Center for Advanced Multimodal Mobility Solutions and Education

USDOT Tier 1 University Transportation Center
Semi-Annual Progress Report #8

Submitted to:	U.S. Department of Transportation Office of the Assistant Secretary for Research and Technology (OST-R)
Grant Number:	69A3551747133
Project Title:	Center for Advanced Multimodal Mobility Solutions and Education (CAMMSE)
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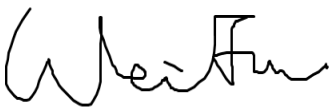
Submission Date:	April 21, 2021
DUNS:	06-630-0096
EIN:	56-0791228
Recipient Organization:	University of North Carolina at Charlotte
Project/Grant Period:	November 30, 2016 - September 30, 2022
Reporting Period Start Date:	October 01, 2020
Reporting Period End Date:	March 31, 2021
Report Term or Frequency:	Semi-annual
Signature of Submitting Official:	

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1. ACCOMPLISHMENTS

1.1. What are the major goals and objectives of the program?

The major goals and objectives of the program as outlined in the proposal include the following categories.

Research

CAMMSE will address the FAST Act research priority area of "Improving Mobility of People and Goods" by conducting multi-disciplinary, multi-modal research, education and workforce development, and technology transfer. CAMMSE is motivated by the recent advances in computing, smartphones and communication technologies, and ubiquitous data to create sustainable, efficient, and growth-enabling multimodal transportation systems. Cutting edge analytical methods and models will enhance the effectiveness, efficiency, and reliability of these systems accordingly. Recent technological advancements enable new perspectives and holistic approaches to address the well-known challenges in multimodal transportation systems planning, design, operations, and maintenance. In particular, the following research topic areas will be established to maximize synergy and adaptability across multiple modes and jurisdictions:

- Increase access to opportunities that promote equity in connecting regions and communities, including urban and rural communities;
- Generate innovations in multi-modal planning and modeling for high-growth regions;
- Develop data modeling and analytical tools to optimize passenger and freight movements;
- Innovations to improve multi-modal connections, system integration and security; and
- Smart Cities.

Leadership

The CAMMSE team is nationally and internationally recognized for its contributions to the field of transportation research, and for its deployment of successful solutions to critical, real-world transportation challenges. In addition, team members are committed advocates and longstanding leaders within the multimodal transportation community and the UTC system itself. Through this UTC grant, the Consortium plans to build on its demonstrated experience to mentor future leaders in the field of transportation. CAMMSE plans to nurture students through skill building and professional development activities that promote notable research scholarships and successful transportation careers.

Education and Workforce Development

With years of collective education, research, and UTC experience, CAMMSE will provide a transportation education program through its partner universities. The program will promote creative and multidisciplinary problem-solving and exposure to a myriad of educational and workforce development experiences. The program will serve to attract, educate, and train future and existing transportation professionals with the know-how to undertake and implement innovative projects being or to be conducted.

The workforce development program will leverage the existing training skills and delivery resources available within partner universities. On-line webinars will be designed and delivered using available technical resources, which could provide Continuing Education Credits (CEUs) to interested course participants. In addition, UTC funds will be used to support and host the monthly transportation seminar series, particularly while classes are in session. The target audience is current students and the local university community. UTC funds will also enhance our ability to host nationally and internationally recognized speakers. The target audience is local and regional (onsite), and national when recording and posting talks online.

CAMMSE will support career-building activities that facilitate student transition from school to the workplace by offering enhanced student research opportunities, research seminars, guest speakers, professional conference travel and other professional networking opportunities. In addition, outreach programs at the pre-collegiate level (elementary to high school) will be designed to spark interest in transportation issues and to encourage youth to consider transportation academic programs and careers. The outreach initiatives will particularly focus on recruiting underrepresented minorities into transportation and other STEM fields.

Technology Transfer

The technology transfer program at CAMMSE is designed to support the USDOT in its objective of "expanding technology transfer to partners and stakeholders" by sharing research results quickly and to the widest possible audience. CAMMSE has demonstrated ability to disseminate research results, spur implementations, and conduct continuing education programs. The technology transfer program is a direct extension of the Center's research and education programs; in other words, these activities are designed to increase the scope and effectiveness of research accomplishments and education initiatives. General objectives within the technology transfer area in CAMMSE will be to:

- Increase the national visibility of CAMMSE research and education activities.
- Increase the availability and speed at which CAMMSE research results are disseminated.
- Provide technical assistance based on CAMMSE research and development.

Collaboration

CAMMSE has an extensive history of forming collaborative relationships at a variety of technical, fiscal and administrative levels. Across all its activities, from conducting pooled fund studies to hosting tech transfer events, CAMMSE will seek to work with collaborators from all sectors.

Diversity

In order for the transportation workforce to reflect the diversity of the national workforce pool, CAMMSE will continue to pursue the development of innovative programs to encourage new entrants, particularly those from groups currently underrepresented in the field. CAMMSE will actively participate in a number of committed activities through which the CAMMSE will increase interest in STEM disciplines and raise awareness of transportation-related careers amongst underrepresented groups.

1.2. What was accomplished under these goals?

Research

CAMMSE was funded by USDOT in November 2016 under the FAST act. During this reporting period, CAMMSE research results have been published in multiple journals, including *Analytic Methods in Accident Research*, *ASCE Journal of Transportation Engineering Part A: Systems*, *Canadian Journal of Civil Engineering*, *Entropy*, *IEEE Access*, *IEEE Transactions on Intelligent Transportation Systems*, *International Journal of Transportation Science and Technology*, *ISPRS International Journal of Geo-Information*, *Journal of Advanced Transportation*, *Journal of Safety Research*, *Sustainability*, *Transportation Planning and Technology*, *Transportation Research Part C: Emerging Technologies*. During this reporting period, CAMMSE research results were also presented at several conferences on different occasions, which include the 100th Annual Meeting of the Transportation Research Board, NCDOT Virtual Research & Innovation Summit, Sixth Biennial Marine Transportation System Innovative Science and Technology Conference, and the Third Annual CAMMSE Virtual Research Symposium.

Leadership

Representing the CAMMSE, Center Director Dr. Wei Fan has been using his expertise to serve on a National Science Foundation (NSF) Review Panel in November 2020. Dr. Wei Fan also served as an

affiliate faculty in the School of Data Science, UNC Charlotte since August 15, 2020. During this reporting period, CAMMSE Center Director and Associate Directors have been actively serving on many editorial boards (e.g., Guest Editor-in-Chief of *Journal of Advanced Transportation* and *Journal of Entropy*; Guest Editor of *Mathematical Problems in Engineering*; Handling Editor of *Transportation Research Record Inaugural Editorial Board,* Associate Editor of the *ASCE Journal of Transportation Engineering, Part A: Systems*, *IEEE Transactions on Intelligent Transportation Systems*, *International Journal of Transportation Science and Technology*, *Current Trends in Civil & Structural Engineering*; Founding Editor-in-Chief of the *Journal of Infrastructure Preservation and Resilience;* Editorial boards of the *Asian Transport Studies, International Journal of Transportation Science and Technology, Journal of Transportation Research Part D, Journal of World Review of Intermodal Transportation Research, Transportation Letters,* and *Transportmetrica A: Transport Science*), and many professional committees (e.g., chair of the Asset Management Subcommittee of TRB's Traffic Signal Systems Committee, the 2020 CAMMSE Research Symposium, and Co-Chair of World Transport Convention Connected and Autonomous Vehicles Section, and member of the ASCE Artificial Intelligence Committee, ASCE Connected & Autonomous Vehicles Impacts Committee, ASCE Public Transport Committee, ASCE Rail Transportation Committees, NCDOT Fully Autonomous Vehicle (FAV) Research Working Group Committee, NCSITE Scholarship Committee, PENC State Board, TRB Standing Committees (A0020C, AHB60, AT050, AW010, AW010(2), AW010(3), and AW020), World Transport Convention Shared Logistics and Transportation Systems Committee, and the Outreach subcommittee of the Lone Star Harbor Safety Committee (LSHSC), Academic Outreach and Membership Officer of Chinese Overseas Transportation Association (COTA), as well as several proposal and book review committees (e.g., NCHRP)).

Education and Workforce Development

CAMMSE has been working with the Institute of Transportation Engineers (ITE) Student Chapter at UNCC in supporting and hosting the bi-weekly transportation seminar series in which guest speakers are invited to UNCC to present their current project activities while classes are in session. The target audience is current students and the local university community. Dr. Fan's transportation research group has also been conducting graduate student seminars on a weekly basis during this reporting period.

CAMMSE Center Staff (Drs. Wei Fan, Martin Kane, and Kim Wilson) has been meeting on a regular basis. Topics discussed among these important regular meetings include, but are not limited to, the annual research symposium, annual transportation summer camp at UNCC, research, education, and outreach as well as technology transfer activities. From November 5 to 6, 2020, CAMMSE successfully held its third annual research symposium virtually through ZOOM because of the COVID-19. Also, the 100th annual meeting of the Transportation Research Board was held virtually from January 5 - 29, 2021, and several presentations were made by CAMMSE faculty and student researchers during the event. CAMMSE has provided a medium for sponsored students to develop important soft skills. All these events required that students interact with the local community and think of creative ways to portray complicated concepts in a simple and easy way to understand. CAMMSE has had impacted both the local community and the sponsored students by encouraging creativity and enhancing connections.

At UNCC, CAMMSE Center Director Dr. Wei Fan taught the "Connected and Autonomous Vehicles" course in the Fall 2020 semester and "Traffic Control and Operation" course in the Spring 2021 semester to several graduate students who were in attendance. Dr. Wei Fan was also invited to give a presentation entitled "Impact of CAVs on the Transportation System, Energy Consumption and the Environment" as a guest lecturer for the CEGR 6090/CEFT8090/INES 8202 Course remotely via ZOOM on UNC Charlotte campus on February 25, 2021. Ph.D. students Yang Li and Pengfei Liu were awarded the Blackburn Memorial Scholarship and Cyrus Painter Memorial Scholarship respectively by the North Carolina Section of the Institute of Transportation Engineers in November 2020. A paper entitled "A multinomial logit model of pedestrian pedestrian-vehicle crash severity in North Carolina" co-authored by CAMMSE Ph.D. graduate Zhen Chen and Center Director Dr. Wei Fan won the award of "Most Cited Article for the Year 2020". This paper was published in 2019 in Volume 8, Issue 1, pp. 43-52 in the *International Journal of*

Transportation Science and Technology. During this reporting period, a total of seven students at UNCC have been involved in CAMMSE projects and six of them were directly supported by CAMMSE.

At Washington State University (WSU), one female Ph.D. student in the Department of Civil & Environmental Engineering has contributed to research activities. Ms. Cheryl A. Reed (outreach coordinator) worked with Olivia R. Willis (a female undergraduate non-engineering student) to revise the manuscript, based on the outreach activities they conducted to engage middle schools and high schools through a targeted online program.

At Texas Southern University (TSU), two undergraduate-level and ten graduate-level transportation-related courses were taught by CAMMSE personnel (Drs. Yi Qi, Mehdi Azimi, and Lei Yu). During the reporting period, there were a total of seven graduate students participated in and supported by CAMMSE research projects, including three male students and four female students. One graduate student Mohammed Rahman graduated with a thesis that was directly supported by CAMMSE. His thesis title was "Impact of Bicycle Corridor Improvement on User's Behavior". In addition, CAMMSE supported student Enamul Karim Fayek received the ITS Texas Scholarship in Fall 2020.

At the University of Texas at Austin (UT Austin), there were a total of five students involved in CAMMSE projects, including both female and male students. One of the five is a doctoral degree candidate, three are master's candidates and one is an undergraduate student.

Technology Transfer

At UNCC, CAMMSE faculty, staff, researchers, and students have been making presentations at different meetings including the NCDOT Virtual Research & Innovation Summit on October 14, 2020, the Third Annual CAMMSE Research Symposium on November 5, 2020, the 100th Annual Meeting of the Transportation Research Board on January 24-28, 2021, NC Transportation Centers of Excellence Year 1 Update and Technical Advisory Panel Meeting on March 18, 2021, and COTA Research Lightning Talks Zoom Webinars on March 29, 2021.

At WSU, two poster presentations were made at the 100th Transportation Research Board Annual Meeting in January 2021.

At TSU, CAMMSE faculty and graduate research assistants published their research findings on peer-reviewed journals and conference proceedings. In addition, CAMMSE faculty Dr. Mehdi Azimi presented his research results at the Sixth Biennial Marine Transportation System Innovative Science and Technology Conference.

At UT Austin, there are a total of three active projects sponsoring two master's students, one Ph.D. student, two principal investigators, and one researcher. One of the best technology transfer tools is the students that work on these CAMMSE research projects. These UT Austin students are key to technology development as they will carry the knowledge and technology developed through CAMMSE projects to the Transportation Engineering industry. They will carry the new technology with them and use it in their new jobs, teach peers how to use the technology, thereby implementing the technology. Most importantly, these new techniques will continue to grow and improve as they are used. The professors at UT Austin have also used their classes to teach the new techniques developed through the CAMMSE UTC, therefore planting the new technology in students that are not directly supported by the UTC. In addition, information developed through UT Austin's research is being shared with the City of Austin as the City functions as a partner in the research efforts.

Collaboration

CAMMSE created a diverse collaboration network with different state and local government agencies, and educational and professional organizations, as well as community practitioners. CAMMSE also worked to build collaborative relations with international transportation centers and universities.

During the reporting period, CAMMSE Center Director Dr. Wei Fan collaborated with several other universities across the country and abroad (e.g., North Carolina A&T University, North Carolina State University, and Tongji University) in co-writing NCDOT and NCHRP proposals and/or papers.

At WSU, Dr. Xianming Shi continued to collaborate with Dr. Kakan Dey at West Virginia University to work on the CAMMSE 2020 Project 16. “Multimodal Connected Vehicle Pilot for Winter Travel”.

TSU collaborated with Texas A&M Transportation Institute and the University of Houston to develop TxDOT proposals. In addition, TSU CAMMSE team also worked closely with the City of Houston, Houston BCycle, and Harris County Engineering Department on the ongoing projects.

UT Austin has partnered with the Women in Transportation Seminar Heart of Texas (WTS-HOT) Student Chapter and the Institute of Transportation Engineers (ITE) / Intelligent Transportation Systems (ITS) Student Chapter. One of the UT-Austin principal investigators was also collaborating with the National Science Foundation (NSF) on 2019 Project 08. Deep-Learning Based Trajectory Forecast for Safety of Intersections with Multimodal Traffic. For this work, UT Austin has collaborated with Prof. Thomaz Edison’s group in ECE at UT Austin, as well as Prof. Linda Boyle’s group in Civil Engineering at the University of Washington.

Diversity

Several Ph.D. students from underrepresented groups have been hired to conduct CAMMSE’s research during this reporting period. For example, at UNCC, six international graduate students (Yang Li, Ms. Zijing Lin, Mr. Pengfei Liu, Mr. Bo Qiu, Mr. Shaojie Liu, and Mr. Li Song all from P.R.China) joined the INES Ph.D. program and they have been working as CAMMSE research assistants. A master student, Mr. Kiavash Riahipour, from Iran, is currently advised by Dr. Wei Fan to conduct his thesis research.

At WSU, two female engineers, Dr. Ji Yun Lee and one female Ph.D. student are involved in a CAMMSE sponsored research project. Furthermore, one female Outreach Coordinator (Cheryl A. Reed, WSU) is actively involved in getting the CAMMSE 2019 Project 15 findings published, which also involved one female undergraduate student (Olivia Willis). One international graduate student (Mr. Yan Zhang, from P.R. China) assisted in the data analysis.

TSU is one of the nation’s largest historically black universities, with most students are minority students. In addition, The students supported by CAMMSE fund include three female students.

UT Austin students sponsored by CAMMSE come from all sorts of diverse backgrounds. Specifically, UT Austin supported four graduate students including three females (Ms. Jennifer, Ms. Meredith, Ms. Carolina) and one male (Mr.Harry) through CAMMSE.

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

At UNCC, the CAMMSE bi-weekly seminars are open to the general public, particularly to the local and state transportation agencies, as well as the industry practitioners. CAMMSE has also been holding the weekly graduate seminar series at UNCC.

At WSU, the two poster presentations at the 100th Transportation Research Board Annual Meeting of Dr. J. Y. Lee provided some professional development for the audience.

At TSU, TSU CAMMSE team started a new “Educational Webinar Series” in Oct 2020, which aims to help our students to learn the career opportunity and professional development in the transportation area from

experts. Also, CAMMSE funding provided research assistantships to our students and gave them opportunities to participate in research projects and receive training.

At UT Austin, Drs. Machemehl and Claudel presented research topics and findings from the CAMMSE program to their graduate and undergraduate classes. Dr. Machemehl teaches an undergraduate senior elective class with approximately 50 students each spring semester and he discusses all the CAMMSE research efforts during his lectures. Most of these students (about 85 percent) will graduate in May 2021 becoming new engineers who bring with them the results of the CAMMSE research projects.

1.4. How have the results been disseminated?

News items and information about CAMMSE have been regularly posted on the website at https://cammse.uncc.edu/news.

In particular, as mentioned previously, UNCC has made many presentations both nationally and internationally. At UT Austin, research results are disseminated through the classroom teaching of the principal investigators and their colleagues. Additionally, two papers are being written for submission to the Transportation Research Board. The results have been disseminated by a conference article. TSU CAMMSE research results were published in peer-reviewed journals and conference proceedings. TSU team also made the presentation at a national meeting. TSU team has also developed three CAMMSE project final reports and published them on CAMMSE website.

1.5. What do you plan to do during the next reporting period to accomplish the goals and objectives?

The following tasks are planned in order to accomplish the goals and objectives of CAMMSE.

(1) CAMMSE is planning to hold the Fourth CAMMSE Transportation Summer Camp from June 14-18, 2021. The camp will include information and activities related to Charlotte Area Transit System (CATS), Charlotte Douglas International Airport (CLT), and NC Transportation Museum.
(2) CAMMSE will issue the RFPs for the year 2021-2022, conduct rigorous peer-reviews, select funded projects, and issue contracts. For all research projects that will be selected for funding in 2021-2022 year 6, the CAMMSE project information forms will be posted and updated on the CAMMSE website as well as on RiP once the subcontracts are officially signed.
(3) All final project reports to be completed for year 4 (2019-2021) will be provided to the Transportation Research Board (Transport Research International Documentation database), the National Transportation Library, the U.S. DOT's Research Hub, the Transportation Library, the Volpe National Transportation Systems Center, FHWA's Research Library, and the U.S. Department of Commerce as required by OST-R.
(4) UT Austin participants will submit papers to the TRB Annual Meeting and Conference for presentation and publication. Additionally, in the next reporting period, UT Austin envisions to work on a new approach that extends Social-STGCNN to account for certain failure cases. These failure cases have been documented in the IEEE CVPR conference paper, and can result in very inaccurate predictions in a limited number of cases. To make the prediction more robust, we envision to modify the deep learning architecture.
(5) WSU researchers will continue their activities in journal article submission/revision and presentations when suitable, while making progress on addressing other CAMMSE objectives.

2. PARTICIPANTS AND COLLABORATING ORGANIZATIONS

2.1. Who has worked on the program?

The members of CAMMSE UTC include the University of North Carolina at Charlotte (UNCC); the University of Texas at Austin (UT Austin); the University of Connecticut (UConn); Washington State University – Pullman (WSU); and Texas Southern University (TSU). Table 1 lists the leadership team members who have worked on the program during this reporting period.

Table 1. CAMMSE Staff Working on the Program

Name	Wei Fan	Randy Machemehl	Nicholas Lownes	Xianming Shi	Yi Qi
Program/Project Role	Center Director	Associate Director at UT Austin	Associate Director at UConn	Associate Director at WSU	Associate Director at TSU
Contribution to Program/Project	Oversees overall operations of the program. Responsible for coordinating with stakeholders and developing and implementing the CAMMSE strategic plan	Serves as liaison between CAMMSE and UT Austin	Serves as liaison between CAMMSE and UConn	Serves as liaison between CAMMSE and WSU	Serves as liaison between CAMMSE and TSU
Funding Support	UNCC	UT Austin	UConn	WSU	TSU
Collaborated with Individual(s) in Foreign Country(ies)	Yes	No	Yes	Yes	Yes
Country(ies) of Foreign Collaborator(s)	P.R.China	No	Australia	P.R.China	P.R.China
Traveled to Foreign Country(ies)	N/A	N/A	N/A	N/A	N/A
If traveled to foreign country(ies), duration of stay	N/A	N/A	N/A	N/A	N/A

2.2. What organizations have been involved as partners?

Table 2. A List of Organizations Creating Partnerships with CAMMSE

Organization Name	Type / Location	Partners Contribution to Project				
		Financial Support	In-kind Support	Facilities	Collaborative Research	Personal Exchanges
Capital Metro – Austin Public Transit	Government /TX		X	X		
Case Western Reserve University	University /OH				X	
Centralina Council of Governments	MPO /NC		X			
Charlotte Area Transit System	Government /NC		X			
City of Austin	Government /TX		X	X	X	
City of Charlotte	Government /NC		X			
City of Houston	Government /TX				X	
Connecticut Department of Transportation	Government /CT				X	
CTTransit	Transit Operator				X	X
Harbin Institute of Technology	University /China				X	
Harris County Engineering Department	Government /NC		X			
Houston Bike Share	Non-profit /TX				X	
Houston BCycle	Non-profit /TX				X	
Houston-Galveston Area Council	Non-profit /TX				X	
North Carolina A&T University	University /NC				X	
North Carolina Department of Transportation	Government /NC		X			
North Carolina State University	University /NC				X	
North Carolina Turnpike Authority Automated Vehicle Proving Ground	Government /NC				X	
Oregon State University	University /OR				X	
Partnership for Strong Communities	Non-profit /CT				X	
PacTrans	UTC /WA				X	
Propeller Club Port of Houston					X	
Texas Department of Transportation	Government /TX		X	X		
Texas Southern University	University /TX	X	X	X		
Tongji University	University /China				X	
University of Houston	University				X	

	/TX					
University of Connecticut	University /CT	X	X	X		
University of North Carolina at Charlotte	University /NC	X	X	X		
University of Texas at Austin	University /TX	X	X	X		
UT's Center for Transportation Research (UT Austin)	University /TX		X	X		
University of Texas at El Paso	University /TX				X	
University of Washington	University /WA				X	
Washington Department of Transportation	Government /WA				X	
Washington State University	University /WA	X	X	X		
West Virginia University (WSU)	University /WV				X	

Our CAMMSE UTC has successfully established an external advisory board which contains members from universities and government agencies. The detailed information about all five advisory board members is provided below:

- Dr. Michael Accorsi, Professor and Senior Associate Dean, School of Engineering, University of Connecticut.
  Email: michael.accorsi@uconn.edu
- Dr. Amit Bhasin, Director, Center for Transportation Research, Associate Professor, Transportation Engineering, The University of Texas at Austin.
  Email: a-bhasin@mail.utexas.edu
- Elizabeth Robbins, Planning Policy & Partnerships Manager, Multimodal Planning Division, Washington State Department of Transportation.
  Email: robbins@wsdot.wa.gov
- Neil Mastin, Research and Development Manager, North Carolina Department of Transportation.
  Email: jmastin@ncdot.gov
- Wade Odell, Research Engineer, Texas Department of Transportation.
  Email: Wade.Odell@txdot

2.3. Have other collaborators or contacts been involved?

Dr. Wei Fan, CAMMSE Director, has been making presentations, working, co-writing, and publishing papers with faculty and researchers from the North Carolina A&T University, North Carolina State University, Key Laboratory of Road and Traffic Engineering, Ministry of Education and College of Transportation Engineering at Tongji University in Shanghai, P.R.China. A collaborative relationship has been successfully developed with those universities.

TSU partnered with the University of Houston and Texas A&M Transportation Institute to develop new proposals.

At UT Austin, the research done under Dr. Claudel has also been supported by the National Science Foundation (CPS: Medium: Collaborative Research: Synergy: Augmented reality for control of reservation-based intersections with mixed autonomous-non autonomous flows). Other collaborators include Prof. Linda Boyle (University of Washington, Civil) and Prof. Edison (UT Austin, ECE).

3. OUTPUTS

3.1. Journal publications, conference papers, and presentations

Journal publications

[1] Al Islam, S. B., Hajbabaie, A., and Aziz, H. A. A real-time network-level traffic signal control methodology with partial connected vehicle information*, Transportation Research Part C: Emerging Technologies*, Volume 121, 102830, October 2020.

[2] Du, S., Akin, M., Bergner, D., Xu, G., and Shi, X., Material Application Methodologies for Winter Road Maintenance Operations: A Renewed Perspective, *Canadian Journal of Civil Engineering*, February 2021.

[3] Huang, J., Song, G., Zhang, J., Li, Z., Wu, Y. and Yu, L. The Impact of Pedestrians and Nonmotorized Vehicle Violations on Vehicle Emissions at Signalized Intersections in the Real World: A Case Study in Beijing, *Journal of Advanced Transportation*, Volume 2021, 8849234, February 2021.

[4] Jiang, Y., Song, G., Zhang, Z., Zhai, Z. and Yu, L. Estimation of Hourly Traffic Flows from Floating Car Data for Vehicle Emission Estimation, *Journal of Advanced Transportation*, Volume 2021, 6628335, March 2021.

[5] Li, J., Liu, J., Liu, P., and Qi, Y. Analysis of Factors Contributing to the Severity of Large Truck Crashes. *Entropy*, Volume 22 (11), 1191. October 2020.

[6] Li, Y. and Fan, W., Optimizing Transit Equity and Accessibility of the City of Charlotte by Integrating Transit Gap Index, A General Transit Feed Specification (GTFS) Data Relevant Performance Metric, *ASCE Journal of Transportation Engineering, Part A: Systems*, Volume 147 (4), 04021005. January 2021.

[7] Li, Y., Song, L. and Fan, W., Day-of-the-Week Variations and Temporal Instability of Factors Influencing Pedestrian Injury Severity in Pedestrian-Vehicle Crashes: A Random Parameters Logit Approach with Heterogeneity in Means and Variances, *Analytic Methods in Accident Research*, Volume 29, 100152, March 2021.

[8] Lin, Z. and Fan, W., Exploring Bicyclist Injury Severity in Bicycle-vehicle Crashes Using Latent Class Clustering Analysis and Partial Proportional Odds Models, *Journal of Safety Research*, Volume 76, pp.101-117. February 2021.

[9] Liu, P. and Fan, W., Exploring the Impact of Connected and Autonomous Vehicles on Mobility and Environment at Signalized Intersections through Vehicle-to-Infrastructure (V2I) and Infrastructure-to-Vehicle (I2V) Communications, *Transportation Planning and Technology*, October 2020.

[10] Liu, S., Fan, W. and Li, Y. Injury Severity Analysis of Rollover Crashes for Passenger Cars and Light Trucks Considering Temporal Stability: A Random Parameters Logit Approach with Heterogeneity in Means and Variances, Accepted for Publication, *Journal of Safety Research*, March 2021.

[11] Qiu, H., Li, X., Zhang, J., Yu, D., Yu, L., Wang, H. and Zhu, S. Single Variable-Constrained NDT Matching in Traffic Data Collection Using a Laser-based Detector, *IEEE Access*. March 2021.

[12] Qu, W., Li, J., Yang, L., Li, D., Liu, S., Zhao, Q., and Qi, Y. Short-Term Intersection Traffic Flow Forecasting. *Sustainability*, Volume 12(19), 8158, October 2020.

[13] Qu, W., Liu, S., Zhao, Q., and Qi, Y. Methods for Identifying Truck Crash Hotspots. *Journal of Advanced Transportation*, October 2020.

[14] Song, L., Fan, W., Li, Y. and Wu, P., Exploring Pedestrian Injury Severities at Pedestrian-Vehicle Crash Hotspots with An Annual Upward Trend: A Spatiotemporal Analysis with Latent Class Random Parameter Approach, *Journal of Safety Research*, Volume 76, pp.184-196, February 2020.

[15] Song, L., Li, Y., Fan, W. and Wu, P., Modeling Pedestrian-Injury Severities in Pedestrian-Vehicle Crashes Considering Spatiotemporal Patterns: Insights from Different Hierarchical Bayesian

Random-Effects Models, *Analytic Methods in Accident Research*, Volume 28, 100137, December 2020.
[16] Song, L. and Fan, W., Exploring Truck Driver-Injury Severity at Intersections Considering Heterogeneity in Latent Classes: A Case Study of North Carolina, Accepted for Publication, *International Journal of Transportation Science and Technology*, December 2020.
[17] Tajalli, M., and Hajbabaie, A. Traffic Signal Timing and Trajectory Optimization in a Mixed Autonomy Traffic Stream*, IEEE Transactions on Intelligent Transportation Systems* , February 2021.
[18] Vishnoi, S. C. and Claudel, C. G. Variable Speed Limit and Ramp Metering Control of Highway Networks using Lax-Hopf Method: A Mixed Integer Linear Programming Approach, *IEEE Transactions on Intelligent Transportation Systems*, Accepted for Publication, March 2021.
[19] Zhang, B., Li, W., Lownes, N. and Zhang, C., Estimating the Impacts of Proximity to Public Transportation on Residential Property Values: An Empirical Analysis for Hartford and Stamford Areas, Connecticut. *ISPRS International Journal of Geo-Information*. Volume 10 (2), 44., January 2021.
[20] Zhu, W., Xiao, X., Huang, Z. and Fan, W., Evaluating the Wheelset Health Status of Rail Transit Vehicles: Synthesis of Wear Mechanism and Data-Driven Analysis, ASCE *Journal of Transportation Engineering, Part A: Systems*, Volume 146, Issue 12, October 2020.

Conference papers

[1] Chen, X, Ye, Q., Fan, A., Zhang, Y. and Yu, L. Developing a Bus Eco-driving Strategy with Consideration of Holding Control. 100th Transportation Research Board Annual Meeting Paper 21-02338, Session 1393, Transportation Research Board of the National Academies, Washington D.C., January 2021.
[2] Ge, M, Song, G., Zang, J., Wu, Y. and Yu, L. Link-based Traffic Volume Forecasting for Dynamic Emission Estimation Based on Pattern Clustering and Recognition. 100th Transportation Research Board Annual Meeting Paper 21-04182, Session 1253, Transportation Research Board of the National Academies, Washington D.C., January 2021.
[3] Ma, J, Chen, X., Han, X. and Yu, L. Integrated Scheduling Optimization Model with Multi-Type Bus Transit Service Patterns Considering Emissions. 100th Transportation Research Board Annual Meeting Paper 21-02339, Session 1375, Transportation Research Board of the National Academies, Washington D.C., January 2021.
[4] Wang, X, Song, G., Zhai, Z., Wu, Y. and Yu, L. Effects of Vehicle Load on Emissions of Heavy-duty Diesel Trucks: A Study based on Real-world Data. 100th Transportation Research Board Annual Meeting Paper 21-04178, Session 1107, Transportation Research Board of the National Academies, Washington D.C., January 2021.
[5] Zhu, S, Li, X., Li, Y., Yu, D., Yu, L. and Lan, Q. Ultra-Wideband (UWB)-Based System for Positioning at Tunneling Construction Site. 100th Transportation Research Board Annual Meeting Paper 21-02804, Session 1205, Transportation Research Board of the National Academies, Washington D.C., January 2021.

Presentations

[1] Cohen, J., Highways and Wealth Distribution: A Geospatial Analysis, Third Annual CAMMSE Virtual Research Symposium, November 5, 2020.
[2] Fan, W., Developing a Data Analytics-Based Systematic Method for Identifying, Ranking, Examining, and Mitigating Freeway Bottlenecks, Invited Lecture Presentation in INES 8102/8104 Infrastructure Systems, UNC Charlotte, Charlotte, NC, Tuesday, October 13, 2020.
[3] Fan, W., Extreme Gradient Boosting (XGBoost) Model for Vehicle Trajectory Prediction in Connected and Autonomous Vehicle Environment, Third Annual CAMMSE Research Symposium, UNC Charlotte Center City, Charlotte, NC, November 5, 2020.
[4] Fan, W., Impact of CAVs on the Transportation System, Energy Consumption and the Environment, Guest Lecture, CEGR 6090/CEGR 8090/INES 8202 Course, UNC Charlotte, Thursday, February 25, 2021.
[5] Fan, W. and Song, L., CAV Impacts on Traffic Intersection Capacity, NC Transportation Centers of Excellence Year 1 Update and Technical Advisory Panel Meeting, March 18, 2021.

[6] Fayek, E.K. and Azimi, M. Application of Artificial Intelligence in Maritime Automation. Sixth Biennial Marine Transportation System Innovative Science and Technology Conference organized by the Transportation Research Board (TRB) and the U.S. Committee on the Marine Transportation System (CMTS), March 15, 2021.
[7] Ivan, J.N., Estimation of Pedestrian Volume Using Geospatial and Traffic Conflict Data, Third Annual CAMMSE Virtual Research Symposium, November 5, 2020.
[8] Lee, J. Y., Instantaneous-Resilience Metric Concerning the Robustness and Redundancy. Poster Presentation, The 100th Transportation Research Board Annual Meeting, Washington, D.C., January, 2021.
[9] Lee, J. Y., Work-Zone Crash Severity Analysis: Development and Use of the Joint Distribution of Crash-Related Variables. Poster Presentation, The 100th Transportation Research Board Annual Meeting, Washington, D.C., January, 2021.
[10] Li, Y. and Fan, W., Optimizing Transit Equity and Accessibility by Integrating Transit Gap Index A Relevant GTFS Data Performance Metrics, Lightning Talk, NCDOT Virtual Research & Innovation Summit, University of North Carolina at Chapel Hill, Chapel Hill, NC, Wednesday October 14, 2020.
[11] Lin, Z. and Fan, W., Investigating Cycling Behavior Considering Different Temporal Characteristics Using Crowdsourced Bicycle Data, Poster Presentation, 2020 NCDOT Virtual Research & Innovation Summit, University of North Carolina at Chapel Hill, Chapel Hill, NC, October 13-14, 2020.
[12] Liu, P. and Fan, W., Analyzing Injury Severity of Rear-End Crashes involving Large Trucks Using a Mixed Logit Model, Poster Presentation, 2020 NCDOT Virtual Research & Innovation Summit, University of North Carolina at Chapel Hill, Chapel Hill, NC, October 13-14, 2020.
[13] Liu, S. and Fan, W., Investigating Factors Affecting Injury Severity in Bicycle-Vehicle Crashes: A Day-of-Week Analysis with Partial Proportional Odds Logit Models, Third Annual CAMMSE Virtual Research Symposium, November 5, 2020.
[14] Liu, S. and Fan, W., Investigating Factors Affecting Injury Severity in Bicycle-Vehicle Crashes: A Day-of-Week Analysis with Partial Proportional Odds Logit Models, Poster Presentation, 2020 NCDOT Virtual Research & Innovation Summit, University of North Carolina at Chapel Hill, Chapel Hill, NC, October 13-14, 2020.
[15] Qiu, B. and Fan, W., Travel Time Forecasting on a Freeway Corridor: a Dynamic Information Fusion Model based on the Random Forests Approach, Third Annual CAMMSE Virtual Research Symposium, November 5, 2020.
[16] Song, L. and Fan, W., Exploring Pedestrian Injury Severities at Pedestrian-Vehicle Crash Hotspots with an Annual Upward Trend: A Spatiotemporal Analysis with Latent Class Random Parameter Approach, Third Annual CAMMSE Virtual Research Symposium, November 5, 2020.
[17] Song, L. and Fan, W., Exploring Pedestrian Injury Severities at Pedestrian-Vehicle Crash Hotspots with An Annual Upward Trend: A Spatiotemporal Analysis with Latent Class Random Parameter Approach, Poster Presentation, 2020 NCDOT Virtual Research & Innovation Summit, University of North Carolina at Chapel Hill, Chapel Hill, NC, October 13-14, 2020.
[18] Song, L. and Fan, W., Time-of-Day Variations and the Temporal Instability of Multi-Vehicle Crash Injury Severities under the Influence of Alcohol or Drugs: Insights from the Economic Cycle after the Great Recession, COTA Research Lightning Talks Zoom Webinars, March 29, 2021.
[19] Song, L, Fan, W. and Liu, P., Exploring the Effects of Connected and Automated Vehicles at Fixed and Actuated Signalized Intersections with Different Market Penetration Rates, The 100th Annual Meeting of the Transportation Research Board, Washington D.C., January 24-28, 2021.

3.2. Website(s) or other internet site(s)

The CAMMSE website is located at http://cammse.uncc.edu/. This website has been used to disseminate any information related to the program. Other internet sites include: http://sboyles.github.io/, https://sites.utexas.edu/machemehl/ and http://www.mass-lab-ut.com/.

3.3. Technologies or techniques

TSU developed a new method, named the state-dependent approximation method, to estimate the truck queue length at marine terminals. The newly developed method was evaluated and compared with the other four existing methods. The evaluation results indicated that the developed model outperformed the other four modeling methods for different states of queue formation and dispersion processes. In addition, this new method can accurately estimate the truck queue length caused by the short-term system oversaturation during peak hours. Therefore, it will be useful for assessing the effectiveness of the countermeasures that are targeted at reducing the peak-hour congestion at marine terminals.

UT Austin has developed a novel computational framework for predicting trajectories of pedestrians around intersections, through a graph theoretic neural network model. The model requires considerably fewer parameters than other models reported in the literature (10 to 100x less), and is faster, for the same level of performance.

3.4. Inventions, patent applications, and/or licenses

Nothing to report.

3.5. Other outputs

CAMMSE Graduate Seminar Series @ UNCC, Sponsored by CAMMSE

[1] “A Comparative Analysis of Short-Range Travel Time Prediction Methods based on the Machine Learning Approach”, Presented by Mr. Bo Qiu, 9-10 am, March 31, 2021, remotely via WebEx .
[2] “Optimal Controls for Trajectory Planning”, Presented by Mr. Shaojie Liu, 9-10 am, March 24, 2021, remotely via WebEx.
[3] “Travel Time Prediction on a Freeway Corridor: a Dynamic Information Fusion Model based on the Machine Learning Approach”, Presented by Mr. Bo Qiu, 9-10 am, March 17, 2021, remotely via WebEx.
[4] “Impacts of CAVs on Transfer-Based DQN Controlled Signal Intersections: Insights from Mixed Traffic and Information Levels (Part 2)" Presented by Mr. Li Song, 9-10 am, March 10, 2021, remotely via Webex.
[5] “Platooning and Trajectory Planning of CAVs at Superstreets”, Presented by Mr. Shaojie Liu, 9-10 am, March 3, 2021, remotely via WebEx.
[6] “Impacts of CAVs on Transfer-based DQN Controlled Signal Intersections", Presented by Mr. Li Song, 9-10 am, February 24, 2021, remotely via WebEx.
[7] “Travel Time Prediction: Comparison of Machine Learning Methods”, Presented by Mr. Bo Qiu, 9-10 am, February 17, 2021, remotely via WebEx.
[8] “A Literature Review on Performances of CAVs at Alternative Intersection and Current Research Status”, Presented by Mr. Shaojie Liu, 9-10 am, February 3, 2021, remotely via WebEx.
[9] “A Simple Case Study on the Application of Deep Neural Network Models", Presented by Mr. Li Song, 9-10 am, January 27, 2021, remotely via WebEx.
[10] “Travel Time Prediction Using the LSTM Method”, Presented by Mr. Bo Qiu, 9-10 am, January 20, 2021, remotely via WebEx.
[11] “A Review of Research Studies on Superstreets”, Presented by Mr. Shaojie Liu, 9-10 am, December 16, 2020, remotely via WebEx.
[12] “Impacts of Connected and Automated Vehicles at Intersections", Presented by Mr. Li Song, 9-10 am, December 9, 2020, remotely via WebEx.
[13] “Travel Time forecasting Research”, Presented by Mr. Bo Qiu, 9-10 am, December 2, 2020, remotely via WebEx.
[14] “An Introduction to Platooning Behaviors of Connected and Autonomous Vehicles” Presented by Mr. Shaojie Liu, 9-10 am, November 25, 2020, remotely via WebEx.
[15] “A Simple Case Study on the Traffic Light Controlled by DQN Technology” Presented by Mr. Li Song, 9-10 am, November 18, 2020, remotely via WebEx.
[16] “Travel Time Forecasting: Future Research Directions”, Presented by Mr. Bo Qiu, 9-10 am, November 11, 2020, remotely via WebEx.

[17] "Job Search and Interview Preparation in the Academic Field", Presented by Ms. Zijing Lin, 9-10 am, October 28, 2020, remotely via WebEx.
[18] Dry runs of the Zoom tech support for the "2020 THIRD ANNUAL CAMMSE VIRTUAL RESEARCH SYMPOSIUM" (which is to be held November 5-6, 2020) by All CAMMSE research assistants, 9-10 am, October 21, 2020, remotely via WebEx.
[19] "Trajectory Optimization for Connected and Autonomous Vehicles at Intersections", Presented by Mr. Shaojie Liu, 9-10 am, October 14, 2020, remotely via WebEx.
[20] "Intelligent Traffic Light Simulation: Basic Knowledge of the Deep Reinforcement Learning Approach", Presented by Mr. Li Song, 9-10 am, October 7, 2020, remotely via WebEx.

ITE Seminar Series @ UNCC, Co-organized and sponsored by UNCC ITE Student Chapter and CAMMSE

[1] "Career Development and Tips for Traffic Engineers", presented by Dr. Zachary Bugg and Mr. Dana Magliola from Kittelson & Associate Inc and NCDOT Logistic + Freight, virtually through WebEx, March 11, 2021.
[2] "Resume Builder and Career Development", presented by Dr. Patrick Madsen from University Career Center, virtually through WebEx, February 3, 2021.
[3] "Career Development and Working Experience as Transportation Engineers", presented by Alex Wiseman and Justin Carroll from STV Inc., virtually through WebEx, December 2, 2020.
[4] "My Journey in Transportation: Reflection and Lessons Learned", presented by Andy Wagner from HNTB, virtually through WebEx, November 18, 2020.
[5] "Why ITE: Career of Traffic Engineering, Before and After School", presented by Ty Pharham from Ramey Kemp Associates, November 5, 2020.
[6] "General Body Meeting and New Student Member Recruitment", presented by Li Song, President of ITE, virtually through WebEx, October 19, 2020.

CAMMSE Educational Webinar Series @ TSU, Sponsored by CAMMSE

[1] "Career Development in Transportation", presented by Ms. Roben Armstrong (Airport Strategic Planning Manager, Clark County Department of Aviation), 6-7 pm, October 2, 2020.

Lunch and Learn Series @ TSU, Co-organized and sponsored by CAMMSE

[1] "Opportunities in the Maritime Industry", presented by Mr. Brian Hill (the U.S. Maritime Administration, a former Admiralty Attorney and former Commander with the U.S. Coast Guard), March 24, 2021.
[2] "Oil and Gas Industry", presented by Mr. Al Brooks (retired oil & gas executive), March 17, 2021.
[3] "Career Development in the Security Industry", presented by is Mr. Jeff Baldwin (a retired Senior Executive with the U.S. Customs and Border Protection Agency and CEO of Baldwin Liaison Consulting, LLC.), March 10, 2021.

Technical Reports

[1] Hajibabai, L., Hajbabaie, A., Tajalli, M., Mirheli, A., and Fan, W. Utilization Measurement and Management of Fleet Equipment (No. NCHRP Project 13-05). National Cooperation Highway Research Program, Washington, D.C. February 2021.
[2] Petrie, J., Qi, Y., Cornwell, M., Sarker, Md A.A., Biswas, P., Du, S., and Shi. X. Design of Living Barriers to Reduce the Impacts of Snow Drifts on Illinois Freeways. Final report for the Illinois Center for Transportation, Springfield, IL. Research Report No. FHWA-ICT-20-012. November 2020. DOI: 10.36501/0197-9191/20-019.

4. OUTCOMES

4.1. Increased understanding and awareness of transportation issues

TSU's research project "Bicycle Network Connectivity and Accessibility: A Study on the Effects of Bike Infrastructures on Bicycle Sharing System Demand" helps transportation professionals to understand how the bike infrastructure, especially bike lane investment, benefits bike-sharing system.

Also, UT Austin's projects give a better understanding of how to improve multi-modal mobility (i.e., vehicles, cyclists, transit) and safety (i.e., considering human body cues to predict vehicle trajectories).

4.2. Passage of new policies, regulation, rulemaking, or legislation

Nothing to report.

4.3. Increases in the body of knowledge

TSU's research project "A New Method for Estimating Truck Queue Length at Marine Terminal Gates" investigated the port congestion problem and developed a new method to estimate terminal gate truck queue length. This research filled a gap in the existing methods and increased the body of knowledge.

UT Austin has formulated new versions of familiar logistics problems that encompass the possibilities of unmanned aerial vehicle technology. These problems are intractable (NP-hard), but the project of UT Austin has developed tailored heuristics that could exploit problem structure and produce reasonable solutions in an acceptable amount of time.

WSU's research project led by Dr. Lee (2021 Project 10) indicated that the benefits of CAVs on supply chain operation and management have not been explored and quantified. Quantitative assessment of the impact of CAVs on a supply chain system is necessary for finding optimal supply chain design and management as the optimization process requires quantitative/objective information. This project fills this research gap and improves knowledge of the effects of CAVs on supply chain performance.

4.4. Improvement of existing techniques, practices, technologies

The current signal timing strategy for the intersections with Contraflow Left-Turn Lanes (CLLs) cannot be directly applied at the signalized intersections with split phasing (SIWSP). To address this problem, Dr. Yi Qi and her team at TSU developed an innovative signal timing strategy, which is referred to as Counterclockwise Split Phasing (CSP) signal timing, for implementing the CLLs at the SIWSPs. The newly developed signal timing strategy greatly improves the existing method and makes it safe to use this innovative intersection design at SIWSPs.

At UT Austin, the field testing of new signal control concepts for bicycles supported jointly by CAMMSE and the City of Austin Transportation Department is nearing completion. The algorithms developed as part of the Social STGCNN paper improved prediction performance over state-of-the-art algorithms by 20%, and this paper has been cited 50 times over the past year. This performance increase persisted until early 2021, when newly published results have improved state-of-the-art performance beyond the Social STGCNN algorithm.

4.5. Enlargement of the pool of trained transportation professionals

At UNCC, three doctoral students graduated and obtained their Ph.D. degrees in December 2020. All of them have been conducting several CAMMSE research projects and are pursuing a career in

transportation after graduation. Dr. Yang Li is now serving as a Research Associate at the University of Wisconsin-Milwaukee. Dr. Zijing Lin is now working as an Assistant Professor at the Dalian University of Technology. Dr. Pengfei Liu is now working as a Traffic Engineer at the Stevens Technical Service Incorporated, Houston, TX.

TSU CAMMSE supported graduate student Mohamrmed Rahman graduated in December 2020 and is now working as a transportation professional. Except for Rahman, TSU CAMMSE also supported other six graduate students. The training and experience they received by participating in various CAMMSE research projects will make them future transportation professionals.

4.6. Incorporation of new techniques, practices, technologies

Since the bicycle signal technology is being jointly field tested by UT Austin CAMMSE researchers and the City of Austin, once testing is complete, implementation will be a simple matter. As a joint sponsor, the City will be ready and able to implement rapidly.

5. IMPACTS

The CAMMSE is currently conducting a variety of research, education and outreach, technology transfer, and diversity activities and as such, the impact of this program can only be preliminarily measured during this reporting period.

5.1. What is the impact on the effectiveness of the transportation system?

TSU's Research project "Analysis of Intermodal Vessel-to-Rail Connectivity" analyzed the existing intermodal systems, identified critical factors and processes that promote the competitiveness of the system, which could improve the effectiveness of intermodal transportation systems.

At UT Austin, the statistical models developed in 2019 Project 05 connect bicycle facility counts to time, demographic data, and weather data to better predict bicycle facility usage. There has been some work done in estimating the impacts of bicycle facilities, but very little has been done to examine the impacts upon minorities or other specific population segments. Estimating bicycle facility usage is the first step in estimating the positive impacts of bicycle facility implementation. Electric vehicles and drones have the potential to improve the efficiency of freight delivery and to reduce emissions associated with the transportation system. The research results from 2019 Project 07 suggest how these technologies can be integrated into logistics operations.

5.2. What is the impact of technology transfer on industry and government entities, on the adoption of new practices, or on research outcomes which have led to initiating a start-up company?

TSU CAMMSE supported students will carry on the knowledge they learned from participating in CAMMSE projects to their future employers.

At UT Austin, the research is performed by students and faculty supervisors who work closely with industry and government entities. The working relationship with industry and government enables immediate technology transfer, plus the students who develop the new technology carry that knowledge with them into their eventual transportation sector employment.

At WSU, for the project led by Dr. Lee (2021 Project 10), the research team will share the quantitative model and the Matlab and Python codes so that supply chain managers or grocery delivery companies (dealing with perishable or semi-perishable products) can use it in their supply chain analyses to design or re-optimize their systems. Given that online grocery shopping and delivery have received great attention especially during the COVID-19 situation (and assuming that this will be a new normal), research outcomes may have broader impacts on society.

5.3. What is the impact on the body of scientific knowledge?

At TSU, CAMMSE team has been working on three new and innovative research projects. By conducting these projects, new methods have been developed, which increased the understanding of transportation issues.

At UT Austin, one of the best technology transfer tools is the students that work on these CAMMSE research projects. These students are key to technology development as they will carry the knowledge and technology developed through CAMMSE projects to the Transportation Engineering industry. They will carry the new technology with them and use it in their new jobs, teach peers how to use the

technology, thereby implementing the technology. Most importantly, these new techniques will continue to grow and improve as they are used.

At WSU, the proposed model in the project (2021 Project 10) led by Dr. Lee will improve understanding of the direct and indirect effects of CAVs on supply chain performance (especially involving fresh or perishable products).

5.4. What is the impact on transportation workforce development?

UNCC organized several transportation seminars which provided students opportunities to communicate with professors and industry experts. What they have learned through these seminars could be of great value for their future works as transportation professionals. In addition, CAMMSE funding provided research assistantships. By participating CAMMSE research, students gained hands-on experience.

TSU CAMMSE faculty Drs. Yi Qi, Mehdi Azimi, and Lei Yu have been teaching two undergraduate-level and ten graduate-level courses during the reporting period. They incorporated the new methods or new techniques they developed through working on CAMMSE projects into their courses. In addition, the "CAMMSE Educational Webinar Series" provided students opportunities to communicate and learn from industry experts. The skills they learn from the series will help them in their career development in transportation in the future.

The professors at UT Austin have also used their classes to teach the new techniques developed through the CAMMSE UTC, therefore planting the new technology in students that are not directly supported by the UTC. In addition, information developed through UT Austin's research is being shared with the City of Austin as the City functions as a partner in the research efforts.

6. CHANGES AND PROBLEMS

6.1. Changes in approach and reasons for change

Nothing to report.

6.2. Actual or anticipated problems or delays and actions or plans to resolve them

WSU mentioned that the COVID-19 pandemic has caused some delays in their CAMMSE project activities. WSU's plan to resolve aforementioned problems will be to catch up some lost time during the next reporting period.

6.3. Changes that have a significant impact on expenditures

The COVID pandemic set several projects back and eliminated some presentation opportunities for CAMMSE researchers at all CAMMSE partner institutions. As we adapt to the new circumstances, it is anticipated that these issues will be mitigated. For example, due to the COVID pandemic, UNCC was not able to recruit any new students and have them physically join UNCC as we used to in the past. Because of such special circumstances, UNCC could not develop any new research proposals in year 5 due to the unavailability of new students.

In short, despite the constraints posed by COVID-19, all CAMMSE partner institutions will take on the challenges and continue working hard to resolve all relevant issues.

6.4. Significant change in use or care of animals, human subjects, and/or biohazards

Nothing to report.

6.5. Changes of primary performance site location from that originally proposed

At CAMMSE, most of our researchers and student workers are working at home due to COVID 19.

6.6. Additional information regarding products and impacts

Nothing to report.

7. SPECIAL REPORTING REQUIREMENTS

(1) External Advisory Board: Available on the program website: https://cammse.uncc.edu/directory/external-advisory-board

(2) Financial and Annual Recipient Share Reports: The SF 425 requirements will be met by separate reports.

APPENDIX

CAMMSE @ UNC Charlotte Funded Projects, 2016-2018 (Year 1), All Completed

University	Principle Investigator	Category	Title of the Funded Project
University of North Carolina at Charlotte	Wei Fan	Advanced Research	Estimation of Origin-Destination Matrix and Identification of User Activities Using Public Transit Smart Card Data
	Wei Fan	Applied Research	Improving the Movements of People and Freight: A Case Study of the Piedmont Atlantic Megaregion
University of Texas at Austin	Randy Machemehl	Applied Research	Forecasting Ridership for Commuter Rail in Austin
	Randy Machemehl	Advanced Research	Corridor Level Adaptive Signal Control
University of Connecticut	Nicholas Lownes	Basic Research	Stochastic Multimodal Network Modeling
	Nicholas Lownes	Basic Research	Robust Routing, Assignment, and Simulation of Transit Systems
Washington State University	Xianming Shi	Applied Research	The Use of Connected Vehicle Technology to Facilitate Multimodal Winter Travel
	Jia Yan	Applied Research	The Effect of Competition of Transport Modes on Mobility
Texas Southern University	Mehdi Azimi Yi Qi	Applied Research	Use of Vessel Automatic Information System Data to Improve Multi-modal Transportation in and around the Ports
	Yi Qi	Applied Research	Use of Innovative Intersection Designs for Improving Mobility and Reducing Roadway Traffic Congestion

CAMMSE @ UNC Charlotte Funded Projects, 2017-2019 (Year 2), All Completed

University	Principle Investigator(s)	Category	Title of the Funded Project
University of North Carolina at Charlotte	Wei Fan	Advanced Research	Use of Multisensor Data in Modeling Freeway Travel Time Reliability
	Wei Fan Martin Kane	Applied Research	Using General Transit Feed Specification (GTFS) Data as a Basis for Evaluating and Improving Public Transit Equity
	Wei Fan Yu Wang	Applied Research	Evaluating the Potential Use of Crowdsourced Bicycle Data in North Carolina
	Wei Fan	Advanced Research	Impact of Connected and Automated Vehicles (CAVs) on Freeway Capacity
	Wei Fan	Advanced Research	Optimal Variable Speed Limit Control for the Mixed Traffic Flows in a Connected and Autonomous Vehicle Environment
University of Texas at Austin	Randy Machemehl	Applied Research	Characterization of Bicycle Rider Behavior among Various Street Environments
	Randy Machemehl	Applied Research	Evolution of Advanced Transit Signal Priority with Gap-Based Signal Recovery Strategy
	Stephen Boyles	Applied Research	Assessment of Parcel Delivery Systems Using Unmanned Aerial Vehicles
	Christian Claudel	Advanced Research	Deep-learning Based Trajectory Forecast for Safety of Intersections with Multimodal Traffic
University of Connecticut	Nicholas Lownes Charles Patton Kelly Bertolaccini	Applied Research	Investigating the Linkage between Transit Access to Services and Affordable Housing Availability
	Karthik Charan Konduri	Advanced Research	Development of Continuous Time, Temporally Constrained and Behaviorally Consistent Tour Pattern Generation System for Modeling the Impacts of Autonomous Vehicle Future
	Norman Garrick Carol Atkinson-Palombo	Applied Research	What Do We Want from Autonomous Vehicles (AVs)? Using Participatory Planning and Scenario Analysis of Alternative Futures to Identify Stakeholders' Desired Outcomes from the Strategic Deployment of Emerging Transportation Technology
Washington State University	Xianming Shi	Applied Research	Developing Friction Data to Support the Optimal Use of Pre-wet Deicing Salt for Enhanced Winter Mobility
	Xianming Shi	Applied Research	Modeling the Macroscopic Effects of Winter Maintenance Operations on Traffic Mobility on Washington Highways
Texas Southern University	Yi Qi Mehdi Azimi Qun Zhao	Applied Research	Determination of Freeway Acceleration Lane Length for Smooth ad Safe Truck Merging
	Yi Qi Mehdi Azimi Qun Zhao	Applied Research	Innovative Countermeasures for Reducing the Truck Waiting Time at Marine Terminals

	Mehdi Azimi Yi Qi Qun Zhao	Applied Research	Investigating the Impact of Different Attributes on Bicycling Mode Share as A Multimodal Connectivity Strategy in Large Cities: A Case Study in Houston

CAMMSE @ UNC Charlotte Funded Projects, 2018-2020 (Year 3), All Completed

University	Principle Investigator(s)	Category	Title of the Funded Project
University of North Carolina at Charlotte	Wei Fan	Applied Research	Predicting Travel Time on Freeway Corridors: Machine Learning Approach
	Wei Fan Martin Kane	Applied Research	Optimizing Transit Equity and Accessibility by Integrating Relevant GTFS Data Performance Metrics
	Wei Fan Yu Wang	Applied Research	Analyzing Cycling Behavior during Different Time Periods Using Crowdsourced Bicycle Data
	Wei Fan	Applied Research	Trajectory Optimization of Connected and Autonomous Vehicles (CAVs) at Signalized Intersections
University of Texas at Austin	Randy Machemehl	Applied Research	Forecasting Bicycle Facility Demand to Estimate Societal Impacts
	Randy Machemehl	Applied Research	Corridor Level Adaptive Signal Control (Phase II)
	Stephen Boyles	Applied Research	Assessment of Parcel Delivery Systems Using Unmanned Aerial Vehicles (Phase II)
	Christian Claudel	Advanced Research	Deep-learning Based Trajectory Forecast for Safety of Intersections with Multimodal Traffic (Phase II)
University of Connecticut	Jeffrey Cohen Nicholas Lownes	Applied Research	Highways and Wealth Distribution: A Geospatial Analysis
	Karthik Konduri Nalini Ravishanker	Applied Research	Are Transportation Network Companies Synergistic with Other Shared Ride Mode Offerings? An Exploratory Analysis of Demand Data from NYC Utilizing High Resolution Spatiotemporal Models
	Norman Garrick Carol Atkinson-Palombo	Applied Research	Understanding the Surprising and Oversized Use of Ridesourcing Services in Poorer Neighborhoods in NYC
Washington State University	Michelle Akin Xianming Shi	Educational Research	Multimodal Transportation Engineering Curriculum for Middle and High School Students
	Xianming Shi	Applied Research	Effects of Incorporating Connected Vehicle Technologies into No-Notice Emergency Evacuation during Winter Weather
	Ali Hajbabaie	Applied Research	Dynamic Speed Harmonization in Connected Urban Street Networks: Improving Mobility
Texas Southern University	Yi Qi Mehdi Azimi Qun Zhao	Applied Research	Development of Guidelines for Implementation of Contraflow Left-Turn Lanes at Signalized Intersections
	Yi Qi Qun Zhao Mehdi Azimi	Applied Research	Signal Timing Strategy for Displaced Left Turn Intersections
	Mehdi Azimi Yi Qi	Applied Research	Impacts of Bicycling Corridor Improvements on Users' Behaviors in Large Cities

CAMMSE @ UNC Charlotte Funded Projects, 2019-2021 (Year 4), Ongoing

University	Principle Investigator(s)	Category	Title of the Funded Project
University of North Carolina at Charlotte	Wei Fan	Applied Research	Travel Time Forecasting on a Freeway Corridor: a Dynamic Information Fusion Model Based on the Random Forests Approach
	Wei Fan Martin Kane	Applied Research	Optimization of Long-Term Highway Work Zone Scheduling
	Wei Fan	Applied Research	Impact of Connected and Autonomous Vehicles on Nontraditional Intersection Design: Superstreets
	Wei Fan	Applied Research	Machine Learning-based Trajectory Optimization of Connected and Autonomous Vehicles
University of Texas at Austin	Randy Machemehl	Applied Research	Quantification of Societal Bicycle Impacts (Phase III)
	Randy Machemehl	Applied Research	Corridor Level Adaptive Signal Control (Phase III)
	Stephen Boyles	Applied Research	Assessment of Parcel Delivery Systems Using Unmanned Aerial Vehicles (Phase III)
	Christian Claudel	Advanced Research	Deep-learning Based Trajectory Forecast for Safety of Intersections with Multimodal Traffic (Phase III)
University of Connecticut	Nicholas Lownes	Advanced Research	Prioritizing People - Mixed Equilibrium Assignment for AV Based on Occupancy
	Nicholas Lownes Timothy Becker	Advanced Research	Using Computational Biology to Mitigate Path Overlap in Transit Assignment
	Jin Zhu	Applied Research	Disaster Resilience through Diverse Evacuation and Emergency Transportation Systems
	John Ivan Amy Burnicki	Applied Research	Estimation of Pedestrian Volume Using Geospatial and Traffic Conflict Data
Washington State University	Xianming Shi	Applied Research	Multimodal Connected Vehicle Pilot for Winter Travel
Texas Southern University	Yi Qi Mehdi Azimi Qun Zhao	Applied Research	A New Method for Estimating Truck Queue Length at Marine Terminal Gates
	Mehdi Azimi Yi Qi	Applied Research	Analysis of Intermodal Vessel-to-Rail Connectivity
	Mehdi Azimi Yi Qi	Applied Research	Bicycle Network Connectivity and Accessibility: A Study on the Effects of Bike Infrastructures on Bicycle Sharing System Demand

CAMMSE @ UNC Charlotte Funded Projects, 2020-2022 (Year 5), Ongoing

University	Principle Investigator(s)	Category	Title of the Funded Project
University of Texas at Austin	Randy Machemehl	Applied Research	Impacts of Speed on Dockless Electric Scooter Crashes
	Randy Machemehl	Applied Research	Optimizing Type and Location of Pedestrian Crossing Signs at Non-signalized Intersections
	Christian Claudel	Advanced Research	Predicting Paths of Controlled Pedestrians at Intersections Using Deep Learning Models
University of Connecticut	John Ivan Amy Burnicki	Applied Research	Estimation of Pedestrian Compliance at Signalized Intersections Considering Demographic and Geographic Factors
	Carol Atkinson Palombo Norman Garrick	Applied Research	An Evaluation of the Transportation Equity Impacts of Uber and Lyft Usage in Chicago
	Nicholas Lownes	Applied Research	Pedestrian Behavior and Interaction with Autonomous Vehicles
Washington State University	Ji Yun Lee	Advanced Research	Effect of Connected and Autonomous Vehicles on Supply Chain Performance
Texas Southern University	Mehdi Azimi Yi Qi	Applied Research	Studying the Impact of Pandemic Outbreaks on Maritime Transportation and Port Operation
	Yi Qi Mehdi Azimi Qun Zhao	Applied Research	Short Term Intersection Traffic Flow Forecasting
	Yi Qi Mehdi Azimi Qun Zhao	Applied Research	The Impacts of COVID-19 on Public Transit

Center for Advanced Multimodal Mobility Solutions and Education