9th Program Progress Performance Report
for
National University Rail (NURail) Center:
Tier 1 University Transportation Center

National University Rail Center - NURail
US DOT OST-R Tier 1 University Transportation Center

Submitted to
U.S. Department of Transportation
Office of the Assistant Secretary for Research and Technology

Grant Period:
30 September 2013 through 30 September 2020

Reporting Period:
1 October 2017 through 31 March 2018

Submitted:
30 April 2018

Submitted to:

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Grant: DTRT13-G-UTC52
Duns: 04-154-4081
EIN: 37-6000511

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1. Accomplishments

The NURail Center is a rail-focused seven-university consortium led by the Rail Transportation and Engineering Center (RailTEC) at the University of Illinois at Urbana-Champaign (UIUC). NURail's principal goals are to achieve a set of Research, Education, Technology Transfer Collaboration and Leadership objectives that not only fulfill center objectives, but support and assist achievement of goals beyond the consortium members. These include the rail industry, AAR and FRA research and workforce development goals. They also include working with other colleges and universities, both domestically and internationally, to advance academic rail education and research quality and quantity.

a. What was accomplished under these goals? **(major activities; specific objectives; significant results (positive and negative); key outcomes)**

NURail Consortium

- NURail Center partners met on Sunday, January 7, 2018 at the 97th Annual Transportation Research Board (TRB) meeting in Washington, DC. Among the items on their agenda were funding, remaining timelines and reporting requirements.

- The NURail Center is planning for its annual meeting. It will be held in Chattanooga, TN on August 1-3 in conjunction with Summerail 2018, which is sponsored by the Freight Rail Transportation Committee (AR040) of TRB.

- Seventeen of the 32 total 2018 AREMA Educational Foundation scholarships given went to students attending NURail Center partner schools.

- Consortium partners wrote two final reports.

University of Illinois Urbana-Champaign

- For the 5th year the NURail Center at UIUC welcomed Hanson Professional Services Inc. and a group of middle and high school students from Springfield, IL to Engineering Open House (EOH) on the UIUC campus on Saturday, March 10. EOH is an annual student-led event featuring two days of exhibits and competitions that showcase the engineering students and is open to the public at no cost. Hanson's group of 17 students plus six adults spent the day examining a portion of the over 250 interactive exhibits on display spread throughout 17 different university buildings.

- *Improving Track Substructure Designs and Settlement due to Complex Dynamic Loads from High-Speed Passenger and Freight Trains (Track Substructure)* - Multiple moving wheels successfully added to the track model. Calculated results match well with field instrumentation collected displacements and forces. To consider the mass inertial influence of a vehicle on the track substructure behavior, a vehicle model of 10 degrees of freedom was created and coupled with existing track model.

Analytical model now able to predict vehicle-track coupled behavior under dynamic loading conditions.

- *Schedule Flexibility and Railway Line Capacity (Line Capacity)* – Simulation experiments completed in summer 2017 so recent efforts have focused on developing results into conference and journal papers that will comprise the final project report.

- *Capacity of Hump Classification Yards (Yard Capacity)* - Preliminary simulation results obtained from the Belt Railway of Chicago hump yard model. Started analysis of results and preliminary analysis supports hypothesized relationships. Input files for additional simulation experiments have been developed.

- *Intermodal Terminal Capacity Factor Interactions (Terminal Capacity)* – Developed sub-models of various intermodal terminal operating components in AnyLogic, including a transloading model, switching logic and roadway/parking network. Developed an experiment design for the capacity simulations.

- *Railroad Grade Crossing Micro-Level Safety and Risk Analysis – Phase 2 (Grade Crossing)* - Analyses completed and draft final report prepared. Under review internally. Report describes how to do risk analysis using accident prediction formula and additional variable.

- *Numerical Investigation of Impact Load Effects on Railroad Track Systems (Load Effects)* - Collected and analyzed majority of field data for light, heavy, and commuter rail transit systems. Data compared to previous relationships that explore parameters that influence the magnitude of loads, especially impact loading. Proposed draft versions of new modal-specific equations for predicting load environment.

- *Optimal Planning of Rail Grinding Activities in Large-scale Networks (Rail Grinding)* – Project is complete and a journal paper was accepted.

- UIUC hosted six William W. Hay Railroad Engineering Seminars between October 1, 2017 and March 30, 2018 reaching a total in-house and online audience of 775 participants. The speakers were:

Date	Name	Company	Presentation Title
12/8/2017	Andreas Hoffrichter	Michigan State University	An Overview of Alternative Motive Power and Hydrogen Fuel Cell Propulsion for Rail Vehicles
2/2/2018	Brennan Caughron	BNSF	BNSF Railway Logistics Park Chicago Wide-Span Crane Expansion Project
2/16/2018	TC Kao	UIUC	The Future of High Speed Rail Systems

3/2/2018	Jeremiah Dirnberger and Ravi Palakodeti	GE Transportation	Leading the Digital Transformation of the Rail Industry
3/16/2018	Juna Snow	Innovated Consulting, LLC	Factoring in the Human Element when Designing for Change in the Railroad Industry
3/30/2018	Bruce Marcheschi	Metra	Introduction to Metra's Engineering Department and Overview of the 2018 Capital Program

University of Illinois Chicago

- Completed paper, "The History of the City of Chicago Central Area Transit Circulation Efforts" which chronicles the evolution of the City of Chicago's efforts, through private and public means, to address the distribution and circulation of people in the city's Central Area. Paper covers the evolution of public transit in the Central Area and the specific efforts in the second half of 20th Century to create a circulation and distribution system.

Michigan Tech University

- Completed one undergraduate student project: *Manistique Transportation Improvements* and started one student project; *LSRC Gaylord Conceptual and Preliminary Design (Lake State Railway Company).*

- Secured co-funding and started a research project; "*Log Movement in the Superior Region – Rate and Capacity Based Analysis of Modal Share*".

- Made two presentations at the *Tenth SHRP 2 "Safety Data Symposium: From Analysis to Results" and* one presentation and a poster at the *97th Transportation Research Board (TRB) Annual Meeting*.

- Completed an undergraduate fellowships for grade crossing research; Darian Reed (CEE) – *Summer Undergraduate Research Fellowship*; *Valuation of Methods to Record Head Orientation in Driving Simulator and In-Vehicle Study Environments*. Secured another undergraduate fellowship (Aaron Dean, MEEM) for *Using Naturalistic Driving Data and Machine Learning to Predict Accident Risk at Highway-Rail Grade Crossings*

- Submitted (and was accepted) a paper to Joint Rail Conference (JRC), AREMA 2018 Annual Meeting, and Human Computer Interface (HCI) conferences.

- Organized 4th Annual Rail Day and Expo and Railroad Night XIII at Michigan Tech on October 3 & 4, 2017.

- Organized Transportation Careers Night at Michigan Tech on February 21, 2018.

- Hosted five guest speakers in Rail Transportation/Technologies.

- Initiated planning for 2018 Michigan Rail Conference on April 13, 2018 and the 2018 Summer Youth Program in Rail and Intermodal Transportation on July 8 – 14.

University of Kentucky

- Continued Experimental In-Track Tie/Ballast Pressure Tests and Evaluations at the trackbed test site on the NS Railway line at Mascot, TN. Ongoing detailed analysis of test results.

- Continued development of a prototype test trackbed for laboratory evaluation of the distribution and magnitudes of pressures at the tie/ballast interface. Testing series in progress. Ongoing analysis of test results. Applied pressures and trackbed deflections are similar to those measured for revenue trains.

- Developed MATLAB based app for hump crossing analysis based on previous NURail project.

University of Tennessee, Knoxville

- *Laboratory Investigation of Steel Tie Performance (Steel Tie)* - Drs. Jerry Rose and David Clarke continuing work on Dr. Huang's project while he is on sabbatical. In-track testing using timber crossties continued at Mascot, TN test site as well as lab testing at UK. Work has demonstrated the applicability of the pressure cell to measurement of tie-ballast interface pressures in track. During the period, the team addressed the technical challenges of using this approach with steel crossties. Initial tests with steel ties failed to provide useful results because of the difficulty in installing the pressure cell and establishing realistic bearing conditions. GEOKON, Inc., pressure cells supplier, is providing technical support to assist in incorporating a measurement sensor into the steel tie. This will allow the tie to be inserted and tamped in the normal fashion, permitting measurement of in-track pressures.

- *Seismic Performance of Stone Masonry and Unreinforced Concrete Railroad Bridge Substructures (Bridge Substructures)* - Dr. Ma's PhD student, Qiang Gui, presented and defended his dissertation proposal which addresses the bridge pier seismic study. Project now in final stages as the research is largely complete. Writing the dissertation, which also serves as the final report, will bring the project near completion.

b. How have the results been disseminated?

NURail Consortium

- Page five in the October 2017 issue of the official newsletter of the Indiana Passenger Rail Alliance, All Aboard Indiana, featured an article on the Midwest Rail Conference. This conference, formerly known as the Michigan Rail Conference, combined forces with two other events; the Summerail 2017 event organized annually by the Freight Rail Transportation Committee (AR040) of the Transportation Research Board, and the NURail Center annual meeting.

University of Illinois Urbana-Champaign

- *Track Substructure* - A journal paper describing this work is currently under preparation.

- *Line Capacity* - A paper describing this research was presented at the Transportation Research Board Annual Meeting in January 2018. Two journal papers describing this work are currently in review.

- *Yard Capacity* - A research update was presented at the INFORMS Annual Meeting in October 2017.

- *Terminal Capacity* - A research update was presented at the INFORMS Annual Meeting in October 2017.

- *Grade Crossing* - Final report is almost complete and will be published in spring or summer of 2018.

- *Load Effects* - Results documented in peer reviewed journal paper that is now in press. Updated results shared with at least two Class I railroads (BNSF and Amtrak) and two transit agencies (LA Metrolink and New York City Transit) at the Fall 2017 RailTEC Infrastructure Industry Partners Update Meeting.

- *Rail Grinding* – A journal paper has been accepted by Computer-aided Civil and Infrastructure Engineering.

University of Illinois Chicago – CUPPA

- Report posted on UTC website through an online abstract with a link to the complete report; a separate news story also was drafted and posted on the UTC site. The news was shared with local and national media and metropolitan planning organizations, and communicated through the UTC's Facebook page. The UIC Public Affairs office included the report in its weekly advisory message.

Michigan Tech University

- Four presentations and one publication were completed during the reporting period. Details are in Section 2.

University of Kentucky

- Presented posters for two papers at the 2018 TRB Annual Meeting in January.
- Will present a paper at the 2018 Joint Rail Conference in April.
- Will present a summary of our trackbed pressure research at the TRB Summerail 2018 meeting in August.

University of Tennessee, Knoxville

- Prepared several papers and presentations on the tie work.
- Bridge pier work will be the subject of a dissertation. Preparing at least three journal papers describing this project.

c. What do you plan to do during the next reporting period to accomplish the goals and objectives?

University of Illinois Urbana-Champaign

- *Track Substructure*: Complete the improvement of current analytical track model by implementation of nonlinear properties of track substructure and use it for simulations of different dynamic loading conditions as well as track substructure. Consolidate the previous conference paper and current results into a journal paper for submission.
- *Line Capacity* - The two journal papers that are currently under review will be consolidated with previous conference papers for form a final project report.
- *Yard Capacity* - Complete simulations for additional experiments (Task 3-5) and conduct associated analysis to quantify capacity relationships and effects associated with different operating parameters. This work has been developed into multiple chapters of a preliminary dissertation document that will be advanced into a draft dissertation during the next reporting period. This work will be presented at the TRB/NURail Summerail meeting in August.
- *Terminal Capacity* - Integrate simulation model components into a single AnyLogic intermodal terminal model and use it to execute the simulations in the experiment design.
- *Load Effects* - Continue to process remaining data from transit field, largely from Metra / UPRR site in Chicago. Compare data to static design loads of railcars and previously developed metrics for predicting dynamic and impact loads.
- *Grade Crossing* - Finalize the report and get it published.

- *Rail Grinding* – Prepare final report and additional publications from this project.

Michigan Tech University

- Finish the research project "*Evaluation of Driver Behavior at Railroad-Highway Grade Crossings Using Naturalistic Driving Study Data*", co-funded with the Federal Railroad Administration.

- Complete student project*; LSRC Gaylord Conceptual and Preliminary Design (Lake State Railway Company).*

- Complete undergraduate fellowship (Aaron Dean, MEEM) for *Using Naturalistic Driving Data and Machine Learning to Predict Accident Risk at Highway-Rail Grade Crossings*

- Present papers at Joint Rail Conference (JRC), AREMA 2018 Annual Meeting, and Human Computer Interface (HCI) conferences.

- Conduct 2018 Michigan Rail Conference and 2018 Summer Youth Program in Rail and Intermodal Transportation.

- Support coordination of the 2018 Railway Engineering Education Symposium.

University of Kentucky

- Continue to measure trackbed pressures at the Mascot test site. Further analyze data and develop models describing magnitudes and distributions of pressures for revenue train operations.

- Continue with development of laboratory calibration tests using the prototype trackbed. Also develop models describing the magnitudes and distributions of pressures for simulated in-track loadings.

University of Tennessee, Knoxville

- Continue tie related tests at Mascot and in the UK lab. Incorporate pressure cell into steel tie and conduct tests. Mr. Gui will deliver chapters in his dissertation/final report addressing the bridge pier project.

2. Products

a. Journal publications:

University of Illinois Urbana-Champaign

- Xie, S., Lei, C. and Y. Ouyang, (2018) "A customized hybrid approach to infrastructure maintenance scheduling in railroad networks under variable productivities." Computer-aided Civil and Infrastructure Engineering. In press.

- Edwards, J.R., A.A. Cook, M.S. Dersch and Y. Qian. 2018. “Quantification of Rail Transit Wheel Loads and Development of Improved Dynamic and Impact Loading Factors for Design”. Journal of Rail and Rapid Transit, In Press.

Michigan Tech University

- Ko S. and P. Lautala, “Advanced Woody Biomass logistics for Co-firing in existing Coal Power Plant: Case Study of the Great Lakes States”, Transportation Research Board 97th Annual Meeting of the National Academies, Washington, DC, January 7-11, 2018 (recommended for publication in Transportation Research Record).

University of Kentucky

- Rose, J.G., Clarke, D.B., Liu, Q. and T.J. Watts, “Application of Granular Material Pressure Cells to Measure Railroad Track Tie/Ballast Interfacial Pressures,” Paper 18-00593, TRR Journal of Transportation, TRB, January.

- Liu, Q., T. Wang and R. Souleyrette, “A 3D Evaluation Method for Rail-Highway Hump Crossings,” Journal of Computer-Aided Civil and Infrastructure Engineering 32 (2017) 124–137, DOI: 10.1111/mice.12244.

University of Tennessee, Knoxville

- Rose, J.G., Clarke, D.B., Liu, Q. and T.J. Watts, “Application of Granular Material Pressure Cells to Measure Railroad Track Tie/Ballast Interfacial Pressures,” Transportation Research Record: Journal of the Transportation Research Board, 2018 (in press).

b. Books or other non-periodical, one-time publications:

NURail Consortium

- Mascoop, D.R. and J.M. Sussman, “High Speed Rail and Local Land Development: Case Studies in London and Las Vegas”, NURail2017-MIT-R04, final report.

- McKinney, J.L, “Railroad Engineering: Hands-On Experience”, NURail2017-RHIT-E02, final report.

University of Illinois Chicago

- Schlickman, S.E. and L. Klabunde. “The History of the City of Chicago Central Area Transit Circulation Efforts”, 2018.

University of Kentucky

- Asphalt Underlayment Highway/Railway At-Grade Crossings: Design, Applications, and Long-Term Performance Evaluations – NURail 2016-UKY-R12a, October 2017.

- Asphalt Underlayment Railway Trackbeds: Designs, Applications, and Long-Term Performance Evaluations – NURail 2016-UKY-R12b, October 2017.

- A Laboratory Test Method for Measuring Realistic Trackbed Pressure at the Tie/Ballast Interface – NURail 2016-UKY-R12c, January 2018.

- In-Track Railway Track Tie/Ballast Interfacial Pressure Measurements Using Granular Material Pressure Cells – NURail 2016-UKY-R12d, January 2018.

- Comparisons of Railway In-Track Tie/Ballast Interfacial Impact Pressure Measurements with Wheel/Rail Surface Impact Load Detector –NURail 2016-UKY-R12e, April.

c. Other publications, conference papers and presentations:

University of Illinois Urbana-Champaign

- Hou, W., Tutumluer, E., Huang, H., Boler, H. and D. Mishra. Analytical Model of Ballasted Track Bridge Approach Validated with Field Measurements. ASCE T&DI International Conference on Rail Transportation (ICRT). Presentation on July 10-12 2017, Southwest Jiaotong University, Chengdu, China.

- Hou, W. and E. Tutumluer. Analytical Model of Ballasted Track under Complex Dynamic Loads. Midwest Rail Conference. Poster on August 15-17, 2017, Kalamazoo, MI.

- Sehitoglu, T., D. Mussanov and C.T. Dick. 2018. Operational schedule flexibility, train velocity and the performance reliability of single-track railways. In: Proceedings of Transportation Research Board 97th Annual Conference, Washington, DC, USA.

- Edwards, J.R. and M. Dersch. 2017. FTA Research Program Update – Loading and Bending Moments. Presented at the 2017 Industry Partners Research Update, Victorville, CA, November 2017.

Michigan Tech University

- Ko S. and P. Lautala, “Advanced Woody Biomass logistics for Co-firing in existing Coal Power Plant: Case Study of the Great Lakes States”, Transportation Research Board 97th Annual Meeting of the National Academies, Washington, DC, January 7-11, 2018.

- Lautala P., Muhire, M., Salim, A., Jeon, M., Nelson, D. and A. Dean, “The Assessment of Driver Compliance at Highway-Railroad Grade Crossings Based on Naturalistic Driving Study Data”, Transportation Research Board 97th Annual Meeting of the National Academies, Washington, DC, January 7-11, 2018.

- Lautala, P., Nelson, D., Jeon, M., and M. Muhire, "Using NDS data to evaluate driver behavior at highway – rail grade crossings", Tenth SHRP 2 Safety Data Symposium, Washington, D.C., October 6, 2017.

- Dean, A., Lautala, P., Nelson, D. and M. Jeon, "Development and Validation of Post-Processing Methods for the SHRP 2 Mask Head Pose Data", Tenth SHRP 2 Safety Data Symposium, Washington, D.C., October 6, 2017.

University of Kentucky

- Rose, J.G., Clarke, D.B., Liu, Q. and T.J. Watts, "Development of a Laboratory Test Method for Measuring Trackbed Pressures at the Tie/Ballast Interface" – Paper 18-00592, TRB Annual Meeting Online, January.

- Souleyrette, R.R., "Level Crossing Research at NURail Universities," Keynote Presentation, SAFER-LC Workshop 2, Paris, France, March 27, 2018.

- Shaw, J.W, Z. Hans, R.R. Souleyrette and P. Savolainen, "Selecting Safety Improvement Projects for Railroad Grade Crossings on Public Highways: Issues and Opportunities," presented in Session 222 at the 97th Annual Meeting of TRB, Washington, DC, Jan. 2018.

- Souleyrette, R. R., "Level Crossing Research at NURail Universities," Keynote Presentation, 4th International Symposium on Railway Operations Research - Optimization and Big Data Analysis in Railway Operations Management, Beijing Jiaotong University, Beijing, China, October 14-15, 2017.

- Shaw, J., Z. Hans, R. Souleyrette and P. Savolainen, "Selecting Safety Improvement Projects for Railroad Grade Crossings on Public Highways: Issues and Opportunities" Proceedings of the 97th Annual Meeting of TRB, Washington, DC, Jan. 2018. 9 pages.

- Rose, J., T.J. Watts and E. Russell, Relationship between Wheel/Rail Surface Impact Loadings and Correspondingly Transmitted Tie/Ballast Impact Pressures for Revenue Train Operations – Joint Rail Conference Paper 2018-6184, April 2018.

University of Tennessee, Knoxville

- Rose, J.G., Clarke, D.B., Liu, Q. and Watts, T.J., "Application of Granular Material Pressure Cells to Measure Railroad Track Tie/Ballast Interfacial Pressures", presented at the 2018 Transportation Research Board Annual Meeting, January 9, 2018.

d. Website(s) or other Internet site(s):

University of Illinois Urbana-Champaign

- NURail consortium website: http://www.nurailcenter.org/index.php

Michigan Tech University

- Michigan Rail Conference; http://www.rail.mtu.edu/mrc2018

- 2017 Summer Youth Program Web site; http://www.rail.mtu.edu/articles/rail-and-intermodal-transportation-summer-youth-program-2018

University of Tennessee, Knoxville

- "Measuring Railroad Track Tie/Ballast Interfacial Pressures", Geokon Corp. newsletter, http://www.geokon.com/Recent-Projects#RR

e. Technologies or techniques:

Michigan Tech University

- Continuing refinement of automated processing methodology to extract data from SHRP2 Naturalistic Driving Study database for creation of "compliance/behavior score" at grade crossings.

f. Inventions, patent applications and/or licenses:

Nothing to report.

g. Other products (i.e. databases, audio/video products):

Michigan Tech University

- Database of almost 15,000+ grade crossing traversal parameters from the SHRP2 data.

3. Participants and Other Collaborating Organizations

a. What other organizations have been involved as partners?

Organization or University Name	Location	Contribution to the Project	Name (First and Last)
Univ. of Kentucky	Lexington, KY	Collaboration	Dr. Jerry Rose
Norfolk Southern Corp.	Knoxville, TN	Test site and field support	Mr. Les Hall
GEOKON, Inc.	Lebanon, NH	Test equipment	Mr. Tony Simmonds
Univ. of TN	Knoxville, TN	In-Kind Support	Dr. David C. Clarke
Norfolk Southern Corp.	Atlanta, GA	In-Kind Support and Matching Funds	Philip Merilli

Belt Railway of Chicago	Chicago IL	In-kind support of base case for yard simulations	Nick Chodorow
Amtrak Philadelphia	Philadelphia, PA	In kind support, provision of WILD data	Steven Melniczuk
Metrolink	St. Louis, MO	In-kind support, access to infrastructure for experimentation	Chuck Clemins
MTA New York City Transit Authority	New York, NY	In-kind support, access to infrastructure for experimentation	Antonio Cabrera
Union Pacific Railroad (UPRR)	Chicago, Metra	In-kind support, access to infrastructure for experimentation	Various employees

b. Additional collaborators:

Name (First and Last)	Company, University, Organization Name	Location	Contribution to the Project
Prof. Qinglie Liu	East China Jiaotong Univ.	Nanchang, PRC	Technical analysis
Mike Hudson	L.B. Foster (Salient)	Dublin, OH	Review Test Plan and Provide Data
Qinglie Liu	East China Jiaotong Univ.	Nanchang, China	Review Test Plan and Derived Data
Omid Ghasemi-Fare	University of Louisville	Louisville, KY	Review Test Plan and Develop Models
Federal Railroad Administration	Washington, DC	Co-funded project	Starr Kidda
Michigan Dept. of Transp.	Lansing, MI	Co-funded project	Nikkie Johnson
City of Manistique	Manistique, MI	Senior Design sponsor	Sheila Aldrich
Lake State Railway Company	Saginaw, MI	Senior design sponsor	Sean Pengelly
Michigan Economic Development Corporation/Alger County	Lansing, MI	Co-funded project	Peter Van Steen (Alger)
Michigan Dept. of Agriculture	Lansing, MI	Co-funded project	Peter Anastor

4. Impact

a. What is the impact on the development of the principal discipline(s) of the program?

University of Illinois Urbana-Champaign

- Terminal capacity constraints are a major issue for the railroads. With major investments in new hump yard projects underway, design and sizing of new yards and terminals is a growing need for the rail industry. Research on interaction between yard and mainline capacity will allow railroad practitioners to make better capital investment decisions to maximize the overall capacity of the rail network through properly balanced investments in mainline and yard projects. Similarly, research to better understand the factors that control intermodal facility capacity will allow railroads to make prudent investments in new and expanded terminals to handle the fast-growing intermodal rail traffic market sector.

- Grade crossing project study directly supports the USDOT Strategic Goals on safety. Findings will help improve safety at highway-railroad crossings. Indirectly supports USDOT Strategic Goals of Economic Competitiveness and Livable Communities by improving safety and reducing delay for motor vehicles and trains, as well as making the grade crossing areas safer for the people living in the area.

- Numerical investigation project supports the DOT goals for safety and state of good repair by providing a better understanding of how railroad track components may deteriorate and from that identifying areas where designs can be improved to mitigate high impacts loads entering the track structure.

University of Illinois Chicago – CUPPA

- Publication of the "History" paper provides future transportation planners with background on the public/private partnerships that drove development of Chicago's existing public transit network; and the analysis of the failed Central Area Circulator project reinforces the need for continued strategic planning to provide effective mobility options for the future.

Michigan Tech University

- Student projects continue to change the principles how we educate our students. Summer Youth Program has had a positive effect on student recruitment. Michigan Rail Conference has become the main rail transportation stakeholder event in the state and Rail Day and Expo (and Railroad Night) on campus.

University of Kentucky

- To provide experimental test data applicable as input for rational structural design of railway trackbeds.

- To assess the relative damage to the track structure from increased pressures imparted to the track structure as a result of increased impact loadings to the rail.

- To utilize rational designs to provide safer and longer service lives for the railway trackbeds and correspondingly reduce trackbed maintenance costs.

b. What is the impact on other disciplines?

University of Illinois Chicago – CUPPA

- The "History" paper provided insight that can benefit transportation planning in other communities that are expanding and need to provide new mobility options.

Michigan Tech University

- Most activities (student projects, rail conference, summer youth program, Rail Day) are designed for multiple disciplines.

c. What is the impact on the development of transportation workforce development?

Michigan Tech University

- Total of 30+ civil engineering and surveying students are involved in the completed and on-going undergraduate student projects. Numerous more involved in outreach activities.

University of Tennessee, Knoxville

- UK graduate student Travis Watts received an internship with Norfolk Southern, partly due to his role in the tie project.

- The work of UTK graduate student Qiang Gui is being sponsored by the bridge project.

d. What is the impact on physical, institutional and information resources at the university or other partner institutions?

University of Illinois Chicago – CUPPA

- The paper chronicles the challenges faced by Chicago to build the proposed Central Area Circulator; this knowledge provides a historical record of that project.

e. What is the impact on technology transfer?

University of Illinois Chicago – CUPPA

- Paper was shared with media resources and through the UTC website and Facebook page. These efforts helped build awareness for the analysis and findings. As of early April, the "History" news story was viewed 36 times and the abstract 20 times on the UTC website. The Facebook post has resulted in more than 360 views.

f. What is the impact on society beyond science and technology?

University of Illinois Urbana-Champaign

- Proper investments in mainline, classification yard and intermodal facility capacity allow railroads to operate more efficiently, lowering supply chain costs and improving reliability of the transportation system, to the economic benefit of society.

- Grade crossing project indirectly supports the USDOT Strategic Goals of Economic Competitiveness and Livable Communities by improving the safety and reducing delay for motor vehicles and train, as well as making the grade crossing areas safer for the people living in the area.

University of Illinois Chicago – CUPPA

- The paper reinforces the need for continued research and analysis into additional public transportation options as cities grow, expand and evolve.

Michigan Tech University

- Michigan Rail Conference is an avenue for larger understanding of rail transportation and attracts participants from outside industry. Summer Youth Program and Rail Day and Expo expand the visibility among students.

5. Changes/Problems

a. Changes in approach and reasons for change

University of Kentucky

- Had to experiment with different types and configurations of pressure cells to optimize and prove the adequacy of the system for accurately and consistently measuring tie/ballast interfacial pressures under typical revenue train operations. This phase of the study represents original research aimed at developing criteria for direct application by the railway engineering profession.

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

NURail Consortium

- NURail Partner and Co-Pi, Joseph M. Sussman, passed away on March 20, 2018. While there are currently no active MIT projects, there are still some unexpended funds. The University of Illinois at Urbana-Champaign will be contacting MIT to see if the university wants to identify and engage another of its faculty members who is interested in conducting research that supports NURail objectives. This individual would also replace Professor Sussman on the leadership team. Alternatively MIT could de-obligate their remaining funds so that it could be used elsewhere within the consortium.

c. Changes that have a significant impact on expenditures

NURail Consortium

- The NURail consortium asked for and was granted a two year no-cost extension.

d. Significant changes in use or care of human subjects, vertebrate animals and/or biohazards

Nothing to report.

e. Change of primary performance site location from that originally proposed

Nothing to report.