4th 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

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

University of Illinois Urbana-Champaign

- During summer 2015 simulation work continued investigating the interaction between mainline and terminal capacity with a focus on the impact of schedule flexibility on mainline operations. Work still in progress with a current focus on the influence of mainline train arrivals and blocking patterns on the capacity of hump classification yards.

Railroad Grade Crossing Micro-Level Safety and Risk Analysis – Phase 2

- Focusing on safety and risk of accidents at railroad crossings; currently conducting literature review to determine the state of the art on safety and risk assessment at RR crossings in the US.

Shared Rail Corridor Adjacent Track Accident Risk Analysis –

- Beginning comprehensive risk assessment for adjacent track accidents (ATA) on shared use corridors.

Numerical Investigation of Impact Load Effects on Railroad Track Systems

- Studying the effect impact load (dynamic load) resulting from defects in the rail and/or wheel and better understand the mechanisms through which this load transfer within various track components.
- Development and validation of finite element models is progressing.

University of Illinois Chicago

Vehicle/Track Interaction

- Continued work on enhancing vehicle/track interaction simulation models based on multibody system algorithms.
- Developing new models for rail vehicles interacting with finite element tracks and visualizing the numerical results.

Improving Track-Bridge Interaction Using Recycled Plastic Crossties

- Tested mechanical performance of recycled plastic cross-ties in the lab and with computer simulations.
- Finalized the simulation of their performance in various bridge designs.

Computational Ballast and Soil Models to Improve Track Transition Design

- Updated coupled rail/substructure simulations to fully capture deformation of soil for post processing.
- Began integrating the viscoplasticity for ballast and subgrade materials into the algorithm.

3D Visualization of Rail Vehicle-Track Interaction –

- Created a PC implementation of 3D visualization procedures for rail vehicle and infrastructure dynamics and their interactions.
- Adapted for the PC platform a program originally engineered to run on the Electronic Visualization Laboratory's CAVE2 virtual reality environment.

Incentivizing Off Peak Delivery of Freight –

- Research phase included a literature review, case studies of off-peak delivery projects in various locations, examination of work complementary to off-peak delivery in metropolitan Chicago, and a review of current local laws and regulations that may impact off-peak delivery.
- Data analysis included evaluation of business by industry and employment throughout the region, a review of area congestion, and exploration of businesses in particular zip codes.
- Design phase began with meetings with a variety of partners who are working together towards implementation of off-peak delivery.
- Objective: If enough businesses can adjust their schedules to accept deliveries when there is less traffic congestion, it could enable truckers to deliver goods more quickly and at less cost.
- Objective: Could result in less traffic congestion, reduced cost of goods, economic benefits and a better environment.
- Outcome: Review of available data and case studies demonstrates that off-peak delivery can yield significant benefits.
- Outcome: After an analysis of possible metropolitan Chicago locations, several locations identified where an off-peak delivery program could substantially reduce peak period traffic volume.
- Outcome: Two locations being targeted to consider for the pilot program: the Chicago Loop and the Northwestern medical facilities and related businesses near North Michigan Avenue.

Michigan Tech University

- Completed organizing the 3rd Annual Michigan Rail Conference.
- Started an undergraduate student project for the "*Lake State Railway Improvements*". "*Life Cycle (LCA) and Life Cycle Cost (LCCA) Analysis of Freight Transportation Alternatives to Copperwood Mine"* Project is appx. 75% complete.

University of Kentucky

Study behavior of track in bridge transition zones

- Used accelerometers and video to evaluate track deflection and movement at bridge approaches exhibiting adequate and poor performances.
- Ascertained pressure distributions and magnitudes at the tie/ballast interface from various combinations of wheel loads, train speeds, and ballast/track conditions. Objective: Determine relative effects of factors on pressure distributions along track having both adequate and poor support.
- Preliminary tests conducted on trackage of TTI Railroad, and proto-type laboratory tests were conducted at the University of Tennessee test track facility.

Study behavior of track in bridge transition zones

- Collected LiDAR 3D profiles for representative sample of Kentucky rail highway grade crossings and accelerometer readings for multiple vehicles, multiple speeds and multiple crossings
- Proposed and tested various measures for evaluating roughness of crossings, including: 1) Maximum and minimum accelerations and 2) Total energy

- Compared vehicle performance relative to design vehicle using: 1) speed bump as control, and 2) single crossing as control.
- Rated crossings using total energy. Developed a methodology to identify hump crossings from a 3D point cloud and implemented hump crossing methodology software.

University of Tennessee, Knoxville

Reesarch

- What is the Extent of Harm in Rail Pedestrian Crashes? Developed work plan, accomplished substantial work, preparing final report. Project resulted in several technical papers in refereed journals and presentations at conferences. Working on submitting research papers to TRB annual meeting.
- Dr. Ma's research group calibrated testing results from lateral impact testing of AASHTO Type-I girder using finite element (FE) modeling and simulated the collision process using the commercial Abaqus software. For the bridge pier project, the group also conducted a preliminary literature review and then summarized their findings.
- Dr. Huang's group prepared the test facility for track load measurement. Initial setup used timber crossties.
- Dr. Jin's group developed a simulation model for yard capacity analysis and verified model using historical data. A Ph.D. student is applying the model in a network capacity analysis.
- Dr. Ji continued with data collection and network preparation for his coal impact study.

Education

- Two UT students worked on safety issues related to rail crossings and non-crossings during the reporting period.
- Industrial Engineering graduate students were exposed to the optimization issues of railway planning and operations in the IE 522 class. New class in railway simulation was offered.
- Graduate student Bumjoon Bae (PhD) received the Frank J. Richter scholarship from the American Association of Railway Superintendents. Graduate student Qiang Qui (PhD) received an AREMA scholarship.

Outreach and tech transfer

- Dr. Khattak serves as "special adviser" to Journal of Transportation Safety & Security, Dr. Nambisan is an editorial board member, and Dr. Clarke is an area editor for rail. Dr. Khattak continued as Editor-in-Chief of SCI-Indexed Journal of Intelligent Transportation Systems and Associate Editor of SCI-Indexed International Journal of Sustainable Transportation.
- Dr. Clarke served as an instructor at the p-REES event sponsored by APTA in July 2015.

Rose-Hulman Institute of Technology

- CE 483 Railroad Engineering has been incrementally updated and modified over the past three years. Most recent course was offered during the 2015 spring quarter with total enrollment of 19 students: 6 Civil Engineering, 7 Mechanical Engineering and 6 Brazilian Exchange students. New module on Railroad Bridges, developed by Structural Engineer John Aidoo, will be incorporated in the 2016 offering of the class.
- New module - Railroad Construction Equipment and Techniques, was recently developed and will be included in fall class CE 445 Construction Methods and Equipment.

- RHIT AREMA Student Chapter has 98 RHIT participants, with 12 students registered as AREMA members. Students from a variety of academic majors make up the membership. Industry Practitioner is Peter Ray PE, Vice President of Engineering, Indiana Railroad. Since its founding the Chapter has held 25 meetings and conducted 18 rail industry site visits.
- Rose-Hulman obtained century old bridge members (pin connections, a roller bearing expansion joint and gusset plate) to be used as a teaching aid. They will be used for a number of statics and structural engineering classes as well as the CE 483 Railroad Engineering class for hands-on review of bridge design concepts.

b. How have the results been disseminated?

University of Illinois Urbana-Champaign

- Prepared paper on the influence of flexible yard departure times on mainline train delay, line capacity and track infrastructure requirements as compared to those for scheduled train operations and submitted to the Transportation Research Board. Paper still under review.
- Shared corridor safety project will initially disseminate results through journal publications and conference presentations. Numerical investigation project has submitted abstracts for publication and presentation at the 2016 JRC conference.

University of Illinois Chicago

- Report titled *Off-Peak Delivery: A Pilot Project for the Chicago Region*, released August 25, 2015 and posted on the UTC website.
- Presentations to metropolitan Chicago stakeholders, at the NURail Annual Meeting, and via webinar through the Center for Urban Transportation Research at the University of South Florida.

Michigan Tech University

- Michigan Rail Conference presentations have been posted at the rail-learning.mtu.edu web site.

University of Kentucky

- Conference presentations and proceedings.

University of Tennessee, Knoxville

- Faculty disseminated NURail related results through several sources, including refereed journals, the internet (websites maintained by UT Center for Transportation Research and Transportation Engineering & Science Program in Civil & Environmental Engineering), and prepared/given presentations at conferences, e.g., for the Transportation Research Board Annual Meeting. Several graduate students are involved in research efforts.

Rose-Hulman Institute of Technology

- NURail Annual Meeting –June 2015
- RHIT AREMA Student Chapter 2014-2015 – James McKinney

- Indiana Rail Road & Rose-Hulman Institute of Technology Partnership – James McKinney
- Reflections and Evaluation of Rail Experiences: RHIT Graduates Employed by Class I Railroads and Undergraduate Student Internships. – James McKinney
- CE 483 Railroad Engineering
- CE 483– Spring 2015 – student evaluations reviewed with recommended changes and enhancements studied for incorporation in the class.

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

University of Illinois Urbana-Champaign

- **Yard capacity project** - working with a Class 1 railroad to develop base case data for simulation of the hump classification yard. Once the data has been processed, simulation experiments to investigate the interaction between mainline train arrival patterns, blocking complexity and yard capacity will commence.
- **Grade crossing project** - continue identifying study corridors for the project and gathering data on crash, traffic, and geometrics.
- **Shared corridor project** - continue developing a semi-quantitative risk model to address the ATA risk.
- **Numerical investigation project** - continue model development, validation and begin a parametric study.

University of Illinois Chicago

Dynamic Modeling of Railroad Vehicles and Vehicle-Track Interaction

- Continue to develop new railroad vehicle/track models using multibody system approaches.

Improving Track-Bridge Interaction Using Recycled Plastic Crossties

- Continue to use laboratory results for recycled plastic crossties as inputs into various computer simulations, including use of plastic ties in high-speed rail bridge design, ABC design
- Work on publications for related to totally precast concrete counterfort retaining wall system for railway bridges.
- Continue to work on experimental and computational study aiming to investigate the structural adhesive behavior at different loading scenarios for HDPE applications.
- Continue to investigate the behavior of structural adhesive by characterizing their mechanical properties, and ii) establish a representative material model that can mimic their behavior and can be used in numerical models for computational studies.
- Continue working on the dynamic behavior of short span railway bridges subjected to high speed train loading. The focus is on the effects of vehicle interaction and bridge support flexibility using numerical simulations based on the finite element formulation.

Computational Ballast and Soil Models to Improve Track Transition Design

- Finish integrating the viscoplasticity for ballast and subgrade materials in to the algorithm.

- Apply the elastic model toward vibrations in nearby structures

3D Visualization of Rail Vehicle and Track and Infrastructure Dynamic simulations

- Complete PC adaptation of the EVL CAVE2 visualization of rail vehicle and infrastructure dynamic data so it is ready to be shared with other NURail partners

Incentivizing Off Peak Delivery of Freight

- Establish website to further educate region about off-peak delivery and draw participants. Survey carriers and receivers about off-peak delivery and current delivery practices. Pursue funding for incentives.

Michigan Tech University

- Complete the LCA/LCCA study. Initiate the organization of 4th Annual Michigan Rail Conference.

University of Kentucky

Study behavior of track in bridge transition zones

- Analysis of data. Imbed 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. Compute single or multiple measures of crossing roughness based on these differences. Rate crossings based on geometric measures. Field validate hump crossings.
- Present findings of rideability assessment and hump crossing evaluation to KYTC. Discuss implications for including findings in rail crossing improvement program.

University of Tennessee, Knoxville

- Dr. Khattak's team plans to work on the final report for the crossing and non-crossing safety project and the following papers:
    - Liu J., A. Khattak, S. Richards, *Are Behavioral Paths that Lead to Severe Crashes at Gated Railroad Grade Crossings Similar across Diverse Geographic Contexts of the United States?* In preparation.
    - Zhang M., A. Khattak, J. Liu, & D. Clarke, *A Comparative Study of Rail-Trespassing Crash Injury Severity at Highway-Rail Grade Crossings and Non-Crossings*. In preparation.
- Dr. Ma's research team will work on in-depth FE modeling to calibrate the collected testing data from the impact test. Next, a parametric study will be performed using the FE model to study collision and damage mechanism caused by over-height vehicles. Will use literature review results to target research approaches for seismic performance assessment and development of effective retrofit measures for old stone masonry and unreinforced concrete railroad bridge piers. Prepare for potential experimental study.
- Dr. Huang's team will complete the steel-tie panel testing and start the analysis of the test results.
- Dr. Ma's group will finish the capacity modeling and analysis for a railway network in the US with validation.

Rose-Hulman Institute of Technology

- Rose-Hulman will be partnering with the Wabash Valley Railroaders Museum to develop railroad displays and hands-on activities that will be used by the Railroad Engineering class, the Rose-Hulman AREMA student chapter, and the greater Terre Haute community.

2. Products

a. Journal publications:

University of Illinois Chicago

- M.H. Motamedi and C.D. Foster "An improved implicit numerical integration of a non-associated, three- invariant cap plasticity model with mixed isotropic-kinematic hardening for geomaterials." International Journal of Numerical and Analytical Methods in Geomechanics. Vol 39, 2015, 1853-1883.
- Lotfy I, and Issa M A, "Evaluation of the longitudinal restraint, uplift resistance, and long-term performance of High Density Polyethylene crosstie rail support system using static and cyclic loading" Journal of Rail and Rapid Transit; In review.
- Lotfy I, Farhat M, and Issa M A, "Effect of Pre-drilling, Loading Rate and Temperature Variation on the Behavior of Railroad Spikes used for High Density Polyethylene Crossties" Journal of Rail and Rapid Transit; In review.

University of Kentucky

- "Evaluating tie support at railway bridge transitions" Stephen T Wilk, Timothy D Stark and Jerry G Rose, Proceedings of the Institution of Mechanical Engineers, Part F – Journal of Rail and Rapid Transit, July 2015.
- McHenry, M., M. Brown, J. LoPresti, J. Rose, and R. Souleyrette, "The Use of Matrix Based Tactile Surface Sensors to Assess the Fine Scale Ballast-Tie 1 Interface Pressure Distribution in Railroad Track," Accepted for Publication in *Transportation Research Record (TRR), Journal of the Transportation Research Board.*

University of Tennessee, Knoxville

- Wang X., A. Khattak, J. Liu, & D. Clarke, Non-crossing rail-trespassing crashes in the past decade: a spatial approach to analysis of injury severity, Safety Science, Volume 82, February 2016, Pages 44–55.
- Liu, J., A. Khattak, S. Richards, & S. Nambisan, What are the differences in driver injury outcomes at highway-rail grade crossings? Untangling the role of pre-crash behaviors, Accident Analysis & Prevention, Volume 85, December 2015, pp. 157–169.
- Li, H., M. Jin, R. Song, S. He, and J. Song, Dynamic Railcar Connection Planning in Classification Yards, Accepted by Transportation Letters, The International Journal of Transportation Research, DOI: http://dx.doi.org/10.1179/1942787515Y.0000000010 , 2015.
- Li, H., M. Jin, and S. He, Sequencing and Scheduling in Railway Classification Yards, Transportation Research Record, Journal of Transportation Research Board, Volume 2475, pp. 72-80, 2015.

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

None

c. Other publications, conference papers and presentations:

University of Illinois Chicago

- C.D. Foster, M.H. Motamedi, and D.A. Weed. “Inelasticity and Mixed-Mode Fracture in Porous Rock”. US National Congress of Computational Mechanics, July 26-30, 2015, San Diego, CA.
- Craig Foster, Ahmed El-Ghandour, Mohammad Hosein Motamedi, Martin Hamper. “Coupled Multibody and Finite Element Modeling for Simulating Vehicle-Track-Substructure Interaction”, NURail Annual Meeting, June 3-4, 2015. Chicago, IL
- Nour, S. and Issa, M., 2015, "Effects of Different Models on Natural Frequencies of Short Span Bridges Used in High Speed Rail," ASME Paper No. JRC2015-5772, pp. V001T01A032
- Farhat M, Rahman M ,Ibrahim M, and Issa M A, “Totally Prefabricated Counterfort Substructure System for Highway and Railway Applications.” Poster session at the 2015 NURail annual meeting in Chicago, IL, June, 2015.
- Lotfy I., Farhat M., and Issa M., “Experimental Evaluation and Modeling of Fastening System for Plastic Composite Crossties.” Two posters at the 2015 NURail annual meeting in Chicago, IL, June, 2015.
- Shibli I, and Issa M A, “Structural Adhesive Behavior : Experimental & Computational Study.” Poster session at the 2015 NURail annual meeting in Chicago, IL, June, 2015.
- Presentation: *Partnering to Create an Off Peak Delivery Pilot Program in Metropolitan Chicago,* presented June 4, 2015 at the NURail Annual Meeting.
- Report: *Off-Peak Delivery: A Pilot Project for the Chicago Region,* August 25, 2015.
- Presentation: *The Potential for Off Peak Delivery in Metropolitan Chicago,* presented June 3, 2015 at the Supply Chain Innovation Network of Chicago and October 15, 2015 via Center for Urban Transportation Research webinar.

Michigan Tech University

- A poster on the LCA analysis results was presented at the 2015 Railway Interchange (Minneapolis, MN) in October, 2015.
- A paper on the LCA analysis results has been accepted for presentation at the 95th TRB Annual Meeting in January, 2016.

University of Kentucky

- Presentation: "Maintaining Adequate Trackbed Support – An Important Railway Infrastructure Issue" to Hay Seminar Series at the University of Illinois, 2014, relating previous trackbed designs to more recent designs. Jerry Rose

- Presentations: "Collaborative Railway Research at the University of Kentucky and University of Tennessee", Korean Railways Research Team Visit, June 23 & 24, 2015 – Jerry Rose
- Two 2015 JRC papers and presentations, both collaborative efforts with University of Illinois and P&L Railroad and CSX Transportation – Jerry Rose

University of Tennessee, Knoxville

- Lautala, P.T., Dick, C.T., Rizos, D., and Clarke, D.B., Toward Next Generation of Railroad Professionals –Collaboration by NURail and Rail Industry, 2015 Annual Conference, American Railway Engineering and Maintenance-of-Way Association, Oct. 7, 2015.
- Liu, J., A. Khattak & S. Richards. What Are the Consequences of Drivers Trespassing Highway-Rail Grade Crossings Equipped with Gates? A Spatial Approach Integrated with Path Analysis, 2015 Road Safety & Simulation International Conference, Orlando, FL, 2015.
- Zhang, M., A. Khattak, J. Liu & D. Clarke, The Role of Rail-Trespassing Crashes at Highway-Rail Grade Crossings and Non-crossing Tracks? A Comparative Study on Injury Severity, NURail Annual Meeting, Chicago, IL, 2015. This paper to be presented at 2015 Road Safety & Simulation International Conference, Orlando, FL, 2015.
- Wang X., A. Khattak, J. Liu, & D. Clarke, Non-crossing Rail-Trespassing Crashes in the Past Decade: A Spatial Approach to Analysis of Injury Severity, TRB paper # 15-0955, Presented at the Transportation Research Board, National Academies, Washington, D.C., 2015, and NURail Annual Meeting, Chicago, IL, 2015
- Liu J., A. Khattak, S. Richards, & S. Nambisan, What are the Differences in Driver Injury Outcomes at Highway-Rail Grade Crossings? The Role of Passive and Active Controls, TRB paper # 15-0959, Presented at the Transportation Research Board, National Academies, Washington, D.C., 2015.
- Jing, Y., Ma, Z.J., Bennett, R.M., and Clarke, D.B., Full-Scale Lateral Impact Testing of Prestressed Concrete Beam, 2016 Precast/Prestressed Concrete Institute Convention and National Bridge Conference (2016 PCI/NBC).
- Clarke, D.B., Rail Transportation – An Infrastructure Overview, Invited Lecture, CE 355, Department of Civil and Environmental Engineering, University of Tennessee, Knoxville, TN, April 14, 2015.
- Clarke, D.B., Railway Maintenance, Invited Lecture, IE 484, Department of Industrial and Systems Engineering, University of Tennessee, Knoxville, TN, April 20, 2015.
- Clarke, D.B., Rail Transportation – An Industry Overview, Invited Presentation, STEM Workshop for Teachers, Knoxville, TN, June 22, 2015.
- Clarke, D.B., Railroad Intermodal Transportation, Invited Lecture, Passenger Railroad Engineering Education Symposium, American Public Transportation Association, Philadelphia, PA, July 8, 2015.
- Clarke, D.B., Train Performance, Invited Lecture, Passenger Railroad Engineering Education Symposium, American Public Transportation Association, Philadelphia, PA, July 9, 2015.
- Clarke, D.B., Rail Intermodal Transportation, Invited Presentation, China Academy of Railway Sciences, Beijing, PRC, July 17, 2015.

- Clarke, D.B., Railway Workforce Development Activities, Invited Presentation, American Association of Railway Superintendents Annual Meeting, Baltimore, MD, July 20, 2015.
- Clarke, D.B., University Role in Transportation Workforce Development Activities, Invited Presentation, Southeastern Association of State Highway and Transportation Officials Annual Meeting, Nashville, TN, August 4, 2015.

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

Michigan Tech University

- 3rd Annual Michigan Rail Conference site http://www.rail.mtu.edu/event/3rd-annual-michigan-rail-conference-0

e. Technologies or techniques:

None

f. Inventions, patent applications and/or licenses:

None

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

University of Illinois Chicago

- Database of potential off-peak delivery receivers in target Chicago locations.

Michigan Tech University

- Michigan Rail Conference presentations have been posted at: 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)
Michigan Dept. of Transp.	Lansing, MI	Matching funds	Nikkie Johnson
Highland Copper	White Pine, MI	Research Data	Carlos Bertoni
Indiana Rail Road	Indianapolis, IN	In-Kind, Student Proj Matl's, Collaborative, Technical Assistance	Thomas Hoback Peter Ray Justin Cronin

Wabash Valley Railroaders Museum	Terre Haute, In	Hands On Education Opportunities	Bill Foster
Supply Chain Innovation Network of Chicago	Chicago, IL	Gathering stakeholders, providing support	Doug Whitley Jim Blackmon Adam Lomasney
World Business Chicago	Chicago, IL	Research support	Liz Jellema
Chicago Metropolitan Agency for Planning	Chicago, IL	Research support	Tom Murtha Alex Beata Jacki Murdock
Mid-West Truckers Association	Chicago, IL	Survey distribution	Don Schaefer
NS	Norfolk, VA	funding	NS Corporate Partnership
NS	Norfolk, VA	funding	NS Foundation
Nichols Foundation	Jacksonville, FL		Gerald Nichols
KY Transportation Cabinet	Frankfort, KY	Funding	Jennifer McCleave
Jeremiah Dirnberger	CSX Transportation	Jacksonville FL	In-kind support of base case for yard simulations
Tennessee DOT	Nashville, TN	Matching funds & data	N/A
Oak Ridge National Lab.	Oak Ridge, TN	Collaborative support	N/A
Univ. of Kentucky	Lexington, KY	Technical assistance	Dr. Jerry Rose
HC Bridge, Inc	Wilmette, IL	Materials, technical assistance	Mr. John Hillman
Norfolk Southern Corp.	Knoxville, TN	Materials donation	Mr. Les Hall
Southern Shores Development, LLC	Knoxville, TN	Test site and services	Mr. Chris Burkhart
Britton Bridge, LLC	Knoxville, TN	Transportation/test setup	Mr. Jerry Britton
Mega Machinery, Inc.	Knoxville, TN	Test assistance	Ms. Megan Dyer
Transportation Test Center, Inc.	Pueblo, CO	Technical assistance	Mr. Duane Otter
Southeastern Transportation Center, UTK	Knoxville, TN	Collaborative support on safety at railroad grade crossings	Dr. Steve Richards & Ms. DeAnna Flinchum
Jeremiah Dirnberger	CSX Transportation	Jacksonville FL	In-kind support of base case for yard simulations

b. Additional collaborators: (ex: interdepartmental or interdisciplinary collaborations, Collaborations with individuals outside the UTC or U.S.)

Name (First and Last)	Company, University, Organization Name	Location	Contribution to the Project
12 individuals	Various	-----	Coordination Group for MI Rail Conf
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
Dan Lau	Dept. of Electrical Engineering, and Visualization Center, Univ. of Kentucky	Lexington	contributed his time, technology and resources to the 3D rail crossing project
Xu Peng	BJTU	Beijing	Collaboration on track maintenance papers
Ahmed Shabana and team	University of Illinois at Chicago	Chicago	vehicle dynamics simulator for grade crossings
Tim Stark	UIUC	Champaign	work on performance of bridge approaches
Shingli Xia (visiting scholar)	Beijing Jiaotong University	Beijing, PRC	Technical assistance
Haidong Li (visiting scholar)	Beijing Jiaotong University	Beijing, PRC	Technical assistance

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.
- Grade crossing project study directly supports the USDOT Strategic Goals on safety. Finding of the study will help improve the safety at highway-railroad crossings. Also

indirectly supports the 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.

- Shared corridor project will advance our understanding on how to most efficiently and effectively manage risk on shared rail corridors thereby providing guidance for tactical and strategic operational control, infrastructure and vehicle design and maintenance, and public (FRA) and private sector policy making.
- Numerical investigation project supports the DOT goals for safety and state of good repair by providing a better understanding of how railroad track components deteriorate and from that identifying areas where designs can be improved.

University of Illinois Chicago

- Closer to implementation of an off-peak delivery pilot project. Research phase was completed, target locations identified, and stakeholders brought together to learn about the benefits of off-peak delivery.

University of Tennessee, Knoxville

- UT research work is enhancing railroad maintenance, operations, and safety. In addition to publications in top journals, they are also working on the implementation of the Highway Safety Manual, which will be useful for railroad crossing and non-crossing safety studies.
- Research underway at UT is creating the knowledge-base and foundation needed for crossing and non-crossing safety countermeasures. Working on injury severity and highlighting the need for quantifying the impacts of countermeasures on not only crash frequencies but also on injury severity. Due to NURail funding, methodological advances in safety modeling of crashes at railroad grade crossings and non-crossings have been made.

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 Kentucky

- Electric Engineering, using structured light to scan object at large scale

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 careers opportunities in the rail industry.

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

Michigan Tech University

- Eighteen civil engineering and surveying students are involved in the Lake State Railway Project and two students in the LCA/LCCA project.

University of Kentucky

- Educating undergraduate and graduate students in civil engineering is the principal impact.

University of Tennessee, Knoxville

- Courses offered during the reporting period:
  - CE 595/IE 591 - 3-D Simulation Modeling of Transportation Systems
  - CE 595 Intelligent Transportation Systems
  - IE 522 – Optimization Methods in Industrial Engineering
- Graduate students are co-authors of railroad related research papers and are being exposed to transportation safety through their courses. This should motivate them to seek careers in transportation.
- UT's railroad continuing education classes continue to provide railroad industry professionals with high quality instruction in topics related to railroad infrastructure and operations.

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 Kentucky

- Instrumentation and mobile field test equipment; test pit (contribution of NS RR to donate track sections and rail car truck (double-axle).

University of Tennessee, Knoxville

- The John D. Tickle Engineering Building is a recently completed facility housing the Departments of Civil & Environmental Engineering and Industrial & Systems Engineering. It has ample space for transportation labs, and houses UT labs used for NURail research.

- The CEE and ISE Departments have several faculty members who are involved in NURail research.

e. What is the impact on technology transfer?

University of Illinois Chicago

- A report was released and several presentations given.

Michigan Tech University

- Over 150 professionals/academics/politicians, etc. participated in the Michigan Rail Conference. Conference had 30 presenters.

University of Tennessee, Knoxville

- Working on speaker series & webinars, Spring and Fall 2015
- Assistance with editing of transportation journals, i.e., Journal of Transportation Safety & Security and Journal of Intelligent Transportation Systems.
- Preparation and delivery of research presentations at NURail, Transportation Research Board, INFORMS, and AREMA annual meetings.
- UT faculty assisted with the 2015 Road Safety & Simulation International Conference (October 6—8, 2015), in Orlando, Florida by submitting technical papers and by playing a major role in reviewing submitted papers. The conference is co-hosted by University of Central Florida & The University of Tennessee. UT faculty, staff and students will present 2 papers at the conference related to NURail work.
- UT faculty disseminate results of NURail funded projects to various stakeholders in the transportation arena. Worked on presenting technical papers in various forums that impact diverse stakeholders, including transportation practitioners, researchers, policy makers, and the private sector. UT faculty have an important impact internationally through collaborations with colleagues in other countries. Dr. Jin will share models with railroads such as CSX and NS.
- UTK continues to employ findings from NURail research in its continuing education classes offered to the railroad industry.

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 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

- Spreading awareness about the potential for off-peak delivery in the Chicago region.

Michigan Tech University

- 150 professionals/academics/politicians, etc. participated in the Michigan Rail Conference. The conference had 30 presenters.

University of Kentucky

- Safety and economy of the general public is impacted.

University of Tennessee, Knoxville

- Highway Safety Manual improvements (a major research initiatives at UT and TDOT) can lead to reductions in hazards and application of new countermeasures that save lives.
- Big Data applications in railroad crossing and non-crossing safety can provide a means to innovate in the growing area of data science.
- Efforts of UT faculty directly contribute to the development of methods and applied knowledge in rail safety; they are training a skilled workforce, forming and expanding social networks that stimulate safety/risk research, and creating new solutions/countermeasures.

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

University of Illinois Chicago

- The Off-Peak Delivery Project will add surveys and a website to induce participation.

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

University of Illinois Urbana-Champaign

- Development of the baseline case for the yard capacity simulations has been delayed due to computer system hardware and software issues at the collaborating Class 1 railroad. The issues are currently being worked through with the railroad but anticipate completing the base case and initial simulation trials by the end of the calendar year.

University of Illinois Chicago

- Recruitment of participants to join the pilot project is moving slowly. Enrollment will be expedited through development of an Off-Peak Delivery Pilot website, informational surveys, and by exploring sources of funding for incentives to participate.

c. Changes that have a significant impact on expenditures

None.

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

None.

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

University of Illinois Chicago

- CUPPA –Off-peak Delivery project has narrowed down its performance site to the Chicago loop and/or the north Michigan Avenue/Streeterville area.