



Center for Advanced Multimodal Mobility Solutions and Education

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A handwritten signature in black ink, appearing to read 'Wei Fan', is positioned below the 'Signature of Submitting Official' label.

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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 *Accident Analysis and Prevention*, *ASCE Journal of Transportation Engineering, Part A: Systems*, *IEEE Transactions on Intelligent Transportation Systems*, *International Journal of Transportation Science and Technology*, *Journal of Advanced Transportation*, *Journal of Transport Geography*, *Traffic Injury Prevention*, *Transportation Planning and Technology*, and *Transportation Research Part C: Emerging Technologies*.

During this reporting period, CAMMSE research results were also presented at many conferences on different occasions, which include the 2020 ASCE Construction Research Congress, Chinese Overseas Transportation Association (COTA) 23rd Winter Symposium, the 99th Annual Meeting of the Transportation Research Board (TRB 2020), North Carolina Section of the Institute of Transportation Engineers (NCSITE) 2019 Annual Meeting, Second Annual CAMMSE Research Symposium (2019), 2019 PacTrans/CSET Conference, 2019 INFORMS Annual Meeting, The 6th Annual UConn School of

Engineering Graduate Students Poster Competition, and the 2019 Chinese Overseas Transportation Association (COTA) 2nd International Symposium on Emerging Trends in Transportation.

Leadership

Representing the CAMMSE, Center Director Dr. Wei Fan has been using his expertise to serve as a panel member for three NCHRP projects, including: 1). NCHRP Synthesis 20-05/Topic 50-10 Availability of Pedestrian Infrastructure Data for Routing and Network Analysis; 2). NCHRP 08-116 Framework for Managing Data from Emerging Transportation Technologies to Support Decision-Making; and 3). NCHRP 03-131 Guidance for Planning and Implementing Multimodal, Integrated Corridor Management. Dr. Wei Fan also served on the National Science Foundation (NSF) Review Panel on January 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*, and *Journal of Transportation of the Institute of Transportation Engineers*; Founding Editor-in-Chief of the *Journal of Infrastructure Preservation and Resilience*; Editorial boards of the *Asian Transport Studies*, *Institute of Transportation Engineers*, *International Journal of Natural Disaster, Accidents and Civil Infrastructure*, *International Journal of Transportation*, *International Journal of Transportation Science and Technology*, *Journal of Infrastructure Preservation and Resilience*, *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., member of the ASCE Connected & Autonomous Vehicles Impacts Committee, ASCE Public Transport Committee, ASCE Rail Transportation Committees, NCSITE Scholarship Committee, PENC State Board, TRB Standing Committees (AHB60, AHD60, AP025, ADB10, ABR10, ABJ70, AFN30, ADC20, ADC60, AFP40, AT050, AW010 and AW020), World Transport Convention Shared Logistics and Transportation Systems Committee, Chair of the asset management subcommittee of TRB's Traffic Signal Systems Committee, Session Chair of the INFORMS, Chair of Symposium Organizing Committee for the 23rd COTA Winter Symposium, Chair for the 2019 CAMMSE Research Symposium, Chair of Session of "Smart Cities: Planning and Operation" at the 2nd COTA International Symposium on Emerging Trends in Transportation, Co-General Chair of the IEEE 38th International Performance Computing and Communications Conference (IPCCC 2019), Outreach subcommittee of the Lone Star Harbor Safety Committee (LSHSC), Academic Outreach and Membership Officer, Chinese Overseas Transportation Association (COTA), and at large member of PENC state board, as well as several proposal and book review committees (e.g., NCHRP).

Education and Workforce Development

CAMMSE has been working with 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, David Weggel, and Martin Kane) 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. In particular, on October 6, 2019, CAMMSE staff and graduate students conducted outreach activities at the Charlotte Kids Festival on the campus of UNCC. Dr. Martin Kane, Shaojie Liu, Yizhe Yang, Li Song and Kelsey Lynch helped organize this event. From November 7 to 8, 2019, CAMMSE successfully held its second annual research symposium on the campus of UNCC. Also, the 99th annual meeting of the Transportation Research Board was held from January 11 to 15, 2020 at Washington, D.C. and two presentations were made by UNCC CAMMSE students during the event. On February 22, 2020, Dr. Martin Kane conducted outreach activities at the Discovery Place representing CAMMSE. Two Ph.D. students of CAMMSE (Zijing Lin and Yang Li) served

as volunteers and helped organize the third annual Mini Civil Conference (MC²) organized by the Department of Civil and Environmental Engineering at UNC Charlotte on Friday February 28, 2020. 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 to understand way. Students also had to use creativity to think of an interesting way to capture young children's attention and keep them engaged. CAMMSE has had impacted both the local community and the sponsored students by encouraging creativity and enhancing connections.

At UNCC, Dr. Wei Fan taught the "Transportation System Analysis" course in the Fall 2019 semester and "Urban Transportation Networks: Operations & Optimization" course in the Spring 2020 semester to several graduate students who were in attendance. From September to December 2019, Ms. Yizhe Yang, a visiting scholar from Hebei University of Technology (China) joined and worked with the CAMMSE research group at UNCC. Ph.D. student Zhen Chen was awarded the Don Blackburn Memorial Scholarship by North Carolina Section of the Institute of Transportation Engineers on November 21, 2019 and he was also the Outstanding Graduate Ph.D. Student Award winner in the UNC Charlotte CEE Department on December 5, 2019. Since January 2020, Mr. Zhen Chen has been hired by Parsons Corporation, Atlanta, GA and is currently pursuing a career in transportation. Ph.D. students Yang Li and Zijing Lin were selected to receive the Roy D. Williams Memorial Scholarship and Emily Blount Honorary Scholarship respectively by the North Carolina Section of the Institute of Transportation Engineers (NCSITE) on November 21, 2019. Zijing Lin also won the First-Place Award in the Second Annual CAMMSE Research Symposium at UNC Charlotte Center City, Charlotte, NC, on November 7, 2019 while Ph.D. student Pengfei Liu won the Second-Place award during the same event. A total of 10 students have been involved in CAMMSE projects and 7 of them were directly supported by CAMMSE.

At Washington State University (WSU), the incoming Ph.D. student Chuang Chen was awarded the Alfred Suksdorf Fellowship, Voiland College of Engineering and Architecture. Ms. Cheryl A. Reed was hired in January 2020 to wrap up the outreach work unfinished by Ms. Michelle Akin. She has been working with two female undergraduate students (Olivia R. Willis and Nicole M. Kim) to plan more outreach activities for selected middle schools and high schools in the Palouse region. This is under the CAMMSE 2019 Project 15 titled "Multimodal Transportation Engineering Curriculum for Middle and High School Students." Dr. Hajbabaie's students won several awards including: Three Minute Thesis Competition at the 99th Annual Meeting of the Transportation Research Board, President Leadership Award, Washington State University Outstanding Research Assistant Excellence Award, Helene M. Overly Memorial Scholarship, Women's Transportation Seminar Scholarships, Perteet Engineering Graduate Fellowship in Civil Engineering, and the Ph.D. Student Workshop on Transportation and Logistics Challenges and Opportunities travel scholarship.

At Texas Southern University (TSU), there were six undergraduate and seven graduate transportation related courses offered by faculties who are associated with CAMMSE. Three master theses were directly supported by CAMMSE, which were "A Method for Estimating Truck Queue Length at Marine Terminal Gates", "Safety Performance of Displaced Left Turn Intersections, Case Studies in San Marcos, Texas", and "Countermeasures for Reducing Truck Congestion at Marine Terminals". In addition, during the report period, one Transportation Seminar was held at TSU.

At the University of Texas at Austin (UT Austin), there were a total of 11 students involved in CAMMSE projects, including both graduate and undergraduate students. Detailed information about the supervisor and the students involved is provided below: Dr. Machemehl: Jenny Hall (MS), Hao Liu (PhD), Carolina Baumanis (Researcher/PhD); Dr. Claudel: Abdualлах Adel Mohamed (PhD), Kun Qian (PhD), Suyash Vishnoi (PhD), Jonathan Butler (Undergraduate), Mohammad Kedwaii (Undergraduate), Muhammed Sadiq (Undergraduate); and Dr. Boyles: Tengkuo Zhu (PhD), Cesar Yahia (PhD).

Technology Transfer

CAMMSE faculty, staff, researchers and students have been making presentations at different meetings including the 2nd COTA International Symposium on Emerging Trends in Transportation (ISETT 2019) on

October, 4, 2019, Second Annual CAMMSE Research Symposium on November 8, 2019, North Carolina Section of the Institute of Transportation Engineers (NCSITE) Annual Meeting on November 21, 2019, the 23rd COTA Winter Symposium, Washington, D.C. on January 12, 2020, and The 99th Annual Meeting of the Transportation Research Board, Washington, D.C. on January 12, 2020.

At UT Austin, there are a total of four active projects sponsoring 1 master's student, 7 PhD students, 3 undergraduate students, 3 principal investigators, and 1 researcher. One of the best technology transfer tools are the students that work on these CAMMSE research projects. These UT Austin students are key to the 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. UT students are invited to spend time in the City Traffic Control Center representing a valuable learning environment, but the learning is really two-way as the City engineers and students learn from each other.

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, during this time, Dr. Xianming Shi at WSU collaborated with Oregon State University and University of Washington on a Connected Vehicle research project. Dr. Ali Hajababaie made a transition to become an assistant professor at North Carolina State University, while remaining an affiliated faculty member with WSU.

During the reporting period, TSU collaborated with other universities on developing new proposals. For example, TSU collaborated with University of Houston on one national NSF proposal. In addition, TSU collaborated with Houston METRO, City of Houston and University of Houston on a Department of Energy (DOE) proposal.

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 is also collaborating with the National Science Foundation (NSF) on 2019 Project 08. Deep-Learning Based Trajectory Forecast for Safety of Intersections with Multimodal Traffic.

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 (Mr. Zhen Chen, Mr. 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, one female Outreach Coordinator (Cheryl A. Reed, WSU) is actively involved in the CAMMSE 2019 Project 15. One female minority undergraduate (civil engineering) student (Nicole Kim, WSU), and

another female undergraduate student (Olivia Willis) were involved in CAMMSE 2019 Project 15. One international graduate student (Mr. Chuang Chen, from P.R. China) worked on CAMMSE projects. During August to December 2019, a female international Ph.D. student (Aya Shatanawi, from Jordan) joined the Transportation Engineering PhD. Program, and started the literature review for the CAMMSE Project 16 titled "Effects of Incorporating Connected Vehicle Technologies into No-Notice Emergency Evacuation during Winter Weather".

TSU is one of the nation's largest historically black universities, and majority of students are minority students. During the report period, 5 graduate students have been working as research assistants and supported by CAMMSE. Among them, 2 are female students.

At UT Austin, students sponsored by CAMMSE come from all sorts of diverse backgrounds. Specifically, UT Austin supported two females (Ms. Jennifer Hall and Ms. Carolina Baumanis) and nine males (Mr. Hao Liu, Mr. Abdullah Adel Mohamed, Mr. Kun Qian, Mr. Suyash Vishnoi, Mr. Jonathan Butler, Mr. Mohammad Kedwaii, Mr. Muhammed Sadiq, Mr. Cesar Yahia, and Mr. Tengkuo Zhu) through CAMMSE.

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

The bi-weekly seminars at UNCC 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 UT Austin, CAMMSE students attended the 2020 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.

At TSU, CAMMSE organized the Transportation Seminar Series, which is open to faculty, students and general public. During the reporting period, one seminar was held: "Resilience of Ports and The Marine Transportation System", by Katherine Flynn Chambers, Research Physical Scientist, U.S. Army Engineer Research and Development Center, Washington D.C., March 10, 2020. Also, CAMMSE funding provides research assistantships to students who want to develop their careers in transportation.

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. UT Austin has presented the results through conference proceedings, technical reports, technical presentations and website in: <http://sboyles.github.io/>, <https://sites.utexas.edu/machemehl/> and <http://www.mass-lab-ut.com/>.

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 initially planned to hold the Fourth CAMMSE Transportation Summer Camp from June 22-26, 2020. The camp will include 1 day of field trip (Traffic control center, transportation museum, and Light Rail UNCC station). However, due to the recent outbreak of COVID-19, the camp has been cancelled and we are currently exploring the possibility of holding it in July 2020, if at all possible.
- (2) CAMMSE will issue the RFPs for the year of 2020-2021, conduct rigorous peer-reviews, select funded projects and issue contracts. For all research projects that will be selected for funding in

2020-2021 year 5, 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 3 (2018-2020) 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) Attend the 7th Annual UTC Conference for the Southeastern Region, which has been rescheduled to Fall 2020, to present papers based on CAMMSE research.

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		
Centralina Council of Governments	MPO /NC		X			
Charlotte Area Transit System	Government /NC		X			
City of Austin	Government /TX		X	X		
City of Charlotte	Government /NC		X			
City of Houston	Government /TX				X	
Connecticut Department of Transportation	Government /CT				X	
Houston Bike Share	Non-profit /TX				X	
Houston-Galveston Area Council	Non-profit /TX				X	
Houston Metro	Government /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	
PacTrans: Region 10 UTC	UTC /WA				X	
Partnership for Strong Communities	Non-profit /CT				X	
Texas Department of Transportation	Government /TX		X	X		
Texas Southern University	University /TX	X	X	X		
Tongji University	University /China				X	
University of Connecticut	University /CT	X	X	X		
University of Houston	University /TX				X	
University of North Carolina at Charlotte	University /NC	X	X	X		
University of Texas at Austin, Center for Transportation Research	University /TX	X	X	X		
University of Texas at El Paso	University				X	

	/TX					
University of Washington	University /WA				X	
Washington Department of Transportation	Government /WA				X	
Washington State University	University /WA	X	X	X		
Wuhan University of Science and Technology	University /China				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 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 between two universities. Dr. Fan is currently also building a collaborative relationship with several other universities (e.g., Wuhan University of Science and Technology and Shijiazhuang Tiedao University). During the reporting period, CAMMSE Center Director Dr. Wei Fan also collaborated with several other universities (e.g., North Carolina A&T University, and North Carolina State University) on co-writing NCDOT and NCHRP proposals.

One of the UT-Austin principal investigators is also collaborating with the National Science Foundation (NSF) on CAMMSE 2019 Project 08. Deep-Learning Based Trajectory Forecast for Safety of Intersections with Multimodal Traffic.

TSU teamed up with Houston Metro, City of Houston and University of Houston (UH) to develop a new proposal for the Department of Energy (DOE). In addition, TSU collaborated with UH on developing a new NSF proposal.

At WSU, the collaborators have been involved in the CAMMSE related activities mainly by contributing domain knowledge or exchanging the latest information on connected vehicle technologies. The PacTrans: Region 10 UTC has been involved by sharing the interests in exploring CV technologies for better winter road maintenance operations and in reaching out to K-12 groups.

3. OUTPUTS

3.1. Journal publications, conference papers, and presentations

Journal publications

- [1] Chen, Z. and Fan, W., Analyzing Travel Time Distribution Based on Different Travel Time Reliability Patterns Using Probe Vehicle Data, *International Journal of Transportation Science and Technology*, Volume 9, Issue 1, pp. 64-75, March 2020.
- [2] Gu, J.J., Jiang, Z., Fan, W., Wu, J. and Chen, J., Real-Time Passenger Flow Anomaly Detection Considering Typical Time Series Clustered Characteristics at Metro Stations, *ASCE Journal of Transportation Engineering, Part A: Systems*, Volume 146, Issue 4, February 2020.
- [3] Huang, J., G. Song, J. Zhang, C. Li, Q. Liu, and L. Yu. The Impact of Violations of Bicycles and Pedestrians on Vehicle Emissions at Signalized Intersections, *Journal of Advanced Transportation*, Volume 2020, Article ID 7539829, March 2020.
- [4] Islam, S., Aziz. H. and Hajbabaie, A. Stochastic Gradient-based Optimal Signal Control with Energy Consumption Bounds, Accepted for Publication, *IEEE Transactions on Intelligent Transportation Systems*, Accepted.
- [5] Lin, Z. and Fan, W., Modeling Bicycle Ridership using Crowdsourced Data: An Ordered Probit Model Approach, Accepted for Publication, *ASCE Journal of Transportation Engineering, Part A: Systems*, March 2020.
- [6] Lin, Z. and Fan, W., Modeling Bicycle Volume Using Crowdsourced Data from Strava Smartphone Application, Accepted for Publication, *International Journal of Transportation Science and Technology*, March 2020.
- [7] Liu, P. and Fan, W., Exploring the Impact of Connected and Autonomous Vehicles on Freeway Capacity Using a Revised Intelligent Driver Model, *Transportation Planning and Technology*, Volume 43, Issue 3, pp. 279-292, March 2020.
- [8] Liu, P. and Fan, W., Exploring Injury Severity in Head-on Crashes Using Latent Class Clustering Analysis and Mixed Logit Model: a Case Study of North Carolina, *Accident Analysis and Prevention*, Volume 135, 105388, February 2020.
- [9] Liu, P. and Fan, W., Modeling Head-on Crash Severity with Drivers under the Influence of Alcohol or Drugs (DUI) And Non- DUI, *Traffic Injury Prevention*, Volume 21, Issue 1, pp. 7-12, 2020.
- [10] Niroumand, R., Tajalli, M., Hajibabai, L. and Hajbabaie, A. Joint Optimization of Vehicle-group Trajectory and Signal Timing: A New Phase for a Mixed-autonomy Traffic Stream, Accepted for Publication, *Transportation Research Part C: Emerging Technologies*, Accepted.
- [11] Tajalli, M., Mehrabipour, M. and Hajbabaie, A. Cooperative Signal Timing and Speed Optimization in Connected Urban-Street Networks, Accepted for Publication, *IEEE Transactions on Intelligent Transportation Systems*.
- [12] Teng, J., Chen, T. and Fan, W., An Integrated Approach to Vehicle Scheduling and Bus Timetabling for an Electric Bus Line, *ASCE Journal of Transportation Engineering, Part A: Systems*, Volume 146, Issue 2, February 2020.
- [13] Zhao, J., Fan, W. and Zhai, X.H., Identification of Land-use Characteristics Using Bicycle Sharing Data: A Deep Learning Approach, *Journal of Transport Geography*, Volume 82, January 2020.
- [14] Zhu, W., Wei, J. and Fan, W., Data Fusion Approach for Evaluating Route Choice Models in Large-Scale Complex Urban Rail Transit Networks, *ASCE Journal of Transportation Engineering, Part A: Systems*, Vol. 146, Issue 1, 04019056, January 2020.

Conference papers

- [1] Jinna, H., Qi, Y., Zhao Q. and Azimi, M. Countermeasures for Reducing Truck Congestion at Marine Terminals, Presentation at the 99th Transportation Research Board Annual Meeting, Washington, DC, Jan.12-16, 2020.

- [2] Liu, H. and Machemehl, R. A Queueing Theory Based Stochastic Traffic Delay Model for Adaptive Signal Control. 99th Annual Meeting of the Transportation Research Board, Washington, DC, Jan.12-16, 2020.
- [3] Liu, P., and Qi, Y. Analyzing Injury Severity of Large Truck Crashes Using a Partial Proportional Odds Model: A Case Study in Texas, Presentation at the 99th Transportation Research Board Annual Meeting, Washington, DC, Jan.12-16, 2020.
- [4] Qi, Y., Liu, S., Zhao Q. and Qu W. Development of a Progression-Based, Signal-Timing Strategy for Continuous Flow Intersections, Presentation at the 99th Transportation Research Board Annual Meeting, Washington, DC, Jan.12-16, 2020.
- [5] Zhu, J., Zhang, L., and Ren, Z. How Transportation Infrastructures Make Human Resilience Possible: Towards A Conceptual Framework. ASCE Construction Research Congress, Tempe, AZ, March 8-10, 2020.
- [6] Zhu, T., Boyles, S.D. and Unnikrishnan, A. Electric Vehicle Traveling Salesman Problem with Drone. 99th Annual Meeting of the Transportation Research Board, Washington, DC, Jan.12-16, 2020.

Presentations

- [1] Azimi, M., Lan, L., Rahman, M. and Qi, Y. Impact of Different Attributes on Bicycling Mode Share in Houston. US DOT CAMMSE University Transportation Center Research Symposium, Charlotte, NC, November 2019.
- [2] Chen, Z. and Fan, W., Use of Multisensor Data in Modeling Freeway Travel Time Prediction, Poster Presentation, Second Annual CAMMSE Research Symposium, UNC Charlotte Center City, Charlotte, NC, November 7, 2019.
- [3] Chen, C. and Shi, X. Artificial Neural Networks Modeling for the Macroscopic Effects of Winter Maintenance Operations on Traffic Mobility. A poster presentation for the PacTrans/CSET Conference, Seattle, WA. October 11, 2019.
- [4] Cheng, C., Shi, X., Akin, M., He, Y. Applying ANN Models for Mobility Benefits Analysis of Winter Maintenance Operations on Washington Highways. Poster at the 2nd CAMMSE Research Symposium, Charlotte, NC. November 7, 2019.
- [5] Cohen, J. Highways and Wealth Distribution: A Geospatial Analysis, 2019 Second Annual CAMMSE Research Symposium, UNC-Charlotte, November 7, 2019.
- [6] Fan, W., Disruptive Technologies in Transportation: Implications and Opportunities, Institute of Transportation Engineers (ITE) Student Chapter, UNC Charlotte, Charlotte, NC, Thursday, February 27, 2020.
- [7] Fan, W., Developing A Systematic Method for Identifying and Ranking Freeway Bottlenecks Using Vehicle Probe Data, Workshop, Second Annual CAMMSE Research Symposium, UNC Charlotte Center City, Charlotte, NC, November 8, 2019.
- [8] Fan, W., Optimal Variable Speed Limit Control in Connected Autonomous Vehicle Environment for Relieving Freeway Congestion, Second Annual CAMMSE Research Symposium, UNC Charlotte Center City, Charlotte, NC, November 7, 2019.
- [9] Fan, W., Optimal Variable Speed Limit Control in Connected Autonomous Vehicle Environment for Relieving Freeway Congestion, The 2nd COTA International Symposium on Emerging Trends in Transportation (ISETT 2019), Rome Tre University, Meeting Room 1, Roma, Italy, Friday, October 4, 2019.
- [10] Islam, S. and Hajbabaie, A. A Program for Multimodal Traffic Signal Timing Optimization in Urban Street Networks. The 99th Annual Meeting of the Transportation Research Board, Washington, DC, January 12-16, 2020 (Poster).
- [11] Islam, S. and Hajbabaie, A. A Scalable and Real-time Approach for Optimal Signal Control in a Multi-modal Semi-connected Vehicle Environment. INFORMS Annual Meeting, Seattle, WA October 20-23, 2019 (Lectern).
- [12] Islam, S., Aziz, H. and Hajbabaie, A. Stochastic Gradient-based Optimal Signal Control with Energy Consumption Bounds. INFORMS Annual Meeting, Seattle, WA October 20-23, 2019 (Lectern).

- [13] Jinna, F., Tao, T., Zhao, Q., Qi, Y. and Azimi, M. Countermeasures for Reducing Truck Congestion at Marine Terminals. US DOT CMMSE University Transportation Center Research Symposium, Charlotte, NC, November 2019.
- [14] Li, Y. and Fan, W., Optimizing Transit Equity and Accessibility by Integrating Relevant GTFS Data Performance Metrics, North Carolina Section of the Institute of Transportation Engineers (NCSITE) Annual Meeting, McKimmon Center, North Carolina State University, Raleigh, North Carolina, Thursday, November 21, 2019.
- [15] Li, Y. and Fan, W., Using General Transit Feed Specification (GTFS) Data as a Basis for Evaluating and Improving Public Transit Equity, Poster Presentation, Second Annual CMMSE Research Symposium, UNC Charlotte Center City, Charlotte, NC, November 7, 2019.
- [16] Lin, Z. and Fan, W., Modeling Bicycle Ridership Using Crowdsourced Data: An Ordered Probit Model Approach, Presentation, Young Professionals Lightning Talk, The 23rd COTA Winter Symposium and The 99th Annual Meeting of the Transportation Research Board, Washington, D.C., Sunday, January 12, 2020.
- [17] Lin, Z. and Fan, W., Modeling Bicycle Volume Using Crowdsourced Bicycle Data from Strava, Poster Presentation, Second Annual CMMSE Research Symposium, UNC Charlotte Center City, Charlotte, NC, November 7, 2019.
- [18] Liu, P. and Fan, W., Exploring the Impact of Connected and Autonomous Vehicles on Freeway Capacity Using Microscopic Traffic Simulation, Presentation, Young Professionals Lightning Talk, The 23rd COTA Winter Symposium and The 99th Annual Meeting of the Transportation Research Board, Washington, D.C., Sunday, January 12, 2020.
- [19] Liu, P. and Fan, W., Exploring the Impact of Connected and Autonomous Vehicles on Freeway Capacity Using Microscopic Traffic Simulation, Poster Presentation, Second Annual CMMSE Research Symposium, UNC Charlotte Center City, Charlotte, NC, November 7, 2019.
- [20] Lownes, N. Low Income Housing Access to Public Transportation, 2019 Second Annual CMMSE Research Symposium, UNC-Charlotte, November 7, 2019.
- [21] Mehrabipour, M. and Hajbabaie, A. A Distributed Gradient-Based Approach for Cell Transmission Model-Based System Optimal Dynamic Traffic Assignment. The 99th Annual Meeting of the Transportation Research Board, Washington, DC, January 12-16, 2020 (Poster).
- [22] Mehrabipour, M. and Hajbabaie, A. A Distributed Gradient Approach for Cell Transmission Model-based System Optimal Dynamic Traffic Assignment. INFORMS Annual Meeting, Seattle, WA October 20-23, 2019 (Lectern).
- [23] Mohebifard, R. and Hajbabaie, A. Optimal Traffic Metering Locations and Levels in Urban Transportation Networks. The 99th Annual Meeting of the Transportation Research Board, Washington, DC, January 12-16, 2020 (Poster).
- [24] Mohebifard, R. and Hajbabaie, A. Trajectory Optimization of Connected and Automated Vehicles at Roundabouts. The 99th Annual Meeting of the Transportation Research Board, Washington, DC, January 12-16, 2020 (Poster).
- [25] Mohebifard, R. and Hajbabaie, A. Optimal Traffic Metering Locations and Levels in Urban Transportation Networks. INFORMS Annual Meeting, Seattle, WA October 20-23, 2019 (Lectern).
- [26] Mohebifard, R. and Hajbabaie, A. Trajectory Optimization of Connected Self-Driving Vehicles at Roundabouts. INFORMS Annual Meeting, Seattle, WA October 20-23, 2019 (Lectern).
- [27] Niroumand, R., Tajalli, M., Hajibabai, L. and Hajbabaie, A. A New Signal Phase for Vehicle Group-Based Trajectory and Signal-Timing Optimization in Mixed Connected and Automated Vehicle Environments. The 99th Annual Meeting of the Transportation Research Board, Washington, DC, January 12-16, 2020 (Poster).
- [28] Niroumand, R., Tajalli, M., Hajibabai, L. and Hajbabaie, A. A Novel Trajectory Control Logic for Intersections with a Mix of Connected Human-driven and Automated Vehicles. INFORMS Annual Meeting, Seattle, WA October 20-23, 2019 (Lectern).
- [29] Rahman, M., Qi, Y. and Azimi, M. Houston Bike-Share System and Equity Considerations for Underserved Communities. US DOT CMMSE University Transportation Center Research Symposium, Charlotte, NC, November 2019.

- [30] Ren, Z. and Zhu, J. A Quantitative Method in Measuring Diversity of Multi-modal Transportation Systems. The 6th Annual UConn School of Engineering Graduate Students Poster Competition, Storrs, CT, March 11, 2020.
- [31] Shi, X. Connected Infrastructure for Enhanced Winter Roadway Maintenance Operations: Current Practices and Potential Opportunities. 2nd CAMMSE Research Symposium, Charlotte, NC., November 7, 2019,
- [32] Shi, X., He, Y., Akin, M. Exploring Weather-Related Connected Vehicle Application for Improved Winter Travel. A presentation at the 99th TRB Annual Meeting, Washington, D.C., Jan. 15, 2020,
- [33] Smith, R. Investigating the Linkage Between Transit Access to Services and Affordable Housing Availability. 2019 Second Annual CAMMSE Research Symposium, UNC-Charlotte, November 7, 2019.
- [34] Tajalli, M. and Hajbabaie, A. A Lagrangian-Based Signal Timing and Trajectory Optimization in a Mix of Self-Driving and Human-Driven Vehicles. The 99th Annual Meeting of the Transportation Research Board, Washington, DC, January 12-16, 2020 (Poster).
- [35] Tajalli, M. and Hajbabaie, A. A Lagrangian-based Signal Timing and Trajectory Optimization in a Mixed Connected and Automated Vehicle Environment. INFORMS Annual Meeting, Seattle, WA October 20-23, 2019 (Lectern).
- [36] Tajalli, M., Mirheli, A., Hajbabaie, A. and Hajibabai, L. Utilization Prediction of Highway Fleet Equipment. The 99th Annual Meeting of the Transportation Research Board, Washington, DC, January 12-16, 2020 (Lectern).
- [37] Toman, P., Zhang, J., Ravishanker, N. and Konduri, K.C. Dynamic Predictive Models for Ridesourcing Services in New York City Using Daily Compositional Data, 2019 Second Annual CAMMSE Research Symposium, UNC-Charlotte, November 7, 2019.

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 two methods, including:

- (1) A comprehensive signal-timing strategy for continuous flow intersections based on traffic progression. Traffic simulation-based experiments showed the new signal-timing strategy outperform the existing signal plans.
- (2) An analytical model for estimating the required freeway acceleration lane lengths for both heavy trucks and passenger cars by considering speed, traffic volume and acceleration characteristics of heavy trucks.

UConn's research team has developed an entropy-based method to quantify the level of diversity of a multimodal transportation system from both infrastructure and travel behavior perspectives. The proposed method was tested in a case study of Hartford, CT.

UT Austin also developed two novel methods, including:

- (1) Mohamed, A., Hua, X., Zhou, X., Claudel, C. (2019) IEA: Inner Ensemble Average within a convolutional neural network. Center for Transportation Research. <https://arxiv.org/abs/1808.10350>.
- (2) Mohamed, A., Claudel, C. (2019) MCRM: Mother Compact Recurrent Memory. Center for Transportation Research. <https://arxiv.org/abs/1808.02016>

3.4. Inventions, patent applications, and/or licenses

Nothing to report.

3.5. Other outputs

CAMMSE Graduate Seminar Series @ UNCC, Sponsored by CAMMSE

- [1] "Modeling Pedestrian-Vehicle Collision Severity Based on Multinomial Logit Models", Presented by Bo Qiu, 9-10am. March 25, 2020, remotely via Webex.
- [2] "A Day of Week and Time of Day Analysis of Pedestrian-Involved Crashes in North Carolina: A Preliminary Result", Presented by Yang Li, 9-10am. March 18, 2020, EPIC CEE Conference Room 3344.
- [3] "Modeling Bicyclist Injury Severity in Bicycle-motor Vehicle Crashes Occurred in Urban and Rural Areas: A Mixed Logit Analysis", Presented by Zijin Lin, 9-10am. March 11, 2020, EPIC CEE Conference Room 3344.
- [4] "Vehicle Trajectory Prediction Using Machine Learning Methods - Literature Review", Presented by Pengfei Liu, 9-10am. February 26, 2020, EPIC CEE Conference Room 3344.
- [5] "Literature Review on Modeling Connected and Autonomous Vehicles at Intersections", Presented by Shaojie Liu (CAMMSE INES Ph.D. research assistant), 9-10am. February 19, 2020, EPIC CEE Conference Room 3344.
- [6] "Car Following Model for Simulation-Based Connected and Automated Vehicle: from IDM to MIXIC", Presented by Li Song, 9-10am. February 12, 2020, EPIC CEE Conference Room 3344.
- [7] "The Performance Comparison of Machine Learning Algorithms for Travel Time Forecasting", Presented by Bo Qiu, 9-10am. February 5, 2020, EPIC CEE Conference Room 3344.
- [8] "Bi-Level Optimization of Long-Term Highway Work Zone Scheduling Considering Elastic Demand", Presented by Yang Li, 9-10am. January 29, 2020, EPIC CEE Conference Room 3344.
- [9] "Bicycle Safety Analysis at Intersections Based on Strava Data", Presented by Zijin Lin, 9-10am. January 22, 2020, EPIC CEE Conference Room 3344.
- [10] "Analyzing Injury Severity of Rear-End Crashes involving Large Trucks Using a Mixed Logit Model: A Case Study in North Carolina", Presented by Pengfei Liu, 9-10am. January 8, 2020, EPIC CEE Conference Room 3344.
- [11] "Transportation Job Seeking: Sources and Techniques", Presented by Zhen Chen, 9-10am. December 4, 2019, EPIC CEE Conference Room 3344.
- [12] "The Distributions and Basic Theory Review of Discrete Choice Models", Presented by Bo Qiu, 9-10am. November 20, 2019, EPIC CEE Conference Room 3344.
- [13] "Overview of Ensemble Learning Methods", Presented by Yang Li, 9-10am. November 13, 2019, EPIC CEE Conference Room 3344.
- [14] "Mapping Cyclist Activity and Injury Risk with Smartphone Crowdsourced Data and Bicycle Counts", Presented by Zijin Lin, 9-10am. October 30, 2019, EPIC CEE Conference Room 3344.
- [15] "Car Following Models - Modelling Vehicle Driving Behavior", Presented by Pengfei Liu, 9-10am. October 23, 2019, EPIC CEE Conference Room 3344.
- [16] "Use of Multisensor Data in Modeling Freeway Travel Time: Variability Analysis and Prediction", Presented by Zhen Chen, 9-10am. October 16, 2019, EPIC CEE Conference Room 3344.
- [17] "Topics about Travel Time Prediction", Presented by Bo Qiu, 9-10am. October 9, 2019, EPIC CEE Conference Room 3344.

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

- [1] "General body meeting with NCSITE Young Member Committee", lectured by Kimley Horn and Ty Parham, from Ramey Kemp & Associates. EPIC 3336, March 11, 2020.
- [2] "Disruptive technologies in transportation: implications and opportunities", lectured by Dr. Wei Fan, the Center Director of CAMMSE, EPIC 3344, February 27, 2020.
- [3] "NCSITE young member committee talk", lectured by Andy Wagner from HNTB, Cliff Lawson from Timmons Group, Alexander Wiseman from STV Group Inc and Ty Parham from Ramey Kemp Associates, EPIC 3222, November 4, 2019.

Technical Reports

Nothing to report.

4. OUTCOMES

4.1. Increased understanding and awareness of transportation issues

The direct impact of UT Austin's projects is 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).

TSU's research project "Impacts of bicycling corridor improvements on users' behaviors in large cities" increased the understanding and awareness of bicycle infrastructure issues. Through examining the relationship between bicycle infrastructure and behavior of bicyclists, the potential impacts of bicycle infrastructure projects were investigated.

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 "Development of Guidelines for Implementation of Contraflow Left-Turn Lanes at Signalized Intersections" investigated an innovative intersection design, Contraflow left-turn lane (CLL). The impacts of CLL on the intersection operational performance were systematically analyzed. In addition, a model was developed for estimating the length of the CLL that will maximize the operational benefits of this new design.

Ensemble learning is a method of combining multiple trained models to improve model accuracy. Research team from UT Austin proposed the usage of such methods, specifically ensemble average, inside Convolutional Neural Network (CNN) architectures by replacing the single convolutional layers with Inner Average Ensembles (IEA) of multiple convolutional layers. Empirical results on different benchmarking datasets show that CNN models using IEA outperform those with regular convolutional layers. A visual and a similarity score analysis of the features generated from IEA explains why it boosts the model performance.

LSTMs and GRUs are the most common recurrent neural network architectures used to solve temporal sequence problems. The two architectures have differing data flows dealing with a common component called the cell state (also referred to as the memory). UT Austin attempts to enhance the memory by presenting a modification that they call the Mother Compact Recurrent Memory (MCRM). MCRMs are a type of a nested LSTM-GRU architecture where the cell state is the GRU hidden state. The concatenation of the forget gate and input gate interactions from the LSTM are considered an input to the GRU cell. Because MCRMs has this type of nesting, MCRMs have a compact memory pattern consisting of neurons that acts explicitly in both long-term and short-term fashions. For some specific tasks, empirical results show that MCRMs outperform previously used architectures.

4.4. Improvement of existing techniques, practices, technologies

From the Adaptive Signal Control Project that was conducted by UT-Austin, we have improved existing technologies that will allow people to have less delay, resulting in decreased emissions and better quality of life.

TSU's research project "Signal Timing Strategy for Displaced Left Turn Intersections" developed a new signal timing strategy for an innovative intersection, Displaced Left Turn intersection (DLT). Since DLT is relatively new and only implemented in a few states, there are few existing guidelines available for

designing DLT intersections, including signal timing plans. This research developed a comprehensive signal timing strategy based on traffic progression.

4.5. Enlargement of the pool of trained transportation professionals

At UNCC, a doctoral student Zhen Chen graduated and obtained his Ph.D. degree in December 2019. He has been conducting several CAMMSE research projects and is pursuing a career in transportation at the Parsons Corporation, Atlanta, GA since January 2020.

At UT Austin, a doctoral student Hao Liu essentially completed his dissertation developing advanced signal timing techniques. He will formally defend his dissertation on 24 April 2020.

Three CAMMSE sponsored master students graduated at TSU. During their studies in TSU, they participated in CAMMSE research. The education they received at TSU and CAMMSE makes them trained transportation professionals.

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 can only be preliminarily measured during this reporting period.

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

TSU CAMMSE projects are focused on different aspects, such as multi-modal transportation. All research findings could improve the effectiveness of the whole transportation system.

Research conducted with the City of Austin has produced a methodology for prioritizing signal re-timing activities. The city maintains over 1000 signals and traditionally has chosen the re-timing target on the basis of the time since last retiming (they can re-time about one-third of their signals each year). The new methodology should significantly improve signal efficiency by reducing user costs & emissions. Although this project was not totally supported by CAMMSE (the City funded most of the work), the connection provided by CAMMSE to the federal UTC program was extremely important to project success.

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?

At TSU, new methods and models developed by CAMMSE research projects are presented to government agencies and transportation industry through published papers, presentations and technical reports. Recommendations on how to apply the new methods or models are also provided which make the adoption of new practices possible. For example, research project “Signal Timing Strategy for Displaced Left Turn Intersections” developed a new signal timing strategy for Displaced Left Turn intersections. Applying this new strategy could improve the operational performance of the intersections.

At UT Austin, the research is performed by students and faculty supervisors who work closely with industry and government entities. As with the signal re-timing 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?

Research projects conducted by TSU CAMMSE team are innovative and advanced, which could increase the understanding of transportation issues, and expand the body of knowledge.

5.4. What is the impact on transportation workforce development?

TSU CAMMSE team regularly organizes transportation seminars to faculty, students, transportation professionals and general public. These events expose them to state-of-the-art and state-of-the-practice in transportation area. CAMMSE sponsored students have the opportunities to participate in research projects, and receive extensive training for their future work as transportation professionals.

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

Nothing to report.

6.3. Changes that have a significant impact on expenditures

Ms. Michelle Akin, P.E. has served as the PI for the CAMMSE 2019 Project 15. titled “Multimodal Transportation Engineering Curriculum for Middle and High School Students” (April 2019 – September 2020). She has resigned from WSU in June 2019 but promised to deliver the draft project final report by December 2019. As per Dr. Xianming Shi at WSU, she is no longer responding to emails or phone calls asking for any update on that report. So, starting January 2020, Dr. Xianming Shi has worked with Cheryl Reed and undergraduate students to conduct additional outreach activities and aim to deliver the project draft final report in the next reporting period. A request for PI change may be necessary and there is also significant uncertainty in light of the travel constraints posed by the COVID-19 pandemic, which prevents researchers from visiting the local schools or conducting the designed events.

For the CAMMSE 2019 Project 16 titled “Effects of Incorporating Connected Vehicle Technologies into No-Notice Emergency Evacuation during Winter Weather”, the Ph.D. student dropped out of WSU after December 2019. Despite the constraints posed by COVID-19, Dr. Xianming Shi and his assistant Chuang Chen will continue to work on the project to catch up on the schedule and aim to deliver the draft final report in July 2020. One challenge that WSU ran into is that a research intern they recruited for this project was delayed for his arrival to Pullman, WA, for at least four months, due to the outbreak of COVID-19. Dr. Ali Hajibabae has left WSU for North Carolina State University, but he remains to be affiliated with WSU and plans to complete the CAMMSE Project under the WSU contract with UNCC.

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

Nothing to report.

6.6. Additional information regarding products and impacts

With respect to CAMMSE 2019 Project 08. Deep-Learning Based Trajectory Forecast for Safety of Intersections with Multimodal Traffic (Continuation), since the beginning of the project, researchers at UT Austin have worked on modeling the interactions between pedestrians and rest of vehicles and used deep learning methods for this. Since the deep learning methods are not very robust, they have investigated modifications of the standard architecture (MCRM: Mother Compact Recurrent Memory) and have worked on improving robustness through ensemble averaging (IEA: Inner Ensemble Average within a convolutional neural network). They now have preliminary results on the actual problem but would like not to share these results in reports as they are about to submit them to the CVPR conference (deadline on November 15). After the deadline, they will publish these.

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 and 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
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CAMMSE @ UNC Charlotte Funded Projects, 2018-2020 (Year 3), Ongoing

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



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