

5th 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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A handwritten signature in black ink, appearing to read 'Chris Barkan', with a stylized flourish at the end.

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1. Accomplishments

A number of efforts within the NURail Center continue to be focused on appropriately and responsibly spending any remaining funds from NURail's original grant (number DTRT12-G-UTC18) which expires on January 31, 2017 before dipping into NURail's second grant (number DTRT13-G-UTC52). While more professors and researchers are beginning to use funding from the second grant, the number of accomplishments, publications or other products that can be attributed to these expenditures is still limited.

a. What was accomplished under these goals?

University of Illinois Urbana-Champaign

- Schedule Flexibility and Railway Line Capacity
 - Developed plan for future simulation work and recruited a grad student to conduct research.
- Capacity of Hump Classification Yards
 - Obtained access to the CSX Hump Yard Simulation System along with traffic data.
 - Conducted an extensive exercise to normalize the data and transform it into a base case for simulation experiments.
 - Developed input data for the initial factorial experiment and the corresponding scenarios are currently being simulated. Recruited a grad student to assist with research.
- Railroad Grade Crossing Micro-Level Safety and Risk Analysis – Phase 2
 - Explored risk at each railroad grade crossing based on accident prediction models and accident history and discussed validation of the idea.
 - One idea was applied to a small set of data and improvements are being made.
- Shared Rail Corridor Adjacent Track Accident Risk Analysis
 - In the previous phase the most important contributors to the risk of train accidents on shared-used rail corridors were identified. In this phase under this reporting period, a probabilistic risk assessment methodology was developed to analyze adjacent track accident (ATA) risk.
 - Created an event tree to identify scenarios for adjacent track accidents and performed a fault tree analysis to identify basic events that contribute to such accidents.
- Numerical Investigation of Impact Load Effects on Railroad Track Systems
 - Building on prior knowledge of heavy-axle freight loading and impact loading conditions, this research has investigated the loading conditions on rail transit systems. Initially, research was conducted using existing data collected using wheel impact load detectors (WILDs) that are currently deployed.
 - Developed plans to install instrumentation on rail transit systems to gather first hand data on loading conditions.

University of Illinois Chicago

- Dynamic Modeling of Railroad Vehicles and Vehicle-Track Interaction (Vehicle-Track)
 - Continued work on enhancing vehicle/track interaction simulation models based on multibody system algorithms.
 - Developed new models for rail vehicles interacting with finite element tracks and visualizing the numerical results.
- Improving Track-Bridge Interaction Using Recycled Plastic Crossties (Track-Bridge)
 - Tested mechanical performance of recycled plastic cross-ties in the lab and with computer simulations.
 - Finished working on experimental and computational study aiming to investigate the structural adhesive behavior at different loading scenarios for HDPE applications.
 - Finalized investigating the behavior of structural adhesive by characterizing their mechanical properties, and ii) established a representative material model that can mimic their behavior and can be used in numerical models for computational studies.
 - Finished using laboratory results for recycled plastic crossties as inputs into various computer simulations, including use of plastic ties in high-speed rail bridge design, and ABC design.
- Computational Ballast and Soil Models to Improve Track Transition Design (Soil)
 - Implemented a model for simulating bridge approaches of trains. Currently running simulations to evaluate different scenarios.
 - Applied model to simulate vibrations in nearby structures.
 - Integrated viscoplasticity model with rail model.
- 3D Visualization of Rail Vehicle-Track Interaction (3D)
 - 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.
- Off-Peak Delivery of Freight (Off-Peak)
 - Surveyed Mid-West Truckers Association members about delivery practices and interest in participating in an off-peak delivery pilot project.
 - Prepared memo of policy and regulatory options and met with the Managing Deputy Commissioner of CDOT to discuss options.
 - Several discussions with UI Labs – City Digital about a possible freight transportation demand management initiative. Continued to communicate with SINC and briefed the new SINC Executive Director on this and other freight activities.
 - Attended several meetings of the CMAP freight committee covering various freight policy, planning and data issues.

Massachusetts Institute of Technology

- In October discussed NURail research project findings with the representatives of East Japan Railway Company (JR East) and received useful feedback from these experts.

- Visited JR East headquarters for a series of meetings in February. Presented second year of work developing and applying the JR East Market Selection Process to various High Speed Rail (HSR) developments around the world.
- Two Regional Transportation and High-Speed Rail (R/HSR) research group graduates, supported by NURail, won Council of University Transportation Centers Charley V. Wootan Memorial Awards for best MS and PhD theses.
- R/HSR group members presented at TRB 95th Annual Meeting in Washington, D.C.

Michigan Tech University

- Work is under way in organizing 4th Annual Michigan Rail Conference.
- Undergraduate student project for the “*Lake State Railway Improvements*” was rolled to second semester (with new teams) and two other student projects that started under NURail 2011 grant were rolled over to this grant for completion.
- Draft MS report on “*Life Cycle (LCA) and Life Cycle Cost (LCCA) Analysis of Freight Transportation Alternatives to Copperwood Mine*” project was submitted for review.
- Launched marketing for 2016 Summer Youth Program in Rail & Intermodal Transportation.
- Launched activities by the Railway Engineering Education Symposium (REES) Academic content committee.

University of Kentucky

- Studied 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 rideability. 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 (Steel Tie)
 - Research group, led by Dr. Huang, finished both timber and steel crosstie track panel testing using the test facility. Two loading modes of tests were performed: monotonic loading and cyclic loading.
 - In addition, field test was performed at Flat Rock, Kentucky.
 - Analyzing the data and will write technical reports and paper based on the results.
- Seismic Performance of Stone Masonry and Unreinforced Concrete Railroad Bridge Substructures (Seismic)
 - This team, led by Dr. Ma, has conducted an in-depth literature review on seismic performance assessment and dynamic experimentation methods.
 - Testing plan under development.

Rose-Hulman Institute of Technology

- CE 483 Railroad Engineering has been incrementally updated and modified over the past four years. A new module on Railroad Bridges, developed by Structural Engineer John Aidoo, is incorporated in the 2016 offering of CE 483 Railroad Engineering.
- A new module - Railroad Construction Equipment and Techniques, was recently developed and was included in CE 445 Construction Methods and Equipment.
- The RHIT AREMA Student Chapter, chartered December 2012, has 98 RHIT participants, with 12 students registered as AREMA members. Students from a variety of academic majors make up the membership.
- Indiana Railroad provided track components for a “Hands-On Learning Lab”. Included were track ties, switch stand ties, tie plates, cut spikes, plugs and a frog. Switch point rails are being acquired.
- Offered Railroad Engineering program to local Girl Scout troop and middle school students. Program involved 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. This successful program will be offered to a community wide STEM program for middle school students.

b. How have the results been disseminated?

University of Illinois Urbana-Champaign

- Schedule Flexibility and Railway Line Capacity
 - Presented paper on the influence of flexible yard departure times on mainline train delay, line capacity and track infrastructure requirements at the Transportation Research Board (TRB) Annual Meeting in January 2016 and published in the Transportation Research Record Journal.
- Capacity of Hump Classification Yards
 - Presented progress on constructing the base case to CSX on several occasions and was also presented at the 2016 Joint Rail Conference (JRC).
- Railroad Grade Crossing Micro-Level Safety and Risk Analysis – Phase 2
 - Completed final report for Phase 1 and submitted to NURail Center for publication on its website. Report describes the micro level safety analysis procedure that is essential in risk assessment in Phase 2.
- Shared Rail Corridor Adjacent Track Accident Risk Analysis
 - Presented paper on fault tree analysis of adjacent track accidents on shared-use rail corridors at TRB in January 2016.
- Numerical Investigation of Impact Load Effects on Railroad Track Systems
 - Presentations relevant to this topic were given at TRB 2016 and JRC 2016 to audiences that included rail transit experts that provided feedback about methods to improve the analysis and ensure maximization of the value of the study to end users.

University of Illinois Chicago

- Soil: Two theses have been published; see one-time publications
- Off-Peak:
 - Direct meetings and discussions with interested parties.
 - Phase 1 report is posted on the Urban Transportation Center website.
 - Center for Urban Transportation Research (CUTR) webinar.

Massachusetts Institute of Technology

- Presentations at TRB.
- Journal publications.

Michigan Tech University

- Kalluri, S., Lautala, P., Handler, R., *Comparative Life Cycle Assessment of Road and Multimodal Transportation Options – A Case Study of Copperwood Mine*, Transportation Research Board 95th Annual Meeting of the National Academies, Washington, DC, January 12-16, 2016. (presented in poster session).

University of Kentucky

- One published paper in the Journal of Transportation Safety and Security.
- Draft doctoral dissertation completed.
- Four NURail final project reports.
- Presented two TRB posters, one panel presentation, two annual meeting conference papers published and one paper in press for TRR Journal.

University of Tennessee, Knoxville

- Both research teams plan to disseminate their results through journal papers and technical reports now under development.

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

University of Illinois Urbana-Champaign

- Schedule Flexibility and Railway Line Capacity
 - Conduct simulations to investigate the allocation of train delay between scheduled and flexible trains in congested networks.
- Capacity of Hump Classification Yards
 - Complete simulations for the initial factorial experiment with the objective of summarizing the results in a journal paper by August 1st.
- Railroad Grade Crossing Micro-Level Safety and Risk Analysis – Phase 2
 - Develop ideas for risk calculation at each crossing and apply them using a part of the FRA database.
 - Examine validity of the ideas using a different set of data from the FRA database.
- Numerical Investigation of Impact Load Effects on Railroad Track Systems

- Continue to process existing data from WILD sites and begin preliminary processing of field data from UIUC-installed experimental sites on light and heavy rail transit.
- Data will be compared to the 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

- Vehicle-Track: Continue to develop new railroad vehicle/track models using multibody system approaches.
- Track-Bridge: Work on publications related to totally precast concrete counterfort retaining wall system for railway bridges.
- Track-Bridge: 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.
- Soil: Use the vehicle/track model to evaluate approach slabs for reducing settlement.
- 3D: 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.
- Off-Peak:
 - Further discussions with UI Labs – City Digital staff and others to develop a freight transportation demand management initiative in cooperation with CDOT, CMAP and SINC.
 - Encouraging SINC to host a meeting with truckers to discuss off-peak delivery and explore their interest in favorable pricing for off-peak deliveries.
 - Prepare report with what has been learned and discussing various options for shifting deliveries of goods from peak to off-peak times.
 - Submit funding request to a local foundation to support SINC freight programs.
 - An abstract has been submitted to Transport Chicago for possible presentation at its June 10, 2016 conference.

Massachusetts Institute of Technology

- Continue plan with several students on track to complete their Masters theses in June 2016.
- Recruit new graduate students to begin the academic year starting September 2016.

Michigan Tech University

- Complete the final report of LCA/LCCA study and present a paper *Comparative Life Cycle Assessment of Road and Multimodal Transportation Options – A Case Study of Copperwood Mine* at the ASME/ASCE/IEEE 2016 Joint Rail Conference.
- Host the 4th Annual Michigan Rail Conference.
- Complete all three on-going student projects.
- Host the 2016 Summer Youth Program in Rail and Intermodal Transportation.
- Present a paper “*Harnessing Undergraduate Students as Rail Industry Technology Developers/Problem-Solvers*” (abstract accepted) that highlights Michigan Tech student projects at 2016 AREMA Annual Meeting.

University of Kentucky

- Publish doctoral dissertation.
- Draft master's thesis.
- Complete project report on condition index.

University of Tennessee, Knoxville

- Steel Tie: Finish analyzing test results and proceed with writing reports and journal papers.
- Seismic: Finalize detailed work plan for their experimental study and complete the theoretical analysis before hopefully beginning the experimental work.

Rose-Hulman Institute of Technology

- Partner with 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 Urbana-Champaign

- Dick, C.T. and D. Mussanov. 2016. Operational schedule flexibility and infrastructure investment: capacity trade-off on single-track railways. *Transportation Research Record: Journal of the Transportation Research Board*. 2546: 1-8. DOI: 10.3141/2546-01.

University of Illinois Chicago

- 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 press, accepted for publication on 04 January 2016.
- 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*, DOI: 0954409715620755 first published on December 10, 2015.
- Nour, S., and Issa, M., (2016) "High Speed Rail Short Bridge-Track-Train Interaction Based on the Decoupled Equations of Motion in the Finite Element Domain", *ASME Journal of Computational and Nonlinear Dynamics*, Under review.
- Shibli A and Issa M A, "Structural Adhesive Interface Behavior: Experimental & Computational Study", *International Journal of Adhesion & Adhesives*, under review.

- Shibli A and Issa M A, “Structural Behavior of Adhesively Bonded High Density Polyethylene Composite Beams”, International Journal of Adhesion & Adhesives, under review.

Massachusetts Institute of Technology

- Levy S., Pena-Alcaraz M., Prodan A., Sussman J.M., (2014). Analyzing the Financial Relationship between Railway Industry Players in Shared Railway Systems: The Train Operator's Perspective. Journal of the Transportation Research Board, No. 2475. Link to the paper: <http://esd.mit.edu/WPS/2014/esd-wp-2014-25.pdf>.
- Carlson S. Joel, Sussman J.M., (2014) Understanding Crude Oil Transport Strategies in North America (p.pdf ESD-WP-2014-03) Submitted to the Journal of the Transportation Research Forum.
- Heywood, R and J. Sussman, Regional Governance and Hub Stations: The Impact of Development and Transport Connections, accepted for the ASCE 2016 International Conference on Transportation and Development, Houston, TX, June 2016 – to be submitted to follow-on journal based on the conference proceedings.
- Westrom, R and J. Sussman, HSR as Transit: The continuing transportation-driven evolution of metropolitan form (.pdf ESD-WP-2014-24) Submitted to the Journal of the Transportation Research Forum.

University of Kentucky

- Malloy, B., J. Rose, and R. Souleyrette, “Rehabilitation of Railway/Highway At-Grade Crossings: Recommendations and Guides,” accepted for publication in the Transportation Research Record (TRR), Journal of the Transportation Research Board.
- Wang, T., R.R. Souleyrette, D. Lau, A. Aboubakr and E. Randerson. “A Dynamic Model for Quantifying Rail-Highway Grade Crossing Roughness.” Journal of Transportation Safety and Security. Online. DOI: 10.1080/19439962.2015.1048016, 05 November 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,” Transportation Research Record (TRR), Journal of the Transportation Research Board. No. 2476, 2015, pp. 23-31.
- Stark, TD, Wilk, ST, Rose, JG, “Design and Performance of Well-Performing Railway Transitions, Paper TRB 16-5926, Transportation Research RECORD, Journal of the Transportation Research Board, Washington, DC, January 2016, 17 pages.

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

University of Illinois Urbana-Champaign

- Juan C. Medina, Shiyu Shen, Rahim F. Benekohal, 2016. Micro and Macro Level Safety Analysis at Railroad Grade Crossings, Report submitted to NURail, University of Illinois at Urbana-Champaign, March 2016.

University of Illinois Chicago

- Master's Thesis "3D FEM and MBS coupling of railroad dynamics with vibrations of surrounding building structures" Chaitanya Joshi, University of Illinois at Chicago.
- PhD Thesis "Numerical Simulation of Mechanical Behavior of Geomaterials from Strain Hardening to Localized Failure" Mohammad Hosein Motamedi, University of Illinois at Chicago.

Massachusetts Institute of Technology

- Levy and Sussman, Challenges and Opportunities in Implementation of the Future California Rail Network, ESD Working Paper, (.pdf [ESD-WP-2015-10](#)).
- Agosta, Carlson and Sussman, Energy Resource Transportation Governance: Case Studies of The Alberta Oil Sands and The Argentinian Vaca Muerta Shale Oil Fields, ESD Working Paper, (.pdf [ESD-WP-2015-09](#)).
- Pena Alcaraz, Webster and Sussman, Analysis of Capacity Pricing and Allocation Mechanisms in Shared Railway Systems: Lessons for the Northeast Corridor, ESD Working Paper, (.pdf [ESD-WP-2015-04](#)).
- Masdar Institute of Science and Technology: Project on HSR in Abu Dhabi, progress reports.

c. Other publications, conference papers and presentations:

University of Illinois Urbana-Champaign

- Lin, C-Y., M.R. Saat and C.P.L. Barkan. 2016. Fault Tree Analysis of Adjacent Track Accidents on Shared-Use Rail Corridors. In: *Proceedings of Transportation Research Board 95th Annual Conference*, Washington, D.C, January 2016.

University of Illinois Chicago

- *The Potential for Off Peak Delivery in Metropolitan Chicago* presented by Jim LaBelle October 15, 2015 via a webinar hosted by the Center for Urban Transportation Research.

Massachusetts Institute of Technology

- Joseph Sussman, Session Chair, "Transportation Infrastructure", *ILP/CEE Conference on Innovation in Infrastructure* MIT, Cambridge, MA, November 2015.
- Sam Levy (MST '15) presented work co-authored by A. Awadagin Faulkner (CEE undergraduate '16) and Professor Sussman "Best of the Best: Raising the Bar on Intercity Passenger Rail Performance."
- Application of Multicriteria, Multistakeholder Decision Analysis to Federal Transportation Performance Management Patton Doyle (MST '16) presented his ongoing Master's thesis research, which relates to the evaluation of HSR markets, as part of the Dwight David Eisenhower Transportation Fellowship Program Research Showcase.

Michigan Tech University

- Kalluri, S., Lautala, P., Handler, R., Comparative Life Cycle Assessment of Road and Multimodal Transportation Options – A Case Study of Copperwood Mine, Transportation Research Board 95th Annual Meeting of the National Academies, Washington, DC, January 12-16, 2016.

University of Kentucky

- Rose, J. and R. Souleyrette, “Asphalt Railway Trackbeds: Recent Designs, Applications and Performances”, Proceedings of the Annual AREMA Conference, Minneapolis, MN, October 2015, 18 pages.
- Stark, TD, Wilk, ST, Rose, JG, Moorhead, W., “Effect of Hand Tamping on Transition Trackbed Behavior, Proceedings of the Annual AREMA Conference, Minneapolis, MN, October 2015, 10 pages.
- Rose, J., B. Malloy, and R. Souleyrette. “Effect of Enhanced Trackbed Support on Railway/Highway At-Grade Crossing Performance.” Proceedings of the 95th Annual Meeting of TRB, Washington, DC, Jan. 2016. 18 pages.
- Blandford, Ben, T. Brock and R. Souleyrette. “Multi-Scalar Analysis of Transit-Oriented Development for New Start Commuter Rail.” Proceedings of the 95th Annual Meeting of TRB, Washington, DC, Jan. 2016. 14 pages.
- Wilk, ST, Stark, TD, Rose, J, “Non-Invasive Techniques for Measuring Vertical Transient Track Displacements”, Paper TRB 16-3636, Proceedings of the 95th Annual Meeting of Transportation Research Board, Washington, DC, January 2016 18 pages.

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

University of Illinois Urbana-Champaign

- The NURail Center website: <http://www.nurailcenter.org/index.php>

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>

e. Technologies or techniques:

Nothing to Report

f. Inventions, patent applications and/or licenses:

Nothing to Report

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

Massachusetts Institute of Technology

- Video: 1.011 content and philosophy. MIT, Cambridge, MA December 2015.

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)
Supply Chain Innovation Network of Chicago (SINC)	Chicago, IL	Gathering stakeholders, providing support	Debbie Halvorson, Frank Beal, Jim Blackmon, Adam Lomasney
UI Labs-City Digital	Chicago, IL	Exploring possible joint project	Adam Hecktman, Elliot Dam
CMAP - 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
Indiana Rail Road	Indianapolis, IN	In-Kind, Collaborative, Technical Assistance, Student Project Materials	Peter Ray, Justin Cronin
Wabash Valley Railroaders Museum	Terre Haute, In	Hands On Education Opportunities	Bill Foster
Student Project Materials	Peter Ray		
Masdar Institute of Science and Technology	Abu Dhabi, UAE	Funding for related research on HSR in Abu Dhabi	
Michigan Dept. 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
NS	Norfolk, VA	funding	NS Corporate Partnership
Nichols Foundation	Jacksonville, FL	funding	Gerald Nichols

UIUC	Urbana, IL	collaboration	Tim Stark
Univ. of Tennessee	Knoxville	collaboration	Baoshan Huang

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 Conference
8 individuals	Various	-----	REES Academic Content Committee
Dan Lau	Department of Electrical Engineering and Visualization Center, Univ. of Kentucky	Lexington	Time, technology and resources to the 3D rail crossing project
Jeremiah Dirnberger	CSX Transportation	Jacksonville FL	In-kind support of base case for yard simulations

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. Findings 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 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

- Soil: Project developed models which can be used to evaluate potential for settlement at track transitions.
- Off-Peak: Developed better understanding of off-peak delivery and the challenges involved in implementing a pilot program. Began to analyze other options to shift deliveries from peak to off-peak times. Helped attract UI Labs-City Digital to do a freight transportation demand management initiative, which could make it easier to achieve positive change.

Michigan Tech University

- Long-term goal of LCA/LCCA analysis is to develop a more data-based approach for DOTs to evaluate alternative project types, when their support for such development is requested.

University of Kentucky

- Crossing rating methodologies will allow highway agencies to better prioritize funds to improve performance and safety of crossings.

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

- Soil: Development of models which can be used to evaluate potential for settlement at track transitions.

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?

University of Illinois Chicago

- Soil: Graduated one MS and one PhD student.

Michigan Tech University

- Total of 45 civil engineering, surveying, electrical engineering, materials engineering and science students are involved in the Lake State Railway Project and two other undergraduate student projects.
- Two students are involved in the LCA/LCCA project.

University of Kentucky

- Principle impact is educating undergraduate/graduate students in civil engineering.

Rose-Hulman Institute of Technology

- Expectations for CE/EE/ME students to consider railroad engineering internships as well as 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 Norfolk Southern RR to donate track sections and rail truck.)

e. What is the impact on technology transfer?

University of Illinois Chicago

- Center for Urban Transportation Research (CUTR) webinar
- Urban Transportation Center (UTC) website

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.

Michigan Tech University

- LCA/LCCA type analysis are important aspects when minimizing the effects of future industrial/transportation

University of Kentucky

- Safety and economy of the general public is impacted.

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

- Off-Peak: No source of incentive funds has been found for the program therefore voluntary participation by receiving businesses is unlikely. Exploring other options to shift deliveries from peak to off-peak times:
 - a) favorable pricing by carriers for off-peak deliveries;
 - b) policy and regulatory actions;
 - c) developing a technology-assisted transportation demand initiative with UI Labs – City Digital and Microsoft.

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

University of Illinois Chicago

See 5a.

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.