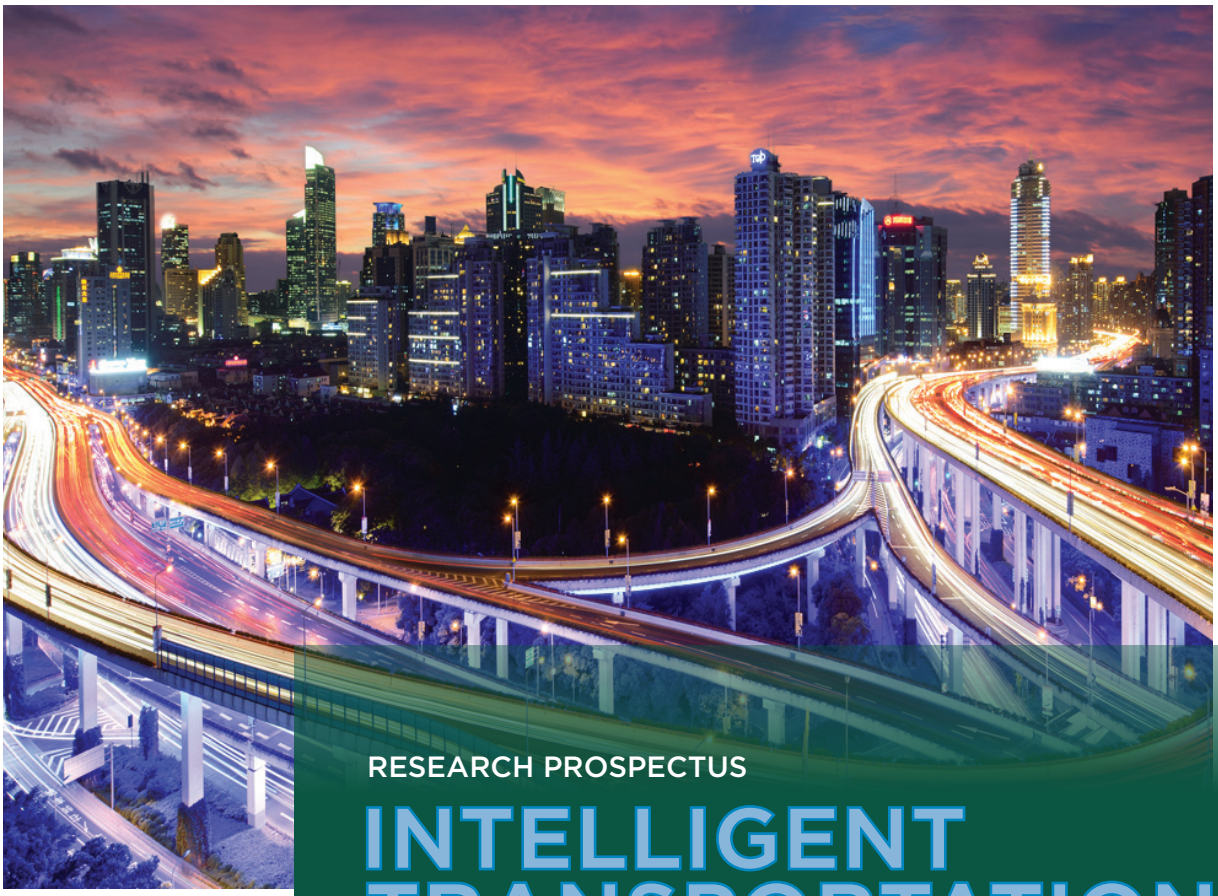


RESEARCH PROSPECTUS

INTELLIGENT TRANSPORTATION SOLUTIONS

A Path Towards Sustainable Smart Cities in the United Arab Emirates

MARCH 2016

UMS جامعة العلوم الحديثة University of Modern Sciences

NDSU NORTH DAKOTA STATE UNIVERSITY

INTERNATIONAL PARTNERSHIP FOR RESEARCH AND DEVELOPMENT

SMART CITY SOLUTIONS

The challenges of mobility, safety, security, and the environment persist worldwide. Smart city solutions involve a complex mix of information, communication, and transportation technologies to address those challenges by delivering sustainable solutions that contribute to "happy living" for all, the United Arab Emirates (UAE) measure of success for smart city initiatives.

Smart cities involve coordinated developments to:

1. grow the economy
2. create transparent government services
3. create a culture of inclusion, innovation, and continuous learning
4. develop a high quality of living with cultural vitality and access to education
5. assure resource efficiency to sustain environmental health, and
6. advance the mobility of people, goods, and ideas.

This prospectus for NDSU/UMS research focuses on the dimension of mobility where advancements in transportation technologies and services will create a solid foundation for building smart cities.

دبي الذكية
SMART DUBAI
HAPPY LIVING لحياة أسعد

A TRANSPORTATION VISION FOR SMART DUBAI

Dubai has one of the world's fastest growing economies and the largest free-trade zone in the world.

When completed in 2030, Dubai will have the world's largest container port. Planners forecast that by 2020, Dubai will attract 33% more tourists and the population will grow by at least 50%. The Dubai Road and Transport Authority forecasts that even though 20% of the population will be using public transportation by 2020, the number of cars on the roads will increase by 60%. Tourism, real estate, aviation, and trade are the top revenue sources for the Emirate. The Dubai Cruise Terminal will become the biggest cruise hub in the world, attracting 7 million tourists annually.

As the most populous city in the emirates, a chronically congested transportation system could potentially become its greatest threat. Within only two days of its opening in 2009, nearly 10% of the population rode the Dubai Metro, which is currently the longest fully automated driverless train system in the world. Imagine that Dubai also becomes the first city in the world to achieve a fully integrated and automated multimodal transportation system that achieves zero delays in moving people, goods, and waste. Even more impressively, Dubai will achieve this feat with zero crashes, zero property damages, and zero environmental pollution.

Intelligent transportation solutions have the potential to decrease travel time and increase travel time reliability through the existing roadways, railways, and waterways. Autonomous vehicle technologies will be the most transformational development for society since the Internet. Driverless vehicles will change the way we live and do business internationally. These vehicles will avoid crashes and move faster in very narrow lanes by forming platoons of vehicles that communicate wirelessly to coordinate movement.

Therefore, cities will modify some of their existing infrastructure by narrowing lanes, removing shoulders, eliminating medians, and repurposing street parking. Such modifications could quadruple flow capacity and simultaneously accommodate special-purpose managed lanes. First-class managed lanes will accommodate personal, law enforcement, and emergency vehicles for an appropriate toll. High-durability lanes will accommodate heavy vehicle and freight traffic platoons.

> "An urban transportation system for Smart Dubai with zero delays, zero crashes, zero property damages and zero environmental pollution"

These specially built lanes will deteriorate less rapidly and require fewer maintenance actions that normally disrupt traffic. Cloud technologies that enable ride-on-demand, dynamic journey sharing, and shared vehicle ownership, will increase the utilization per vehicle and simultaneously reduce the number of vehicles by at least five-fold. Fewer vehicles will curb congestion and reduce the need for long-term parking spaces.

Fully automated and air-conditioned pods will shuttle passengers from door to door and between long-haul autonomous transit modes. Autonomous bus modules will minimize underutilization by demand-forecasted arrival at terminals, link as bus-trains through long haul segments, and automatically separate to reach different destinations. With fewer personal vehicle owners, many homes will repurpose garages and driveways. Riders will waste less time in traffic and use transit time more enjoyably. Goods and services will arrive sooner and become more affordable.

All of these ideas embody a significant number of difficult questions that require substantial research for answers. Achieving this vision will require a new generation workforce capable of understanding, implementing, operating, and maintaining such solutions. New computing infrastructure and control centers will produce dynamic routing algorithms, update digital maps to guide autonomous vehicles, and optimize scheduling algorithms for demand-driven personal and shared transit.

Millions of embedded and remote sensors will measure all aspects of the system's performance, condition, and vulnerabilities. Sensor fusion techniques and big data analytics will process voluminous data to monitor performance and physical security. Sense and respond algorithms will deploy robotic construction vehicles to repair road damage and remove disabled vehicles with minimal traffic disruptions.

> "Autonomous vehicle technologies will be the most transformational development for society since the Internet"

Wireless communication technologies and new implementation standards will become the new backbone of future intelligent transportation networks. Therefore, practitioners will need to understand the fundamentals of these technologies to assure that deployed components operate reliably and efficiently through coordinated, modular, and scalable architectures. The next generation of transportation scientists

and engineers will guide the allocation and management of the wireless communication spectrum as demand and utilization changes over time. Practitioners will learn to assess the potential for interference among wireless networks, identify emerging vulnerabilities, and protect the system from cyberattacks.

The challenges will be numerous and extend far beyond the technologies. Researchers must study and anticipate changes in the public attitude and behavior toward a fully integrated and automated transportation system. Business models, regulations, insurance, cyber-security, physical security practices, and digital services will change. The transition from a technology-enabled transportation system to a fully autonomous multimodal transportation system will require a smart multidisciplinary and interdisciplinary roadmap to manage the risks, address the uncertainties, and account for human factors. Vehicle and infrastructure changes must be carefully coordinated to prevent travel disruptions while the present system transitions to the future system.

> "Intelligent Transportation Solutions will enable Dubai to become the first city in the world to achieve a fully integrated and automated multimodal transportation system"

Therefore, the next generation of practitioners must rally stakeholders, embrace the vision, and align goals towards a common purpose of "bringing happiness to the people" and "making Dubai the smartest city in the world." ■

RESEARCH COLLABORATION

Connected, automated, and autonomous vehicle technologies now offer limitless potential. Sustaining their deployment and maintenance requires interdisciplinary knowledge of the technology fundamentals and their impacts on planning, policies, and decision-making for the advancement of good governance.

The leaders of tomorrow will excel and innovate by first understanding the unique and dynamic transportation needs of the UAE through context specific research and field studies. The collaborative partnership between North Dakota State University (NDSU) in the United States and the University of Modern Sciences (UMS) in Dubai brings together global expertise and local capabilities to forge a path towards building sustainable smart cities. The UMS-NDSU collaborative project will conduct aggressive research in the following three distinct phases:

Research and develop problem statements that are important to the region

- Mobility and accessibility definitions (facility types, interrelationships, capacity measures, flow theory, parking)
- Congestion types, measures, causes (case studies contrast Dubai and travel demand forecasts with other regions)
- Impact complexities (economy, safety, security, environment, productivity, planning for short- and long-range)
- Enhancements (case studies of how deployed solutions worldwide improve mobility efficiency and safety)
- Security of transportation systems (interdependencies, cyber-systems, physical systems, complex adaptive)

Research and identify the individual technology packages, their benefits, and the costs

- Intelligent Transportation Systems-Traditional (ITS-T)
  - Traveler information and advisory systems (dynamic signage, onboard equipment, CCTV, smartphone app)
  - Traffic flow control (adaptive signaling, ramp metering, variable speed limits/ warnings, transit priority)
  - Automatic electronic payments (toll tags, transit cards, RFID, ALPR, OCR, GPS, barcodes, smartphones)
  - Pre-clearance systems (vehicle classification, high-speed WIM, roadside inspection, freight scanners)
  - Technologies for managed facilities (HOV, HOT, ETL, reversible lanes, preemptions, integrated corridors)
  - Smart parking solutions (occupancy sensors, parking reservation systems, metering technologies, apps)
  - Security and privacy impacts to the region (survey of concerns, proposed solutions, regional relevancy)
  - Case studies of practices to compare and contrast Dubai with other areas
- Intelligent Transportation Solutions-Next Generation (ITS-NG)
  - Connected Vehicles technologies and architectures (V2V, V2I, V2P, P2I, P2P, I2I)
  - Connected Vehicles major applications (information, ride sharing, crash avoidance, driver assist, platoons)

- Automated and Autonomous Vehicles (multimodal issues, rail, trucks, transit, personal rapid transit)
- Cloud Computing (advisory systems: security threats, weather, work zones, incidents, detours, traffic)
- Big Data (travel time forecasting, maintenance decision-support, flow optimization, parking availability)
- Internet-of-Things, M2M, SCADA (relationships, intersections, and interdependencies)
- Remote Sensing (surveillance, satellites, UAS technology, emergency response, incident management)
- Security and privacy impacts (threat to physical infrastructure, cyber-system vulnerabilities, encryption)
- Case studies of present and emerging practices worldwide to compile inventory of lessons learned

Research and develop best practices, and guidelines for sustainable deployment and maintenance

- Stakeholder alignment (highway, transit, public safety, non-motorized, environmental, public-private partners)
- Systems engineering (architectural and data flows, interoperability, interfaces, equipment, human factors)
- Technology diversity (sensors, wireless standards, spectrum assignments, computing standards, data analysis)
- Security and privacy considerations and interdependencies (insurance, target marketing, cyber-physical threats)
- Regulatory, policy, and institutional issues; interdependencies (regional, cross-jurisdictional, land use)
- Multimodal planning and multi-jurisdictional integration (non-motorized, motorized, multimodal, intermodal)
- Practical issues of deployment (infrastructure and power support, multimodal planning, maintenance tools)
- Funding and sustainability roadmaps (miles traveled, emissions, congestion pricing, marketing, multimodal)
- Case studies to catalog best practices, lessons learned, and emerging issues from deployed solutions worldwide

THE UPPER GREAT PLAINS TRANSPORTATION INSTITUTE

The Upper Great Plains Transportation Institute is a part of North Dakota State University, a student-focused research university located in the north-central United States. The university provides affordable access to an excellent education at a top-ranked research institution that combines teaching and research in a rich learning environment. It educates future leaders who will create solutions to global challenges and shape a better world.

The UGPTI was created in 1967 by the North Dakota legislature "to conduct and supervise research in the field of transportation in order to facilitate acquisition of a wider knowledge and understanding of marketing factors associated with the geographical location of the state of North Dakota and the upper great plains." Since its inception, the institute's research and outreach focus has expanded from ag commodity and freight transportation issues to include highway planning and design, traffic analysis, transit, intelligent transportation, transportation technology and transportation safety and security. The Institute has had a long and successful partnership with both the ND Department of Transportation and the US Department of Transportation.

Partnership with NDDOT

The Institute created, in partnership with the NDDOT a Student Support Center, engaging graduate and undergraduate students to learn the latest software and technologies in the planning and designing of highway/roadway construction projects. Students receive hands-on training, working directly with NDDOT staff.

Also in partnership with the NDDOT and ND MPOs (Metropolitan Planning Organizations in the 4 major cities) (info on ITS and traffic operations and travel demand modeling; transit coordination, ITS applications and mobility planning; transportation safety program (seat belt safety, 24/7 project, etc.)

Partnership with USDOT

UGPTI has been the lead university of a consortium of universities in federal region 8, conducting research, education and training on transportation infrastructure and the movement of passengers and freight. Through this effort, the Institute works in cooperation with other universities in the region – Colorado State University, South Dakota State University, University of Utah, Utah State University, University of Wyoming, University of Denver, and the University of Colorado Denver. Recent effort has focused on issues related to rapid growth in the energy development sector,

including, infrastructure planning and asset management, technology deployment for asset monitoring, truck size and weight issues, highway safety, alternative materials for infrastructure construction, and environmental impacts and mitigation related to transportation.

Educational Program

Transportation and logistics is a science that integrates instant global communications and technology. NDSU's challenging educational programs coordinated by the UGPTI and offered through NDSU's College of Graduate and Interdisciplinary Studies prepare students for a wide variety of careers in this growing field. Students learn from faculty, policy makers and professionals who bring diverse expertise, perspectives and experience to the classroom.

NDSU is a student-focused, land-grant research university established in 1890. Its interdisciplinary transportation and logistics program offers both masters' and Ph.D. degrees. Graduates are in demand nationally and internationally by colleges and universities, private industry, consulting firms, and state, federal and local government agencies. NDSU's world-class academic programs draw students from around the globe to a vibrant campus and community. For more information on NDSU, visit www.ndsu.edu/

For the most current information on graduate programs in Transportation and Logistics at NDSU, go to www.ndsu.edu/transportation

Programs include:

Doctorate in Transportation and Logistics: In the Ph.D. program, students conduct in-depth research in specialized areas while developing a breadth of knowledge in transportation and logistics. NDSU's interdisciplinary program of study and research crosses traditional disciplinary and departmental boundaries, preparing graduates to tackle the complex nature of transportation and logistics challenges around the globe.

Master of Managerial Logistics: Graduates achieve success in industries as diverse as manufacturing, retailing, national security, emergency management, and disaster relief. Students expand their career options around the globe whether serving in the military or working in the private sector. Students may earn their MML degree online, anywhere in the world. Graduates will meet logistical challenges by improving joint logistical efficiency and effectiveness, acquiring in-depth understanding of today's complex supply chain, implementing new technology, managing change, and making decisions with uncertainty.

Transportation & Urban Systems: Graduates will lead transportation agencies and municipalities in improving livability in communities by integrating transportation with other components of the urban environment. They will apply new technology and techniques in planning, operations and security. NDSU's program is unique in its systems approach and emphasis on analytical and spatial concepts. Students may pursue an M.S. option, a non-disquisition Master of Transportation and Urban systems or enroll in a certificate program aimed at practicing professionals. ■

COLLABORATION WITH THE UNIVERSITY OF MODERN SCIENCES

UMS No Limits NDSU
R&D PARTNERSHIP

The University of Modern Sciences in Dubai, UAE, and North Dakota State University in Fargo, ND, in the United States, are engaged in a broad bi-lateral collaborative effort to enhance their research and academic programs. The universities are jointly developing and implementing a research-based academic curriculum to explore and serve the needs of clientele both in the United Arab Emirates and in the United States.

Activities under this international effort include:

- Development of collaborative research in intelligent transportation solutions
- Joint educational programs in transportation and urban systems
- Exchange and professional development opportunities for students, staff, and faculty
- Joint seminars and workshops
- Cultural exchange
- Sharing of new technologies and new methods of management

In 2015, the University of Modern Sciences in Dubai and North Dakota State University began exploring a possible relationship to enhance their research and academic programs. An institutional memorandum of understanding was signed in May 2015, which formalized collaborative relationship and process between the two universities. Based on the success of the activities outlined in the memorandum of understanding, the two universities signed a memorandum of agreement in February 2016. Under the agreement, the universities formally entered into a collaborative research and education development partnership, focusing on bilateral cooperation in scientific research and academic activity. The universities will jointly develop and implement a research-based academic curriculum to explore and serve the needs of clientele both in the United Arab Emirates and in the United States. In accordance with the aim and objectives of the agreement, a UMS-NDSU collaborative partnership funding program is sponsored by the University of Modern Sciences for the joint research and development effort of the two universities in the areas of intelligent transportation solutions, sustainable urban systems and logistics, security and emergency management.

At North Dakota State University, this collaborative funding program and research effort is administered through the Upper Great Plains Transportation Institute (UGPTI) and jointly supervised by the director of UGPTI and the head of emergency management department at NDSU. At the University of Modern Sciences, this collaborative agreement, its funding program and research effort is under the jurisdiction of the Provost for International Development & Research and supervised directly by UMS board of trustees. ■

NDSU AND THE USDOT SMART CITIES CHALLENGE

The UGPTI and the MPC are partners with the City of Denver (Colorado) in submitting a grant Application to the U.S. Department of Transportation's Smart Cities Challenge.

The Denver application was one of seven finalists chosen from 78 applications. The USDOT has pledged up to $40 million (funding subject to future appropriations) to one city to help it define what it means to be a "Smart City "and become the country's first city to fully integrate innovative technologies – self-driving cars, connected vehicles, and smart sensors – into their transportation network.

In the second phase of the competition, the seven finalists will receive a $100,000 grant to further develop its proposal. USDOT will select the winning city based on its ability to think big, and provide a detailed roadmap on how they will integrate innovative technologies to prototype the future of transportation in their city.

Denver metropolitan region provides a unique opportunity for demonstrating the benefits of integrated land use/ transportation planning, empowered by a host of emerging technologies. Some of the region's advantages include: a second-generation light rail transit system, an innovative regional bus system, a state-of-the-art airport terminal, an innovative land-use planning process that is linked to the public transportation system, and a growing and diverse population.

North Dakota State University's Upper Great Plains Transportation Institute (UGPTI) and the Mountain-Plains Consortium will bring their collective expertise, research, and outreach capabilities to this effort. In addition to leading NDSU's interdisciplinary Transportation and Logistics education program, UGPTI has established research centers in Advanced Traffic Analysis; Agriculture, Energy, and Industrial Freight; Small Urban and Rural Transit; Transportation Safety Systems; and Surface Mobility Applications and Real-time Simulation Environments. The latter focuses on advancements in low-power sensing, wireless communications, and mobile computing to support multi-modal transportation system efficiencies, responsiveness, reliability, sustainability, safety, and security.

In addition, NDSU is the lead university of the Mountain-Plains Consortium (MPC)—a competitively selected regional university transportation center sponsored by the U.S. Department of Transportation which includes Colorado State University, South Dakota State University, University of Colorado Denver, University of Denver, University of Utah, University of Wyoming, and Utah State University, in addition to NDSU. Collectively, the MPC universities offer a wide-range of capabilities to address the research, technology transfer, and workforce development needs of this challenge. ■

KEY FACULTY

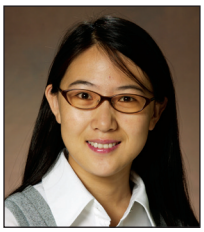
UMS-NDSU collaborative funding program has commissioned its sponsorship for intelligent transportation solutions project for sustainable smart cities in the UAE.

The core research team at UGPTI consists of:

Dr. Denver Tolliver was named director of the Upper Great Plains Transportation Institute in 2012. He has been with UGPTI since 1984, serving as associate director from 2003 to 2012. In addition, Tolliver is director of the Mountain-Plains Consortium (MPC), a multi-university consortium that serves as the university transportation center in federal Region 8; director of the interdisciplinary graduate program in Transportation and Logistics at North Dakota State University; executive director of the Transportation Research Forum; and chairman of the Transportation Leadership Graduate Certificate Program, a national online education program that involves 13 major universities located throughout the United States, with participation from many others.
During his career, Tolliver has been awarded more than $20 million in grant funding. He has authored and co-authored more than 150 transportation research papers, including reports for federal and state agencies. His research interests include: highway systems modeling, multimodal transportation planning, freight transportation, and energy and environmental analysis.

Dr. Jarret Brachman is the VP and Global Threat Intelligence Manger for Wells Fargo. He is also a collaborator and affiliated staff member of the Upper Great Plains Transportation Institute. Brachman is an internationally recognized specialist on counterterrorism and violent extremist movements. He serves as a senior adviser for agencies across the U.S. military, intelligence and law enforcement communities, and instructs on domestic extremism for the FBI. He began his career as a graduate fellow with the CIA's Counterterrorist Center where he concentrated on tracking al-Qaida's senior leadership. In 2004, Brachman joined the Combating Terrorism Center at West Point and became its first director of research. In that role, he oversaw the Center's research projects on terrorist ideology, strategy and use of the Internet for recruitment and propaganda. In 2008, Brachman published his first book, "Global Jihadism: Theory and Practice." He also was hired that year to launch a new security research and training center at UGPTI. He routinely keynotes government counterterrorism conferences and is regularly featured across international media outlets including, NPR, CNN, the AP, the Washington Post and the New York Times. His research interests include: violent extremist ideologies and movements, international and domestic terrorist threats, transportation security, Al-Qaida leadership and strategy, adversary strategic messaging (use of online and mobile media).

Raj Bridgelall has a Ph.D. degree in transportation and logistics and more than 25 years of industry and academe experience. He has 140 U.S. patents issued or pending in the areas of sensing, wireless communications, and mobile computing. Until 2004, he served as a Chief Technologist at Motorola Corporation where he pioneered radio frequency identification technology, optical sensing, and personal area networks. Subsequently, he led two wireless sensor network companies as Vice President of Engineering and as Chief Technology Officer. Currently, Dr. Bridgelall is Director of the SMARTSe Intelligent Transportation Systems program at the North Dakota State University. His research interests include: intelligent transportation systems, automated vehicles, connected vehicles, smart cities, big data analytics, advancements in transportation technologies, sensing and computing for transportation applications (RFID, wireless communications, remote sensing)



Dr. Pan Lu is an associate research fellow with the Upper Great Plains Transportation Institute at North Dakota State University. Previous research has focused on asset management, freight transportation, sustainable transportation, rail transportation, and GIS-T applications. Additional research interests statistical modeling and applications, multi-modal transportation, and applied operations research. She began work with the UGPTI as a graduate research assistant in 2005. She became a research analyst in 2010 and became an associate research fellow in 2012. She teaches the following graduate courses: Transportation System I, Transportation System II, Logistic Decision Making.

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