

Asset and Infrastructure Management (AIM)

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Department of Civil and Environmental Engineering (CEE)
Department of Geography and Earth Sciences (GES)
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Existing and Emerging Excellence (Category One)

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Executive Summary

Infrastructure represents the most expensive assets that our nation owns and operates. Managing infrastructure assets is typically complex and challenging due to tight timelines and strained budgets. Therefore, tactical management should take place to not only bring assets back to good service conditions but also to ensure *resiliency* and *sustainability*. That is where life cycle management (LCM) comes in. LCM covers all phases of a facility, including planning, design, construction, operation, and recycling, and involves advanced techniques such as needs analysis, cost-benefit analysis, portfolio optimization, and geospatial analysis. The breadth and sophistication of LCM make it difficult to be implemented in many industry sectors, causing further deteriorations of quality and performance of infrastructure assets. **Asset and Infrastructure Management (AIM) researchers participating in this proposal are experienced and have the skills, knowledge, and vision to address confounding issues posed in both long-standing and emerging grand challenges driving infrastructure needs of both public and private entities.**

America's infrastructure is expected to need over \$4.5 trillion in investment from 2016 to 2025 in order to function properly. The funding gap is estimated to be around \$2.1 trillion. As resources to plan, design, construct, operate and maintain infrastructure become increasingly limited, it will be critical that owners, such as federal/local/state agencies and private entities are able to obtain long-lasting benefits from their capital investments. To support our nation's growing population and economy, horizontal infrastructure such as roadways, bridges, airports, ports, and railways and utilities, as well as vertically constructed facilities, such as commercial buildings, terminals, warehouses, and other structures need to be efficiently managed over the lifecycle using innovative LCM cradle-to-cradle solutions to optimize resources and capital funding. These solutions will need to support smarter and more cost-effective design decisions, efficient construction methods, sustainable materials use, and resource recovery. As the built environment ages, decisions on maintenance, repair, and rehabilitation will need to be data-driven and must support service life extension while also improving capacity, serviceability, and safety.

An **actively growing team** of AIM researchers at UNC Charlotte brings over 120 years of experience in managing horizontal and vertical infrastructure to 92 funded research projects at the state, national, and international levels (NSF, NSFC, FHWA, DOE, USDA, NCDOT, DOJ, Duke Energy Corporation, etc.), with a total external funding of more than **\$28 million** (close to **\$15 million** in the past 5 years). These projects have provided financial support to 144 students (52 undergraduates, 77 M.S., and 15 Ph.D.). Diffusing and disseminating the knowledge learned from research and practice plays a significant role in the success of our society. These researchers have authored or co-authored more than 549 publications (234 in the past 5 years). Likewise, technology transfer and workforce development has been central to the applied research portfolio with prior efforts generating practitioner tools, patented technologies, and industry outreach.

The Federal government is planning to invest \$2 trillion in the near-term to address America's aging infrastructure. Prior achievements and garnered prominence in LCM place the AIM research team in a unique position to secure high profile research and contribute to professional societies that are well aligned with regional and national priorities and UNC Charlotte's R1 Commission. ***A number of specific large, multi-investigator funding opportunities on the near-term horizon are being targeted by the team to further expand the portfolio of work being performed in this domain, facilitate growth in our STEM and non-STEM doctoral programs, and provide resources to support postdoctoral and research staff.*** The evidence of institutional support offered by a designation of AIM as an area of excellence will improve the likelihood of success of securing these large research projects in the future.

Evidence of Strength and Excellence

The key question facing many agencies, industries, and utilities is: how can we improve, restore and maintain critical physical infrastructure while addressing societal needs, optimizing the use of constrained resources, and not jeopardizing public safety? Infrastructure life cycle management (LCM) solutions incorporating data-driven decision-making, advanced materials and design strategies, risk-informed condition assessment and performance monitoring, and sustainable recovery and reuse of assets are central to this challenge. These areas are also aligned with significant multi-investigator research funding opportunities that have organically led to the research and scholarship collaborations of the AIM team highlighted in this proposal, garnered regional and national prominence, supported vibrant graduate research opportunities, and led to meaningful technology transfer, as detailed below.

The AIM team includes a group of researchers from **three different departments and two colleges**. Despite the diverse background of the team, genuine **synergistic collaboration** has led to a significant portfolio of externally funded research activities and joint publications. AIM research related to Pavement Management, Bridge Management, Facilities Management, and Geographic Information Science has totaled \$5M, \$5M, \$3M, and \$2M, respectively, **representing an existing area of excellence at UNC Charlotte**. Figure 1 conveys collaborative efforts within the team with the number of joint proposals and joint publications indicated for each linkage between individual researchers. The majority of the linkages with relatively low counts are associated with more recently developed collaborations, which highlights the prior success of this team in expanding to **new areas of opportunity and engaging new tenure-track faculty**.

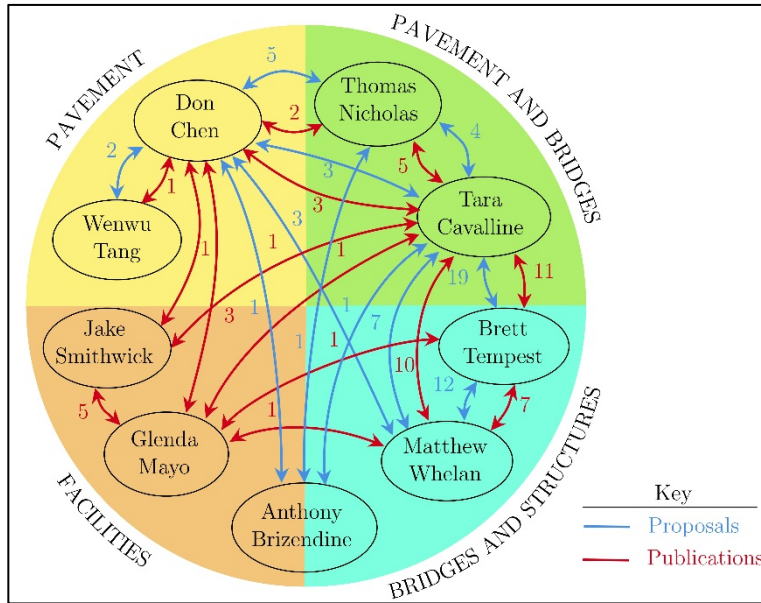


Figure 1. AIM's collaborative expertise

scanning has evaluated facility structural integrity after a fire.

Examples of Regional Impact and Accolades

- Drs. Chen, Nicholas, and Cavalline have worked on the development of several key components of NCDOT's PMS. Two research projects led by Dr. Chen and two by Dr. Cavalline were selected by the American Association of State Highway and Transportation Officials (AASHTO) Value of Research Task Force as examples of state DOTs providing "Transportation Excellence through Research."

Examples of Local Impact and Accolades

- Dr. Cavalline has performed studies on concrete airfield pavements since 2002 to support the Pavement Management Program at Hartsfield-Jackson Atlanta International Airport, the most heavily trafficked airport in the world. Her work in evaluating concrete condition and alkali-silica reactivity is used in the airport's pavement project programming.
- Dr. Mayo recently completed 3D scans of all mechanical rooms on UNCC campus (250,000 SF). Additional work with 3D LiDAR

- Drs. Cavalline, Tempest, and Whelan have performed several studies to advance implementation of innovative concrete materials and test methods for NCDOT’s bridges and pavements as well as promote data-driven decision-making in the NCDOT Bridge Management System (BMS). Recently, studies focused on performance engineered mixtures (PEM) have identified NC’s performance targets for innovative testing technologies that support construction of long-lasting concrete infrastructure. Methodologies developed in their BMS research have been implemented by NCDOT and recently adopted by the FHWA in the creation of national bridge deterioration models that will be leveraged by other state agencies.
- Drs. Mayo and Smithwick have explored critical technology in facility asset management in the use of drone technologies and 3D scanning. Their recent collaborative effort also utilized GIS to assist NCDOT with freight planning for the NCDOT Ferry Service. Separate work related to product evaluation practices with NCDOT has also been undertaken.

Examples of National Impact and Accolades

- Dr. Cavalline is a member of the four-university, ten-consultant team supporting FHWA’s Cooperative Agreement “Advancing Concrete Pavement Technology Solutions,” a five-year, \$9.0M initiative to deploy new cost-effective designs, materials, and construction practices for concrete pavements, which has a primary focus on technology transfer and information dissemination to support agencies and industry.
- Dr. Smithwick has formed a strong partnership with the International Facility Management Association (IFMA). His research has resulted in the deployment of the most extensive, widely used FM benchmarking tool in the United States. He was invited to serve as a facility benchmarking panelist for the Committee on Facilities Staffing Requirements for the Veterans Health Administration (VHA) through the National Academies of Sciences, Engineering, and Medicine, and was commissioned to professional education seminars to more than 4,000 facility professionals.
- Drs. Chen and Mayo conducted a research project entitled “A Study on Fatigue Damage Mechanisms of Panels of Glass Façades” sponsored by the National Natural Science Foundation of China (NSFC). Two methods were developed to parametrically model and analyze structural integrity of curtain walls using Finite Element Analysis (FEA). New and existing glass façades were modelled in 3D using cutting-edge technologies.

Graduate Education, Doctoral and Postdoctoral Training

- AIM researchers support both STEM doctoral research through the INES, CE, and Geography degree programs. Collectively, the research portfolio of the AIM team has provided financial support to 144 students (52 undergraduates, 77 M.S., and 15 Ph.D.).
- Doctoral students have received prestigious fellowships (NIJ Graduate Research Fellowship in STEM) and have secured positions in national laboratories and academia. One doctoral recipient secured a 3-year postdoctoral research assistantship at Turner Fairbank Highway Research Center and another is currently a Research Assistant Professor.

Technology Transfer, Intellectual Property, and Commercialization

The AIM research portfolio encompasses both basic and applied research, with significant number of prior efforts being directed toward addressing immediate needs of state and federal entities by implementing research results through technology transfer. As an example, Dr. Whelan was recently awarded a US patent stemming from research funded by Duke Energy to develop and commercialize a technique for nondestructive condition assessment of timber distribution poles for asset management. The potential for the development of a spin-off company from research conducted in AIM is significant, particularly given the applied focus of the team.

Alignment with Regional and National Priorities

The past accomplishments and ongoing work of AIM researchers contributes heavily to regional and national priorities established by the Fixing America’s Surface Transportation (FAST) ACT and the Moving Ahead for Progress in the 21st Century (MAP-21) legislation. AIM capabilities are directly aligned with and support each of the seven national goal areas included in MAP-21: safety, infrastructure condition, congestion reduction, system reliability, freight movement and economic vitality, environmental sustainability, and project delivery. In addition, a recognition of the need to ensure the sustainability and longevity of constructed facilities in a new era of transformative technologies and automation has presented emerging opportunities for research in facility management that are being supported by federal agencies, national laboratories, and industry, as they move toward a cradle-to-cradle stewardship approach to managing assets.

Moving forward, AIM researchers have adopted a strategic plan to direct their **future efforts toward specific regional, state, and national opportunities**, as outlined in the Table 1. In this table, specific funding agencies and opportunities aligned with the expertise of team are listed along with tentative proposal titles that incorporate **creative and original concepts**. These examples specifically target large (>\$500k), collaborative multi-investigator opportunities offering resources to **support doctoral researchers as well as postdoctoral researchers** and other research support staff. A subset of these large opportunities has been pursued unsuccessfully in the past by members of the AIM team. The distinction of institutional area of excellence and associated additional institutional support is expected to significantly improve the likelihood of success in proposal resubmissions, particularly for opportunities such as the University Transportation Centers (UTCs) that require significant evidence of institutional support.

Table 1. AIM targeted funding opportunities for the next five years.

Focus Area	Funding Agency	Funding Opportunity	Proposal Team (initials)	Tentative Proposal Topic/Title
Transportation	USDOT	University Transportation Centers (UTC)	TC, MW, DC, TN, BT, WT	Integrated Planning and Systems Management for Pavements and Bridges
Transportation	NCDOT	University Transportation Centers of Excellence	DC, MW, TC, TN, BT, WT	GIS-Based Transportation Asset Management
Transportation	NCHRP or USDOT	Grant	DC, WT, TN, TC, BT, MW	Applications of Deep Learning and GIS in Pavement Management Systems
Transportation	NCHRP	Synthesis	JS, GM, TC	Synthesis of State Transportation Agency’s Product Evaluation Tracking Tools and Product Categories
Transportation	NCHRP	Synthesis	JS, GM, DC	Operations and Maintenance Performance Benchmarks of State Transportation Facilities
Facilities /Utilities	Dept. of Energy	Connected Communities	JS, GM, DC, AB, WT	A Data-driven Tool for Efficient Buildings to Interact with the Grid
Utilities	Construction Engineering Research Laboratory	Grant	DC, WT, GM, AB	Integration of BIM and GIS for critical systems
Facility Management	Dept. of Energy	Grant	AB, JS, GM, DC	Facility Management of Net-zero Energy Buildings
Facility Management /Workforce Training	National Institute for Occupational Safety and Health (NIOSH)	Grant	JS, GM, TN	Incorporating Prevention through Design (PtD) Principles to Address Facility Maintenance Safety Concerns

Supporting Documents

Name	Title	Contribution/Expertise	Funding awards (past 5 years)	Total Funding	Publications (past 5 years)	Total Publications
Anthony Brizendine	Professor and Chair, ETCM	Geotechnical Engineering: earth structures/risk analysis/probabilistic modeling/finite element analysis, Continuous Improvement & Outcomes Assessment, Educational pedagogy, workforce development and training	\$ 1,670,000	\$ 6,041,020	3	24
Tara Cavalline	Associate Professor, ETCM	Concrete and cementitious materials, construction quality assurance pavements, bridges, structural forensics, masonry	\$ 2,619,693	\$ 3,296,266	55	83
Don Chen	Professor, ETCM	Pavement performance monitoring, pavement management system, structural integrity analysis using BIM (curtain walls)	\$ 1,381,937	\$ 2,164,949	18	45
Glenda Mayo	Assistant Professor, ETCM	Construction data ontology and taxonomy, BIM, Facility Management and assets (asset management and condition assessment). LiDAR scanning /point-cloud use.	\$ 680,434	\$ 1,160,483	39	39
Tom Nicholas	Associate Professor, ETCM	Bridge Rating and Rehabilitation. Structural Performance and strengthening. Pavement performance and assessment., Transportation program financing and performance	\$ 974,960	\$ 3,937,189	14	48
Jake Smithwick	Assistant Professor, ETCM	Facility management performance benchmarking, procurement optimization	\$ 1,045,013	\$ 1,045,013	53	75
Wenwu Tang	Associate Professor, GES	Geographic Information Science; Spatial analysis and modeling, Web GIS, Spatial Cyberinfrastructure	\$ 2,771,372	\$ 3,277,688	47	93
Brett Tempest	Associate Professor, CEE	Concrete and cementitious materials, recycling, sustainability	\$ 2,299,527	\$ 4,247,253	19	43
Matt Whelan	Associate Professor, CEE	Bridge management systems and deterioration modeling, nondestructive evaluation and condition assessment, structural health monitoring,	\$ 1,547,987	\$ 3,105,037	33	99
GRAND TOTAL			\$ 14,990,923	\$ 28,274,898	281	549

List of Participating Faculty Members

Name	Title	Department
Anthony Brizendine	Professor and Chair	Department of Engineering Technology & Construction Management (ETCM)
Tara Cavalline (co-Leader)	Associate Professor	ETCM
Don Chen (Leader)	Professor	ETCM
Glenda Mayo	Assistant Professor	ETCM
Tom Nicholas	Associate Professor	ETCM
Jake Smithwick	Assistant Professor	ETCM
Wenwu Tang	Associate Professor	Department of Geography and Earth Sciences/Center for Applied Geographic Information Science/School of Data Science
Brett Tempest	Associate Professor	Department of Civil and Environmental Engineering (CEE)
Matt Whelan (co-Leader)	Associate Professor	CEE