

Request for Research Funding for FY 2020-2021

Requesting Office	State Traffic Engineering and Operations Office	Priority High	2 of 6
Proposed Title	Environment for Testing and Assessing Infrastructure Support of Connected Vehicle and Cooperative Highway Automation Applications		
Justification	<ul style="list-style-type: none"> • Vehicle connectivity and cooperative driving automation (CDA) will have transformative impacts on the transportation system. An important component of vehicle connectivity and cooperative driving automation is the infrastructure support through vehicle-to-infrastructure (V2I) communications with the roadside equipment (RSE) and/or with the cloud. There are about 30 connected vehicle (CV) mobility and safety applications and several other cooperative automation applications that require support from the infrastructure. The various infrastructure elements including the CV RSEs, controllers, and central software will play a major role in ensuring the success of these applications. • Realizing the importance of testing the infrastructure component of the CV applications, a research project funded by the FDOT and entitled “Assessment of the Infrastructure Readiness for Connected Vehicle-to-Infrastructure Applications on Arterial Streets” will develop methods for testing the vendor implementations of the infrastructure side of CV applications. As part of this effort, a hardware-in-the-loop simulation (HIL) environment will be developed for testing three selected CV V2I safety and mobility applications. The HIL environment will allow the RSE and signal controllers to be interfaced with a computer that hosts a microscopic simulation model. However, this development will not allow the testing of the impacts of the applications on the vehicular and pedestrian streams because there are no vehicle-in-the loop and pedestrian-in-the-loop component of the simulation. In addition, the developed environment does not address the testing and assessment of cooperative automated vehicle applications such as those related to speed harmonization, platooning parameter setting, lane assignment, traffic optimization for signal control (TOSCo), eco approach driving, and so on. Such testing and assessment of the infrastructure support of CV and CDA will require the inclusion of connected vehicle in the loop, automated vehicle in the loop, and pedestrian-in-the-loop; in addition to the roadside hardware in the loop that is being developed. • The Federal Highway Administration (FHWA) has invested in CARMASM as an open source cooperative driving automation platform to encourage the development and testing of cooperative driving automation technologies. In addition to the on-board vehicle equipment and software, the CARMASM system has a Cloud component referred to as CARMASM Cloud that provides information to support and enable cooperative automated driving. CARMASM Cloud enables communications with vehicles and pedestrians, the definition of geofences, identifying and communicating cooperative driving parameters (such as speed, lane, platooning parameters, etc.), rules of practice, conditions in which automated vehicles can operate in, and so on. Such capabilities will have to be deployed at traffic management centers and thus there is a need to specify the needed capabilities at the traffic management centers and the roadside in addition to testing methods to support these capabilities. • This project will identify the required capabilities traffic management centers and the roadside to support cooperative driving and vehicle connectivity. The project development will support the work force development/training of FDOT staff on transportation system management and operations (TSM&O) activities related to CDA. The project will extend the roadside HIL environment developed in the FDOT project mentioned above to include CARMASM vehicle in the loop, CARMASM Cloud environment in the loop, and pedestrian in the loop in addition to the HIL interface (RSE and signal controller), already included in the HIL developed in the previously approved project. The resulting environment will synchronize the simulation and the real-world movement of the CARMASM vehicle and pedestrians that are in communication with the infrastructure. The vehicle will interact with the simulated vehicles in the model as if they are real vehicles and allow the testing of connected vehicle and cooperative automation under various congestion and control environments. 		

	<p>The project development will:</p> <ul style="list-style-type: none"> • Identify the needed support at the traffic management centers and roadside for CDA and CV applications and the associated details such as data needs, parameter setting requirements and methods, and required interfaces with other modules of traffic management center software • Develop and demonstrate methods for testing and evaluating the implementations of the infrastructure components of cooperative vehicle applications • Provide simulation environment to evaluate the impacts of CV-based applications and cooperative automation applications on mobility and safety of the traffic streams by assessing the impacts of the real-world CV and connected automated vehicles (CAV) on other vehicles, pedestrians, and traffic control in the simulation. • Recommend updates to the related standards and guidelines of the Department based on the developed methods • Provide an environment to support the identification of the needs for work force development and for supporting the training of FDOT staff on the TSM&O activities associated with CDA. <p>The project activities will be according to the taxonomy and definitions for terms related to CDA presented in the upcoming update to the SAE J3216 standards. The project will utilize small scale automated vehicles, referred to as F 1/10th (1/10th the size of full scale passenger car) with on-board CARMA software, as part of the research activities. This type of vehicles will be used as part of the FHWA CARMA F 1/10th program.</p>
<p>Impact</p>	<ol style="list-style-type: none"> 1. With the anticipated cooperative automated driving implementation, central software at the regional transportation management centers (RTMCs) and roadside equipment will implement algorithms to decide on parameters such as the gap and length of platoon, traffic speed, lane assignment, etc. The project will identify the required capabilities to support CV and CDA at the traffic management center and the roadside and will develop methodology and guidelines for testing the infrastructure components of the cooperative automated vehicle. The developed methodology and guidance will identify the infrastructure requirements for such applications and the required testing. Such guidelines will be required for successful cooperative vehicle automation and CV applications in Florida. The FDOT TSM&O and CAV programs, FDOT TERL, FDOT RTMCs, and signal operation agencies will benefit from such developments. 2. The project will allow the assessment of the impacts of CV-based applications and cooperative vehicle automation on system performance and thus support strategic and tactical TSM&O decisions to invest in, provide, and operate the infrastructure necessary for the applications. 3. The project will allow the assessment of various application parameters under different conditions to support RTMCs management and operations in activating the plans associated with CV and CDA and selecting the parameters to be communicated to the CV and CAV. 4. The project will support the FDOT in the work force development effort related to CDA in identifying the need for additional capabilities and in the training of the FDOT staff on the TSM&O activities related to CDA
<p>Affected Offices</p>	<p>FDOT TSM&O central office, FDOT district TSM&O programs, and TERL</p>
<p>Existing Work</p>	<p>Examples of the work reviewed on the use of vehicle-in-the-loop and hardware in the loop to test and assess cooperative automation includes:</p> <p>Liu, H. and Y. Fen, “Development of an Augmented Reality Environment for Connected and Automated Vehicle Testing,” Report No. 2019-UMTR-4, Center for Connected and Automated Transportation, University of Michigan, January 2019.</p> <p>Szendrei, Z., N. Varga, and L. Bokor, “A SUMO-Based Hardware-in-the-Loop V2X Simulation Framework for Testing and Rapid Prototyping of Cooperative Vehicular Applications,” VAE 2018, LNME, pp. 426–440, 2018. https://doi.org/10.1007/978-3-319-75677-6_37</p> <p>Mukherjee, P., “Investigation of Cooperative Adaptive Cruise Control with Experimental Validation,” Thesis University of Minnesota, July 2016.</p> <p>Ma, J. et al., “Hardware-In-The-Loop Testing of Connected and Automated Vehicle Applications: A Use Case For Queue-Aware Signalized Intersection Approach and Departure,” Transportation Research Board Annual Meeting, Washington, D.C., January, 2018.</p>

	<p>“Platform for Change: TTI Provides FHWA a New Way to Test CV/AV Technologies — Texas A&M Transportation Institute,” https://tti.tamu.edu/news/platform-for-change-tti-provides-fhwa-a-new-way-to-test-cvav-technologies, Accessed 12.19/2018.</p> <p>CARMA Project website and documents were reviewed including the following examples among others:</p> <p>Tiernan, T., P. Bujanovic, P. Azeredo, W.G. Najm, and T. Lochrane, “CARMA Testing and Evaluation of Research Mobility Applications,” DOT-VNTSC-FHWA-19-15, Prepared for Federal Highway Administration Turner-Fairbank Highway Research Center by VOLPE Center, July 2019.</p> <p>FHWA, “Deployment of Cooperative Automated Vehicle Capabilities: Integrated Prototype II - Architecture for CARMA System Version 3.0,” Draft Report. February 2019.</p> <p>Cronin, B., “Cooperative Automation Research Mobility Applications (CARMA),” Texas A&M Transportation Technology Conference, May 8,</p> <p>Lochrane, T., “Driving Innovation CARMA,” A Presentation Made by the FHWA in a FDOT Webinar, August 2019.</p> <p>“CARMA Meetup at Florida Automated Vehicle Summit,” Presentations Made in Conjunction with the FAV Summit in Miami, FL, November 2019.</p> <p>Other related reviewed documents include the following examples:</p> <p>Staplin, L., Mastromatto, T., Lococo, K. H., Kenneth W. Gish, K. W., & Brooks, J. O., “The effects of medical conditions on driving performance,” Report No. DOT HS 812 623, the National Highway Traffic Safety Administration, Washington, DC, September 2018.</p> <p>Wang J., Y. Shao, Y. Ge, and R. Yu, “A Survey of Vehicle to Everything (V2X) Testing,” Sensors, January 2019.</p> <p>FHWA, “V2I Hub Deployment Guide,” Final Report, FHWA-JPO-18-644, July 3, 2018</p>		
<p>Keywords Used In Existing Work Search (Cannot leave blank)</p>	<p>Cooperative Automated Vehicles, Hardware-in-the-Loop, Vehicle-In-the-Loop, CARMA, Augmented Reality, Connected Vehicle Applications</p>		
<p>Related Contracts (Give contract numbers)</p>			
<p>Funding Request</p>	<p>\$275,000.00 (including \$15,000 for the purchase of F 1/10th automated vehicles)</p>	<p>Anticipated Duration</p>	<p>20 months</p>
<p>Project Manager</p>	<p>Raj Ponnaluri and Javier Rodriguez (D6)</p>	<p>Contracting Method</p>	<p>Direct contract with Florida International University and Dr. Mohammed Hadi as the Principal Investigator</p>
<p>Urgency</p>	<p>1</p>	<p>The advent of CAV especially with CDA is the main means to connected infrastructure preparedness with the five levels of the automation as proposed by the Society of Automotive Engineers. This project leverages the FHWA’s CARMA research and development (R&D) initiative, and explores the needs and impacts of data, parameter setting requirements and methods, and required interfaces with other modules of traffic management center software and other FDOT processes. These elements in combination with the related standards and guidelines of the Department are required to maximize the benefits from utilizing the available open source software tool provided by CARMA for the objective of improving safety and mobility needs of all road users. As such this project will support FDOT in identifying the required capabilities to support CV and CDA, making the decisions in investing in such capabilities, testing the technologies and products to support these capabilities, and setting the associated operation and management parameters.</p>	

Implementability	1	FHWA's CARMA is an implementation tool with cooperative driving automation; this tool will be utilized by this project to further enhance the anticipated data utility and demonstrate methods for testing and evaluating the implementations of the infrastructure components of cooperative vehicle applications. This is an implementation project which will be conducted in partnership with a District, to be identified after project selection.
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Project Benefits (Succinct, complete explanation)

The project helps identify the impacts of CV-based applications and cooperative vehicle automation on system performance and thus support strategic and tactical TSM&O decisions to invest in, provide, and operate the infrastructure necessary for the applications. The project will allow the assessment of various application parameters under different conditions to support RTMCs management and operations in activating the plans associated with CV and CDA and selecting the parameters to be communicated to the CV and CAV.

It is expected that the cooperative vehicle technology will become available in the next few years. This project will provide important inputs to the FDOT to provide the required capabilities to ensure safe and effective cooperative driving, while taking a full advantage of cooperative driving to support the management and operations of the transportation system. The developed testing environment will provide a basis for the FDOT to assess various technologies to be operated on the state highways as well as the digital and physical infrastructure readiness to support cooperative driving.

With the constraints on the FDOT budget, it is important to assess the impacts of the investment in the infrastructure to support emerging technologies like connected vehicles and cooperative automated driving compared to the investment in more traditional deployments and enhancements. The developed environment will allow such assessment based on key performance indicators that are related to the strategic goal and objectives of the FDOT.

The utilization of simulation modeling will allow the testing of the many parameters associated with the CV-based and CDA-based application and selecting them before implementing these parameters in the field avoiding the potential of utilizing parameters that do not produce the anticipated benefits and ensuring the selection of best set of parameters.

Project Benefits (Select all that apply and explain)	Quantifiable Benefits (units, dollars, etc...if applicable)	Methodology or Data Sources Used to Determine Quantifiable Benefits. If not applicable, please give justification of project benefits
○ Materials Enhancement	Yes	The operation of CAV will provide data that support the agency in determining the quality of the materials of marking, signing, and pavement
○ Materials Savings		
○ Time Savings	Yes	CV-based and CDA applications are anticipated to have significant mobility applications. Previous research shows that vehicle automation can result in significant increase in lane capacity, up to 100% at 100% marker penetration of CAV. However, more recent studies presented in the transportation research board (TRB) 2020 annual meeting showed that the increase in capacity in the weaving and merging/diverging areas is a little bit lower than those reported above for basic highway segments, although the increase in capacity due to different levels of automation is still very significant.
○ Lives Saved/Injuries Prevented	Yes	CV-based and CDA applications are anticipated to have significant safety applications. Previous research shows reductions in crash rates from 20% to 100%, depending on the level of automation and market penetration.
○ Other (Explain)		

*Comments should explain and support urgency, financial benefit, and implementability scores