

6th 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

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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 is working to improve and expand rail education, research, workforce development, and technology transfer. This includes working with other colleges and universities, both domestic and international, the rail industry, AAR and FRA.

As the original NURail Grant (number DTRT12-G-UTC18) is drawing to a close researchers are beginning to utilize funds from this grant. The number of active projects is increasing and soon there will be more accomplishments, publications or other products that can be attributed to these expenditures.

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

NURail Consortium

- Approximately 50 students from NURail Center partner universities attended the 2016 AREMA conference in Orlando, FL in August. In addition to attending technical sessions and giving poster presentations, many students worked the NURail booth in the exhibition hall.
- The University of Illinois at Urbana-Champaign's (NURail's lead university) two teams scored first and second in the AREMA "Student Quiz Bowl" competition. The other NURail partner universities also placed well in the contest. The match consisted of four rounds of questions related to railroad engineering, operations, history and trivia.
- The Railway Academic Conference (TRAC) was held on the UIUC campus on July 12 – 14, 2016. Eighty attendees participated in this three-day event, with Railroad Engineering Education Symposium (REES) activities and the NURail Annual Meeting each comprising half of the program. Building on similar goals and objectives, TRAC further informed educators, industry professionals, and students about current developments in railroad engineering education, workforce development and outreach programs.
- The winner of NURail's 3-Minute Thesis competition this year was Ahmed El-Gandour, a PhD student from the University of Illinois at Chicago. The title of his presentation was "Coupled Finite Element and Multibody Dynamics for Studying Bridge Approaches".

University of Illinois Urbana-Champaign

- *Shared Rail Corridor Adjacent Track Accident Risk Analysis* - Developed a research framework for the probability of train presence on the adjacent track in an intrusion scenario, which is a foundation of quantification of the train presence probability.
- *Railroad Grade Crossing Micro-Level Safety and Risk Analysis – Phase 2* - Examining different ways of formulating risks. The final decision has not been made yet.
- *Numerical Investigation of Impact Load Effects on Railroad Track Systems* – Investigated the loading conditions on rail transit systems. Installed instrumentation on rail transit systems to gather first hand data on loading conditions.
- *Optimal Planning of Rail Grinding Activities in Large-scale Networks* – Project was approved and started this month.

- *Schedule Flexibility and Railway Line Capacity* – Initial simulations have been completed to investigate the allocation of train delay between combinations of scheduled and flexible trains in congested networks (project Task 2). Simulation results are currently under analysis.
- *Capacity of Hump Classification Yards* - Input data for the initial factorial experiment (Task 2) was developed and the corresponding scenarios are currently being simulated.

University of Illinois Chicago

- *Modeling of Rail Track Substructure for Coupling with Vehicle Dynamics Model* - Applied the coupled finite element/multibody model to the problem of bridge approaches. Examined methods of mitigating the approach and recently formulated an approach to account for viscous stresses in the system. Implementing that in model.
- *Railway Infrastructure Materials and Design* – Conducted two major studies:
 - 1) Pullout behavior of headed anchors used in Totally Prefabricated Precast Concrete Counterfort Retaining Wall System (TPCCRW) examined experimentally and analytically using Nonlinear Finite Element Analysis (NLFEA). Study took into consideration two different block thicknesses, two IDOT certified types of headed anchors and types of concrete grout, three different bar sizes and four different embedment depths. Blocks tested under axial tensile loading conditions. Structural behavior of pullout specimens was characterized by fracture of steel anchors regardless of size and embedment depth.
 - 2) Numerical model of train-track-bridge interaction was formulated based on the method of dynamic condensation and the assumption of no-jump at the wheel-rail interface. Results revealed that vertical bridge acceleration, exceeding safe limits, is a problem for spans less than 30m notwithstanding that the vehicle interaction and track effects improve the dynamic calculations with reduced responses particularly at resonance speeds. Better dynamic predictions were achieved with linear vertical spring-dampers and rotational springs at the bridge boundaries with the later having an effect of decreasing responses.

Massachusetts Institute of Technology

- *The Evaluation of International HSR Markets for JR East: A Systems Approach* - Three group representatives traveled to Tokyo in August for research meetings presenting new research advancements and clarified the statement of work. Project includes development for benefit cost analysis, performance measure evaluation and development of a matrix/teaching note presenting suggested methods of evaluation as part of the Year-1 HSR CLIOS template.

Michigan Tech University

- Successfully organized 4th annual Michigan Rail Conference with almost 200 total participants.
- Undergraduate student project for the *Lake State Railway Improvements* was completed; two other student projects started under NURail 2011 grant completed as well.
- MS report on “*Life Cycle (LCA) and Life Cycle Cost (LCCA) Analysis of Freight Transportation Alternatives to Copperwood Mine*” project was completed.
- 2016 Summer Youth Program in Rail and Intermodal Transportation was completed with 8 students.
- Co-led the organization of 2016 The Rail Academic Conference.
- Organized 3rd Annual Rail Day & Expo and Railroad Night XII at Michigan Tech.
- Started two research projects; *Life Cycle Assessment (LCA) of Ore Transportation Route/Mode Alternatives for Eagle Mine* and *Highway-Rail Grade Crossing Research with NDS data and driver simulator* (project with parallel funding from FRA).

- Started one undergraduate student project: *Peshekee Yard Development and Site Improvement Design – Phase 1*

University of Kentucky

- *Study behavior of track in bridge transition zones* - Analyzed data. Imbedded pressure cells within the track structure to ascertain pressure distributions at open-track sites and along the transitions to bridges.
- *Implementation of a rail crossing condition index*
 - Fit planes through point clouds to calculate volumetric and point differences that may affect vehicular accelerations. Computed multiple measures of crossing roughness based on these differences. Rated crossings based on geometric measures. Field validated hump crossings.
 - Presented findings of ride ability assessment and hump crossing evaluation to KYTC. Discussed implications for including findings in rail crossing improvement program.
- Continued to update “Railroad (Engineering) and Facilities Design and Analysis” class at University of Kentucky

University of Tennessee, Knoxville

- *Laboratory Investigation of Steel Tie Performance* –
 - Tested different loading scenarios of wood ties and steel ties. Compared load distribution in ballast.
 - Based on test results, a paper titled "Laboratory Evaluation of Pressure Distribution under Steel and Timber Crossties in Railway Track" was accepted by TRB for presentation at the 96th TRB Annual Meeting.
 - Abstract titled “Full scale laboratory testing of pressure distribution under a steel crosstie” has been accepted by the First International Conference on Rail Transportation (ICRT) that will be held at the Southwest Jiaotong University in China. Full paper being written and will be submitted.
- *Seismic Performance of Stone Masonry and Unreinforced Concrete Railroad Bridge Substructures* - Reviewed existing experimental studies related to seismic performance of masonry structures. Lab testing program is under development based on the literature-review study.

Rose-Hulman Institute of Technology

- "CE 483 Railroad Engineering" had a new module on Railroad Bridges incorporated in the spring quarter 2016 offering.
- "CE 445 Construction Methods and Equipment" added a new module in fall 2016 called Railroad Construction Equipment and Techniques. Thirteen construction and railroad students are enrolled in the course.
- Haley Hands-On Learning Lab - In a partnership where students in CE483 receive hands-on experience with some of aspects of railway construction and operation. Two Hands-On sessions were conducted:
 - **Session 1** - Track Construction - Allowed students to construct a temporary section of track including moving ties, tie spacing, moving joint bars using rail dogs, installing tie plates, ensuring proper track gage, spiking the rail to the plates and ties, and removing and storing the supporting equipment upon completion.
 - **Session 2** - Rolling Stock and Turnouts - Demonstration and tour of facilities where students were encouraged to operate air hose couplings, coupler operations, air brake operation and brake shoe removal. Students toured the Caboose and the Troop car. Interlocking controls and turn out components were introduced.

- Developed K-12 Outreach Program to introduce middle school students to Railroad Engineering. Offered to middle school students and both Girl Scout and Boy Scout troops. Program involves solving several track alignment scenarios: sidings for meets and passes; crossing diamonds and track turnouts; yard classification operations; calculation of rail section weight; and operation of a computer simulated locomotive.
- RHIT AREMA student chapter hosted several K-12 rail-related activities.
 - **Girl Scout/Middle School Event** – Activities included problem statements which required girls to lay wooden track in specific configurations, dimensional analysis problems, and a computer simulated train driving game.
 - **Discovering STEM** - Ran activity booth at the annual Discovering STEM event in the Student Recreation Center at Rose-Hulman. Activities included problem statements that required laying wooden track in specific configurations and a hump yard problem where different cars had to be rearranged to go to different cities. Around fifteen different groups of Girl Scouts solved the problems in the allotted ten minutes per round.

b. How have the results been disseminated?

NURail Consortium

- In the August 2016 issue of Railway Track & Structures (RT&S), AREMA President Brian A. Lindamood discussed in his monthly column the importance of viewing employees as a company asset and making the investment of time to foster the development of the generation of future railroaders. He ties this in with the fact he attended NURail's TRAC conference.
- NURail website has been releasing one new video a month for the 2016 calendar year. Each video asks a different member of the NURail leadership team to answer a question about rail education, research or general interest topic.

University of Illinois Urbana-Champaign

- *Shared Rail Corridor Adjacent Track Accident Risk Analysis* - The probability model framework for train presence has not been presented in public, but the full model will be presented at the 2017 Joint Rail Conference.
- *Optimal Planning of Rail Grinding Activities in Large-scale Networks* – Project was approved and started this month.
- *Schedule Flexibility and Railway Line Capacity* - A paper abstract describing research was submitted and accepted for presentation at the International Association of Railway Operations Research conference in Spring 2017. A second paper abstract describing research was submitted and accepted for presentation at the International Heavy Haul Association conference in Fall 2017.
- *Capacity of Hump Classification Yards* - Summary of initial progress on this project was presented at the 2016 Joint Rail Conference.

University of Illinois Chicago

- Published research in the Journal of Rail and Rapid Transit.
- Presented at The Railway Academic Conference in Urbana, IL; both in a poster and as part of a “three-minute thesis” competition.
- Two papers were written on the two mentioned studies and were sent for review. In addition, the results of the first study were included in the Ph.D. thesis of the student Maen Farhat and the results of the second study were included in the Ph.D. thesis of the student Said Nour.
- A custom technology transfer communications plan was developed for each completed Urban Planning and Public Affairs research project. Key elements included drafting and distributing

a news story to media, posting the news story as web content, promoting findings via social media, media relations efforts that led to news coverage, inclusion in webcasts and presentations and direct promotion of the research to transit agencies, planning organizations and academic departments.

Massachusetts Institute of Technology

- Presentations at TRB and journal publications.

Michigan Tech University

- Michigan Rail Conference presentations and recordings are posted online at <http://rail-learning.mtu.edu/>
- Several publications/presentations were made during the reporting period (see details in 2c below)

University of Kentucky

- Published one doctoral dissertation.
- Submitted four TRB papers.
- Submitted Paper to CACAIE Journal (in press)
- Published project report: NURail Project ID: 2015-UKY-R09 (A), “Monitoring of Well-Performing Bridge Transition Trackbeds Using Accelerometers”
- Published project report: NURail Project ID: 2015-UKY-R09 (B), “Evaluating the Effects of Variable Tie Support at Railway Bridge Transitions”
- Published project report: NURail Project ID: NURAIL2015-UKY-R10 (B), “Implementation of a rail crossing condition index: Hump Crossing Evaluation”
- Published project report: NURail Project ID: NURAIL2015-UKY-R10 (A), “Implementation of a rail crossing condition index: Rideability Assessment”
- Published project report: NURail Project ID: NURAIL2014-UKY-E02, “Multimodal Course Enhancement and Distance Education”
- Published project report: NURail Project ID: NURail2012-UKY-E01, “Rail Engineering and Education Symposium Materials”
- Two presentations at 2016 TRB/ASCE/ASME Joint Rail Conference, Columbia, SC

University of Tennessee, Knoxville

- Presentations at international conferences (such as TRB and ICRT mentioned above), journal papers, and technical reports.

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

NURail Consortium

Teleconference call between the NURail Center Leadership Team and the NURail Executive Advisory Board members in early December to seek guidance and input on accomplishing NURail's goals and objectives as well as obtain feedback on NURail's past accomplishments.

University of Illinois Urbana-Champaign

- *Railroad Grade Crossing Micro-Level Safety and Risk Analysis – Phase 2* - Narrow down the choices for risk calculation at each crossing 2-3 methods. Then, apply them to crossing data that is in the FRA database. Examine validity of the ideas using a different set of data from the FRA database.
- *Shared Rail Corridor Adjacent Track Accident Risk Analysis* - Fully develop the quantitative probability model for train presence on adjacent tracks in intrusion scenarios.
- *Optimal Planning of Rail Grinding Activities in Large-scale Networks* – Focus on developing advanced mathematical models and solution techniques for the rail grinding scheduling problem. 1) Conduct intensive literature review to understand current practice on rail grinding scheduling, and 2) Develop model formulations and solution algorithms that can handle various real-world constraints and business rules.
- *Schedule Flexibility and Railway Line Capacity* - Conduct simulations to investigate capacity benefit of converting flexible trains to scheduled operations in congested networks (Task 3). Preliminary Task 2 results will be presented at the INFORMS conference in November 2016.
- *Capacity of Hump Classification Yards* -Complete simulations for the initial factorial experiment (Task 2).
- *Numerical Investigation of Impact Load Effects on Railroad Track Systems* - Continue to process data from WILD sites and field data from UIUC-installed experimental sites on light and heavy rail transit. Compare data to static design loads of railcars that have already been acquired as a part of the initial paper study for this project.

University of Illinois Chicago

- Implement our viscous mode, finalize results for the bridge approach problem, and submit for publication. Apply models to examine vibrations in nearby buildings. Finalize the outputs of bridge model and analyze the results of the model.
- Expand the research on prestressed concrete crossties with Basalt Fiber Reinforced Polymer (BFRP) bars.

Massachusetts Institute of Technology

- Continue on the current plan. Recruited a new graduate student who began the new academic year in September 2016. Daniel Mascoop worked on the project while an undergrad and is now studying for his Masters in City Planning.

Michigan Tech University

- Complete collaborative projects with MDOT and submit final reports.
- Initiate organization of 5th annual Michigan Rail Conference which will expand to a multistate and multi-organization event.
- Complete on-going student project.
- Start marketing for 2017 Summer Youth Program in Rail and Intermodal Transportation.
- Present paper at TRB Annual Meeting.

University of Kentucky

- Publish master's thesis and additional papers.

University of Tennessee, Knoxville

- *Steel Tie Performance* - Perform field testing (if possible) and compare results. Final report will be compiled and more papers written and submitted for possible publication.
- *Seismic Performance* - Finalize lab testing program and preparation for upcoming testing in the next reporting period.

Rose-Hulman Institute of Technology

- Partnering with Wabash Valley Railroaders Museum and Indiana Rail Road to expand railroad displays and hands-on activities used by the Railroad Engineering class, Rose-Hulman AREMA student chapter, and greater Terre Haute community.
- Offer K-12 Railroad Engineering Outreach Program to local Girl Scout troops, Cub Scout/Boy Scout troops, and middle school students. AREMA Student Chapter to continue participation in the Discovery STEM Program.

2. Products

a. Journal publications:

University of Illinois Urbana-Champaign

- Lin, X., J.R. Edwards, M.S. Dersch and C.J. Ruppert, Jr. 2016. Load Quantification for Light Rail, Heavy Rail, and Commuter Rail Transit Infrastructure. In: *Proceedings of the 11th World Congress on Railway Research*, Milan, Italy, June 2016.

University of Illinois Chicago

- A.I. El-Ghandour, M.B. Hamper, and C.D. Foster. “Coupled Finite Element and Multibody Dynamics Systems Modeling of a 3D railroad system”. *Journal of Rail and Rapid Transit*, Vol. 230 No. 1, 2016, 283-294. (published – previously accepted)
- Five publications were sent for review. These publications will be reported in next reporting cycle.

Massachusetts Institute of Technology

- Levy and Sussman, Challenges and Opportunities in Implementation of the Future California Rail Network (<http://trrjournalonline.trb.org/doi/abs/10.3141/2546-09>)
- Sridhar and Sussman, first year program report on *Transportation in the Emirate of Abu Dhabi: A Systems Approach*
- Pena Alcaraz, Webster and Sussman, Analysis of Capacity Pricing and Allocation Mechanisms in Shared Railway Systems: Lessons for the Northeast Corridor (.pdf [ESDWP-2015-04](#))
- Masdar Institute of Science and Technology: Project on HSR in Abu Dhabi
- Various progress reports
- Sridhar and Sussman, Draft working paper on *Transportation Investment and Economic Development*

University of Kentucky

- Liu, Q., T. Wang and R. Souleyrette, “A 3D Evaluation Method for Rail-Highway Hump Crossings,” *Journal of Computer-Aided Civil and Infrastructure Engineering*. In Press.

- Malloy, B., J. Rose, and R. Souleyrette, “Rehabilitation of Railway/Highway At-Grade Crossings: Recommendations and Guides,” *Transportation Research Record (TRR), Journal of the Transportation Research Board*. No. 2545, 2016, pp. 100-114.

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

Nothing to report

c. Other publications, conference papers and presentations:

University of Illinois Urbana-Champaign

- Lin, X., J.R. Edwards, M.S. Dersch and C.J. Ruppert, Jr. 2016. Load Quantification for Light Rail, Heavy Rail, and Commuter Rail Transit Infrastructure. In: *Proceedings of the 11th World Congress on Railway Research*, Milan, Italy, June 2016.

Michigan Tech University

Peer Reviewed Conference Proceedings

- Lautala P., Dick T., Railway Engineering Education Symposium: Evolving to Rebuild a Growing Rail Academic Community, Transportation Research Board 96th Annual Meeting of the National Academies, Washington, DC (Accepted for presentation. Transportation Research Record publication pending submittal of final version)
- Kalluri, S., Lautala, P., Handler, R., Comparative Life Cycle Assessment of Road and Multimodal Transportation Options – A Case Study of Copperwood Mine, ASME/ASCE/IEEE 2016 Joint Rail Conference, Columbia, SC, April 12-15, 2016 (Winner of the best student technical paper)
- Addison, P., Lautala P., Oommen T., Vallos, Z., Embankment Stabilization Techniques for Railroads on Permafrost, ASME/ASCE/IEEE 2016 Joint Rail Conference, Columbia, SC, April 12-15, 2016
- Deilamsalehy, H. Havens, T., Lautala P., Detection of Sliding Wheels and Hot Bearings Using Wayside Thermal Cameras, ASME/ASCE/IEEE 2016 Joint Rail Conference, Columbia, SC, April 12-15, 2016
- Landry, S., Jeon, M., Lautala P., Nelson, D., Getting Active with Passive Crossings: Investigating the Use of In-Vehicle Auditory Alerts for Highway-Rail Grade Crossing, ASME/ASCE/IEEE 2016 Joint Rail Conference, Columbia, SC, April 12-15, 2016

Other Publications

- Pouryousef, H., Lautala, P., *Hybrid Optimization of Train Schedules (HOTS) for Stop Pattern and Dwell Time Analysis*, 11th World Congress in Railway Research, Milan, Italy, May 29 – June 2, 2016

Conference Abstracts/Presentations

- **Lautala, P.**, Jeon, M., Landry, S., Nelson, D., *Design and Evaluation of In-Vehicle Auditory Alerts for Railroad Crossings*, Global Level Crossing Safety & Trespass Prevention Symposium 2016, Helsinki, Finland, June 12-16, 2016
- **Lautala, P.**, Jeon, M., Nelson, D., *Driver Behavior at Level Crossings Using Naturalistic Driving Study Data*, Global Level Crossing Safety & Trespass Prevention Symposium 2016, Helsinki, Finland, June 12-16, 2016

University of Tennessee, Knoxville

- Two conference papers will be published next year and presentations are expected to be given at TRB and ICRT.

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

University of Illinois Urbana-Champaign

- In this six-month period, the NURail Center website has had 5,131 unique visits to the website with 15,483 page loads. (<http://www.nurailcenter.org/index.php>)

University of Illinois Chicago

- Pedestrian/Cyclist Safety Web Page -- <https://utc.uic.edu/research/pedestrianbicyclist-warning-devices-and-signs-at-cta-rail-highway-grade-crossings/>

Massachusetts Institute of Technology

- Regional Transportation Planning and High-Speed Rail Research Group:
<http://web.mit.edu/hsr-group/>

Michigan Tech University

- 4th Annual Michigan Rail Conference site: <http://www.rail.mtu.edu/event/4th-annual-michigan-rail-conference>
- 2016 Summer Youth Program web site: <http://www.rail.mtu.edu/event/rail-and-intermodal-transportation-summer-youth-program-2016>
- Rail learning site hosting presentations and recordings from Michigan Rail conference and TRAC: <http://rail-learning.mtu.edu/>

e. Technologies or techniques:

Michigan Tech University

- Use of magnetic viewing film for rail defect detection (to replace dye penetrants)

f. Inventions, patent applications and/or licenses:

Nothing to report

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

Michigan Tech University

- Rail learning site hosting presentations and recordings from Michigan Rail conference and TRAC: <http://rail-learning.mtu.edu/>

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)
Indiana Rail Road	Indianapolis, IN	In-Kind, Collaborative, Technical Assistance Student Proj. Materials	Peter Ray Justin Cronin
Wabash Valley Railroaders Museum	Terre Haute, In	Hands On Education Opportunities	Bill Foster
Masdar Institute of Science and Technology	Abu Dhabi, UAE	Funding for related research on HSR	
Indian National Railroads	India	Funding for related research on HSR	Brijesh Dixit
JR East	Tokyo	Funding for related research on HSR	
Michigan Department of Transportation	Lansing, MI	Matching funds/ project oversight	Nikkie Johnson
Highland Copper	White Pine, MI	Research Data	Carlos Bertoni
Lake State Railway	Saginaw, MI	Undergraduate project support/financial support	John Rickoff
JM Longyear	Marquette, MI	Undergraduate project support	Jake Hayrynen
Eagle Mine	Marquette, MI	Graduate Research project support	Matt Johnson
University of Kentucky	Lexington, KY	Helped acquire steel-tie panel and ballast. Also helped w/testing devices & procedures	Dr. Jerry Rose
Norfolk Southern Corporation	Knoxville, TN	Donated steel-tie panel and ballast.	Mr. Les Hall
Center for Urban Transportation Research	Tampa, Florida	Financial	
Illinois Department of Transportation	Chicago, Illinois	Financial	
Jeremiah Dirnberger	CSX Transportation	Jacksonville FL	In-kind support of base case for yard simulations

b. Additional collaborators:

Name (First and Last)	Company, University, Organization Name	Location	Contribution to the Project
Dr. Bill Eccles – Electrical Engineering	RHIT	Terre Haute, In	Class Module Development
Dr. John Aidoo – Civil Engineering	RHIT	Terre Haute, In	Class Module Development

Dr. Mike Moorhead – Mechanical Engineering	RHIT	Terre Haute, In	Class Module Review
12 individuals	Various	-----	Coordination Group for Michigan Rail Conf.
8 individuals	Various	-----	REES Academic Content Committee

4. Impact

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

University of Illinois Urbana-Champaign

- *Railroad Grade Crossing Micro-Level Safety and Risk Analysis – Phase 2* - 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 grade crossing areas safer for people living in the area.
- *Capacity of Hump Classification Yards* - Terminal capacity constraints are a major issue for 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.

University of Illinois Chicago

- Models can be used to evaluate bridge approach mitigation strategies, which can reduce costs for track owners.
- Vibration analysis will help in the design of methods to reduce vibrations.
- Prestressed concrete crossties with Basalt Fiber Reinforced Polymer (BFRP) research provides an innovative solution to drawbacks frequently reported by the industry such as corrosion of prestressed concrete crossties with steel strands. The combination of prestressed concrete crossties with BFRP can greatly reduce the cost of repair and replacement for corroded crossties and boost their cost effectiveness.

Michigan Tech University

- Increased use of student projects is slowly changing the principles how we educate our students.

University of Tennessee, Knoxville

- It is still too early to report on the impact.

Rose-Hulman Institute of Technology

- "CE 483 Railroad Engineering" – Technical elective for Civil Engineering students
- "CE 445 Construction Methods and Equipment" – Technical elective for Civil Engineering students
- RHIT AREMA Student Chapter – Opportunity for Civil Engineering and other engineering students to learn about the rail industry and explore career opportunities in the industry

b. What is the impact on other disciplines?

University of Illinois Chicago

- Developing numerical models that can be applied to a variety of dynamic systems including coupled finite element and multibody problems. Other applications specifically include vehicle/soil interaction and geotechnical modeling for structures.
- Research impacts the rail and precast concrete industry. In addition, research positively impacts environment through reducing the use of wooden timber cross-ties.

Michigan Tech University

- Most activities (student projects, rail conference, summer youth program) are not designed for a specific discipline.

Rose-Hulman Institute of Technology

- CE 483 Railroad Engineering – Technical elective for Mechanical and Electrical Engineering students.
- RHIT AREMA Student Chapter – Open to all RHIT students to learn about the rail industry and career opportunities in the rail industry.

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

University of Illinois Chicago

- Currently working with one MS and one PhD student on the project.

Michigan Tech University

- Total of 61 civil engineering, surveying, electrical engineering, and materials engineering and science students are involved in the completed and on-going undergraduate student projects.

Rose-Hulman Institute of Technology

- Expectations for CE/EE/ME students to consider railroad engineering internships as well as a potential career path.

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

University of Illinois Chicago

- Developing software packages that can be used by partner institutions for analysis.

Michigan Tech University

- Rail learning site is slowly becoming a warehouse for rail related conference recordings, especially Michigan Rail Conference recordings.

e. What is the impact on technology transfer?

Michigan Tech University

- Materials at Rail Learning site are available for large audiences.

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

University of Illinois Urbana-Champaign

- Proper investments in mainline and yard 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 improves safety and reduces delay for motor vehicles and trains, as well as making the grade crossing areas safer for people living in the area.

University of Illinois Chicago

- Ultimately models will be able to be used to reduce maintenance costs, reducing costs of shipping.
- Vibration analysis will increase occupant comfort in buildings near railways.

Michigan Tech University

- Michigan Rail Conference is an avenue for larger understanding of rail transportation and attracts participants from outside industry.

Rose-Hulman Institute of Technology

- Exposure of undergraduate engineering students to railroad engineering and career opportunities in the rail and related design, construction, rail support industries.

5. Changes/Problems

a. Changes in approach and reasons for change

Nothing to report

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

Nothing to report

c. Changes that have a significant impact on expenditures

Nothing to report

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