Center for Advanced Multimodal Mobility Solutions and Education

USDOT Tier 1 University Transportation Center
Semi-Annual Progress Report #10

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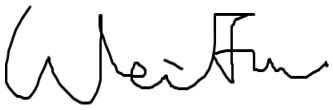
Signature of Submitting Official:	

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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 *ASCE Journal of Cold Regions Engineering, ASCE Journal of Urban Planning and Development*, *Canadian Journal of Civil Engineering, IEEE Access, IEEE Transactions on Intelligent Transportation Systems, Information Sciences, International Journal of Transportation Science and Technology, Journal of Advanced Transportation,* and *Transport Policy.* During this reporting period, CAMMSE research results were also presented at several conferences on different occasions, which include the North Carolina Department of Transportation Research & Innovation Summit, the 4th Annual CAMMSE Virtual Research Symposium, the 21st COTA International Conference of Transportation Professionals, the 101st Annual Meeting of the Transportation Research Board, the Department of Civil and Environmental Engineering Graduate Research Symposium at UNC Charlotte, and the 7th Annual UTC Conference for the Southeast Region, C2SMART UTC virtual event, TexITE Houston February Luncheon, ICCV 2021 ROAD Workshop, IEEE PerCom CoMoRea 2022, and ASCE Construction Research Congress.

Leadership

Representing the CAMMSE, Center Director Dr. Wei Fan won the Outstanding Associate Editor Award of *International Journal of Transportation Science and Technology* in January 2022. 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., Editor-in-Chief of *Journal of Infrastructure Preservation and Resilience*, Guest Editor of *World Electric Vehicle Journal, Special Issue Title: Emerging Technologies in Electrification of Urban Mobility*, Handling Editor of *TRR Inaugural Editorial Board, Transportation Research Record*, Associate Editor of *Accident Analysis and Prevention, ASCE Journal of Transportation Engineering, Part A: Systems*, *Current Trends in Civil & Structural Engineering, IEEE Transactions on Intelligent Transportation Systems, International Journal of Transportation Science and Technology;* Editorial Board of *Asian Transport Studies, International Journal of Transportation Science and Technology*, *Journal of Transportation Research Part D*, *Journal of World Review of Intermodal Transportation Research;* and many professional committees (e.g., General Secretary of Chinese Overseas Transportation Association (COTA), Co-Chair of World Transport Convention Connected Autonomous Vehicles Section, Advisory Board Member of ASCE National Artificial Intelligence (AI) Committee, Member of ASCE National Connected & Autonomous Vehicles Impacts Committee, ASCE National Public Transport Committee, ASCE National Rail Transportation Committee, American Society of Civil Engineers (ASCE), NCDOT Fully Autonomous Vehicle (FAV) Research Working Group Committee, NCSITE Scholarship Committee, PENC State Board, TRB Standing Committees (A0020C, ACP60, AP075, AHB60, AW010, AW010 (2)(3), AW020, AT050), Secretary of TRB Standing Committees (AP075), World Transport Convention Shared Logistics and Transportation Systems Committee, head of Publicity for the UT-Austin Student Transportation Council, the Symposium Steering Committee Member for the 24th COTA Winter Symposium, the Organizing Committee Member for the 20th and 21st COTA International Conference of Transportation Professionals, the Organizing Committee Member for the 5th International Conference on Transportation Infrastructure and Materials, as well as several proposal and paper review panels/committees (e.g., NCHRP (17-108, 08-157, 17-102), NDSEG Scholarship Evaluation Panel, Luxembourg National Research Fund (LNR), Independent Research Fund Denmark, other USDOT Tier 1 UTCs, and TRB 101st Annual Meeting).

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 4 to 5, 2021, CAMMSE successfully held its fourth annual research symposium virtually through ZOOM because of COVID-19. Also, several presentations were made by CAMMSE faculty and student researchers during the 101st annual meeting of the Transportation Research Board from January 9 - 13, 2022. 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 "Transportation Systems Analysis" course in the Fall 2021 semester and "Connected and Autonomous Vehicles" course in the Spring 2022 semester to several graduate students who were in attendance. 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. During this reporting period, Bo Qiu and Li Song won the Second and Third Place Awards respectively at the Fourth Annual CAMMSE Virtual Research Symposium that was held on November 5, 2021. Li Song and Shaojie Liu were awarded the prestigious Don Blackburn Memorial Scholarship and the Roy D. Williams Memorial Scholarship, respectively on November 18, 2021. Paul D. Cribbins Cup was also awarded to UNCC for its Outstanding ITE Student Chapter on November 18, 2021. Yang Zhao was awarded the Women's Transportation Seminar (WTS) Charlotte Metro Chapter Mary N. Clayton

Honorary Scholarship in January 2022. Bo Qiu was selected by CAMMSE UTC to receive the USDOT Student of the Year Award on January 8, 2022. Besides, Charlotte-Douglas Airport FAA Seminar was held on Oct 26, 2021 and Dr. Martin Kane conducted outreach in this event.

At WSU, Jie Zhao won the First Place Award at the 4th Annual CAMMSE Research Symposium in November 2021. Vishnupriya Jonnalagadda was granted the Waheed Uddin Diversity Graduate Research Fellowship. Yan Zhang won the 2021 Milton Pikarsky Memorial Award for Outstanding Doctoral Dissertation by CUTC.

At TSU, five undergraduate-level and seven graduate-level transportation-related courses were taught by CAMMSE personnel (Drs. Yi Qi, Mehdi Azimi, and Ms. Ursurla Williams). During the reporting period, there were a total of six graduate students and one undergraduate student participated in research projects supported by CAMMSE, including three female students. One graduate student Lijie Zhou graduated with a thesis directly supported by CAMMSE. His thesis title was “A Study of Impact of Infrastructures on Public Bicycle-Sharing System Demand”.

At UT Austin, there were a total of 6 students involved in CAMMSE projects, including both female and male students. They are Jenny Hall (PhD), Karen Kalter (MS), Carolina Baumanis (Researcher/PhD) under the supervision of Dr. Machemehl and Abduallah Adel Mohamed (PhD), Suyash Vishnoi (PhD), Warren Vu (Undergad) under the supervision of Dr. Claudel.

Technology Transfer

At UNCC, CAMMSE faculty, staff, researchers, and students have been making presentations at different meetings including the North Carolina Department of Transportation Research & Innovation Summit on October 6, 2021, the 4th Annual CAMMSE Virtual Research Symposium from November 4-5, 2021, the 21st COTA International Conference of Transportation Professionals on December 17, 2021, the 101st Annual Meeting of the Transportation Research Board from January 9-13, 2022, the Department of Civil and Environmental Engineering Graduate Research Symposium at UNC Charlotte on March 18 and 25, 2022, and the 7th Annual UTC Conference for the Southeast Region from March 24-25, 2022.

At WSU, two presentations invited by the METER Group and the WSU Office of Research were made on October 14 and 20, 2021, respectively, Also WSU researchers made several presentations in meetings including the fourth Annual CAMMSE Research Symposium in November 2021, the International Joint Research Center for Resilient Infrastructure on November 13, 2021, Society for Risk Analysis Annual Meeting in December 2021, the TriDurLE Annual Symposium in December 2021, and the 20th and 21st Joint COTA International Conference of Transportation Professionals on December 17, 2021.

TSU CAMMSE faculty and graduate research assistants published their research findings in peer-reviewed journals and conference proceedings. In addition, Dr. Yi Qi was invited to present her research at the C2SMART virtual event, and the TexITE Houston February Luncheon.

At UT Austin, there are a total of four active projects sponsoring one master’s student, four PhD students, one undergraduate 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, teaching 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 has been actively collaborating with several other universities across the country and abroad (e.g., NCA&T and NC State University) in conducting research, co-writing proposals and/or papers. Dr. Martin Kane at UNCC worked together with Austin Transportation Department on the Smart Streets program in Austin, TX.

At TSU, Dr. Mehdi Azimi partnered with Texas A&M Transportation Institute (TTI) to develop a new proposal submitted to TxDOT. In addition, he also collaborated with the American Bureau of Shipping (ABS) on his current research project.

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.

Diversity

Several Ph.D. students from underrepresented groups have been hired to conduct CAMMSE's research during this reporting period. For example, at UNCC, seven international graduate students (including Mr. Bo Qiu, Mr. Shaojie Liu, Mr. Li Song, Mr. Tianjia Yang, Mr. Chengying Hua, Ms. Yang Zhao, and Mr. Hengcong Guo, all of them came from P.R.China) joined the INES Ph.D. program and they have been working as CAMMSE research assistants. Two master students, Mr. Kiavash Riahipour from Iran and Ms. Ruth Kandolo from Congo, is currently being advised by Dr. Wei Fan to conduct their thesis research.

At WSU, one female engineering faculty member and two female PhD students in the Department of Civil & Environmental Engineering at WSU contributed to the CAMMSE site activities. Furthermore, one female Outreach Coordinator Cheryl A. Reed assisted in the CAMMSE 2022 Project 15.

With TSU being one of the nation's largest historically black universities, most students are minority students. During the reporting period, six students were supported by the CAMMSE fund, including three females. Our supported students have different backgrounds and are from different countries, including Nigeria, Afghanistan, and China.

At UT Austin, the CAMMSE funds have supported several undergraduate and graduate students from various countries including Egypt, India and China. These funds have also supported both male and female students.

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, eight presentations by researchers provided some professional development for the audience. In addition, the research activities at WSU have been performed as part of two PhD students' dissertation research.

TSU provides research assistantships to students who are interested in developing their careers in the transportation area. Students worked closely with our faculty members to receive extensive training. Also, CAMMSE TSU organized and co-sponsored the following "Department of Transportation Studies EVENTS": "Jobs at Port Houston" presented by Mr. Ms. Jacquie Young-Hall (Port of Houston) on February 14, 2022, "Scholarships and Opportunities with USCG" presented by LCDR Timothy Tilghman (U.S. Coast Guard) on February 16, 2022, "Opportunities with Houston Public Works" presented by Ms. Veronica O. Davis, P.E. (Houston Public Works) on February 17, 2022, "Scholarships and How to Become an Import/Export Specialist" presented by Ms. Jenn Davis (Houston Customs Brokers & Freight Forwarders Association) on March 4, 2022. During these events, students had the opportunities to learn from and network with industry experts.

UT Austin presented papers at the TRB Annual Meeting. Attending this conference provided students the opportunity to network with practitioners, alumni, and academic professionals. Conferences are incubators for both personal relationships and research ideas/findings, providing rich professional development experience for students. CAMMSE research has been accepted for podium presentation at the TRF Annual Meeting in St. Louis, MO. 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 60 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 2022 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 before, UNCC has published many journal papers and made many presentations both nationally and internationally. The research of WSU has been disseminated through the presentations mentioned earlier. At TSU, CAMMSE research results were published in peer-reviewed journals, conference proceedings, as well as invited presentations. CAMMSE faculty and students presented ten papers at the 101st Transportation Research Board Annual Meeting. In addition, Dr. Yi Qi and Dr. Azimi also integrated their research results into the courses they taught. UT Austin has presented the results through published papers, technical reports, and technical presentations. Research results are disseminated through the classroom teaching of the principal investigators and their colleagues.

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 Fifth CAMMSE Transportation Summer Camp from June 20 - 24, 2022. The camp will include information and activities related to Charlotte Area Transit System (CATS), Charlotte Douglas International Airport (CLT), and NC Transportation Museum.
(2) All final project reports to be completed for year 5 (2020-2022) and some final project reports to be completed for year 6 (2021-2022) 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.
(3) WSU researchers will continue their activities in journal article submission/revision and presentations when suitable while making progress on addressing other CAMMSE objectives (especially the CAMMSE 2022 Project 15).
(4) TSU team will continue making progress on current research projects; continue to encourage students to participate in CAMMSE research projects; attend conferences to present research findings; and continue hosting seminars for students.
(5) In the next reporting period, Suyash Vishnoi at UT Austin will work on the comparison of various state estimation methods such as Kalman Filter variants and Moving Horizon Estimation for TSE using the second-order ARZ traffic flow model. Suyash Vishnoi will also study the impact of differential privacy of traffic data on the performance of various TSE techniques using simulation software like VISSIM and SUMO. Karen Kalter will refine current models of predicting interchange ramp volumes and synthesize current models with research from previous reporting periods. She will complete a thesis on this topic. Carolina Baumanis and Jennifer Hall will present results from the Machine Learning Approach to predict bicycle demand work at the TRF Annual Meeting in St. Louis, MO. Additionally, this work has been submitted to a TRF Journal and is currently under review.

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
American Bureau of Shipping	Non-profit /TX				X	
Capital Metro – Austin Public Transit	Government /TX		X	X		

Centralina Council of Governments	MPO /NC		X			
City of Austin	Government /TX				X	
City of Charlotte	Government /NC		X			
City of Houston	Government /TX				X	
Connecticut Department of Transportation	Government /CT				X	
CT Transit	Transit Operator				X	X
Harris County	Government /NC				X	
Houston Bike Share	Non-profit /TX				X	
Houston BCycle	Non-profit/ TX				X	
Houston-Galveston Area Council	Non-profit /TX				X	
International Association of Maritime and Port Executives	Non-profit /Intl.				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/O R				X	
PacTrans	UTC/WA				X	
Texas A&M Transportation Institute	University /TX				X	
Texas Department of Transportation	Government /TX		X	X		
Texas Department of Transportation – Dallas District	Government /TX		X	X		
Texas Southern University	University /TX	X	X	X		
University of Houston	University /TX				X	
University of Connecticut	University /CT	X	X	X		
University of North Carolina at Charlotte	University /NC	X	X	X		
University of Queensland				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 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 and co-writing papers with faculty and researchers from North Carolina A&T University and North Carolina State University. A collaborative relationship has been successfully developed between these universities. Dr. Fan has also been working with other researchers at UNC Charlotte on a research project entitled “Geo-FRIT: A Web-based Geospatial Analytics Tool for Quantifying Freight Risk and Resilience in Transportation”, which was sponsored by NCDOT.

At WSU, Dr. Xianming Shi has met with the Economic Development Director at the City of Pullman, Washington to discuss possible collaboration in mobility solutions, and he has met with the Director of WSU Vancouver School of Engineering and Computer Science to discuss possible collaboration in mobility solutions.

TSU collaborated with Texas A&M Transportation Institute (TTI) and American Bureau of Shipping.
In this reporting period, UT Austin collaborated with Dallas District of TxDOT.

3. OUTPUTS

3.1. Journal publications, conference papers, and presentations

Journal publications

[1] Gu, J.J., Jiang, Z.B., Fan, W. and Chen, J., Short-Term Trajectory Prediction for Individual Metro Passengers Integrating Diverse Mobility Patterns with Adaptive Location-Awareness, Accepted for Publication, *Information Sciences*, March 2022.

[2] Yang, Y., Cui, H., Ma, X., Fan, W., Zhu, M. and Yao, S., Evaluating the Impacts of Optimization Horizon on the Shared Autonomous Vehicle Reservation Request System, *Journal of Advanced Transportation*, Volume 2022, Article ID 7304148, January 2022.

[3] Song, L. and Fan, W., Traffic Signal Control Under Mixed Traffic with Connected and Automated Vehicles: A Transfer-Based Deep Reinforcement Learning Approach, Volume 9, pp. 145228-145237, *IEEE Access*, October 2021.

[4] Liu, S., Li, Y. and Fan, W., Mixed Logit Model Based Diagnostic Analysis of Bicycle-Vehicle Crashes at Daytime and Nighttime, Accepted for Publication, *International Journal of Transportation Science and Technology*, October 2021.

[5] Guo, R., Liu, J., Zhao, Q., & Qi, Y., Signal timing and geometric design at contraflow left-turn lane intersections, *International Journal of Transportation Science and Technology*, October 2021.

[6] Qi, Y., Liu, J., Tao, T., & Zhao, Q., Impacts of COVID-19 on public transit ridership, *International Journal of Transportation Science and Technology*, November 2021.

[7] Ren, Z., Fusco, G., Lownes, N., and Zhu, J., Entropy-based Diversity Quantification of Multimodal Transportation Systems: Physical Infrastructure Perspective versus Travel Behavior Perspective, *ASCE Journal of Urban Planning and Development*, 10(2): 44, 2022.

[8] Smith, R., Bertolaccini, K. and Lownes, N. E. Improving Transit Access Measures in Affordable Housing Funding Criteria, Volume 106, pp. 239-248, *Transport Policy*, 2021.

[9] Nugroho, S.A., Vishnoi, S.C., Taha, A.F., Claudel, C.G. and Banerjee, T, Where Should Traffic Sensors Be Placed on Highways? *IEEE Transactions on Intelligent Transportation Systems*, 2021.

[10] Qi, Y., Cornwell, M., Shi, X. Field Test of Living Snow Fences along Illinois Freeways. *ASCE Journal of Cold Regions Engineering*, Volume 35, Issue 4, December 2021.

Conference papers

[1] Liu, J., Y. Qi and J. Tao, Predicting the Severity of Large Truck Crashes Using Machine Learning Methods Transportation Research Board, accept for presentation at the 101st Transportation Research Board Annual Meeting, Washington, D.C., January 2022.

[2] Ma, J., X. Chen, X. Zhang, and L. Yu, Exploring the Willingness to Pay for High-occupancy Toll Lanes Based on a Hybrid Utility and Regret Model Considering Latent Variables. The 101st Transportation Research Board Annual Meeting Paper 22-04030, Session 1129, Transportation Research Board of the National Academies, Washington, D.C., January 2022.

[3] Zhang, Y., X. Chen, Y. Zhao, J. Ma, and L. Yu, A Proposed Methodology for Measuring the Environmental Effect of Automated Bus Considering Platooning. The 101st Transportation Research Board Annual Meeting Paper 22-04095, Session 1311, Transportation Research Board of the National Academies, Washington, D.C., January 2022.

[4] Jiang, Y., G. Song, Y. Wu, T. Wang, and L. Yu, The Impact of Cold-start Emissions on Air Pollution Exposure during Active Travel: A Case Study in Beijing. The 101st Transportation Research Board Annual Meeting Paper 22-04517, Session 1196, Transportation Research Board of the National Academies, Washington, D.C., January 2022.

[5] Meng, D., G. Song, H. Lu, Y. Wu, and L. Yu, Comparative Analysis of Platoon Stability of Car-Following Models for Emission Estimation. The 101st Transportation Research Board Annual Meeting Paper 22-04521, Session 1196, Transportation Research Board of the National Academies, Washington, D.C., January 2022.

[6] Ding, S., X. Chen, and L. Yu, Platoon Recognition in a Connected and Autonomous Vehicles Environment. The 101st Transportation Research Board Annual Meeting Paper 22-03869, Session xxx, Transportation Research Board of the National Academies, Washington, D.C., January 2022.
[7] Chen, X, K. Ma, J. Liu, and L. Yu, Design of Intermodal Hub-and-Spoke Freight Network Considering Hub Failure. The 101st Transportation Research Board Annual Meeting Paper 22-04906, Session xxx, Transportation Research Board of the National Academies, Washington, D.C., January 2022.
[8] Chen, X, Y. Wang, Z. Fu, and L. Yu, Impact Analysis of Surrounding Vehicles Behavior on Autonomous Truck Platoon. The 101st Transportation Research Board Annual Meeting Paper 22-04648, Session 1392, Transportation Research Board of the National Academies, Washington, D.C., January 2022.
[9] Fusco, G., and Zhu, J, Knowledge and Perception of Single-Family Residential Building Resilience and Its Impact on Disaster Evacuations Decisions, ASCE Construction Research Congress, Arlington, VA, March 2022.
[10] Hall, J., Baumanis, C. and Machemehl, R., Modeling Impacts of COVID-19 on Capital Metro Ridership, Proceedings of the Transportation Research Board 101st Annual Meeting, Washington, D.C., January 2022.
[11] Baumanis, C., Hall, J. and Machemehl, R., A Machine Learning Approach to Predicting Bicycle Demand During the COVID-19 Pandemic, Proceedings of the Transportation Research Board 101st Annual Meeting, Washington, D.C., January 2022.
[12] Mohamed, A., Chen, H., Wang, Z. and Claudel, C., Skeleton-Graph: Long-Term 3D Motion Prediction From 2D Observations Using Deep Spatio-Temporal Graph CNNs, proceedings of the 2021 International Conference on Computer Vision (ICCV), Montreal, Canada, October 2021.
[13] Mohamed, A., Lejarza, F., Cahail, S., Claudel, C. and Thomaz, E. HAR-GCNN: Deep Graph CNNs for Human Activity Recognition from Highly Unlabeled Mobile Sensor Data, to appear, IEEE PerCom CoMoRea 2022, Pisa, Italy, March 2022.

Presentations

[1] Liu, S. and Fan, W., The Impact of Connected and Autonomous Vehicles on the Superstreets, University Graduate School Research Symposium, UNC Charlotte, March 25, 2022.
[2] Fan, W., Developing a Systematic Method for Identifying, Ranking, Examining, and Mitigating Freeway Bottlenecks, Workshop, The 7th Annual UTC Conference for the Southeast Region, Florida Atlantic University, Boca Raton, FL, Friday, March 25, 2022.
[3] Fan, W. and Li, Y., Assessing Public Transit Equity and Accessibility Based on General Transit Feed Specification Data, The 7th Annual UTC Conference for the Southeast Region, Florida Atlantic University, Boca Raton, FL, Thursday, March 24, 2022.
[4] Chen, Z. and Fan, W., Use of Multi-sensor Data in Modeling Freeway Travel Time Prediction: Advanced Machine Learning-Based Approach, Poster Presentation, The 7th Annual UTC Conference for the Southeast Region, Florida Atlantic University, Boca Raton, FL, Thursday, March 24, 2022.
[5] Song, L. and Fan, W., Traffic Signal Control in Connected and Automated Environment: A Transfer-Based Deep Reinforcement Learning Approach While Accounting for Mixed Traffic Flow on Varying Information Levels, Department of Civil and Environmental Engineering Graduate Research Symposium, UNC Charlotte, March 18, 2022.
[6] Liu, S. and Fan, W., The Impact of Connected and Autonomous Vehicles on the Superstreets, Department of Civil and Environmental Engineering Graduate Research Symposium, UNC Charlotte, March 18, 2022.
[7] Song, L. and Fan, W., Traffic Signal Control in Connected and Automated Environment: A Transfer-Based Deep Reinforcement Learning Approach While Accounting for Mixed Traffic Flow on Varying Information Levels, The 101st Annual Meeting of the Transportation Research Board, Washington D.C., January 9-13, 2022.
[8] Fan, W. and Lin, Z., Evaluating the Potential Use of Crowdsourced Bicycle Data for Cycling Activities and Safety Analysis, Invited Keynote Presentation, Multimodal Public Transit Modeling and Analytics Session, The 21st COTA International Conference of Transportation Professionals, Chang'an University, Xi'an, China, December 17, 2021.

[9] Song, L. and Fan, W., Traffic Signal Control in Connected and Automated Environment: A Transfer-Based Deep Reinforcement Learning Approach While Accounting for Mixed Traffic Flow on Varying Information Levels, Fourth Annual CAMMSE Virtual Research Symposium, UNC Charlotte Center City, Charlotte, NC, November 5, 2021.
[10] Liu, S. and Fan, W., Platooning-Based Trajectory Planning of Connected and Autonomous Vehicles at Superstreets, Fourth Annual CAMMSE Virtual Research Symposium, UNC Charlotte Center City, Charlotte, NC, November 5, 2021.
[11] Qiu, B. and Fan, W., Travel Time Forecasting on a Freeway Corridor: a Dynamic Information Fusion Model based on the Random Forests Approach, Fourth Annual CAMMSE Virtual Research Symposium, UNC Charlotte Center City, Charlotte, NC, November 5, 2021.
[12] Fan, W. and Li, Y., Modeling and Evaluating Public Transit Equity and Accessibility by Integrating General Transit Feed Specification Data, Fourth Annual CAMMSE Virtual Research Symposium, UNC Charlotte Center City, Charlotte, NC, November 4, 2021.
[13] Fan, W., Overview of Thrust 1: CAV Impacts on Traffic Intersection Capacity and Transportation Revenue, NC Transportation Center of Excellence on Connected and Autonomous Vehicle Technology (NC-CAV) Update, North Carolina Department of Transportation Research & Innovation Summit, UNC Chapel Hill, Chapel Hill, NC, October 6, 2021.
[14] Song, L. and Fan, W., Modeling Pedestrian-Injury Severities in Pedestrian-Vehicle Crashes Considering Spatiotemporal Patterns: Insights from Different Hierarchical Bayesian Random-Effects Models, North Carolina Department of Transportation Research & Innovation Summit, UNC Chapel Hill, Chapel Hill, NC, October 6, 2021.
[15] Liu, S. and Fan, W., Investigating Operational Performance of Connected and Autonomous Vehicles on Signalized Superstreets, North Carolina Department of Transportation Research & Innovation Summit, UNC Chapel Hill, Chapel Hill, NC, October 6, 2021.
[16] Qi, Y., Improving Contraflow Left-Turn Lane Design at Signalized Intersections to Decrease Traffic, C2SMART virtual event, February 18, 2022.
[17] Qi, Y., Contraflow Left-Turn Lane Design at Signalized Intersections, TexITE Houston February Luncheon, February 9, 2022.
[18] Azimi, M., Analysis of Intermodal Vessel-to-Rail Connectivity, Fourth Annual CAMMSE Virtual Research Symposium, UNC Charlotte Center City, Charlotte, NC, November 4, 2021.
[19] Ivan, J. and A. Burnicki., “Estimation of Pedestrian Compliance at Signalized Intersections Considering Demographic and Geographic Factors”, Fourth Annual CAMMSE Virtual Research Symposium, UNC Charlotte Center City, Charlotte, NC, November 4, 2021.
[20] Fusco, G., and Zhu, J., Knowledge and Perception of Single-Family Residential Building Resilience and Its Impact on Disaster Evacuations Decisions, ASCE Construction Research Congress, Arlington, VA, March 9-12, 2022.
[21] Hall, J., Modeling the Impacts of COVID-19 on Capital Metro Ridership Presentation, Fourth Annual CAMMSE Virtual Research Symposium, UNC Charlotte Center City, Charlotte, NC, November 4, 2021.
[22] Hall, J., Baumanis, C. and Machemehl, R., Modeling Impacts of COVID-19 on Capital Metro Ridership, Proceedings of the Transportation Research Board 101st Annual Meeting, Washington, D.C., January 2022.
[23] Baumanis, C., Hall, J. and Machemehl, R., A Machine Learning Approach to Predicting Bicycle Demand During the COVID-19 Pandemic, Proceedings of the Transportation Research Board 101st Annual Meeting, Washington, D.C., January 2022.
[24] Mohamed, A., Chen, H., Wang, Z. and Claudel, C., Skeleton-Graph: Long-Term 3D Motion Prediction From 2D Observations Using Deep Spatio-Temporal Graph CNNs, proceedings of the 2021 International Conference on Computer Vision (ICCV), Montreal, Canada, October 2021.
[25] Mohamed, A., Lejarza, F., Cahail, S., Claudel, C. and Thomaz, E. HAR-GCNN: Deep Graph CNNs for Human Activity Recognition from Highly Unlabeled Mobile Sensor Data, to appear, IEEE PerCom CoMoRea 2022, Pisa, Italy, March 2022.
[26] Zhao, J., Lee, J.Y. Assessing resilience for supply chain systems subjected to multiple risks. 2021 Society for Risk Analysis Annual Meeting, Virtual Meeting, December 2021. (poster presentation)
[27] Ghasemi, S.H., Lee, J.Y. Assessment of the post-earthquake traffic flow capacity of a highway bridge using a reliability-based approach. The 2021 TriDurLE Annual Symposium, Virtual, December 2021.

[28] Shi, X. Sustainable Road Maintenance Operations for Better Winter Mobility and Resilience. Keynote Presentation for the 20th and 21st Joint COTA International Conference of Transportation Professionals, Online, December 17, 2021.
[29] Shi, X., Li, J.Y. Ongoing WSU Work in the Nexus of Transportation and Climate. Keynote Presentation for the 1st International Workshop on Resilient Infrastructure. International Joint Research Center for Resilient Infrastructure, Tongji University, Online, November 13, 2021.
[30] Lee, J.Y. Effect of connected and autonomous vehicles on supply chain performance. Fourth Annual CAMMSE Virtual Research Symposium, UNC Charlotte Center City, Charlotte, NC, November 4, 2021.
[31] Shi, X., Dey, K., Ashraf, Md. T., Carrola, A. Effect of Multimodal Connected Vehicle App on Transit Stop Catchment Area. Fourth Annual CAMMSE Virtual Research Symposium, UNC Charlotte Center City, Charlotte, NC, November 4, 2021.
[32] Shi, X. Selected WSU Work in the Transportation – Climate Nexus. A presentation invited by the WSU Office of Research, Pullman, WA, October 20, 2021.
[33] Shi, X. Selected Sensing Topics from the Smart and Green Infrastructure Group at WSU Pullman. Invited Presentation for the METER Group, Pullman, WA, October 14, 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

Nothing to report.

3.4. Inventions, patent applications, and/or licenses

Nothing to report.

3.5. Other outputs

CAMMSE Graduate Seminar Series @ UNCC, Sponsored by CAMMSE

[1] “Impacts of Connected and Automated Vehicles on Deep Reinforcement Learning Controlled Intersection Systems", Presented by Mr. Li Song (CAMMSE INES Ph.D. research assistant), October 6, 2021, EPIC CEE Conference Room 3344.
[2] “The Impact of Connected and Autonomous Vehicles (CAVs) on the Performance of Superstreets", Presented by Mr. Shaojie Liu (CAMMSE INES Ph.D. research assistant), October 13, 2021, EPIC CEE Conference Room 3344.
[3] “Lane Changing Model and Local Obstacle Avoidance Algorithm", Presented by Ms. Yang Zhao (CAMMSE INES Ph.D. research assistant), October 20, 2021, EPIC CEE Conference Room 3344.
[4] “Review on Self-learning Algorithms for Traffic Flow Prediction Models and Techniques in the Research of Driverless Cars", Presented by Mr. Chengying Hua (CAMMSE INES Ph.D. research assistant), October 27, 2021, EPIC CEE Conference Room 3344.
[5] “Travel Time Forecasting on a Freeway Corridor: a Dynamic Information Fusion Model based on the Machine Learning Approach", Presented by Mr. Bo Qiu (CAMMSE INES Ph.D. research assistant), November 3, 2021, EPIC CEE Conference Room 3344.
[6] “Introduction of Car Following Model", Presented by Mr. Tianjia Yang (CAMMSE INES Ph.D. research assistant), November 10, 2021, EPIC CEE Conference Room 3344.
[7] “Impacts of CAV Penetration Rates at Intersections under Fixed Traffic Demands", Presented by Mr. Li Song (CAMMSE INES Ph.D. research assistant), November 17, 2021, EPIC CEE Conference Room 3344.

[8] “Signal Control with Dynamic and Mixed Integer Programming Approach", Presented by Mr. Shaojie Liu (CAMMSE INES Ph.D. research assistant), November 24, 2021, remotely via Zoom.
[9] “Signal Optimization with MILP", Presented by Mr. Shaojie Liu (CAMMSE INES Ph.D. research assistant), January 5, 2021, remotely via Zoom.
[10] “Lane Changing Model: Classical Model and Research Trends", Presented by Ms. Yang Zhao (CAMMSE INES Ph.D. research assistant), January 19, 2021, remotely via Zoom.
[11] “Injury Severities Analysis of Time-of-day Variations and Temporal Instability In Nontypical-Sideswipe Collisions: A Random Parameter Model with Heterogeneous Mean and Heteroscedastic Variance", Presented by Mr. Chengying Hua (CAMMSE INES Ph.D. research assistant), January 26, EPIC CEE Conference Room 3344.
[12] “Intersection Management with CAV: A Review", Presented by Mr. Tianjia Yang (CAMMSE INES Ph.D. research assistant), February 2, 2021, remotely via Zoom.
[13] “Basics of Multi-agent Deep Reinforcement Learning", Presented by Mr. Li Song (CAMMSE INES Ph.D. research assistant), February 9, 2021, remotely via Zoom.
[14] “Applying Signal Optimization Techniques in Superstreet-A Preliminary Experiment", Presented by Mr. Shaojie Liu (CAMMSE INES Ph.D. research assistant), February 16, 2021, remotely via Zoom.
[15] “Spatiotemporal COSTMAP Inference for MPC via Deep Inverse Reinforcement Learning", Presented by Ms. Yang Zhao (CAMMSE INES Ph.D. research assistant), February 23, 2021, remotely via Zoom.
[16] “The Scientometrics Review on Technological Evolution and Emerging Trends of Traffic Prediction: Tasks, Challenges and Research Network", Presented by Mr. Chengying Hua (CAMMSE INES Ph.D. research assistant), March 2, 2021, remotely via Zoom.
[17] “Transit Signal Priority with CAV: A Review", Presented by Mr. Tianjia Yang (CAMMSE INES Ph.D. research assistant), March 16, 2021, remotely via Zoom.
[18] “Multi-agent Deep Reinforcement Learning Controlled Signal Corridor", Presented by Mr. Li Song (CAMMSE INES Ph.D. research assistant), March 30, 2021, remotely via Zoom.

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

[1] “Suggestion for Transportation Engineers”, lectured by Mr. Andy Wagner and Mr. Ty Parham, remotely via Zoom, October 28, 2021.
[2] “Safety Professional Career & OSH in Transportation”, lectured by Mr. Michael Benjamin, assistant professor, from Occupational Safety and Health at UNC Charlotte, remotely via Zoom, January 27, 2022.
[3] “ITE Involvement & Career Advice”, lectured by Ms. Stacie L. Phillips, PE, from Kimley-Horn, Inc, remotely via Zoom, February 24, 2022.
[4] “Career Paths for Transportation Engineering & Resource Available at ITE”, lectured by Mr. Ty Parham, chairman of NCITE, remotely via Zoom, March 18, 2022.

Department of Transportation Studies EVENTS @ TSU, organized and sponsored by CAMMSE

[1] “Jobs at Port Houston”, presented by Mr. Ms. Jacquie Young-Hall (Port of Houston), February 14, 2022.
[2] “Scholarships and Opportunities with USCG”, presented by LCDR Timothy Tilghman (U.S. Coast Guard), February 16, 2022.
[3] “Opportunities with Houston Public Works”, presented by Ms. Veronica O. Davis, P.E. (Houston Public Works), February 17, 2022.
[4] “Scholarships and How to Become an Import/Export Specialist”, presented by Ms. Jenn Davis (Houston Customs Brokers & Freight Forwarders Association), March 4, 2022.

Technical Reports

[1] Liu, J., Liu, J., Shi, X., Honavar Nazari, M. Snow and Ice Treatment Products Evaluation. Report No. CMR-21-009. Prepared for the Missouri Department of Transportation, Jefferson City, MO. December 2021.

4. OUTCOMES

4.1. Increased understanding and awareness of transportation issues

TSU's research project "The Impacts of COVID-19 on Public Transit" developed a random-effects panel data model to investigate the impacts of COVID-19 on the public transit ridership in the top twenty metropolitan areas in the U.S. In addition, correlation analysis was conducted to further analyze the impacts of the identified socioeconomic factors. The findings of this study can help public transit agencies and local transportation planning organizations better understand the causes and patterns of changes in public transit ridership during the pandemic.

Research done under Dr. Randy Machemehl (UT Austin) characterizing public transportation during the pandemic in Austin, TX gleaned insights into how and why public transportation failed to supply essential travel to minority groups.

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

Nothing to report.

4.3. Increases in the body of knowledge

Research done by Dr. Christian Claudel (UT Austin) has increased the body of knowledge in two aspects: The first aspect is the ability to predict human motion from video and other sensor data. The prediction algorithms allow a better understanding of the uncertainty associated with human motion prediction, and the impact of pose on prediction quality. The second aspect is the determination of optimal selection of connected vehicles data for the purpose of traffic monitoring. Selecting only a subset of the available data is very important, since it allows faster computational time to obtain traffic estimates. The present research has increased the knowledge of the selection process.

4.4. Improvement of existing techniques, practices, technologies

TSU's research project "Development of Guidelines for Implementation of Contraflow Left-turn Lanes (CLL) at Signalized Intersections" developed a systematic method for determining the length of CLL and the signal timing plan for implementing CLL at signalized intersections. The results of a case study showed that the redesigned CLL intersection with the proposed method outperforms the existing CLL intersection in terms of the average traffic delay, average vehicle travel time, and average queue length, and the CLL intersection can achieve its best performance at the recommended CLL lengths. This research provides useful guidelines to traffic engineers in the implementation of this innovative intersection design.

The work done under Dr. Christian Claudel (UT Austin) on Skeleton-Graphing has improved the state of the art for prediction techniques with imagery data. Predicting human paths is of utmost importance in the context of automated vehicles. Since collisions can happen anytime during regular traffic operations, it is important to determine the likelihood of a collision, to solve the problem of planning the path of the automated vehicle accordingly. Research under Dr. Randy Machemehl (UT Austin) explores a gap in existing traffic volume prediction. Prior research has largely focused on predicting volumes for freeway entrance/exit ramps, but rarely discusses volumes for interchange ramps. Interchange ramps often do not have permanent traffic counters, so this research will provide a useful tool for transportation engineers to estimate interchange ramp volumes without the need to install new traffic counters.

One project Dr. Xianming Shi (WSU) recently finished provides insights on setback distances and species for future living snow fence (LSF) designs in the State of Illinois, with anticipated mobility benefits. Seven

LSF sites with different species and site configurations and their control sites were selected along Illinois freeways. All sites are within the right-of-way (ROW). Measurement grids and stakes were used to catch the snow accumulation pattern at each test site. Volumes of snow trapped by LSF sites and their control sites were calculated using the cross-section method and compared using t-tests. Field measurement indicated that a major portion of the incoming snow was deposited near the snow fence in the downwind direction. The t-test results showed that LSF sites trapped significantly higher volumes of snow than control sites without snow fences. The field tests evidenced that LSFs 3.7–6 m (12–20 ft) high with 30–55% porosity and an offset distance of 27.4–36.5 m (90–120 ft) within ROW of IL freeways are effective in trapping and depositing snow before it reaches the roads. Suitable species include Grey Dogwood, Indigo Bush, Staghorn Sumac, and American Plum.

4.5. Enlargement of the pool of trained transportation professionals

At UNCC, CAMMSE supported doctoral student Mr. Bo Qiu graduated and obtained his Ph.D. degree in December 2021.

4.6. Incorporation of new techniques, practices, technologies

Nothing to report.

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 cannot be comprehensively measured during this reporting period.

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

The optimal sensor selection problem solved by Suyash Vishnoi (UT Austin) helps improve computational time associated with traffic state estimation, and thus, enables algorithms to estimate traffic at larger scales with the same computational cost, improving the knowledge of the state of the transportation network (and thus the effectiveness of any control algorithm based on the current state).

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's collaboration with industry or government partners such as the American Bureau of Shipping helps with the technology transfer. The newly developed methods or models were able to be shared with our partners and possibly be implemented in practice.

The research is performed by students and faculty supervisors at UT Austin, who work closely with industry and government entities. As with the traffic volume estimation project, 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.

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

At TSU, by conducting CAMMSE projects, new methods or models were developed.

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, teaching 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.

One paper Dr. Xianming Shi (WSU) recently published contributes to the body of scientific knowledge relevant to winter mobility on roadways. Specifically, the state of the knowledge was synthesized and guidelines were developed to inform the use of materials, including types of materials, application strategies, application rates, and application equipment for winter maintenance operations by roadway agencies.

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 offers research assistantships to students. By participating in projects and being mentored by CAMMSE faculty members, students learned new methods and technologies and will carry them into their future works.

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 Dallas District of TxDOT as a partner in the research efforts.

6. CHANGES AND PROBLEMS

6.1. Changes in approach and reasons for change

One female student the WSU team recruited from Iran to start her Ph.D. work for CAMMSE 2022 Project 15 declined the offer. As such, one current Ph.D. student, Chuang Chen, will continue to work on this project instead, along with Dr. Yong Deng and Dr. Xianming Shi at WSU.

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

At UT Austin, there are delays in cleaning and collecting large data. The proposed solution is to hire undergrads. Additionally, with the proposed scooter crash project, there has been very little scooter activity and therefore crashes on campus since UT Austin no longer allows scooters to park on campus. The lack of data makes the evaluation of the geo-spatial speed reduction on campus difficult to measure. The plan is to expand the scope of the project area to measure how injuries have changed pre- and post-pandemic. The UT-Austin research team will aim to use at least two data sources: (1) Austin-Travis County Emergency Medical Services (ATCEMS) incident reports, and (2) Emergency Department (ED) syndromic surveillance chief complaint data from local area hospitals.

6.3. Changes that have a significant impact on expenditures

The COVID pandemic has brought many challenges to all CAMMSE partner institutions. As we are getting back to normal, all CAMMSE partner institutions are actively taking 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), All Completed

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

CAMMSE @ UNC Charlotte Funded Projects, 2021-2023 (Year 6), Ongoing

University	Principle Investigator(s)	Category	Title of the Funded Project
University of North Carolina at Charlotte	Wei Fan	Applied Research	Evaluating and Comparing the Impact of Connected and Autonomous Vehicles on Conventional Intersections and Superstreets
	Wei Fan	Advanced Research	Real-time Traffic Flow Prediction based on Spatiotemporal Patterns in Connected and Autonomous Vehicles Environment
	Wei Fan	Advanced Research	Online Cooperative Lane-changing Model of Connected and Autonomous Vehicles
	Wei Fan	Applied Research	Impact of Connected and Autonomous Vehicles on Signalized Intersections with Transit Signal Priority
University of Texas at Austin	Randy Machemehl	Applied Research	Impacts of Speed on Dockless Electric Scooter Crashes (Phase II)
	Randy Machemehl	Applied Research	Optimizing Type and Location of Pedestrian Crossing Signs at Non-signalized Intersections (Phase II)
	Randy Machemehl	Applied Research	Developing Robust Smart Traffic Signal Control
University of Connecticut	Nicholas Lownes	Advanced Research	Prioritizing People - Mixed Equilibrium Assignment for AV Based on Occupancy (Phase II)
	Nicholas Lownes	Advanced Research	Pedestrian Behavior and Interaction with Autonomous Vehicles (Phase II)
	Jin Zhu	Applied Research	Disaster Resilience through Diverse Evacuation and Emergency Transportation Systems (Phase II)
	John Ivan Amy Burnicki	Applied Research	Estimation of Pedestrian Compliance at Signalized Intersections Considering Demographic and Geographic Factors (Phase II)
Washington State University	Xianming Shi	Applied Research	Prediction of Traffic Mobility Based on Historical Data and Machine Learning Approaches
Texas Southern University	Mehdi Azimi Yi Qi	Applied Research	Investigating the Impact of COVID-19 Pandemic Outbreak on Bike Share Usage and Ridership: A Case Study in Houston
	Yi Qi Mehdi Azimi Qun Zhao	Applied Research	Countermeasures for Maintaining Safe and Effective Public Transit Service in the Post-COVID-19 Era
	Yi Qi Qun Zhao Mehdi Azimi	Applied Research	Investigate Age Impacts on Controlled Flight into Terrain (CFIT) Crashes in General Aviation

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