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



National University Rail Center - NURail

USDOT OST-R Tier I University Transportation Center (UTC)

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1. Accomplishments

a. What are the major goals of the program?

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.

Numerous projects from this NURail grant have been completed while some professors and researchers are still spending their final funds. Because there is a smaller number of active projects there are fewer accomplishments, publications or other products that can be attributed to these expenditures.

b. What was accomplished under these goals?

University of Illinois Urbana-Champaign

- Final reports were written for these projects and are available online:
 - o Spacing and Length of Passing Sidings in the Incremental Capacity of Single Track
 - o Factors Affecting Commuter Rail Energy Efficiency
 - o Concrete Crosstie Fastener Sub-System Testing and Modeling
 - o Railroad Grade Crossing Micro-Level Safety and Risk Analysis
 - Development of a 3D FEM Model for Concrete Tie and Fastening Systems
 - o Causal Analysis of Passenger Train Accidents on Freight Rail Corridors
 - Shared Rail Corridor Adjacent Track Accident Risk Analysis
- Railroad Capacity and Optimization (Capacity): Completed additional research on distribution of delay between long and short trains on single-track lines. Developed new capacity screening tool approach for evaluation of railway capacity expansion projects.
 PhD student prepared draft preliminary dissertation document on these topics. Presented one conference paper and two conference presentations on these topics.
- Railway Maintenance Planning (Maintenance): Developing optimization model for aggregation of railway maintenance activities in extended work windows. PhD student completed preliminary document on these topics and passed preliminary examination. Presented one conference presentation on this topic.
- Hay Seminar Series: Hosted five on-campus seminars from industry experts that were also broadcast online. Total both online and in person attendees for the seminars was 618.
- Engineering Open House: Together with the UIUC AREMA Student Chapter, NURail sponsored railway engineering exhibits at the UIUC Engineering Open House event attended by 20,000 people, including over 12,000 primary and secondary students.
- Minority Student Outreach: At Engineering Open House in March, hosted 30 minority students from Springfield, IL nominated by their schools for interest in STEM topics.

University of Illinois Chicago

There were four original research projects within UIC-College of Urban Planning & Public Affairs (CUPPA):

- Three final reports were written:
 - o Rail Crossing Safety (Rail Safety)
 - o GIS Analysis of Environmental Impacts of Rail Development (GIS)
 - o Economic Impacts of Freight Mode Choice (Freight) projects.
- Final report being reviewed/edited for the Value Capture Coordination (VC) project.

Massachusetts Institute of Technology

Graduate student research team working on the NEC, CA HSR, Midwest HSR (Chicago to Urbana/Champaign) and the relation of HSR to urban transportation systems (case study of Penn Station and the Hudson River Tunnels in New York City).

- Group has weekly meetings at which the various members present their work.
- Participated in several outreach meetings on the NEC and made useful contributions to discussions based on NEC work.
- Two recent graduate students were presented with Charley V. Wootan Memorial Awards at the CUTC 95th TRB reception on January 9, 2016 for best theses in Policy and Planning.

Michigan Tech University

Completed three student projects:

- Improvements in Lake State Railway Saginaw Rail Yard included:
 - o a new weather shelter for locomotive wash and fueling activities.
 - o track improvements to support parking of unit trains up to 7,800 feet in length,
 - o drainage improvements throughout the yard,
 - o and site work in the surrounding community to accommodate the unit train concept. Project co-supported by Lake State Railway and MDOT.
- Investigated magnetic film as an alternative identification method to identify cracks in cutout rails (currently done by dye penetrant). Student team leader continuing development as a summer intern for the project co-supporter, CN Railway.
- Project to identify contaminated wheels at a hump yard before the retarders get contaminated. Students developed and tested laboratory methodology to measure coefficient of friction on a wheel. Project co-supported by Norfolk Southern Railway.

Education:

• CE 4407 Transportation Design class lectures replaced with video lectures and interactive classroom sessions consisting of competitions and example problems.

Outreach and Technology Transfer:

- Hosted industry speakers: Derek Yu from Alstom, Philip Pasterak from PB, Bradley Howard from NY Air Brake, Martita Mullen from CN, and Ken Filpus from MDOT.
- Dr, Pasi Lautala participated in breakfast panel discussion on the *Upper Peninsula Infrastructure Needs* for the Keweenaw Economic Development Association.
- Lautala, 4 graduate students and 4 undergrads participated in the 2016 Joint Rail Conference in Columbia, SC. All graduate students presented a technical paper and Sumanth Kalluri won best student technical paper with his paper "Toward Integrated Life Cycle assessment and Life Cycle Cost Analysis for Road and Multimodal Transportation Alternatives A Case Study of the Highland Copper Project"
- Dave Nelson led collaboration between RTP and Michigan Tech Civil Department at Construction Career Days event, attended by nearly 1,700 students from more than 50 Michigan high schools.

- Lautala and Hamed Pouryousef had a poster presentation at the World Congress for Railway Research in Milan, Italy
- Lautala made two presentations at the Global Level Crossing Safety & Trespass Prevention Symposium 2016 in Helsinki, Finland.

Computer Vision and Machine Learning Method for Detection and Assessment of Wheel Anomalies Using Sensor Fusion of Thermal and Visible Spectrum Cameras Project

- Project completed and final report submitted.
- Paper published in the Journal of Rail and Rapid Transit.

The Effects of Auditory Warnings and Driver Distraction on Rail Crossing Safety Project

- Project completed and MS Thesis submitted to the University.
- Results suggest auditory alerts designed and tested in the study improved visual scanning behaviors of pilot participants, as well as encouraged more compliant driving behavior on approach to RR crossings.
- Improved driver behavior remained after auditory warnings were removed.
- Overall, participants rated auditory warnings positively.
- Manuscript for journal publication is under development.

Integrated Life Cycle Assessment (LCA) and Life Cycle Cost Analysis of Multi Modal Freight Transportation Alternatives to Copperwood Project

- Completed LCA portion of project and submitted MS Report to the University.
- Continued research in LCCA methodologies, concentrating on better understanding of alternative funding programs by MDOT for transportation infrastructure projects.

Alloy Design and Testing of Austempered Ductile Iron for Rail Wheels Project

• Completed research work for project and developed draft final report.

Rail Embankment Stabilization for Cold Climate Railroads – Case of Hudson Bay Railway Project

- Completed research work and developed draft final report for Omnitrax, Inc. review.
- Submitted MS thesis to the University and submitted a paper.

University of Tennessee, Knoxville

- Continued analysis of Hybrid Composite Beams (HCB) data for use in final report.
- Reduced Coal Consumption team completed data collection and continued network model updates.
- Project reports (draft or final) were submitted for other projects.
- Conducted continuing education classes focused on railroad infrastructure. Preliminary results from HCB research incorporated into railroad bridge short course presented in May.

c. How have the results been disseminated?

NURail Consortium

NURail website continues to be updated and maintained. For the six-month period from

January – June 2016 the site averaged 26 new visitors each day. There are now 34 completed research final reports and 5 completed education final reports. A total of 39 research briefs are available on our website.

University of Illinois Urbana-Champaign

- Conference Presentations: Papers and presentations were delivered at:
 - o TRB Annual Meeting in Washington D.C. in January.
 - Joint Rail Conference in Columbia SC in March.
- Capacity:
 - One TRB paper from 2016 published in the Transportation Research Record journal, a second TRB paper from 2016 is currently in-press for the Transportation Research Record journal.
 - Made multiple presentations of NURail research on this topic at railway capacity workshops held at the University of Birmingham in the UK and KTH Royal Institute of Technology in Sweden.
- Seven final reports were written for projects and are available online.

University of Illinois Chicago

• Three completed final reports were submitted and are available online.

Massachusetts Institute of Technology

- Results disseminated through professional publications and presentations, as noted in section 2 below.
- Participated in several NEC public participation meetings
- Five new Masters theses: three MSTs, one ESD SM and one dual MST/MCP.
- Much of our work appears on the following website: http://web.mit.edu/hsrgroup/index.html

Michigan Tech University

Student Projects:

Final design presentations/posters/reports were conducted for the following undergraduate student projects. Outcomes of each project were also presented by selected students in the Joint Rail Conference 2016.

- "Saginaw Rail Yard Improvements", Civil and Environmental Engineering senior design project, spring semester (fifteen students in three teams)
- Canadian National Railway Cold Weather Defect Detection
- Railroad Car Wheel Contaminant Detection

Effects of Auditory Warnings and Driver Distraction on Rail Crossing Safety Project

- Submitted MS thesis
- Presented a paper in the Joint Rail Conference (JRC2016) in Columbia, SC.
- Presented research results in the Global Level Crossing Safety & Trespass Prevention Symposium 2016 in Helsinki, Finland.

Integrated Life Cycle Assessment (LCA) and Life Cycle Cost Analysis of Multi Modal Freight Transportation Alternatives to Copperwood Project

- Submitted MS Report.
- Presented a poster at the 2016 TRB Annual Meeting.

• Presented paper at the Joint Rail Conference 2016.

Computer Vision and Machine Learning Method for Detection and Assessment of Wheel Anomalies Using Sensor Fusion of Thermal and Visible Spectrum Cameras

 Submitted MS Thesis to the University and submitted a paper to AIMS Geosciences Journal.

d. What do you plan to do during the next reporting period to accomplish the goals?

University of Illinois Urbana-Champaign

- Capacity: Draft PhD dissertation and several journal papers on the impact of passenger train operation on freight train efficiency in shared corridors are under development. Completed dissertation anticipated late 2016, completing this project.
- Planning: Draft PhD dissertation and several journal papers on an optimization model for aggregation of railway maintenance activities in extended work windows are under development. Completed dissertation anticipated late 2016, completing this project.
- Outreach and Education: Hay Seminar Series: UIUC will host (and broadcast online) several oncampus seminars from industry experts during the Fall semester.
- The Railway Academic Conference (TRAC): Continue coordination and planning of TRAC event to be held on UIUC campus in July 2016. Event will bring railway academics and industry practitioners together to discuss current and future challenges related to workforce development, student recruiting and collaborative research for the railway industry. Will also serve as the 2016 Railway Engineering Education Symposium to train other university professors on railway engineering concepts and principles related to passenger service.

University of Illinois Chicago

• VC: Complete the final report and work to craft a new tech transfer plan for it.

Massachusetts Institute of Technology

- Current graduate students will continue on the project.
- Considering adding another graduate student and undergrad.

Michigan Tech University

All projects this grant have been completed or transferred to NURail, Tier-1 grant. Final
reports will be submitted on remaining projects and conference/journal publications will be
submitted on selected projects.

University of Tennessee, Knoxville

• Both active projects should be in the final report phase.

2. Products: What has the program produced

a. Publications, conference papers, and presentations

University of Illinois Urbana-Champaign

- Kippen, F.B. and C.T. Dick, 2016. Capacity of Single-Track Railway Lines with Short Sidings to Support Operation of Long Freight Trains. Presented at the 2016 Joint Rail Conference, Columbia, SC, April 2016.
- Lovett, A.H., C.T. Dick and C.P.L. Barkan, 2016. Evaluating Track Maintenance Aggregation in Extended Work Windows on Freight Railroad Lines. Presented at the 2016 Joint Rail Conference, Columbia, SC, April 2016.
- Shih, M-C, C.T. Dick and P-Y Liao. 2016. A Decision Support Screening Tool for Infrastructure Capacity Planning on Single-track Lines. Presented at the 2016 Joint Rail Conference, Columbia, SC, April 2016.
- Tang, H., C.T. Dick, B.M. Caughron, X. Feng and C.P.L. Barkan. 2016. A model for optimal selection of projects to improve running time and operating cost efficiency on passenger rail corridors. Accepted, Transportation Research Record: Journal of the Transportation Research Board.
- Bastos, J.C., M.S. Dersch, J.R. Edwards and B.O. Andrawes. 2016. Determination of the Influences of Deteriorated Track Conditions on Gauge Widening in Concrete Sleeper Track. In: 2016 World Congress on Railway Research, Milan, Italy, June 2016.
- Csenge, M.V., Y. Qian, M.S. Dersch and J.R. Edwards. 2016. Resilient Concrete Crosstie and Fastening System Designs for Light Rail, Heavy Rail, and Commuter Rail Transit Infrastructure. In: 2016 World Congress on Railway Research, Milan, Italy, June 2016.
- Ghosh, A., M.J. Greve, M.S. Dersch, J.R. Edwards and C.P.L. Barkan. 2016. Analyzing Rail Seat Load Distributions on Concrete Sleepers using Matrix Based Tactile Surface Sensors. In: 2016 World Congress on Railway Research, Milan, Italy, June 2016.
- 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: 2016 World Congress on Railway Research, Milan, Italy, June 2016.
- Wolf, H.E., J.R. Edwards, M.S. Dersch, Y. Qian and D.A. Lange. 2016. Field Measurement of Bending Moments in Prestressed Concrete Monoblock Sleepers. In: 2016 World Congress on Railway Research, Milan, Italy, June 2016.
- Ghosh, A., J.R. Edwards and M.S. Dersch. 2016. Effect of Design Rail Cant on Concrete Crosstie Rail Seat Pressure Distribution. In: *Proceedings of the 2016 Joint Rail Conference*, Columbia, SC, April 2016.
- Zhu, Z., J.R. Edwards, Y. Qian and B.O. Andrawes. 2016. Fatigue Analysis of Rail-Head-to-Web Fillet at Bolted Rail Joint under Various Impact Wheel Load Factors and Support Configurations. In: *Proceedings of the 2016 Joint Rail Conference*, Columbia, SC, April 2016.

Massachusetts Institute of Technology

- Levy, Sam, A. Awadagin Faulkner and Joseph Sussman. *Best of the Best: Raising the Bar on Intercity Passenger Rail Performance*. TRB 95th Annual Meeting in Washington DC January 11, 2016.
- Doyle, Patton. Presented Master's thesis research as part of the Dwight David Eisenhower Transportation Fellowship Program Research Showcase. TRB 95th Annual Meeting in Washington DC January 12, 2016.
- Moody, Joanna, Gabriel Goblet-Langlois, Lauren Alexander, Jonathan Campbell and Jinhua Zhao. *Travel Behavior Across Modes*. TRB 95th Annual Meeting in Washington DC, January 12, 2016.
- Heywood, Rebecca and Joseph Sussman. Managing New York's Penn Station: A Multiscale Approach. Poster presentation at the CESUN Symposium, June 2016, George Washington University.

Michigan Tech University

- Final NURail reports submitted for research projects: MTU-R01, R03&09, R05, and education projects MTU-E01, E02, E04.
- Final design reports for the undergraduate student projects:
 - o "Saginaw Rail Yard Improvements", Civil and Environmental Engineering senior design project, spring semester (fifteen students in three teams)
 - o Canadian National Railway Cold Weather Defect Detection
 - o Railroad Car Wheel Contaminant Detection

[Peer Reviewed Paper, Conference Proceedings, and Presentation]

- Kalluri, S., Lautala, P.; Comparative Life Cycle Assessment of Road and Multimodal Transportation Options A Case Study of Copperwood Project; Proceedings of the TRB 2016 Annual Meeting, Washington-DC, Jan. 2016
- 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
- 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

[Conference Proceedings, and Presentation]

 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 Presentation: abstract only]

- 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

b. Journal publications:

University of Illinois Urbana-Champaign

 Tang, H., C.T. Dick, B.M. Caughron, X. Feng and C.P.L. Barkan. 2016. A model for optimal selection of projects to improve running time and operating cost efficiency on passenger rail corridors. Accepted, Transportation Research Record: Journal of the Transportation Research Board.

- Van Dyk, B.J., J.R. Edwards, M.S. Dersch, C.J. Ruppert and C.P.L. Barkan. 2016.
 Evaluation of dynamic and impact wheel load factors and their application in design processes. Online, *Journal of Rail and Rapid Transit*. DOI:10.1177/0954409715619454.
- Zhu, K., J.R. Edwards, Y. Qian and B. Andrawes. 2016. Finite element analysis of the effects of bolt condition on bolted rail joint stresses. *Transportation Research Record: Journal of the Transportation Research Board*. 2545: 36–45. DOI: 10.3141/2545-05.
- Greve, M.J., M.S. Dersch, J.R. Edwards, C.P.L. Barkan, J. Mediavilla and B. Wilson. 2016.
 Effect of particle intrusion on rail seat load distributions on heavy haul freight railroads.
 Online, *International Journal of Rail Transportation*. DOI: 10.1080/23248378.2016.1157048.
- Wolf, H.E., Y. Qian, J.R. Edwards, M.S. Dersch and D.A. Lange. 2016. Temperature-induced curl behavior of prestressed concrete and its effect on railroad crossties. *Construction and Building Materials*. 115 (2016) 319–326.

Michigan Tech University

- Deilamsalehy, H. Havens, T., Lautala P., Medici, E., Davis, J., *An Automatic Method for Detecting Train Car Wheel Flat Spots and Hot Bearings Using Thermal Imagery*, Journal of Rail and Rapid Transit (2016) DOI: 10.1177/0954409716638703.
- Pouryousef, H., Lautala P., Watkins, D., *Development of hybrid optimization of train schedules model for N-track rail corridors*, Transportation Research Part C. (2016) 67:169-192, doi:10.1016/j.trc.2016.02.008.

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

Massachusetts Institute of Technology

Completed theses in June 2016:

- Ryota Yasutomi, M.S. Transportation, "An Examination on Viable Pricing Strategies for the Chuo Shinkansen Maglev in Japan".
- Rebecca Heywood, M.S. Transportation and Masters of City Planning, "Multiscale Regional Transportation Governance: Evaluating Cooperation and Decision making at New York Penn Station".
- Patton Doyle, M.S. Transportation, "Multicriteria Multistakeholder Decision Analysis: Applications to Transportation Planning".
- Tatsuya Doi, M.S. Engineering Systems, "Interaction of Lifecycle Properties in High Speed Rail System Operations".
- Joanna Moody, M.S. Transportation, "Development of a Predictive Coalition Building Analysis for Stakeholders of Sociotechnical Systems".

d. Other publications, conference papers and presentations:

Nothing to report.

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

University of Illinois Urbana-Champaign

• UIUC continues to update and maintain the NURail website as appropriate. For the six-

month period from January – June 2016 the site averaged 26 new visitors each day. There are now 34 completed research final reports and 5 completed education final reports. A total of 39 research briefs are available on our website.

Massachusetts Institute of Technology

• Much work appears on this website: http://web.mit.edu/hsrgroup/index.html

University of Illinois Chicago

• VC: Interim report continues to attract strong attention via UTC website with 501 unique views and a long average "dwell" time on the site.

f. Technologies or techniques:

Nothing to report.

g. Inventions, patent applications and/or licenses:

Nothing to report.

h. Other products:

Nothing to report.

3. Participants and Other Collaborating Organizations

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a. 1 at theis				
Organizatio n Name:	Location of the Organization:	Partner's Contribution to the Project:	Name (First and Last)	University
University of	Porto, Portugal	Contributions from	University of	University of
Porto	, 2	students visiting MIT	Porto	Porto
		Joint proposal to FCT in		
		Portugal		
IST	Lisbon, Portugal	Contributions from	IST	IST (University)
(University)		students visiting MIT	(University)	
		Joint proposal to FCT in		
		Portugal		
University of	Coimbra,	Contributions from	University of	University of
Coimbra	Portugal	students visiting MIT	Coimbra	Coimbra
		Joint proposal to FCT in		
		Portugal		
East Japan	Tokyo, Japan	Research sponsor;	East Japan	
Railway		sponsors graduate	Railway Co	
Company		students in residence		
Central	Tokyo, Japan	Sponsors graduate	Central Japan	
Japan		students in residence	Railway Co	
Railway Co				
Region 1	MIT, Cambridge,	Research sponsor	Region 1 UTC	

UTC	MA			
Pontificia	Buenos Aires,	Developing joint project	Prof. Roberto	Pontificia
Universidad	Argentina	with YPF, a major	Agosta	Universidad
Católica		energy provider based in		Católica, Buenos
Argentina		Argentina		Aires, Argentina
CN	Montreal, Quebec	Financial Support	Stephen	University of
			Schlickman	Illinois-Chicago
MDOT	Lansing, MI	Financial and	Tim Hoeffner,	MTU
		Collaborative	Nikkie Johnson	
Omnitrax	Colorado/Canada	Financial &	Ken	MTU
		Collaborative	Koff/Zachary	
			Vallos	
Lake State	Saginaw, MI	Project sponsor	John Rickoff	MTU
Railway	•	2 1		
Pathfinder	Byron Center, MI	Student mentoring/	Robert	MTU
Engineering	•	project review	Goodheart	
CN	Homewood, IL	Project Sponsor and	Gary McLean	MTU
		Guidance	-	
NS	Atlanta, GA	Project Sponsor and	Brian Sykes	MTU
		Guidance	•	

b. Additional collaborators

University of Illinois Chicago

• Staff from transit organizations and municipal authorities in Chicago, San Francisco, New York, and Washington, DC

Massachusetts Institute of Technology

• Brijesh Dixit, an Indian Railways technical staff member, visiting for one year as a Humphrey fellow.

4. Impact

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

University of Illinois Chicago

- VC: Could assist transit and rail capital planners in making more effective decisions concerning the use and development of value capture strategies for funding.
- Rail Safety: The issue of safety at rail crossings has not been studied in great detail for specific user groups such as pedestrians and bicyclists. This research project will continue the work started by the research team in the area of pedestrian safety at rail crossings and expand on it with additional data and analysis.
- GIS: Advance the existing environmental impact assessment of rail infrastructure and services by providing a system view of sustainability and one-stop database, so that life cycle impacts and the interactions among environmental, economic, social, and infrastructure systems can be incorporated in rail planning and management.

• Freight: Freight activities and economic outputs are intimately connected. A dearth of tools exist that can quantify the impacts of increase/decrease/shifts in freight activities. This project will strive to develop such a tool based on broad assumptions of General Equilibrium of the Economy.

Massachusetts Institute of Technology

• The issues being researched are inherently interdisciplinary in content and approach. While we advance the field of transportation, we do that in a context of a deeper understanding of regional economics, land use planning, engineering systems and other related fields.

b. What is the impact on other disciplines?

University of Illinois Chicago

- VC: Coordination mechanisms studied under this project will apply and be of use to economic developers, municipal stakeholders, and the private development community.
- Rail Safety: Issues of safety will likely lead to an impact on rail crossing design, safety 19 devices, signs, and markings. On a related note, the attitudes and behavior of the specific user groups will also be documented and extend the body of knowledge in these areas.
- GIS: Integrates safety, infrastructure, operations, planning, public transportation, and multimodal transportation into environmental impact assessment process.
- Freight: Tool can be used for federal and regional transportation planning.

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

University of Illinois Urbana-Champaign

• UIUC taught 5 rail courses in Spring 2016. Total enrollment: 115 undergraduate and graduate students including 16 online students. Many students will be pursuing careers in rail transportation. Classes have dual impact of motivating student interest in such careers and improving their capabilities once they enter the workforce.

University of Illinois Chicago

- Metra management training project will focus on developing current transportation employees into more effective managers.
- VC: Graduate students will continue to assist with research and case studies.
- Rail Safety: Educational tools that provide a better understanding about risks and impacts
 of safety at rail crossings will likely be developed and used in training of rail operators, and
 other stakeholders.
- GIS: Project supported two graduate research assistants; one is a minority female.
- Freight: Research will provide a case study of relationship between freight-related development project & regional economy that can be used as course material.

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

University of Illinois Chicago

- Program will help solidify research connections between internal groups at CUPPA and further develop CN Fellowship program.
- GIS: Integrated environmental database may allow users to specify rail facility or land area of interest, access data from multiple departments, and evaluate the multi-facet environmental impacts in one database. Research may help facilitate coordination among multiple departments in both rail system planning and operation processes.

e. What is the impact on technology transfer?

University of Illinois Chicago

- All projects will be in the public domain and available for use by the public sector and rail industry.
- f. What is the impact on society beyond science and technology?

University of Illinois Chicago

- Research into environmental, safety, and economic issues surrounding freight and passenger rail positively impact society by trying to advance equitable and safe ideas for rail network development.
- Freight: Findings from this study will influence public policy toward prioritizing various needs for public support for economic development/job creation initiatives, including intermodal terminal development.

Massachusetts Institute of Technology

• Research directly affects mobility, economic development and potentially environmental impact and global climate change, all vital critical contemporary issues. Economic growth, environmental protection and social equity will all be advanced if the results of this study – concerned with intercity rail access and its interface to urban transportation -- leads to implementation. Understanding how policies and decisions are made in both the private and public sector can advance "public knowledge attitudes, skills and abilities."

5. Changes/Problems

a. Changes in approach and reasons for change

University of Illinois Chicago

- Delay in final report of the Value Capture project is due to survey delays and has been a major impact. These issues have been resolved and the final report is near completion.
- 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.