic Management, Distraction, and Desirability</td>
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<td>Field Demonstration of Cumulative Travel-time Responsive Intersection Control Algorithm under Connected Vehicle Technology</td>
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<td>Capstone Project</td>
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</tbody>
</table>

### Research Presentations:

The following are research presentations from CVI-UTC research projects that were completed during this reporting period (January 1 – June 30, 2015) and/or accepted/planned for presentation in the upcoming months (noted with *).

Publications:
The following are publications from CVI-UTC research projects that were completed during this reporting period (January 1 – June 30, 2015) and/or accepted/planned for publication in the upcoming months (noted with *).


Websites; other Internet:
CVI-UTC maintains a website to document consortium-related activity (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 the following:

- **Virtual Dynamic Message Sign (VDMS) system**
- **Transit Signal Priority (TSP) application**
- **CTR algorithm has been developed**
- **An application for providing an alert to driver’s approaching a loading school bus**
- **VDMS smartphone application for the Android platform**
- **An application which will utilize radar data to populate remote vehicle information for a BSM for transmission over the air**
- **A naturalistic cycling data collection system that can be used to develop bicycle violation prediction models**
- **A user location-based mobile app and a server program to request flexible transit service**

**Outreach Activities:**

- **VTTI School Days Outreach (K-12 students, teachers, parents)**
- **Virginia Tech Staff Appreciation Day**
- **Media Day in Blacksburg, Virginia**
- **Presented CVI-UTC research to many community groups, businesses, and academic groups during multiple tours of the Virginia Smart Road and VTTI facilities**

**Outcomes:**

<table>
<thead>
<tr>
<th>CVI-UTC research projects</th>
<th>Increased understanding and awareness of transportation issues:</th>
<th>Improved body of knowledge:</th>
<th>Improved processes, techniques and skills in addressing transportation issues:</th>
<th>Enlarged pool of trained transportation professionals:</th>
<th>Greater adoption of new technology:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Funded UGA and GRA direct tuition and work study</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Graduated 3 students and placed in employment or accepted for higher education</td>
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<td>Continued data collection and research on the Smart Road and Northern Virginia Connected Vehicle Testbeds</td>
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<td>8 CVI applications developed, improved, or evaluated on CVI-UTC testbeds</td>
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<td>21 presentations and publications accepted by national and international transportation conferences and institutions</td>
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<td>CVI-UTC research displayed at SAE Government Industry Meeting, 2015</td>
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<tr>
<td>CVI-UTC research displayed at Lifesavers Conference, 2015</td>
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<tr>
<td>Hosted and presented CVI-UTC research at VTTI School Day outreach event, 2015</td>
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<tr>
<td>Co-hosted the International Conference on Managing Pavement Assets, 2015</td>
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<tr>
<td>Hosted and presented CVI-UTC research at Staff Appreciation Day, 2015</td>
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<td>CVI-UTC research displayed at the Intelligent Transportation Systems of America Annual Meeting, 2015</td>
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### Impacts:

<table>
<thead>
<tr>
<th>Event</th>
<th>Safer driver behavior</th>
<th>Increased travel time reliability</th>
<th>Increased intermodal transportation operations</th>
<th>Reduction in carbon and other harmful emissions from transportation sources</th>
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</thead>
<tbody>
<tr>
<td>CVI-UTC research projects</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
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### Special Reporting Requirements

Not applicable for CVI-UTC.