National University Rail Center of Excellence

University of Illinois Urbana-Champaign
University of Illinois Chicago
University of Delaware
Kansas State University
Michigan Technological University
Morgan State University
Rutgers University
University of Texas at Austin
Tuskegee University

Annual Report 2024-2025

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NURail Center of Excellence

The National University Rail Center of Excellence (NURail CoE) is a University Transportation Center (UTC) focused on rail transportation and supported by the U.S. Department of Transportation (US DOT) and Federal Railroad Administration (FRA). The NURail CoE is a nine-University consortium led by the Rail Transportation and Engineering Center (RailTEC) at the University of Illinois at Urbana-Champaign (UIUC) and hosted by the Grainger College of Engineering within the Department of Civil and Environmental Engineering at UIUC.

This publication is a report of the NURail Center of Excellence's transportation research, education and workforce development, and technology transfer activities for May 3, 2024 – May 2, 2025.

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The entire NURail CoE team contributed to the content of this report. Photographs by NURail CoE faculty, staff, or students, unless otherwise noted.

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U.S. Department of Transportation
Federal Railroad Administration

Christopher P.L. Barkan
Director

J. Riley Edwards
Senior Associate Director

Marcus Dersch
Co-Director of Research

Emma Ehrenhart
Associate Managing Director

RailTEC assistant professor J. Riley Edwards, from left, IDOT Secretary Omer Osman, FRA Administrator Amit Bose, U.S. Representative Nikki Budzinski, U.S. Senator Dick Durbin, Illinois professor and NURail CoE Director Chris Barkan, Illinois Provost John Coleman, University of Illinois Chicago NURail CoE university partner P.S. Sriraj, Illinois Vice Chancellor for Research and Innovation Susan Martinis cut a ribbon to kick off the National University Rail Center of Excellence at Yeh Student Center at Newmark Civil Engineering Lab on May 29, 2024.

It is my privilege to introduce the National University Rail Center of Excellence (NURail CoE) and our nine-university consortium. Each of our partners brings unique complementary strengths to railway transportation engineering research and education. We are proud to be the first Center of Excellence sponsored by the Federal Railroad Administration.

Our mission is to conduct basic and applied research that will result in innovative solutions that improve the safety, efficiency, and reliability of the passenger and freight rail transportation system in the United States. We are committed to supporting rail job growth by attracting, inspiring, and educating a new generation of students in railway transportation engineering and equipping them with the knowledge they will need to pursue effective, impactful private and public sector rail careers.

The NURail CoE fosters research collaboration by leveraging the technical expertise and capabilities of our consortium members. Our research partners include leaders in railway safety, infrastructure, system connectivity, and operation. They further leverage their talents by engaging with their students and other specialized faculty at their universities.

Our research will provide the engineering and scientific foundation to address strategic objectives identified by the US DOT and specific priorities of FRA, FTA, AAR, ASLRRA, AREMA, APTA, and other rail sector organizations. Our work benefits from extensive input provided by private and public-sector rail stakeholders that helps ensure its beneficial impact.

We are dedicated to tackling important challenges such as achieving zero derailments, reducing rail infrastructure cost while increasing its reliability, service life, and capacity, eliminating trespassing and grade crossing incidents, preventing hazardous materials releases, improving rail transportation system development, and more effective development and delivery of capital projects.

Beyond our research mission, the center supports development and teaching of courses on railway engineering and transport, thereby attracting high-caliber students and educating them in fundamental principles unique to these disciplines. These individuals represent the future of rail transportation. The education they receive through the NURail CoE will directly contribute to the enduring excellence of America's rail system.

Sincerely,

Chris Barkan - University of Illinois

Member Institutions

The University of Illinois Urbana-Champaign (UIUC) is a leader in railway engineering research and education in North America, with a rich history of significant contributions dating back more than a century. UIUC has expanded its Rail Transportation and Engineering Center (RailTEC) through rail research and educational programs during the past 25 years. UIUC's long and distinguished leadership in railroad transportation reflects a deep institutional knowledge and commitment to the field, including expertise in traditional rail disciplines as well as new and emerging research areas critical to safe, economical, energy efficient, reliable passenger and freight rail.

The University of Illinois Chicago (UIC) is a leader in transportation planning, rail and public transit, freight, and intermodal modeling and behavior. The Urban Transportation Center (UTC) is a research unit dedicated to innovative transportation research and education that provides technical assistance on urban transportation planning, policy, operations, finance and management. UTC is a nationally recognized innovator in research, education, and engagement that benefits transportation networks in cities and metropolitan areas across America.

The University of Delaware (UD) Railroad Engineering and Safety Program provides undergraduate and graduate courses, including a Graduate Certificate in Railroad Engineering, as well as a full range of railway-related research with a strong focus on track, vehicle-track interaction, and the application of data science (data analytics) to railway inspection and maintenance management.

Kansas State University (K-State) has deep rail industry ties with many engineering and business alumni previously or currently serving at the executive level for many Class I and short line railroads. Upgraded laboratory facilities enable faculty to evaluate concrete crossties — from material testing to structural design — and test unique concrete mixtures and their durability. K-State leads and administers the Rural Railroad Safety Center funded by FRA.

Michigan Technological University (MTU) established the Rail Transportation Program in 2007 and has developed into a one of the national leaders for railway education, research, and workforce development programs. In addition to railroad research projects led by faculty and staff across multiple disciplines, MTU has an extensive workforce development and education portfolio ranging from K-12 education to tech transfer for industry professionals. These include the Tracks to the Future program, the Rail Transportation Minor, and organizing the Michigan/Midwest Rail Conference.

Morgan State University (MSU) is an HBCU and Maryland's Preeminent Public Urban Research University. MSU frequently uses Baltimore as a living laboratory to address underserved and underinvested communities' needs. MSU's Transportation and Urban Infrastructure Development is part of the CRISI program titled, "Development and Implementation of HBCU-based Rail Engineering Program for Underrepresented Communities."

Rutgers University (RU) is the home of the Center for Advanced Infrastructure and Transportation and the Rutgers Rail and Transit Program, a leading academic hub for rail- and transit-related research, education, and workforce development. RU's projects and expertise include grade crossing safety, trespassing prevention, infrastructure data mining, intelligent rail systems, and hazardous material transportation safety and risk.

The University of Texas at Austin (UT) offers rail-focused courses and is conducting leading research on railway operations, network efficiency, alternative energy, and safety through the Texas Railway Analysis & Innovation Node (TRAIN). UT's rail research portfolio also includes developing advanced technologies for rail and track defect detection, and design of railroad bridge structures to resist increasing loads due to longer and heavier trains.

The Tuskegee University (TU) College of Engineering has been conducting rail engineering research and education for more than 20 years. TU is an HBCU with capabilities in mechanical, fracture and fatigue testing, microstructural analysis, welding failure analysis, and heat treatment.

Leadership

Chris Barkan
University of Illinois Urbana-Champaign
Director

J. Riley Edwards
University of Illinois Urbana-Champaign
Senior Associate Director

Marcus Dersch
University of Illinois Urbana-Champaign
Co-Director of Research

Emma Ehrenhart
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Co-Principal Investigator

Eric Fitzsimmons
Kansas State University
Co-Director of Education

Pasi Lautala
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Co-Director of Education

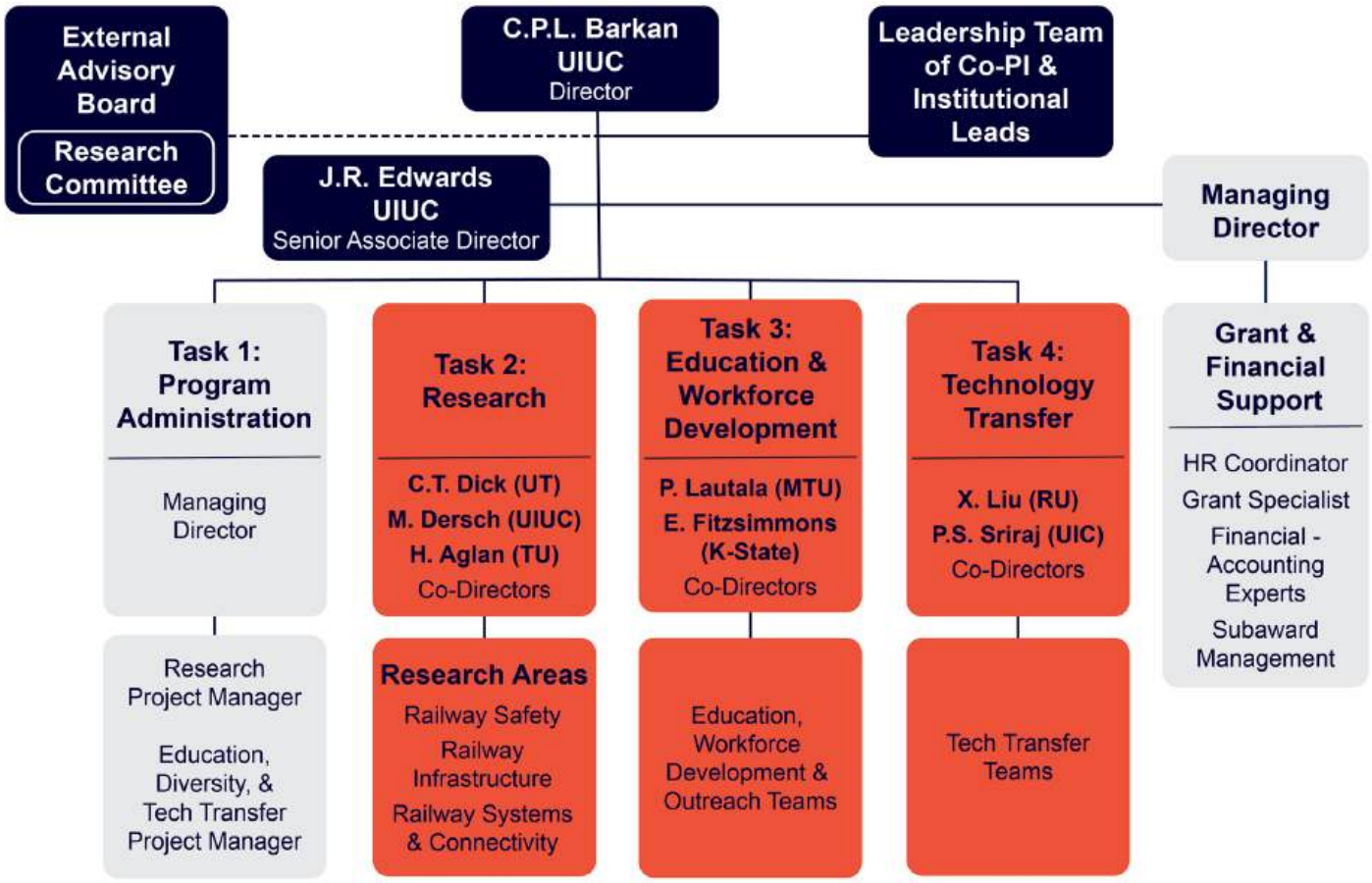
Hyeon-Shic Shin
Morgan State University
Co-Principal Investigator

Xiang Liu
Rutgers University
Co-Director of Technology Transfer

C. Tyler Dick
University of Texas at Austin
Co-Director of Research

Heshmat Aglan
Tuskegee University
Co-Director of Research

Organizational Chart



Advisory Board

Michael Rush *Association of American Railroads*
Jo Strang *American Short Line and Regional Railroad Association (ASLRRA)*
Brian Sooter *American Public Transportation Association (APTA)*
Shayne Gill *American Association of State Highway and Transportation Officials (AASHTO)*
John Cech *BNSF Railway*
Paula Pienton *CN Railway*
Steve Melniczuk *Amtrak*
Marc Tuozzolo *New Jersey Transit*
Sergio Pecori *Hanson Professional Services*
Kevin Day *Herzog*
Jeff Fries *KB Signaling*
Eric Sherrock *ENSCO*
Kari Gonzales *MxV Rail*
Bob Guy *The International Association of Sheet Metal, Air, Rail and Transportation Workers (SMART)*
Roy Morrison *Brotherhood of Maintenance of Way (BMWE)*
Holly Bieneman *Illinois Department of Transportation*
Tarek Omar *US DOT Federal Railroad Administration (FRA)*
Mark Patterson *US DOT Federal Railroad Administration (FRA)*

Timeline

Ribbon Cutting

U.S. Senator Dick Durbin, U.S. Representative Nikki Budzinski, FRA Administrator Amit Bose, IDOT Secretary Omer Osman, Illinois professor and NURail CoE Director Chris Barkan, among others, helped kick off the National University Rail Center of Excellence (NURail CoE) with a ribbon cutting ceremony at Yeh Student Center at Newmark Civil Engineering Lab on 29 May 2024.

October 2023
NURail CoE Established

May 2024
Ribbon Cutting

First Annual Meeting

Michigan Technological University (MTU) hosted the first NURail CoE annual meeting on 13 August 2024 in conjunction with the Michigan Rail Conference. Representatives from each of the nine NURail CoE partners discussed their plans and projects. FRA Program Manager Tarek Omar and FRA Associate Administrator Mark Patterson were present to introduce NURail CoE and its mission to the larger rail community.

June 2024
International Crosstie & Fastening System Symposium

August 2024
- **First Annual Meeting**
- **Michigan Rail Conference**

AREMA

NURail CoE students and faculty attended the American Railway Engineering and Maintenance-of-Way Association (AREMA) 2024 Annual Conference & Expo on 15-18 September 2024 in Louisville, KY.

Fall 2024
AREMA

Fall Semester 2024
William W. Hay Seminars

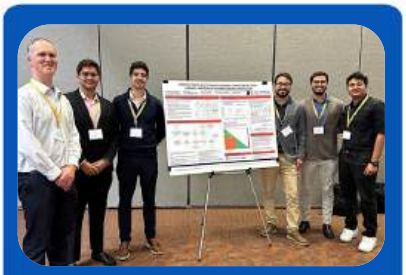
NURail CoE Established - October 2023

The U.S. Department of Transportation's Federal Railroad Administration (FRA) has awarded the University of Illinois Urbana-Champaign (UIUC) as the lead institution for the Fiscal Year 2022-2023 Rail Research and Development Center of Excellence program. This $5 million grant establishes NURail CoE to develop the future workforce while advancing research and expansion that enhances the safety, efficiency, and reliability of both passenger and freight rail transportation.

Railroad Environmental Conference

Representatives from three NURail CoE partner universities presented research at the 2024 Railroad Environmental Conference (RREC), including Michigan Technological University, Morgan State University, and University of Texas at Austin. The 26th RREC was a two-day event on 29-30 October 2024 at the iHotel and Illinois Conference Center in Champaign, IL. NURail CoE also had a booth in the exhibit hall.

October 2024
Railroad Environmental Conference



Big Data Conference

The University of Delaware, hosted the Big Data Conference on 11-12 December 2024, in Newark, Delaware. Approximately 160 guests attended this year's conference which introduced new and emerging analysis techniques and how those methods can be applied to the large volume of inspection and operational data collected by railways to improve maintenance programs.

December 2024
Delaware Big Data Conference

NURail CoE at TRB

In total there were nearly 70 separate references involving NURail CoE universities and organization partners covering rail, freight transportation, and public transportation, including 15 authors who are NURail CoE PIs or researchers, one workshop chair, six session chairs, one committee meeting chair, and one discussion panelist.

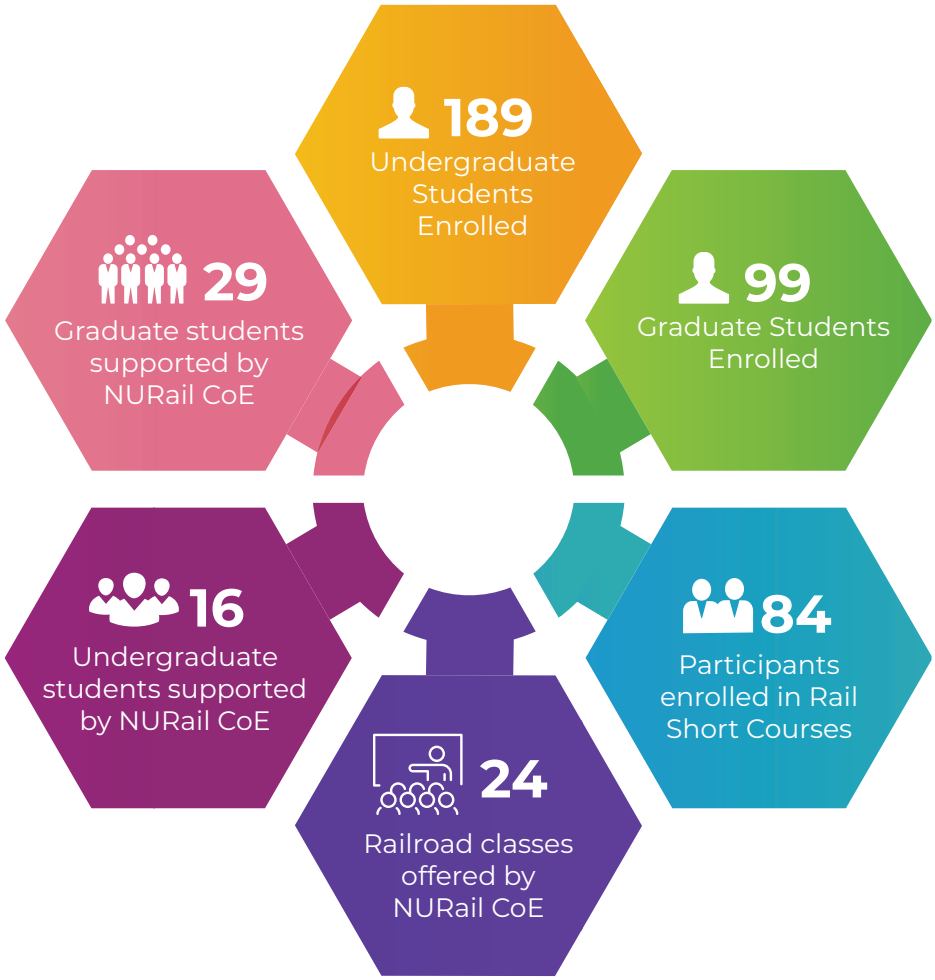
January 2025
NURail CoE at TRB

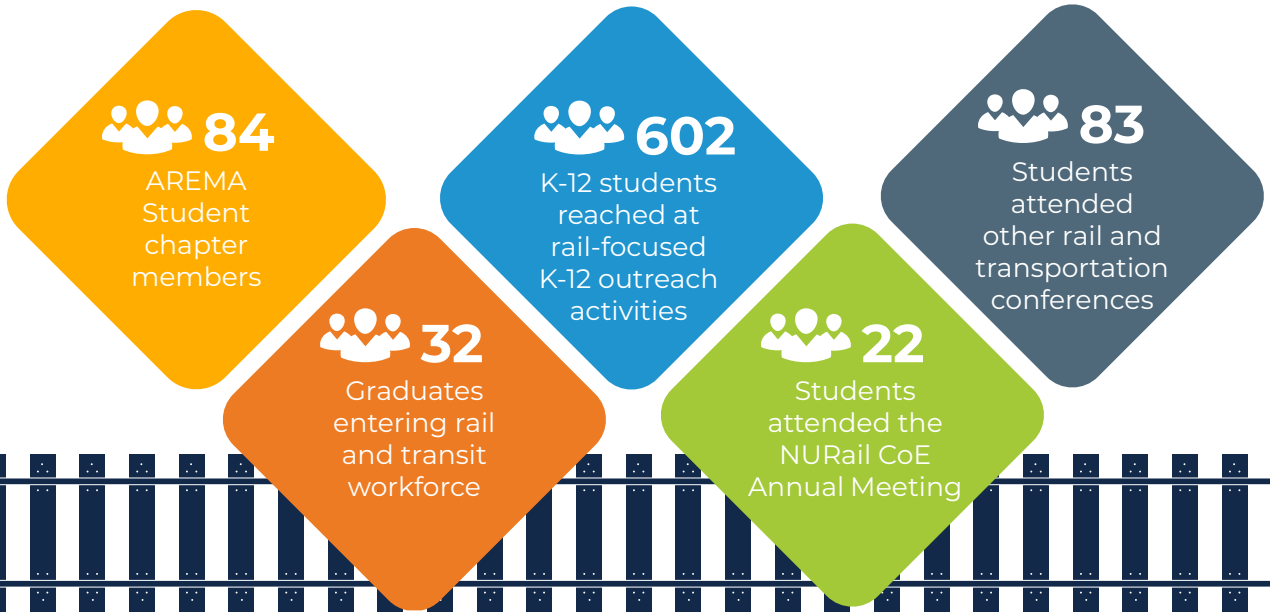
Spring Semester 2025
Urban Transportation Center Seminar Series

NURail CoE By the Numbers

Education & Workforce Development

NURail CoE had 266 students enrolled in rail courses and 88 students specializing in rail transportation engineering. Of those students, 179 were minority or female students. Of the graduating students, 32 graduate students and 7 undergraduate students entered the rail and transit workforce. Twenty-two students attended the NURail CoE Annual Meeting and 83 students attended other rail and transportation conferences. NURail CoE provided five rail-focused K-12 outreach activities throughout the year which reach over 600 students.





Technology Transfer

Conferences C

900+ Attendees

NURail CoE hosted five conferences, Railroad Environmental Conference (396 attendees), International Crosstie & Fastening System Symposium (130 attendees), Michigan Rail Conference (122 attendees), Rail Night (63 attendees), and Delaware's Big Data Conference (200 attendees) for a total of 911 attendees.

Seminars S

1200+ Attendees

NURail CoE hosted twelve seminars at three different universities for a total of 1256 participants. This included both in-person and online participants.

University of Illinois Urbana-Champaign

ILLINOIS

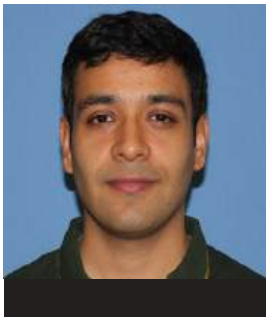
Example visualization of the IBRM's output in a track segment color-coded based on the associated risk at a tie-by-tie level.

With recent developments in track inspection technologies and their adoption by the rail industry, infrastructure owners now have access to a substantial amount and variety of data related to their track infrastructure condition. Many of these data, and the information extracted from them, are direct inputs into the most common buckle risk modeling methodologies available in the industry. This research project aims to leverage these data and methodologies to estimate the track's propensity to buckle linearly on a tie-by-tie basis along an entire rail corridor.

Buckled tracks are one of the most common and severe track-related causes of derailments in the U.S. Track buckles are caused by the buildup of compressive stresses in the rail (due to thermal expansion) overcoming the track's lateral strength, resulting in the track buckling to release those stresses. While management of rail stresses in continuously welded rail (CWR) track is still considered one of the most important research topic areas within the industry, it only looks to improve the demand side of the buckle track equation.

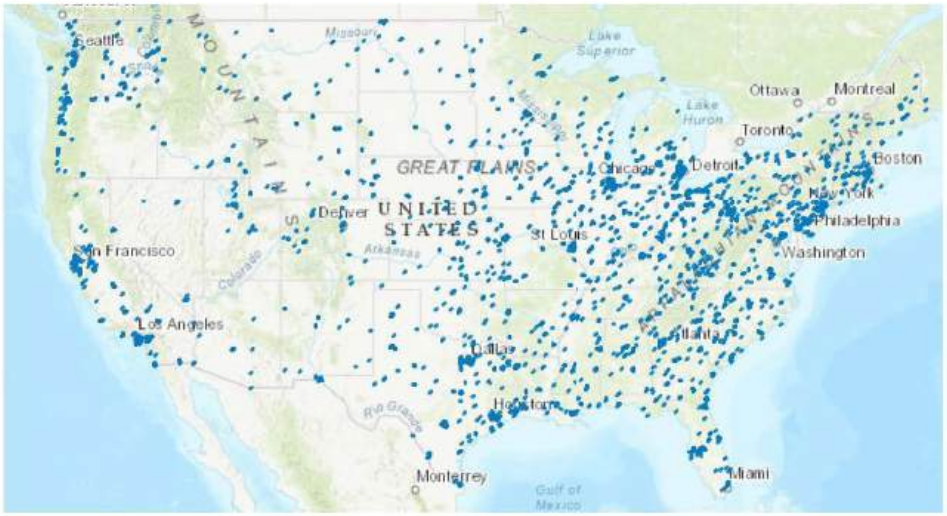
Year 1 project accomplishments include the development of an initial version of the Illinois Buckle Risk Model (IBRM) that combines novel track condition data streams with laboratory and field data to calibrate inputs into CWR-SAFE. Outputs are expressed as Buckling Safety Margin (BSM), indicating reserve strength for prioritizing maintenance and preventing track buckles. Early results are encouraging and demonstrate the IBRM's flexibility and scalability for buckle risk assessment.

Neeraj Thakur



Neeraj Thakur is pursuing his master's degree in Civil Engineering with a focus on transportation with an expected graduation in August 2025. After completing his BE in civil engineering, Neeraj worked as an Engineer and Senior Divisional Engineer for the Government of Nepal. He was mostly involved in construction and maintenance of physical infrastructures such as bridges and roads. His research has primarily dealt with track buckling and using inspection systems to collect data to identify potential track buckling areas for maintenance. Track buckles have been a major safety concern for North American railroads. Continuously Welded Rails (CWR) lack joints that can accommodate rail expansion, making the track susceptible to lateral buckling due to compressive thermal forces.

University of Illinois Chicago



This map from the Bureau of Transportation Statistics shows North American Rail Network (NARN) Rail Yards.

The preliminary review of literature on the economic impacts of freight rail infrastructure and the economic impact research employing quasi-experimental analysis has been completed. Based on the information learned from the literature review, a detailed research plan for the study has been developed.

A database of available data on both freight rail infrastructure and economic indicators is being built. Both publicly available and proprietary data are being explored. Specifically, historical geospatial data on rail tracks and freight terminals in the U.S. from 1996 has been obtained. The map above shows the railyard data from the US DOT. The prospect of using DataAxle, a proprietary economic database, to obtain historical data on business establishments and employment is being explored.

In March 2025, Brian Christian, a Fulbright Scholar studying at UIC's Urban Planning and Policy Program, was appointed as a graduate research assistant. This project is expected to begin in Year 2.

Brian Christian

Brian Christian has been assisting faculty researchers on the NURail CoE study that centers on providing analyses of the economic impacts of railroads on surrounding communities. He is tasked with a wide range of data collection and organization related to the economic impacts generated by rail infrastructures across the United States. The data, which covers historical development of rail infrastructures and economic growth, is gathered from various governmental departments.

The scope of the project is massive, and Brian relies on a wide range of technological resources, like ArcGIS to organize and analyze spatial data. The primary goal of the study is to identify how proximity and accessibility to rail infrastructures can help communities become more prosperous, leading to enhanced commercial development, employment opportunities, and economic growth in the United States. Brian noted that he is very excited about participating in the railroads economic impacts study and employing his data analysis, spatial visualization, and written communication skills.

University of Delaware

Delaware students with guest speaker George Gavala who presented in an overview of the The Role of the Federal Railroad Administration: Rulemaking and Enforcement.

As railroads increase use of autonomous track geometry measurement systems, coupled with traditional measurement cars, hy-rail inspection and walking inspection, the reliability of inspection can increase. The additional data captured by autonomous inspection allows for a better understanding of track geometry perturbation growth. The distribution of accuracies associated with alternative inspection methods must be taken into account when defining the risk of a defect, which drives inspection frequency surfacing maintenance. This research project fuses these data sources to better understand track geometry perturbation growth, particularly in those areas where high impact forces and high lateral to vertical force ratios can be experienced, which may lead to derailment. The perturbation growth data is then used with inspection accuracy to be developed from published sources as well as the provided data. This in turn is used to optimize automated inspection.

Walking inspectors can become complacent or may not be well trained and defects may be hard to see or missed. This can cause the risk of derailment to increase. The type of traffic and speed of operations influence the consequences of a derailment. Historic track performance with regard to previous inspection offers an opportunity to understand the risk of defects occurring. Optimizing the visual inspection frequency can reduce derailments and offer the railroads cost efficiencies, based on past track performance. The proposed research will evaluate historic inspection records that include identification of defects, as well as condition observations. This data can be utilized to understand track performance. The repeated inspection data can be used to evaluate the change in condition, given the frequency of inspection. Coupling this data, along with visual inspection efficacy (modeled as a probability distribution based on previous research) allows for understanding the impact of changing the inspection frequency. This research will develop a model that provides the impact of changing the inspection frequency given these performance characteristics.

Manisha Kandel

Manisha Kandel is pursuing her master's degree in Civil Engineering at the University of Delaware, with an expected graduation date of Spring 2026. She completed her bachelor's degree in 2022 from Tribhuvan University with a focus on transportation systems and applied machine learning. Her work on traffic prediction modeling use deep learning methods proposed a hybrid model for predicting both traffic flow rate and occupancy/congestion rate simultaneously. This is a foundation for her current research which consider deep learning methods in understanding the risk associated with walking/visual inspection considering frequency of inspection given historic performance of the track.

Kansas State University

Kansas State University CE 690 / 816 Railroad Engineering class touring BNSF's Topeka locomotive shop

Pre-tensioned concrete railroad ties provide an inherent corrosion resistance of the restressing steel since it is in direct contact with the high-pH concrete during casting. This high-pH environment causes a thin oxide layer to form on the prestressing steel which, in turn, serves to passivate the steel and prevent further corrosion. This passive layer will then protect the concrete for many years unless it is destroyed by the ingress of chemicals (salts, sulfates, etc.) or a lowering of the pH.

One limiting aspect of these pre-tensioned ties, however, is their lack of rotational capacity. In areas of poor ballast maintenance, ties are forced to bend under train loadings to conform to the ballast geometry. When this occurs, the prestressing tendons in these ties experience high stress levels at cracking locations which, in-turn, will reduce the service life and can result in pre-mature failures.

One alternative to the pretensioned concrete tie that has gained traction in recent years is the post-tensioned concrete tie. Post-tensioned ties are fabricated by purposefully shielding the steel prestressing tendons from the surrounding concrete during fabrication to allow the tensioning process to take place after the concrete has cured. This fabrication approach has several advantages including a reduced initial setup costs for manufacturing and increased rotational capacity of the overall ties, since the induction of flexural cracking does not significantly increase the prestressing tendon stress.

However, this fabrication method leaves the prestressing tendons susceptible to corrosion since the passivation layer is never formed as the tendons do not have direct contact with the high-pH concrete. The Hybrid Tie being investigated in this study serves to utilize the best combinations from both the pre-tensioned and post-tensioned concrete tie approaches. The hybrid concrete tie is a pre-tensioned concrete tie with un-bonded prestressing tendons in the central portion. This provides the durability and corrosion protection of pre-tensioned systems along with the increased rotation capacity of post-tensioned systems.

Michael Dishman

Michael Dishman, a junior in Kansas State University's Civil Engineering Department, is actively engaged in the project titled "Development of a Hybrid Concrete Crosstie with Increased Rotational Capacity." This research has three distinct phases: designing pre-tensioned concrete specimens (prisms) based on current industry standards; fabricating both standard and hybrid pre-tensioned concrete prisms; and conducting load tests to failure to assess their flexibility, followed by data analysis. So far, Michael has examined existing tie designs used by Class I railroads to establish the prism properties for this study. Additionally, he has contributed to the setup of the prestressed concrete bed and is preparing to cast the prisms this summer.

Michigan Technological University

Keynote speaker, Patrick Fuchs, Surface Transportation Board, presenting at the 2024 Michigan Rail Conference hosted by Michigan Tech, Michigan DOT, and NURail CoE.

Michigan Tech, in collaboration with Michigan Department of Transportation and NURail Center of Excellence hosted the Michigan Rail Conference 'Pivot to the Future' in August 2024. The conference had more than 120 participants, and a total of 25 professional industry and academic speakers. Sponsored events also included the student scholarship fundraiser golf outing, opening reception, educational sessions, closing reception, and field visits to various industry locations around Detroit, MI.

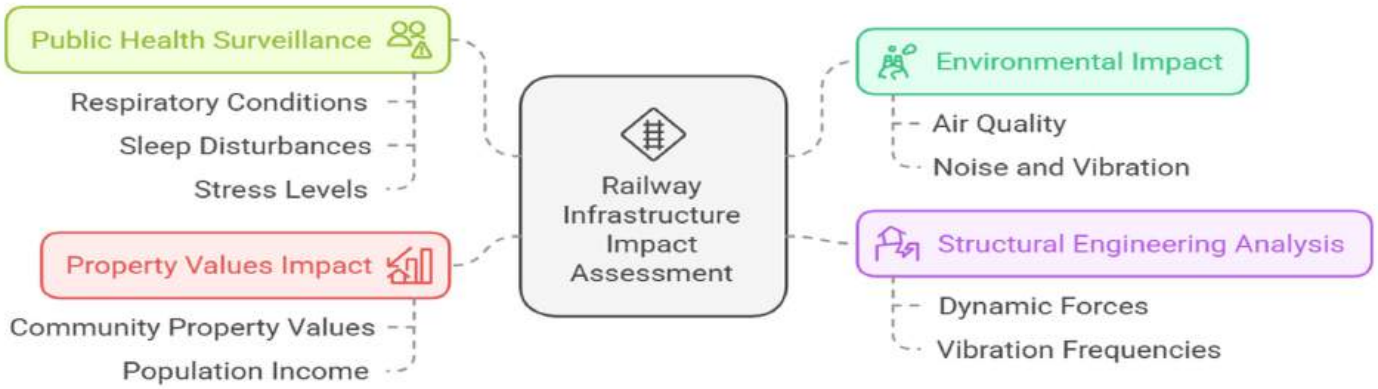
The first project MTU researchers have begun work on is "Enhancing Accuracy of Ultrasound Imaging in Detecting Surface Cracks in Metal Using Microbubbles." This project began with a comprehensive literature review, which established a solid understanding of Rolling Contact Fatigue (RCF)—including crack initiation and propagation mechanisms, damage types, and key influencing factors such as material properties, lubrication, and environmental conditions. In parallel, experimental setups were developed using a 0.4 mm diameter silicone microtube positioned beneath a metallic sample to simulate a simplified crack geometry. Ultrasound Localization Microscopy (ULM), implemented with the Verasonics system, demonstrated the ability to detect motion of microbubbles, sand, and metal beads within the tube, serving as contrast agents for defect visualization. The next phase involves testing ULM with known cracks in metallic samples.

The second project is Life-Cycle Cost Assessment of Coastal Rail Infrastructure. This project began data collection and literature review and is built upon the current project with the FRA. Models have been developed to estimate coastal rail tracks and bridges vulnerabilities against storm-induced surges and waves. A probabilistic hazard model based on synthetic storm data was developed and merged with physics based and data driven fragility models for rail ballast and embankment and bridge decks to estimate service life of rail tracks. There are plans to integrate this model with direct and indirect costs to estimate life cycle costs for various mitigation scenarios such as elevating tracks or shifting them away from shorelines.

Mohammad Anas Taeb

Mohammad Anas Taeb is a Fulbright Scholar and has a master's degree in civil engineering. He is pursuing a Ph.D. while working on the research project titled "Developing an LCA Framework for Railway Track Maintenance Operations." He has been engaged in the FRA's "Tracks to the Future" program for the past two years. In this role, he coordinated activities tailored for high school students, which included the preparation of materials, and delivered classroom instruction. Recent environmental changes and improved access to data inspires him to work on seeking optimal sustainable solutions aligned with the railway industry's evolving economic and environmental objectives.

Morgan State University

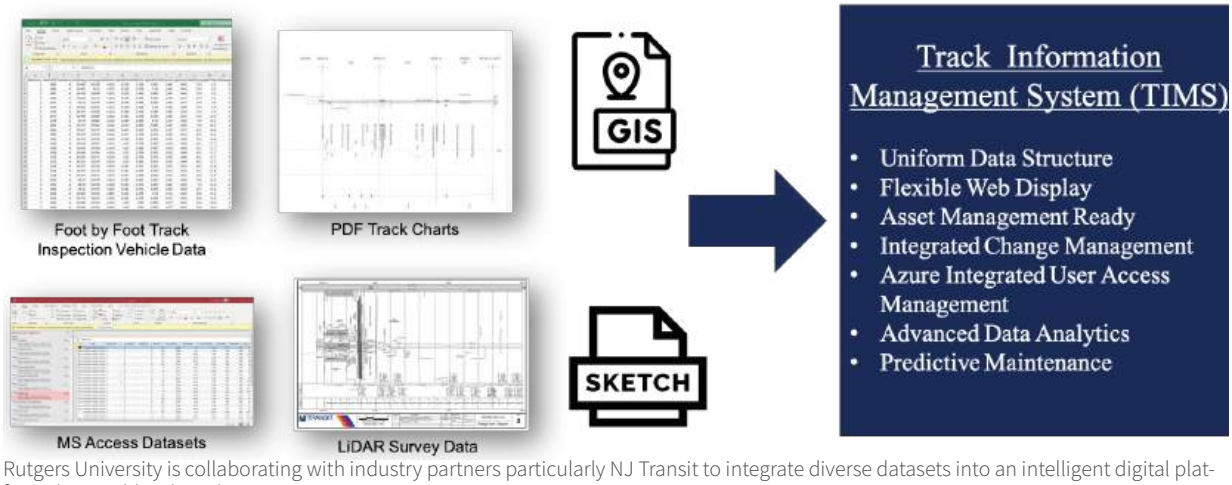


The research team at Morgan State University is conducting a comprehensive investigation into the multidimensional impacts of freight rail activities in a major metropolitan area. This study places particular emphasis on residents' perceived safety and the operational realities of the freight rail industry, as well as externalities such as ambient noise and ground vibration and effects on residential property values. Grounded in the interdisciplinary frameworks of public perception and urban economics, the project uses a mixed-methods approach. It integrates qualitative data from resident surveys and interviews with quantitative modeling techniques, including the application of a hedonic pricing model to estimate the impact of freight-related impacts on real estate. To build a solid foundation for the study, the team has conducted an initial review of existing research on freight rail impacts nationwide and has compiled an inventory of publicly available data on regional freight rail activities in Maryland. This includes identifying key data sources related to train traffic, infrastructure, ambient noise, and land use patterns. With the recent addition of two graduate research assistants, the project is now positioned to advance more rapidly. During the upcoming summer months, the team will prioritize the completion of a comprehensive literature review and the refinement of its research questions, conceptual framework, and methodological strategies. Simultaneously, a draft survey instrument will be developed to capture residents' experiences with freight-related effects. Parallel efforts will focus on continued data acquisition and the development of GIS-based spatial analyses. This project is expected to begin in Year 2.

Derrick Mirindi

Derrick Mirindi is a second-year doctoral student pursuing a Ph.D. in Architecture, Urbanism, and Built Environment. In this study, by using an integrated modeling approach that compares machine learning algorithms (e.g., decision tree (DT), random forest (RF), support vector machine (SVM), artificial neural network (ANN), etc.) and numerical simulations (e.g., finite element method (FEM), boundary element method (BEM), etc.) to address air quality and vibration propagation intensity, his main goal is to quantify and mitigate the effects of railway vibration. Information technology and AI applications are among his areas of interest.

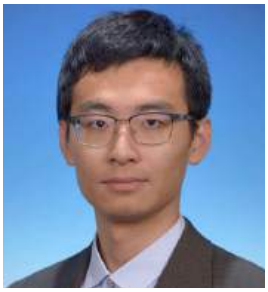
Rutgers University



Rutgers University is collaborating with industry partners particularly NJ Transit to integrate diverse datasets into an intelligent digital platform that enables data-driven asset management.

Rail infrastructure is a critical component of the national economy, with track systems representing some of the most valuable assets in the railroad industry. Key datasets, including track layout data, condition monitoring data, repair and maintenance records, are frequently siloed across departments, limiting their combined utility in streamlining track asset management and safety analyses. This research addresses these challenges by developing an integrated informatics-enabled intelligent platform to unify disparate datasets into a centralized data warehouse. The platform leverages temporal-spatial data analysis to integrate and overlay track chart data with various types of condition monitoring data and other operational records, enabling advanced data analytics for track asset management. Statistical and machine learning techniques will be applied to analyze and predict track changes, identify degradation trends, and ultimately support proactive inspection and maintenance planning. The project will focus on building a digital intelligent platform in collaboration with NJ Transit that provides seamless access to their various types of enterprise and asset data, supporting complex data queries and condition monitoring data analysis. While developed in close collaboration with NJ Transit, the platform is adaptable for use by other railroads facing similar challenges. This research advances the state of infrastructure management by breaking down data silos and enabling data-driven decision-making. The outcomes will contribute to improved safety and operational reliability of rail systems.

Mulin Wan



Mulin Wan is a Ph.D. student in Civil Engineering at Rutgers University, specializing in rail systems analysis and safety. He holds a B.S. in Electrical Engineering from Beijing Jiaotong University and an M.S. in Civil Engineering from the University of Illinois at Urbana-Champaign. At Rutgers, Mulin is involved in the development of the Track Information Management System (TIMS) and has utilized data provided by rail agencies to analyze and evaluate strategies for improving operational efficiency and reducing train delays. In addition to his research, Mulin actively mentors fellow students and serves as Treasurer of the Rutgers AREMA Student Chapter. He also participates in community outreach events such as Rutgers Day and fosters connections with industry professionals.

University of Texas at Austin

The University of Texas at Austin is home to a rapidly emerging North American university academic and research program in railway engineering centered around the Texas Railway Analysis & Innovation Node (TRAIN). The TRAIN lab is led by C. Tyler Dick, Ph.D., P.E., an Assistant Professor of Civil, Architectural and Environmental Engineering (CAEE) at UT Austin who offers multiple courses on railway engineering topics while supervising students working on a range of railway operations, efficiency and safety topics. Specifically, Dr. Dick is leveraging NURail CoE project funding to expand and enhance the Cost Uncertainty and Risk of Rail Electrification with New Technologies (CURRENT) model that was previously developed with FRA support. The ongoing work will allow CURRENT to better evaluate intermittent freight rail electrification with overhead catenary system (OCS) and batteries by optimizing OCS placement and modeling battery degradation with use over time.

Dr. Dick's research focus is complemented by that of UT Austin CAEE Professor Salvatore Salamone who has a long history of research non-destructive evaluation and inspection of structures, including leading work on ultrasonic rail inspection and applying other emerging technologies to detecting defects in track infrastructure. In partnership with BNSF Railway, Dr. Salamone is using NURail CoE support to investigate the potential of using noncontact laser-based vibration measurements of the rail to detect internal track defects.

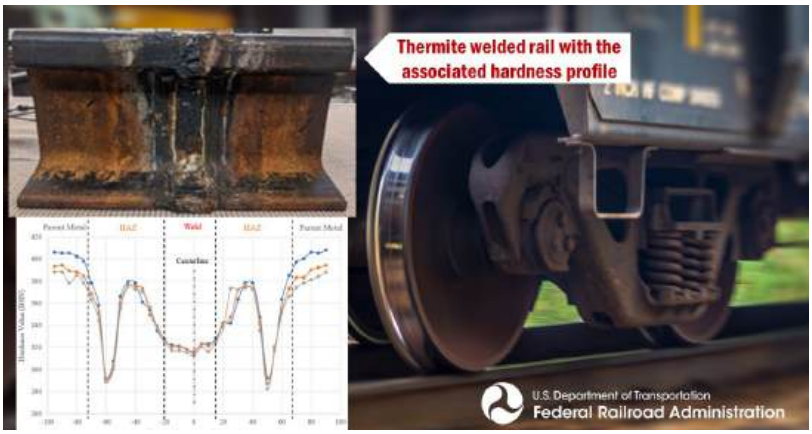
Through the support of the NURail CoE, UT Austin CAEE Assistant Professor Yunlan (Emma) Zhang has also been able to begin investigating the potential of architected instability-based metamaterials (AIMs) to strengthen the track structure. AIMs have the potential to be designed in such a way that increases in temperature autonomously increase the lateral stiffness of track ballast layers and thereby reducing the risk of track buckles due to thermal expansion forces in the rail that also increase with temperature. This "anti-fragile" response of getting stronger with increasing temperature could unlock novel, resilient track structure designs.

Part of the TRAIN lab team poses at Leander station while riding the hybrid commuter rail "Red Line" operated by Austin CapMetro.

Rydell Walthall

Rydell Walthall is a Ph.D. student with the UT Austin TRAIN lab that is investigating the economics of freight railway electrification. Rydell obtained his undergraduate degree in Civil Engineering with a transportation focus at UT Austin before completing a dual-Masters in Public Affairs and Civil Engineering, also at UT Austin. His M.S. thesis, supervised by Dr. Michael Walton, was entitled "Rail electrification's potential for emissions abatement in the freight industry: a case study of a transcontinental rail corridor". Continuing this line of research into his doctoral studies, Rydell began working for Dr. Dick as a graduate research assistant in Fall 2022, and was the primary architect of the Cost Uncertainty and Risk of Rail Electrification with New Technologies (CURRENT) model developed for the FRA in 2024.

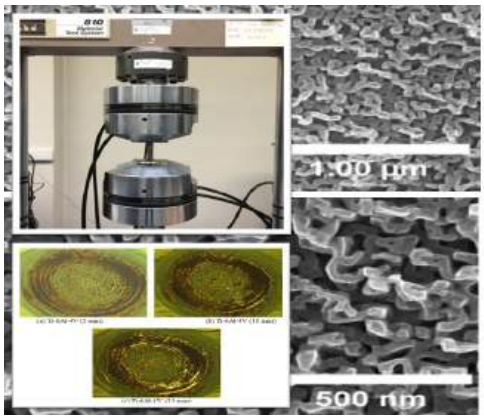
Tuskegee University



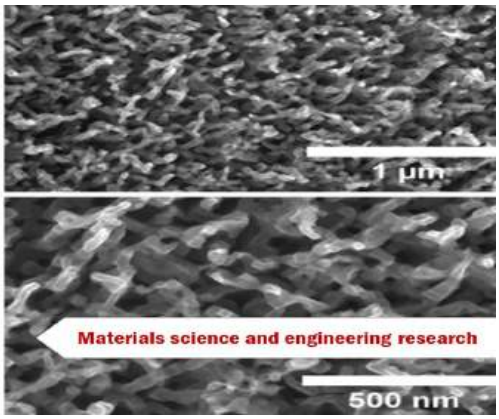
Hardness profile of a thermite weld

Research at Tuskegee University in the Mechanical Engineering Department includes fracture and failure analysis, corrosion, additive manufacturing, degradation of materials under extreme conditions, processing and characterization of ultra-high temperature ceramic matrix composites (CMCs), flow diagnostics, microfluidic actuator design, fatigue crack propagation studies in bainitic pearlitic, and manganese steels, rail steel repairs, energy efficient cementitious compounds.

Thermite welding is the most widely used technique for in-track welding or replacing a damaged part of a rail. This process produces a Welded Zone (WZ) and a Heat Affected Zone (HAZ) with inhomogeneous microstructures and hardness, resulting in lower mechanical, fracture and fatigue properties of the thermite weld compared with the parent rail. The proposed research focuses on investigating the fatigue crack growth behavior of the weld zone and the HAZ for both thermite welds and a GMAW (gas metal arc welding) repair technique, developed by Tuskegee University. Conventional and inverse slow bend test on the modified GMAW repairs and thermite weld repairs will be performed according to AREMA standard test methods.



Pulse laser exposure of Titanium Alloy (Ti-6Al-4V)



Low Energy He+ Ion Irradiation of Molybdenum

Al-Rajean Allie

Al-Rajean Allie is a mechanical engineer who completed his bachelor's degree at the University of Technology, Jamaica. He is currently pursuing his master's in mechanical engineering at Tuskegee University under the mentorship of Dr. Hashmat Aglan. Al-Rajean is engaged in research focused on improving rail steel weld performance, specifically investigating thermite and GMAW welded rails. His work involves a comprehensive evaluation of the mechanical properties of these welds using tensile testing, hardness testing, fatigue testing, fracture testing, and both scanning electron microscopy (SEM) and optical microscopy. The goal of his research is to support the development of slot welding as a field-ready technique for rail repair and construction. Through his work, Al-Rajean aims to contribute to a deeper understanding of weld performance, helping to inform practical applications in the rail industry.

Year 1 Project Table

Project ID	Principal Investigator	University	Department	Project Title
KSU-I1	Robert Peterman	Kansas State University	Civil Engineering	Development of a Hybrid Concrete Tie for Increased Rotational Capacity and Resilience
MTU-I1	Quang Tran & Paul Sanders	Michigan Technological University	Materials Science and Engineering	Enhancing Accuracy of Ultrasound Imaging in Detecting Surface Cracks in Metal Using Microbubbles
MTU-I2	Yousef Darestani	Michigan Technological University	Civil, Environmental, and Geospatial Engineering	Life-Cycle Cost Assessment of Coastal Rail Infrastructure
RU-SC1	Xiang Liu	Rutgers University	Civil and Environmental Engineering	Data Integration and Informatics for Track Asset Management
TU-S1	Heshmat Aglan	Tuskegee University	Mechanical Engineering	Fracture and Fatigue Damage Tolerance of Arc Welded Railhead and Thermite Weld Repairs
UD-S1	Allan Zarembski	University of Delaware	Civil, Construction and Environmental Engineering	Risk Based Track Surfacing Model
UD-S2	Joseph Palese	University of Delaware	Civil, Construction and Environmental Engineering	Risk Based Walking Inspection Frequency Model
UIUC-I1	Riley Edwards	University of Illinois Urbana-Champaign	Civil and Environmental Engineering	Buckle Risk Modeling Leveraging Track Geometry and Condition Data
UIUC-I2	Ramez Hajj	University of Illinois Urbana-Champaign	Civil and Environmental Engineering	Combined Grade Crossing Track/Highway Multiphysics Model
UIUC-I3	John Popovics	University of Illinois Urbana-Champaign	Civil and Environmental Engineering	Quantifying Lateral Track Capacity Using Nondestructive Nonlinear Vibration Response
UIUC-I4	Erol Tutumluer	University of Illinois Urbana-Champaign	Civil and Environmental Engineering	Field Ballast Condition Evaluation Using Machine Vision and Artificial Intelligence
UIUC-SC1	Kirill Levchenko	University of Illinois Urbana-Champaign	Electrical and Computer Engineering	Positive Train Control with Asymmetric Authentication and Key Management
UT-I1	Yunlan (Emma) Zhang	University of Texas at Austin	Civil, Architectural and Environmental Engineering	Strengthening the Railway Track Lateral Resistance by Reinforcing Ballast with Architected Instability-based Metamaterials (AIMs)
UT-S1	Salvatore Salamone	University of Texas at Austin	Civil, Architectural and Environmental Engineering	Rail Defect Detection System Based on Non-contact Vibration Measurements
UT-SC1	C. Tyler Dick	University of Texas at Austin	Civil, Architectural and Environmental Engineering	Optimizing Efficiency and Cost of Innovative Strategies for Freight Rail Motive Power Energy Supply
UT-SC2	C. Tyler Dick	University of Texas at Austin	Civil, Architectural and Environmental Engineering	Comparing Freight Rail Propulsion Strategies for Efficient and Economical US Mainline Operations

Education & Technology Transfer

Railroad Environmental Conference

RREC features presentations by railroaders, consulting engineers, academics and others involved in all aspects of railroad environmental topics. 2024 had 400 attendees.

Delaware Big Data Conference

Railways use advanced technology to gather extensive data on track, equipment, and operations. This "Big Data" requires new analysis techniques to convert it into useful information for planning maintenance and operations.

Michigan Rail Conference

The Michigan Rail Conference "Pivot to the Future" had 122 total registrations and over 25 professional industry speakers.

International Crosstie & Fastening System Symposium

The International Crosstie and Fastening System Symposium is held on the campus of the University of Illinois at Urbana-Champaign. This two day conference consists of presentations, and discussions that focuses on the state of the art in timber, concrete, steel, and composite crosstie and fastening system design, performance, research, modeling, and inspection.

William W. Hay Seminar Series

University of Illinois Urbana-Champaign hosts a seminar series that is available both on-campus and on-line to all that wish to join.

Urban Transportation Center Seminar Series

University of Illinois Chicago hosted a series of seminars focused on rail transportation in Spring 2025.

John A. Angold Railroad Seminar Series

Kansas State University hosted a series of seminars focused on rail transportation in Spring 2025.

NURail CoE had two jointly organized workshops and/or sessions at other conferences: American Railway Engineering and Maintenance-of-Way Association (AREMA) & Transportation Research Board (TRB). In total, there were 70 presentations by NURail CoE partners from University of Delaware, Kansas State University, Michigan Technological University, Morgan State University, Rutgers University, University of Texas at Austin, University of Illinois-Chicago, and University of Illinois Urbana-Champaign.

University of Illinois Urbana-Champaign

Sunav Dahal is a Ph.D. student studying the mechanics and monitoring methods for track structures.

Kelin Ding is a Ph.D. student in Civil Engineering, is conducting research on railway ballast fouling conditions and particle shape characteristics using computer vision and deep learning techniques.

Jose Gustavo Ramos and Kamyar Kosarneshan are Ph.D. students in Civil Engineering quantifying the effect of non-uniform longitudinal resistance and longitudinal rail creep on rail stress management and track buckle risk.

Panshul Jindal is an M.S. student in Computer Science developing applications for data analytics to streamline track health and structural capacity quantification.

Yash Kakde is an M.S. student in Computer Science developing a method to autonomously identify rail track maintenance activities.

Jaeik Lee is a Ph.D. student in Civil Engineering studying improved designs of railway special trackwork and the influence of adding resiliency into the track structure.

Richard Liu is a M.S. student in Computer Science, security of rail communications.

Neeraj Thakur is an M.S. student in Civil Engineering developing a methodology to quantify a railroad's track buckle risk using track geometry and component health data.

David Wasilewski is an M.S. student in Civil Engineering quantifying the effect of longitudinal rail differential displacement on rail neutral temperature and buckle safety.

University of Illinois Chicago

Brian Christian is a Fulbright Scholar from Indonesia and he is working on quantifying the economic impacts of rail on local businesses.

Zach Perkins is a first year M.S. of Urban Planning and Policy student who is working on understanding the factors that affect use of commuter rail.

Vivian Aguilar is a first year M.S. of Urban Planning and Policy student who is working with Zach on the above project.

University of Delaware

Manisha Kandel is an M.S. student in Civil Engineering with research focusing on risk based visual track inspection.

Johnson Chukwu is an M.S. student in Civil Engineering with research focusing on risk based track geometry inspection.

Michigan Technological University

Mohammad Bagheri is a Ph.D. student fully supported for the spring, summer and fall 2025 semesters, working on life cycle cost assessment of coastal railroads.

Linh Nguyen is a Ph.D. student in Civil Engineering analyzing ultrasound signals for detecting surface cracks on rail tracks.

Andrew Bunge, Sam Vellequette, and Jacob Longstreth are M.S. students in Materials Science and Engineering working on the FRA project Wire Arc Additive Manufacturing (WAAM) for Weld Enhanced Cast Steel Coupler Knuckles from 2022 to the present.

Morgan State University

Derrick Mirindi is a Ph.D. student in Architecture, Urbanism, and Built Environment. His primary task is modeling rail freight vibration and noise around the communities along freight corridors. He is also supervising a master's research assistant.

Claire Githinji is an M.S. student in City and Regional Planning. Her primary role is to inventory available information, including relevant literature and data, and support Mr. Mirindi.

Rutgers University

Mulin Wan and Weitian Li are both Ph.D. students in Civil Engineering, analyzing track infrastructure data to understand track condition and use the information to predict track degradation in support of Track Information Management System (TIMS) development.

University of Texas at Austin

Rydell Walthall is a Ph.D. student in Civil Engineering examining approaches to optimize intermittent freight rail electrification with catenary and batteries.

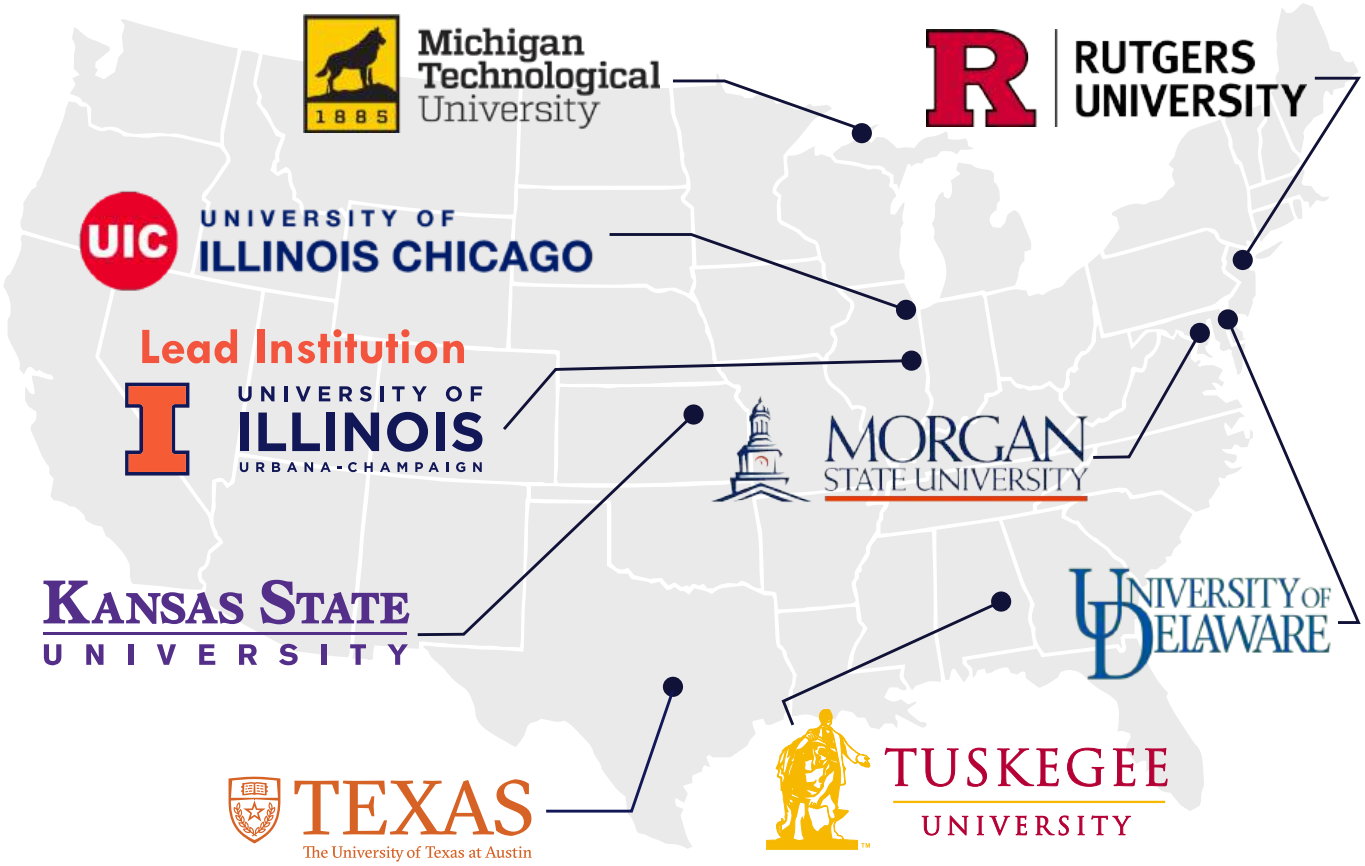
Jinghang Weng is a Ph.D. student in Civil Engineering, exploring the use of laser Doppler Vibrometer measurements for rail defect detection.

Sibo Zhang is a Ph.D. student in Civil Engineering working on modeling the interaction between track ballast and architected materials using the Discrete Element Method (DEM).

Chaisiri Okoun is an M.S. student developing an analytical model to predict the behavior of architected instability-based metamaterials under temperature variations, with the goal of estimating strength improvements that can enhance track performance.

Tuskegee University

Al-Rajean Allie is an M.S. student in Mechanical Engineering investigating Thermite Welded Rail Hardness Profiles and Associated Microstructures.



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