U.S. Department of Transportation
Research and Innovative Technology Administration
University Transportation Center Grant Agreement

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Mod 1, 2, & 3
Mountain-Plains Consortium, North Dakota State University
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North Dakota State University
Upper Great Plains Transportation Institute
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Reporting Period End Date: March 31, 2019
Semi-Annual PPPR#11

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1. Accomplishments: What was done? What was learned?

a. What are the major goals of the program?

The overall objectives are to: (1) conduct basic and applied research, the products of which are judged by peers or other experts in the field of transportation to advance the body of knowledge in transportation; (2) offer an education program in transportation that includes multidisciplinary course work and participation in research; (3) conduct workforce development activities and programs to expand the workforce of transportation professionals; and (4) provide an ongoing program of technology transfer to make transportation research results available to potential users in a form that can be readily used. Other program goals are to select projects and activities using peer review principles and procedures and client input that: (1) address the Secretary's five strategic goals, and (2) leverage UTC funds with matching funds from state and local governments and private industry. The chief operational goals are to make important contributions to research and technology transfer in key areas related to the Secretary's goals of State of Good Repair, Safety, and Economic Competiveness, Environmental Sustainability, and Livable Communities while addressing critical issues of the region and stakeholder groups.

b. What was accomplished under these goals?

i. Project Selection

- Ninety research projects were selected from 2013 to present under this grant. Projects have been selected for the original grant, Modification 1, 2, and 3. The projects reflect substantial input and matching resources from state departments of transportation and MPOs in the region. Collectively, this set of projects addresses all five of the Secretary's strategic goals and several of USDOT's requested emphasis areas under State of Good Repair—e.g., (1) bridge condition monitoring, (2) locating critical infrastructure defects, (3) identifying tools to prevent and detect corrosion in transportation infrastructure, (4) analytical tools for infrastructure performance management, and (5) methods and criteria to measure performance of new materials and methods. MPC projects selected under this grant include; MPC-371,409, MPC-446 to MPC-532. A complete list of selected projects can be found in Appendix A – https://www.mountain-plains.org/resources/progress/downloads/2019-MPC-PPPR11-DTRT13-G-UTC38-Appendix-A.pdf

ii. Educational Accomplishments

The transportation and transportation-related courses offered during this reporting period are listed in Table 1, organized by major subject area. In some cases, courses with the same titles were offered at more than one MPC university.

Table 1: Transportation and Transportation-Related Courses Offered This Period

Major Subject Area	Course Title
Engineering & Design	1. CIVE 508 Bridge Engineering 2. CIVE 566 Intermediate Structure Analysis 3. CEE 216/216L Materials and Lab 4. CEE 282 Civil Engineering Computer-Aided Design 5. CEE 346/346L Geotechnical Engineering and Lab 6. CEE 353 Structural Theory 7. CEE 443 Matrix Structural Analysis 8. CEE 432 Hydraulic Engineering 9. CEE 455 Steel Design 10. CEE 436/536 Advanced Hydraulic Engineering 11. CEE 458/558 Design of Timber Structures 12. CEE 492/592 S01 Soil and Subgrade Stabilization

	13. CEE 755 Advanced Reinforced Concrete 14. CVEN 4602 Highway Engineering 15. CVEN 5602 Advanced Street & Highway Design 16. CVEN 5682 Pavement Design 17. URPL 3000 Planning the Built Environment 18. CVEEN 3520 Transportation Engineering 19. CVEEN 3510 Civil Engineering Materials 20. CVEEN 5500 Materials Sustainability 21. CVEEN 5510 Highway Design 22. CVEEN 5570 Pavement Design 23. CVEEN 5305 Introduction to Foundation Engineering 24. CVEEN 7310 Advanced Foundation Engineering 25. CVEEN 3310 Geotechnical Engineering 26. CVEEN 6310 Foundation Engineering 27. CVEEN 5220/6220 Concrete II 28. CVEEN 7260 Seismic Rehabilitation 29. CVEEN 5560/6560 Transportation Planning 30. CVEEN 7545 Traffic Network Modeling 31. CE 3500 Transportation Engineering 32. CE 3600 Soil Mechanics 33. CE 4510 Pavement Design 34. CE 5510 Pavement Design 35. CE 5660 Soils and Rock Slope Engineering 36. CE 4555 Geometric Design of Highways 37. CE 5555 Geometric Design of Highways 38. CE 4970 Design Squad Coop 39. CE 5585 Pavement Management System 40. CEE 2240 Engineering Surveying 41. CEE 3160 Civil Engineering Materials 42. CEE 5010 Matrix Analysis/Finite element 43. CEE 5070 Structural Steel Design 44. CEE 5350 Foundation Analysis and Design 45. CEE 6130 Structural Dynamics and Seismic Design 46. CEE 6930 Structural Design Loads 47. TL 715 Introduction to ERP 48. TL 725 ERP Configuration
Freight & Logistics	1. TRAN 4010 Introduction to Transportation Systems 2. TRAN 4330 Principles of Supply Chain: Management and Technologies 3. TRAN 4080 Transportation Law and Regulation: Domestic and International 4. CVEEN 6920 Optimization in Transportation 5. TL 711 Logistics Systems 6. TL 788 Research in Transportation and Logistics 7. TL 811 Modeling for Logistics Research 8. TL 733 Case Studies in Logistics 9. TL 721 International Logistics Management 10. TL 831 Modeling for Transportation and Logistics Decision Analysis
Planning & Environment	1. URPL 5050 Urban Development 2. URPL 6350 Form and Formation of Cities

	3. URPL 6355 Urban Redevelopment Strategies 4. URPL 6365 Parks and Public Spaces 5. URPL 6400 Community Development 6. URPL 6399 Introduction to Sustainable Urban Infrastructure 7. URPL 6410 Social Justice in Planning 8. URPL 6600 Regional Planning 9. TRAN 4710 Transportation Finance 10. TRAN 4020 Transportation Economics 11. TRAN 4060 Transportation Marketing and Sales Tools 12. TRAN 4330 Principles of Supply Chain Management and Technologies 13. CVEEN 3520 Transportation Engineering 14. CVEEN 5560 Transportation Planning 15. CVEEN 6560 Transportation Planning 16. CVEEN 7545 Traffic Network Modeling 17. CEE 4200 Engineering Economics 18. CEE 6930 Green Infrastructure 19. TL 754 Urban Transportation Systems Analysis 20. TL 782 Highway Planning and Logistics 21. TL 756 Transportation and Land Use Integration
Public Transportation	1. CVEN 5800 Transit Design 2. URPL 6560 Transit, Bicycle & Pedestrian Planning 3. TRAN 4080 Transportation Law and Regulation: Domestic and International 4. TRAN 4320 Transportation Management, Leadership, and Values 5. TRAN 4800 Analysis of Freight & Passenger Transportation Business Segments 6. TRAN 4840 Multimodal Passenger-Freight Transportation Systems 7. CVEEN 5560/6560 Transportation Planning 8. TL 786 Public Transportation 9. TL 757 Public Transportation II
Traffic & Operations	1. CEE 363 Highway and Traffic Engineering 2. CVEN 4612 Traffic Impact Assessment 3. CVEN 5612 Traffic Impact Assessment 4. CVEEN 3520 Transportation Engineering 5. CVEEN 7545 Traffic Network Modeling 6. CE 5700 Traffic Flow 7. CE 5540 Traffic Control 8. CEE 5220/6220 Traffic Engineering
Transportation Safety	1. CEE 691 S01 Transportation Analysis and Safety 2. CVEN 5611 Transportation Engineering Statistics 3. CVEN 5662 Transportation System Safety 4. CEE 5230/6230 Geometric Highway Design 5. CEE 5255 Transportation Safety 6. TL 789 Leadership, Ethics and Academic Conduct in Transportation
Transportation Systems	1. CIVE 303 Infrastructure and Transportation System 2. CVEN 5633 Sustainable Transportation Systems 3. URPL 6555 Transportation, Land Use, and the Environment

	4. TRAN 4010 Introduction to Transportation Systems 5. TRAN 4050 Intermodal Transportation Systems 6. TRAN 4850 International Transportation & Supply Chain Management Analysis 7. CVEEN 7545 Traffic Network Modeling 8. CEE 6210 Transportation Systems Analysis 9. TL 855 Geospatial Information Systems for Transportation 10. TL 757 Intelligent Transportation Solutions 11. TL 783 Transportation Systems II

Altogether, 113 transportation and transportation-related courses were offered this reporting period, for a total of 886 transportation courses offered since the beginning of this grant. In addition to the courses listed in Table 1, foundational courses in engineering materials, mechanics, structural analysis, and geotechnical engineering were offered at most MPC universities.

iii. Workforce Development Accomplishments: The following ninety-seven training events were provided for transportation professionals during this reporting period:

- ADA Ramp Design
- Asphalt Paving Maintenance 1 & 2
- Asphalt treatments
- ATSSA Certification & Flagger Certification (2)
- ATSSA Traffic Control (2) Technician & Supervisor
- Autonomous Truck Mounted Attenuator
- Autonomous Vehicle Strategies for Transportation Agencies
- Basics of a Good Road
- Blockchain in the Transportation Industry: Plain Talk and Progress
- Bridge Evaluation, Repair, Load Rating
- Building Trust & Respect
- Communicating with Diplomacy and Tact
- Concrete Manholes & Inlets: Design, Production & Installation
- Concrete Training
- Confined Space Training
- Cracking & Debonding of a Thin Reinforced Concrete Overlay
- Dewatering (Environmental Series
- Digital Signatures & E-Construction
- EDC Exchange
- Employee Motivation
- Evaluation of Asphalt Patching & Crack Sealing Methods & Best Practices Manual
- Fiber-Reinforced Concrete for Structure Components
- Optimization of Pavement Marking Performance
- Non-Destructive Testing of Concrete
- OSHA 10 - Workplace, Equipment and Jobsite Safety
- Pavement Preservation Peer Review (EDC-4)
- Pedestrian and Bicycle Safety
- Personnel & Equipment Detection on Construction Projects – Webinar
- Planning & Delivering Presentations
- Positive Motivation Equals Positive Performance
- Preventing Runovers & Backovers - On Site - City of Bismarck
- Ramsey County Bridge Demo - On Site - Devils Lake
- Regional Local Roads Conference
- Registered Storm Water Inspector
- Registered SWPPP Writer
- Retroreflectivity for Signs
- Road Safety & Temp Traffic Control - On Site - Burleigh County
- Roadway (2) Materials & Drainage
- Roundabouts - Operational Analysis & Lane Configuration
- Roundabouts - Single Lane High Speed
- Rumble Strips - Permanent & Temp Measures & State of Practice

- Fork Lift Certification
- Fraud Awareness
- Heavy Equipment Operation
- Heavy Equipment Safety Operations
- I Am a Leader - On-Site – Bismarck
- Implementation Guidance for Accelerated Bridge Construction in SD
- Interpersonal Competence - Enhance Teamwork
- Job Safety Analysis
- Knowing the Rules and Doing Your Homework
- Lean Mental Models and Problem Solving: Turning Organizational Deficiency to Efficiency
- Local Road Surface Selection Tool
- Mobile & Terrestrial LiDAR & Advancements in Mobile Imaging
- Motor Grader One on One Advanced Training - On Site (2) Bottineau & Burleigh County
- Motor Grader Training - One on One - On Site (6) Bottineau, Burke, Burleigh, Cavalier, Divide, and Grand Forks counties
- Rural Solutions for High Crash Locations – Webinar
- Safety 365 - On site - Emmons & Foster Counties
- Self-Consolidating Concrete for Prestressed Bridge Girders
- Signing 201 - On Site - Morton County Snow Fences
- Structural Fibers in Thin Concrete Overlays
- Temporary Measures during Construction (Environmental)
- The Art & Science of Communication
- Transcending Challenges with a Relentless Focus on Workplace Experience Innovation
- Truck Summit - On Site - Manning - Dunn County & Valley City - Barnes County
- Vampires at Work: Handling Difficult People and Conflict
- WDEA Roundtable Meeting - On Site – Watford City
- Wildlife & Roads Part 1
- Winter Road Maintenance
- Work Zone Training
- WYDOT Certification (3) Asphalt, Concrete & Aggregate

iv. Research Accomplishments

The following six peer reviewed final research reports were published during the reporting period from grant DTRT13-G-UTC38 and previous grants.

Project #	Title	Date	Report No.
MPC-455	Why Are Bike-Friendly Cities Safer for All Road Users?	Dec 2019	MPC-18-351
MPC-463	Rehabilitation Project Selection and Scheduling in Transportation Networks	Dec 2019	MPC-18-358
MPC-564	Quantifying the Range of Variability in the Flexural Strength of Fiber Reinforced Concrete using Monte Carlo Simulation	Dec 2019	MPC-18-371
MPC-510	Business and Commute Optimization System: Development and Denver-Based Case Study	Dec 2019	MPC-18-361
MPC-511	Mechanical Bar Splices for Accelerated Construction of Bridge Columns	Feb 2019	MPC-19-372

MPC-501	Development of Alternative Bridge Superstructures for South Dakota Local Roads	Feb 2019	MPC-19-373
MPC-557	Reassessing Child Pedestrian Mode Choice and Safety via Perceived Parental Rick	Mar 2019	MPC 19-375
MPC-514	Impacts of Ride sourcing on VMT, Parking Demand, Transportation Equity, and Travel Behavior	Mar 2019	MPC 19-379
MPC-503	Characterization of Crushed Base Materials in Wyoming	Mar 2019	MPC 19-378

c. How have the results been disseminated?
The research results are being disseminated in a variety of ways, including: (1) workshops and conferences, (2) videoconferences, (3) online modules, (4) presentations at conferences, (5) publications, (6) Internet-based dissemination including broadcast emails, website postings, and webinars, and (8) a variety of social media means to include Facebook, and Twitter posts.

d. What do you plan to do during the next reporting period to accomplish the goals/objectives?
All projects are on track to be completed and research results disseminated through technology transfer completed by the end of the grant period of September 30, 2019.

2. Products: What has the program produced?
Due to the length constraints of this document, a listing of publications, conference papers and presentations from MPC primary investigators have been consolidated into Appendix B. Other products are listed below.

- Publications, conference papers, and presentations, Appendix B – https://www.mountain-plains.org/resources/progress/downloads/2019-MPC-PPPR11-DTRT13-G-UTC38-Appendix-B.pdf
- Website(s) or other Internet site(s);
    - The MPC website is fully operational at: https://www.mountain-plains.org/
    - The MPC Center Director can be found at: https://www.mountain-plains.org/personnel/
    - **South Dakota State University**

    1. A webpage has been developed for the DT Bridge Rehabilitation project including the project sponsors, personnel, summary, work plan, publications, and main findings including photographs and videos. The webpage can be found at: https://sites.google.com/people.unr.edu/mostafa-tazarv/research/rehab-of-dt-bridges

    2. A webpage has been developed for the Bar Couplers project including the project sponsors, personnel, summary, work plan, publications, and main findings including photographs and videos. The webpage can be found at: https://sites.google.com/people.unr.edu/mostafa-tazarv/research/bar-couplers

    3. A webpage has been developed for the Load Rating of DT Bridges project including the project sponsors, personnel, summary, work plan, publications, and main findings including photographs and videos. The webpage can be found at: https://sites.google.com/people.unr.edu/mostafa-tazarv/research/load-rating-dt-bridges

- Technologies or techniques;
    - **North Dakota State University -** A crash reporting protocol was drafted to guide tribes that do enter reports into the state CRS system in a limited field, non PII approach. It was shared with the NDDOT. The NDDOT will refine it to incorporate changes in the CRS system and assure consistency with other, similar tribal reports entered previously.
    - **South Dakota State University -** A practical method of hydrograph generation for predicting bridge scour in cohesive soils using the SRICOS method was developed. The method utilizes a series of maximum annual floods sampled randomly from the Log Pearson Type III distribution.

A screening tool was also developed for identifying bridge sites where use of the SRICOS method is advisable or more appropriate than the traditional HEC-18 method.

- Inventions, patent applications, and/or licenses; and
  - Nothing to report at this time.
- Other products, such as data or databases, physical collections, audio or video products,
  - Nothing to report at this time.

3. Participants and Other Collaborating Organizations: Who has been involved?

a. What other organizations have been involved as partners?

As projects were selected and work plans completed the timing of match funding and the commitments of collaborators vary widely throughout the life of the grant. During this period, we had fifty-two committed collaborators, who provided different support such as financial, in-kind, equipment, supplies, software, or data support. In addition, many provide a direct link for collaboration of research, survey mechanisms, and project activities.

- Bay Area Transportation Commission, San Francisco, CA, in-kind support
- California State University, Fresno, CA, in-kind support
- CHARISM, Fargo, ND, in-kind support and outreach program
- City of Fort Collins, Fort Collins, CO, in-kind support
- City of Westminster, Westminster, CO, in-kind support
- Clemson University, Clemson, SC, facilities and in-kind support
- CMA-CGM Maritime, Inc., Washington, D.C., in-kind support
- Colorado Associate of Geotechnical Engineers, Denver, CO, in-kind support
- Colorado Dam Safety, Pueblo, CO, technical support
- Colorado Department of Transportation, Denver, CO, in-kind support
- Colorado Water Conservation Board, Denver, CO, financial support
- CoreBrace LLC, West Jordan, UT, in-kind support and collaborative research
- CTS Cement, Anaheim, CA, in-kind support
- Daktronics, Brookings, SD, in-kind and financial support
- Denver Regional Council of Governments, Denver, CO (in-kind support in the form of data)
- Engineering Department of Larimer County, CO, in-kind support
- Engineering R&D Center, US Army Corps of Engineers, facilities and in-kind support
- Forterra Structural Precast, Salt Lake City, UT, in-kind support
- Keolis Commuter Services, Boston, MA, in-kind support
- Mineta Transportation Institute, San Jose, CA, in-kind support
- MnROAD facility, Minnesota Department of Transportation, Monticello, MN, in-kind support and collaborative research
- Mountainland Association of Governments, Orem, UT, subject matter experts
- NDDOT Driver License Division, Bismarck, ND, in-kind support
- NDDOT Safety Division, Bismarck, ND, in-kind support
- North Central Regional Sun Grant Center, Brookings, SD, financial support
- North Dakota Department of Health, Bismarck, ND, in-kind support
- North Dakota Highway Patrol, Bismarck, ND, in-kind support
- Olympus Precast, Bluffdale, UT, in-kind support
- Owens Corning, USA, Seward, NE, in-kind support
- Port of Oakland, Oakland, CA, in-kind support
- RSG, Inc., Salt Lake City, UT, collaborative research
- San Joaquin Regional Transit District, San Joaquin County, CA, in-kind support

- SELECT Center, Logan, UT, collaborative research & in-kind support
- South Dakota Department of Transportation, Pierre, SD, field testing collaboration.
- South Dakota State University, Brookings, SD, in-kind support
- Spirit Lake Nation, Fort Totten, ND, subject matter experts
- Standing Rock Sioux Tribe, Standing Rock Reservation, ND & SD, subject matter experts
- University of Alabama, Tuscaloosa, AL, facilities and in-kind support
- University of Colorado Denver, Denver, CO, facilities and in-kind support
- University of New Mexico, Albuquerque, NM, personal exchanges
- University of Sydney, Sydney, Australia, in-kind use of facilities
- University of Texas at Austin, Austin, TX, facilities and in-kind support
- Urban Drainage and Flood Control District, Denver, CO, in-kind support
- Utah Department of Transportation, Salt Lake City, UT, financial support & subject-matter experts
- Wasatch Front Regional Council, Salt Lake City, UT, subject matter experts
- Wyoming Department of Transportation, Cheyenne, WY, facilities, financial support. & in-kind support
- Wyoming Safety Coalition, Worland, WY, in-kind support
- Wyoming Technology Transfer Center, Laramie, WY, collaborative research

Due to the life of this grant soon coming to a close, the list of collaborators provided match, in-kind, financial, equipment, or collaboration of research shows the strong federal, state, local, and private industry of MPC research.

b. What individuals have worked on the program?
The following are the principal investigators, faculty, administrators, and students participating in MPC research projects this period:

Fourteen principal investigators, faculty, and administrators are participating in MPC projects at **Colorado State University**: Rebecca Atadero, Suren Chen, Yanlin Guo, John W. van de Lindt, Gaofeng Jia, Jeffrey Niemann, Douglas Woolridge, Joseph Scalia, Chris Bareither, Aditi Bhaskar, Thomas Bradley, Paul Heyliger, Peter A. Nelson and Mehmet E. Ozbek. In addition, fourteen students are working on MPC research projects: Abdelrahman Abdallah, Yangyang Wu, Guangyang Hou, Kaisen Yao, Brandon Perry, Min Li, Douglas Woolridge, Zana Taher, Katie Knight, Constance Dayan, Qiling Zou, David Trinko, Aaron Rabinowitz, and Chao Jiang.

Eleven principal investigators, faculty, and administrators are participating in MPC projects at **North Dakota State University** are: Ying Huang, Pan Lu, Raj Bridgelall, Dinesh Katti, Kalpana Katti, Denver Tolliver, Kimberly Vachal, NeTia Bauman, Sharma Kshitij, Kenneth Davis and Laurel Benson. In addition, thirteen students are working on MPC project: Mu'ath Al-Tarawneh, Mohanad Alshandah, Xinyuan Yang, Xinyi Yang, Hafiz Usman Ahmed, Keshab Thapa, H M Nasrullah Faisal, Neeraj Dhingra, Amin Keramati, Xiaoyi Zhou, Leonard Chia, Bhavana Bhardwaj, and Bukola Bakare.

Four principal investigators, faculty, and administrators are participating in MPC projects at **South Dakota State University** are: Junwon Seo, Ahmad Ghadban, Nadim Wehbe, and Rouzbeh Ghabchi. In addition, seven students are working in MPC research projects: Euiseok Jeong, Ibin Amatya, Marco Paulo Pereira Castro, Maria Laura, Velazco Fasce, Prateek Rai, and Brian Kidd.

Eight principal investigators, faculty, and administrators are participating in MPC projects at the **University of Colorado Denver** are: Wesley Marshall, Bruce Janson, Moatassem Abdallah, Caroline Clevenger, Yail Jimmy Kim, Meng Li, Carolyn McAndrews, and Farnoush Banaei-Kashani. In addition, fourteen students are working on MPC research projects: Shahryar Monghasemi, Ahmed Ibrahim, Mallory Redmon, Shalini Mahanthege, Alayna

Truong, Ricardo Gonzalez, Brady Heath, Molly North, Ghazal Batouli, Nick Ferenchak, Nick Coppola, Yaneev Golomber, Shahryar Monghasemi, and Robert Fitzgerald.

One principal investigator, faculty, and administrator is participating in MPC projects at the **University of Denver**: Patrick Sherry. In addition, three students are working on MPC research projects: Sree Sinha, Emma Porter, and Jessica Mantia.

Nine principal investigators, faculty, and administrators are participating in MPC projects at the **University of Utah** are: Xiaoyue Cathy Liu, Chris P. Pantelides, Steven Bartlett, Evert Lawton, Pedro Romero, Chris Pantelides, Tiffany Hortin, Mark Bryant, and Xianfeng Terry Yang. In addition, twenty students are working on MPC research projects: Zhuo Chen, Nima Haghighi, Zhiyan Yi, Roghayeh Zoleikani, Dipendra Thapa, Ijan Dangol, Faramarz Safazadeh, Abu Sufian Mohammad Asib, Shuanli Bao, Swastik Pohkrel, Emad Ghodrati, Henrik Burns, Nadereh Adham, Kaden Harris, Ijan Dangol, Dipendra Thapa, Faramarz Safazadeh, Abi Sufian Mohammed Asib, Bahar Azin, and Qinzheng Wang.

Five principal investigators, faculty, and administrators are participating in MPC projects at the **University of Wyoming** are: Jennifer Tanner, Khaled Ksaibati, Promothes Saha, Er Yue, and Amirarsalan Mehrara Molan.. In addition, eleven students are working on MPC research projects: Md. Tarik Hossain, Fayez AlMutawa, Milhan Moomen, Mustaffa Raja, Mohammed Mahdi Rezapour Mashhadi, Waleed Aleadelat, Omar M. Albatayneh, Mutasem Alzoubaidi, Milhan Moomen, Sahima Nazneen, and Anas Alrejjal.

Nine principal investigators, faculty, and administrators are participating in MPC projects at **Utah State University** are: Ziqi Song, Patrick Singleton, Andrew Sorensen, Robert J. Thomas, John Rice, James Bay, Michelle Mekker, Marvin Halling, and Marc Maguire. In addition, fifteen students are working on MPC research projects: Zhaocai Liu, Prasanna Humagain, Ferdousy Runa, Kevin Brown, Michael Ruiz-Leon, Seth Thompson, Joshua Ward, Nicholas Markosian, Brad Davis, Pilaiwan Vaikasi, Ashikur Rahman, Zhcaocai Liu, Yi He, Pilaiwan Vikasi, and Jared McRory.

USDOT support through this grant, has allowed us to encourage and support 6sixty-one primary investigators and faculty, at eight Universities throughout Region 8. In addition, we have been able to support, mentor, and develop research skills and knowledge in transportation for ninety-seven students from the US and countries all around the world.

c. Have other collaborators or contacts been involved?

Nothing to report at this time.

4. Impact/ Expected Impacts: What is the impact of the program? How has it contributed to transportation education, research, and technology transfer?

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

MPC's research is having meaningful impacts on the body of knowledge and state of practice of: (1) bridge design and rehabilitation, (2) bridge planning and design in seismic- and flood-prone regions, (3) the longevity and cost-effectiveness of paved roads, (4) asset management and road maintenance, (5) highway and truck safety, (6) automated inspection/assessment of transportation infrastructure, (7) sustainability of transportation systems, and (8) traffic modeling.

Improved Bridge Designs and Rehabilitation Methods

MPC research is generating new, innovative, and cost-effective methods to rehabilitate existing bridges and design new bridge components. The outcomes of MPC-512 will aid state DOTs in effectively and economically determining the behavior of in-situ bridges through analysis of prestressed concrete bridge girders over extended

time periods, comparisons of measured versus predicted bridge prestress values, and evaluation of the accuracy of the current AASHTO LRFD methodology for predicting prestress losses. Substantial savings in initial costs and on-going bridge inspection and management expenses can be realized if more bridges are built with the proposed double composite steel design developed in MPC-508. The proposed testing method for bar couplers (from MPC-511) will unify the testing of mechanical bar splices and enable manufacturers to provide design parameters to bridge engineers. In MPC-516, an innovative debonding-control method for carbon fiber reinforced polymer (CFRP) strengthened concrete members is being developed (without the use of external anchorages) that will advance the state-of-the-art of bridge rehabilitation technologies. In MPC-478, measured temperature variations in prestressed concrete bridge girders are being compared with code-predicted temperature variations. Differences between the two sources are being quantified. These findings can be used by bridge engineers to predict short-term behavior at the serviceability state and more accurately forecast the future behavior of precast, prestressed concrete bridges. Using element-level bridge inspection data for management and preservation (as is being implemented in MPC-504) will enhance the effectiveness of routine inspections of transportation systems and enable engineers to extract critical information from varying types of data that are often encountered in real-world applications. The results of MPC-487 (Investigation of Cross Laminated Timber Bridge Decks as a Sustainable Solution for Repair of Deficient Rural Wood Bridges) will be immediately used by practitioners, as MPC researchers have been contacted by a state department of transportation regarding a wood bridge deck replacement project.

Bridge Planning and Design in Seismic- and Flood-Prone Regions

MPC research is delivering new information to improve the design and sustainability of bridges in flood-prone and seismic regions. In MPC-483, a bridge/traffic/earthquake interaction analysis approach is being introduced that could be applied to several types of bridges in the future, having broad-reaching effects on bridge seismic design. The soil liquefaction database being created in MPC-524 has the potential to reduce future earthquake hazards to transportation systems. The methods being developed to seismically retrofit bridge wall piers using fiber reinforced composites in MPC-526 will influence future seismic retrofit and repair methods of such piers. The models and concepts developed in MPC-461 will enhance bridge safety through better understanding of the potential risks of skewed and curved bridges subjected to earthquakes. New methods being developed in MPC-481 (Incorporating River Network Structure for Improved Hydrologic Design of Transportation Infrastructure) will yield more accurate estimates of streamflow, which should improve the safety of bridges and culverts. The reliability-based approach to analyzing flood-prone bridges developed in MPC-448 will enhance mobility and community safety in vulnerable areas with limited road access by optimizing bridge elevations within a network (as opposed to analyzing each bridge individually).

Improved Designs for Longevity and Cost-Effectiveness of Paved Roads

MPC research in pavement design, materials, soils, and engineering practices is extending the longevity of roads and enhancing the cost-effectiveness of capital investments. For example, new knowledge from MPC-529 regarding the performance of surface materials and the measurement of water-cement content in concrete is helping engineers make decisions about how to design longer lasting roads that will perform well for the full design period. Moreover, testing methods to determine the ductility of cemented pavement soils and shoring and cutoff materials derived from MPC-477 are giving pavement designers tools to increase the ductility of pavements using cemented-base materials. The results will be useful for the design of cutoff or retaining structures in construction applications, as well as dam and levee applications.

MPC research is supporting the implementation of advanced pavement design procedures in the region. For example, in MPC-471, design parameters were calibrated to allow the Wyoming Department of Transportation to implement the Mechanistic-Empirical Pavement Design Guide (MEPDG) for roadway design, construction, and rehabilitation of pavements. The project's findings have been incorporated into WYDOT's current MEPDG designs. The findings of another MPC project that characterized crushed bases in Wyoming (MPC-503) have been included in WYDOT's design practices as well. Moreover, the use of geogrid-reinforced pavement systems (being investigated in MPC-587) could provide longer road service life and reduced maintenance in the future. Findings from MPC-522 will help the asphalt industry and state DOT effectively select the asphalt tack coats and their application rates in order to improve pavements' durability.

The results of MPC-509 (Expansive Soil Mitigation for Transportation Earthworks by Polymer Amendment) provide guidance for engineers and DOTs on how commercial polymer-based treatment technologies should be appropriately deployed to mitigate the impact of expansive soils that reduce the life of transportation infrastructure. The impacts of this research on transportation earthworks will be particularly beneficial, allowing the appropriate use of new commercially available treatment technologies. Swelling clay research from MPC-506 will elucidate the key mechanisms that influence the shear strength of expansive (swelling) clays, which are responsible for significant damage to transportation infrastructure. The computational modeling work along with the understanding of key mechanisms, will help improve prediction capabilities of the strengths of swelling clays and contribute towards the more reliable design of transportation infrastructure in swelling clay areas. In general, construction costs will be reduced through increased efficiencies in soil compaction testing derived from MPC-497, which should minimize unnecessary over-compaction.

Asset Management and Road Maintenance

MPC research is helping transportation agencies implement advanced roadway asset management practices (especially for low-volume road networks and paved surfaces) and optimize project selection and investment needs. In MPC-494, a sampling method was designed to select roadway segments with multiple types of assets, representative of the level of maintenance of the full inventory, which will contribute to efficient maintenance practices in the future. Cost and life cycle analysis methods for barrier and drainage systems being developed in MPC-493 (Incorporating Maintenance Costs and Considerations into Highway Design Decisions) will guide future decisions by transportation agencies in the design and installation of these systems, offering the potential for reduced costs and improved efficiency. The optimization models developed for low-volume paved county roads in Colorado and Wyoming (in MPC-472) are providing agencies with tools to more effectively document their road funding needs. Because of MPC-486, transportation infrastructure specialists can implement snow-free surfaces for transportation uses in the future, where resources exist for hydronic radiant heat. MPC-463 (Rehabilitation Project Selection and Scheduling in Transportation Networks) provides transportation agencies with an integrated approach for selecting and scheduling maintenance and rehabilitation projects. Agencies can use the proposed modeling framework to choose a limited number of projects subject to budget constraints and determine the optimal sequence of implementing the selected projects simultaneously within a finite planning horizon.

Highway and Truck Safety

MPC research and technical outreach activities are improving highway safety and large truck operations on freeways. In addition, methods of reporting and analyzing crashes and better identifying the causes of large truck crashes are improving safety throughout the region. As described later, MPC's outreach efforts are targeting road safety improvements on Indian reservations and in tribal communities.

Methods developed in MPC-465 allow practitioners to assess the safety effectiveness of conversions of typical four-legged intersections to continuous flow intersections. Information on the safety performance of different left-turn phase indications being developed in MPC-495 is helpful in modeling future crash frequencies and the selection of left-turn phase indications by site and time of day. Despite their theoretical safety benefits, little research has been undertaken to quantify the safety impact of the diverging diamond interchange (DDI) using real-world crash data. The results from MPC-480 (one of the first studies in the nation to investigate the overall safety impact of DDIs) will be useful in evaluating DDI construction and retrofit projects. The research is expected to have broad impacts on the implementation of innovative interchange and intersection designs. In addition, MPC-482 (Coupled Numerical Simulation of Debris Flow-Soil-Structure Interactions for Flexible Barrier Mitigation Systems) will enhance engineers' abilities to design flexible ring-net barriers along transportation corridors.

Data mined in the Analysis of the Relationship of Roadside Inspections to Large Truck Crashes (MPC-475) will enhance knowledge of the factors that contribute to the severity of commercial truck crashes. Meanwhile, MPC-519 is examining the impacts of truck traffic on selected freeway segments along I-80 in WY, as well as mitigation strategies to minimize negative impacts, through analyses of operational and safety implications that result from the interactions between trucks and passenger vehicles. Since the start of the project, MPC has received additional funding from WYDOT for more research on I-80, where the high truck traffic levels require implementing countermeasures to enhance safety and operational characteristics. In addition, MPC-474 (Highway Safety Manual

Part D: Validation and Application in Wyoming) has helped WYDOT make a decision not to implement passing lanes on a two-lane two-way highway. http://www.trb.org/main/blurbs/178518.aspx. The findings of this report have been used to calibrate reliable Crash Modification Factors CMFs for other countermeasures.

Research on cell phone use provides policy makers, manufacturers, and marketers with insights on consumer attitudes toward automated vehicles; it can also inform them about how to change consumer attitudes toward the technology. A study on driving impairment due to cell phone use (MPC-525) shows that thinking and talking about emotions can affect driving performance; in addition, the study shows that unsafe driving is associated with limited awareness of careless driving. MPC's research has resulted in improved safety culture and fewer accidents and injuries among transportation organization employees, especially in commuter rail operations. Success in the form of the adoption of a standard instrument from MPC-532 as a standard operating tool for planning, prevention, and training has led to improvements in the organizational culture and specific practices and techniques employed by transportation safety professionals.

The tribal crash reporting concepts derived from MPC-518 are positively impacting the capacity for reporting by Indian Nations and improving decision making with respect to transportation safety and infrastructure improvements. As a result of MPC-454 (Regional Implementation of Tribal Transportation Safety Program), multiple low cost safety improvement reports have been prepared for many tribes in South Dakota, North Dakota, and Montana, supporting an on-going effort to implement a comprehensive roadway safety program on reservations throughout the region. In this work, the five-step methodology implemented on the Wind River Indian reservation is being applied on other reservations. Moreover, assistance is being given to tribes in developing strategic highway safety plans.

Sustainability of Transportation Systems

MPC research is identifying new practices to address the impacts of wildfires, road dust, and storm water runoff. The results from Year 1 of Post-Fire Ground Treatments for Protection of Critical Transportation Structures (MPC-447) will enhance disaster preparedness and the ability to respond to post-fire burned soils that need ground cover to mitigate erosion and runoff. Specifically, the findings will help decision makers determine quantities of straw mulch to apply to burned slopes. In addition, the development of mixed media filtration for storm water runoff treatment from MPC-498 will diminish the negative environmental impacts of transportation infrastructure and increase the sustainability of future transportation systems.

In MPC-451 (Assessing the Cost-Effectiveness of Wyoming's CMAQ Unpaved Road Dust Suppression Program), researchers have documented the impacts of dust on human health, crops, and livestock. Based on these findings and the models that have emerged from this study, software has been developed and passed to the WYDOT and FHWA to allocate CMAQ funding. In addition, the study has proven the cost effectiveness of chemical treatments in the state based on numerous before and after treatment dust measurements. MPC's research into electric vehicle power and charging systems holds the potential to dramatically improve air quality. For example, the dynamic wireless power transfer (DWPT) electric bus system being developed in MPC-513 is clean and sustainable and could be widely adopted in the near future. The modeling framework in this study provides practitioners with an effective tool to determine the optimal allocation of DWPT facilities, as well as the battery size of each bus line for a DWPT electric bus system. The principal investigators of MPC-510 have applied the commuting optimization research from the project to an existing business and identified better solutions that will reduce highway travel time, fuel consumption, and emissions.

Automating the Inspection/Assessment of Transportation Infrastructure

MPC research is implementing sensing technologies and other information systems to automate the inspection and assessments of highways, bridges, and railroad tracks. The methodologies developed in MPC-507 (Automating Inspection and Damage Assessment of Transportation Infrastructure with Photographic Imaging) will increase the productivity of engineers when inspecting and monitoring transportation structures and surfaces. MPC-462 is investigating the best means of combining LiDAR data sets from multiple collection efforts and sources. The ITS approach to monitoring railroad infrastructure (conceived in MPC-505) will enhance the efficiency of track condition monitoring and practitioners' understanding of track abnormalities through automated data collection

systems deployed hi-rail vehicles. The railroad industry is engaged in this project and is expecting to utilize the results immediately.

Traffic Modeling

MPC-479 will assist state DOTs and MPOs to better plan, design, and manage the impacts caused by truck traffic (such as congestion, infrastructure development, pavement deterioration, accident, air quality modeling, and safety issues) through new methods that make use of multi-class truck traffic assignment procedures. Moreover, the results will improve mobility of truck traffic along state and interstate highway systems. Applications of a Multi-Agent System with the Large-Scale Agent-Based Model for Freight Demand Modeling (MPC-458) will positively impact practice by identifying innovative simulation techniques for transportation planning.

b. What is the impact on other disciplines?

Colorado State University projects are expected to provide some new FEM models, new findings, new analytical approaches, design guidelines which may be transferred to the government, DOT and industry.

- MPC-447 — Post-Fire Ground Treatments for Protection of Critical Transportation Structures, Year 1The findings have the potential to change the applications rates of straw mulch to limit erosion of new soil slopes and post-burned soil slopes along transportation corridors.
- MPC-461 — Analytical Modeling for Progressive Failure Assessment of Curved and Skewed Highway Bridges Subjected to Seismic Hazards Some new analytical approach can be adopted by the community. Some findings about seismic risks can help people develop better bridge protection plan and strategy. Engineers can use the findings to guide their future bridge seismic design.
- MPC-482 — Coupled Numerical Simulation of Debris Flow-Soil-Structure Interactions for Flexible Barrier Mitigation Systems New finite element model can be used to assess flexible ring-net barriers.
- MPC-483 — Interaction Analysis of Girder Bridges and Traffic System Subjected to Earthquakes, Year 1 We expect that some entities may adopt the proposed method after it is published.
- MPC-486 — Sustainable Heated Pavements for Infrastructure Longevity, Safety and Economic Competiveness The work mainly served to validate design procedures that are in place for maintaining snow-free surfaces that had been developed using experience and practice. This places the use of radiant surfaces on a much more secure theoretical foundation.
- MPC-507 — Automating Inspection and Damage Assessment of Transportation Infrastructure with Photographic Imaging Any method that reduces the need for human contact would reduce costs and place those resources to where they would be most effective. By automating some inspection data collection, resources such as personnel could be optimized.
- MPC-508 — Experimental Evaluation of a New Double Composite System for Steel Bridges The results of the study is expected to impact CDOT practice substantially. Design and construction firms as well as contractors that work with CDOT will have to be familiar and accommodate this new structure type. As such new technology for fabrication and construction might need to be developed. In addition, the less need for inspection and management of these bridges will transfer not only in direct economic savings but also indirect savings since less disruption to traffic is expected.
- MPC-509 — Expansive Soil Mitigation for Transportation Earthworks by Polymer Amendment Results will be transferred to DOTs to help in the assessment of commercial polymer-based expansive soil mitigation technologies. Mechanisms learned from research should assist in refinement of commercial polymer-based expansive soil treatments.

North Dakota State University research will enable transfer of the results to entities in government or industry.

- The state-of-the-art design procedures lack the ability to correctly analyze and accurately predict the engineering response of swelling clays could be valuable to asset management for government and industry. It is estimated that the damage caused to the U.S infrastructure including transportation network caused by swelling clays is of the order of $13 billion annually. This research will provide insight into

molecular interactions-microstructure-property relationships for swelling clays that would lead to robust analysis procedures and accurate predictability of the behavior of swelling clays.

- The agent-based freight modeling can be adopted to the regional and micro-level modeling for the Metropolitan Planning Organizations (MPO). The roadside inspection data and crash analysis has the potential impact of the research has regulatory and operational use at a national level. States may also use the information in their own safety planning and programs.
- Regional and short line railroads may be especially interested in the easy-to-use tool for railroad track condition monitoring that is based on smartphone based sensor networks and algorithms for effective and efficient track condition monitoring.

South Dakota State University research will impact the field of engineering with new methods and practices.

- The SDDOT is conducting a pilot study (summer 2019) on the methods produced from the soil compaction study. If the new compaction testing methods developed under MPC-497 are verified, then the SDDOT (agency) will adopt new methods of compaction testing that will impact the field of construction management and scheduling.
- The low media filtration technology for storm water treatment, (MPC-498) could be used by local and federal agencies to reduce the contamination caused by storm water runoff. It is anticipated that the outcome of this study would impact the environmental and agricultural sciences.
- A digital brochure was developed under MPC-500 for use by DOTs, bridge owners, and bridge engineers to demonstrate procedures for joint rehabilitation in double tee bridges and a visual inspection method was developed under MPC-523 for load rating of double tee bridges. The outcomes of these two projects would benefit transportation planners in rural areas.

University of Wyoming conducts research that affects human life.

- The analysis conducted in MPC-451 Assessing the Cost-Effectiveness of Wyoming's CMAQ Unpaved Road Dust Suppression Program required conducting analysis on the impact of dust on human health, livestock production, as well as crops production. The findings of the report will help health professionals, livestock producers, and ranchers in quantifying the long term impact of dust on people, livestock, and crops close to gravel roads.
- The findings of MPC-472 Developing an Optimization Model for Managing County Paved Roads will help decision makers such as politicians, county commissioners, and county planners in identifying the funding needs for paved roads within their jurisdictions.
- MPC-473 Bicycle and Pedestrian Design for Rural Communities will provide help to city and county planners involved in assessing and designing pedestrians and bicycle facilities.

University of Utah research is multi-disciplined.

- MPC-542: Exploratory Modeling and Analysis for Automated Vehicles in Utah, explores the impact of AV in the state of Utah. Such impact is multi-dimensions, yet the project is mainly focused on examining the induced travel demand from currently mobility-challenged markets - youth and the elderly, and as a result, on the induced vehicle-miles-traveled (VMT). The research develops future year (year 2040) VMT estimates such as result of AV introduction (at various penetration levels) using travel demand modeling for the Wasatch Front region, which ties directly to the economic growth prediction and environmental impacts due to transportation.

Utah State University works with cities and industry on new techniques and practices.

- We have worked with Nibley City, Campbell's Scientific and Bridge Diagnostic with one of these projects. These are not startup companies but the development of the short term data acquisition is a new area for the Bridge Diagnostics and Campbell's. It has made us learn things about software needs as well as hardware needs. The Portland cement stabilized soil is one that could lead to changes in practices.

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

Colorado State University has developed a number of different analytical models, experimental procedure, simulation and test results will greatly help several fields, such as bridge engineering, geotechnical field on pavement, and hydrology of highways.

- MPC-447 — Post-Fire Ground Treatments for Protection of Critical Transportation Structures, Year 1Experimental procedure: Documented the validity of small-scale laboratory tests to assess post-fire erosion and runoff from slopes, which can help evaluate other potential post-fire ground treatments. Numerical model: Developed a numerical model that documents the effectiveness of ground cover to mitigate erosion. Fire science: Developed relationships that document the effectiveness of straw mulch as a post-fire ground treatment to limit erosion to pre-burn levels.
- MPC-448 — Reducing Flood Vulnerability of Communities with Limited Road Access by Optimizing Bridge Elevation, the combination of network approaches and reliability is common for maintenance and other optimization, but this is the first time the bridge heights we're optimized across a network and combined with a hydrodynamic model. It is envisioned that this will provide a foundation for further study.
- MPC-461 — Analytical Modeling for Progressive Failure Assessment of Curved and Skewed Highway Bridges Subjected to Seismic Hazards, some findings help people have better understand the mechanisms of seismic performance of curved and skewed bridge. People can have better approach to analyze seismic risks of skewed and curved bridges. People can enhance the understanding on structural dynamics field for bridges.
- MPC-481 — Incorporating River Network Structure for Improved Hydrologic Design of Transportation Infrastructure, the results have increased our understanding of how channel network structure and organization (via its classification) affects the production of stream flow hydrographs. It has also provided a modeling framework that includes those effects. It has documented the accuracy of the modeling method compared to other methods.
- MPC-482 — Coupled Numerical Simulation of Debris Flow-Soil-Structure Interactions for Flexible Barrier Mitigation Systems, document that a coupled numerical model can link impact forces from a debris flow on a flexible ring-net barrier. This was possible via a simplified block-load mechanism for the debris flow and a sophisticated ring-net.
- MPC-483 — Interaction Analysis of Girder Bridges and Traffic System Subjected to Earthquakes, introduce an analytical method of bridge seismic performance considering interactions with traffic; Provide some insights about the impacts of traffic, which can help the community to understand the nature.
- MPC-486 — Sustainable Heated Pavements for Infrastructure Longevity, Safety and Economic Competiveness, long term performance of heated concrete systems are very much unknown, and monitoring these locations for changes in performance, levels of snow-free maintenance, and actual effectiveness in practice are still being determined. Having these computational tools allows us to 1) predict levels of melting given the system configuration, 2) estimate the required energy inputs to maintain snow-free surfaces, and 3) provide a foundation of work on which these systems can be improved and extended to transportation surfaces.
- MPC-487 — Investigation of Cross Laminated Timber Bridge Decks as a Sustainable Solution for Repair of Deficient Rural Wood Bridges, the project was a preliminary experiment, so it is anticipated that there will be additional larger projects proposed by us and others to develop the body of science.
- MPC-507 — Automating Inspection and Damage Assessment of Transportation Infrastructure with Photographic Imaging, the addition of automated data collection would give a better view of how transportation systems degrade over time. It also allows for untrained personnel to assist with inspections that could then be analyzed separately.

- MPC-508 — Experimental Evaluation of a New Double Composite System for Steel Bridges, new bridge design and behavioral analysis will be introduced to the scientific community.
- MPC-509 — Expansive Soil Mitigation for Transportation Earthworks by Polymer Amendment, the results and findings from this study will increase the base of knowledge on the functionality of commercially available polymer treatment technologies for mitigation of expansive soils in Civil Engineering.

North Dakota State University transportation research has great effect on development of workforce analytical skills.

- The agent-based modeling was popularly adopted for social science and industrial engineering. However, due to the level of granularity and complexity, it has not been adopted in the transportation modeling. This research shows that the model can be applied in the process of transportation modeling and it guided the future researchers.
- The element-level bridge inspection data project is a machine learning application for in-deep understanding of how data could be extracted for information as needed for the transportation systems. The ITS approach to rail performance provides state of the knowledge regarding to inertial signaling data processing.
- The major outcome of this clay swelling research will be a multiscale computational framework for swelling clays to evaluate the mechanical response of swelling clay to external loading. The models incorporate the molecular scale clay-fluid interactions and the evolution of microstructure during swelling, the two critical factors that influence the mechanical properties of swelling clays. These simulation testbeds will provide insight into the key mechanisms that affect the mechanics of swelling clays during swelling. The innovative experiments and experimental techniques developed in this research would not only serve as model development and verification tools but also could lead to the introduction of new experimental techniques for swelling clays.
- Tying the truck road side inspection and crash data will benefit transportation safety professionals by improving their base knowledge on what and how contributing factors. The tribal crash reporting project reinforced previous explanations for tribes not participating in the state CRS. Researchers discovered that the crash reporting protocol was not well understood within most of the tribal communities. It also provided an improved understanding of the opportunities to improve tribal crash reporting within and outside of the state CRS.

South Dakota State University methods and techniques reach the South Dakota work force.

- Field compaction verification is currently evolving, especially for Departments of Transportation where large volumes of granular materials are used in transportation projects. The research outcomes serve as a pathway to future forms of compaction control, including intelligent compaction.
- Development of mixed media filtration for storm water runoff treatment will provide a new tool for storm water best management practices. Data on full-scale tests of newly developed bridge systems will be made available to the research and bridge engineering communities. Additionally, experimental data was collected during strength testing of two severely damaged double-tee girders extracted form an actual bridge. This kind of data is scarce in the literature. Furthermore, two aged double-tee bridges were field tested and data was collected. This was the first field testing of this kind of bridge in South Dakota. Flood hydrograph generation for predicting bridge scour in cohesive soils has provided a better understanding of the time development of pier and contraction scour in cohesive soils.

University of Colorado Denver, MPC projects have successfully added to the scientific body of knowledge on several transportation-related fronts, including: road safety, travel behavior, emerging mobility modes, road design, and advanced infrastructure composites. We expect these results to add to improve future research and add to the debate on the impact of, for examples, ride-hailing services such as Uber and Lyft or change the course of the debate on street trees in the urban clear zone.

University of Denver, research conducted has led to further validation and standardization of the an important measurement tool for assessing organizational culture and climate.

University of Utah, research will enhance traffic control and traffic safety instruction. In addition, the research is expected to enhance psychological science by increasing our knowledge of the dynamics of human performance. The research enhances scientific knowledge in pavement design, and concrete science. The research will also have an impact on geotechnical earthquake engineering and structural engineering.

University of Wyoming, research studies conducted will have lasting values. The bicycle/pedestrian study is unique since it applies to more rural areas. While the other studies will provide agencies with the tools to implement the most advanced techniques for building pavements.

Utah State University, body of knowledge that we are focusing with these projects primarily lies within the Civil Engineering discipline. Although, policy changes sometimes are required to go beyond just this area. Each project has contributed to areas where answers were not available and additional data needed to be collected. We do have three sub disciplines with these research projects. They are Transportation, Geotechnical and Structural.

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

Colorado State University, many research and training opportunities are provided by MPC projects to graduate students (both MS and PhD) at CSU. Some projects also offer opportunity to incorporate some research findings in undergraduate and graduate education.

- MPC-447 — Post-Fire Ground Treatments for Protection of Critical Transportation Structures, project has produced an MS student, who is now an engineering consultant with a geotechnical engineering firm, and a PhD student, who is now an Assistant Professor at Montana State University.
- MPC-461 — Analytical Modeling for Progressive Failure Assessment of Curved and Skewed Highway Bridges Subjected to Seismic Hazards, provide opportunities for graduate students to conduct bridge seismic research and develop skills for future bridge seismic design. Some findings will be incorporated into the bridge engineering course that the PI is teaching.
- MPC-481 — Incorporating River Network Structure for Improved Hydrologic Design of Transportation Infrastructure, project supported two Master of Science students who are expected to become active in the transportation workforce as hydrologists.
- MPC-482 — Coupled Numerical Simulation of Debris Flow-Soil-Structure Interactions for Flexible Barrier Mitigation Systems, project produced one MS student who is current an engineering consultant.
- MPC-483 — Interaction Analysis of Girder Bridges and Traffic System Subjected to Earthquakes, trained graduate students by having them involved in the research.
- MPC-486 — Sustainable Heated Pavements for Infrastructure Longevity, Safety and Economic Competiveness, provided the opportunity for retrofitting or adjusting existing systems to take advantage of these benefits.
- MPC-507 — Automating Inspection and Damage Assessment of Transportation Infrastructure with Photographic Imaging, primary impacts here would be in increased efficiency. More time could be spent where it is needed rather than spent doing time-intensive data collection on site.
- MPC-509 — Expansive Soil Mitigation for Transportation Earthworks by Polymer Amendment, project has supported an M.S. (now PhD) student in the Department of Civil and Environmental Engineering at Colorado State University. Through the research, this project provides valuable training in geotechnical engineering of expansive soils. This student is expected to become part of the transportation workforce as a geotechnical engineer.

North Dakota State University research impacts university resources. The element-level concept for bridge management have been partially adopted in the current courses, including Bridge Evaluations and Rehabilitation for providing opportunities for student learning in transportation systems. Two doctoral students are working on the swelling clays research project and portions of the research work conducted will go towards their dissertation. The students and PIs will present seminars at NDSU and present papers at meetings and conferences for wider dissemination of results to students, researchers and professionals. The students will also author journal and conference manuscripts. Research results will be incorporated in the advanced soil mechanics course in the department of civil and environmental engineering. Several students were involved in the freight ABM project for the last 4 years. The students had experiences in developing models using the agent-based simulation techniques, presentation at the national and international conferences, and writing a paper. The skills learning during the project will be utilized for the students to writer their own research articles and teach in the classrooms in the future. Graduate/undergraduate students are gaining experience in advanced data mining algorithm, gradient boosting modeling, introduced in the research provide knowledge and new modeling options for researcher in transportation safety and related disciplines with the large truck RSI crash project. The need for knowledge continuity regarding a tribe's crash reporting was evident. The tribal crash study showed a need for cross-training and/or succession planning with regard crash reporting by tribal governments. A crash reporting protocol was drafted to guide tribes that do enter reports into the state CRS system in a limited field, non PII approach.

South Dakota State University research impacts university resources.

- Compaction Testing of Granular Materials: Agency costs and construction cost savings realized from this research can be applied to other projects that may not otherwise have been funded, thus generating workforce. Development of Mixed Media Filtration for Storm Water Runoff Treatment: The results of this project can be used to train storm water engineers in transpiration regarding the use of media filtration for storm water management. This project will likely to increase the environmental awareness of the general transportation workforce.
- Rehabilitation of Longitudinal Joints in Double-Tee Bridge Girders: This project provided research opportunity for an MS student with extensive experimental study. The graduate student was then hired by a firm who performs large-scale testing of bridge components.
- Development of an Alternative to the Double Tee Bridge System: Two graduate research students had the opportunity to work on this project. Both gained invaluable experimental experience and both have been hired by large firms designing bridges and buildings.
- Mechanical Bar Splices for Accelerated Bridge Construction of Columns: One graduate research student had the opportunity to work on this project. He gained invaluable experimental experience and is currently perusing his PhD at the University of Akron in the area of transportation infrastructure.
- Development of a Guideline for Selection of Tack Coats in South Dakota: Two graduate students worked on this project. Both of them are trained and one of them has already joined the transportation workforce.
- Methodology for Load Rating Double-Tee Bridges: Two graduate research students had the opportunity to work on this project. Both gained invaluable experimental experience and one is graduate at this time and was hired by a firm to perform bridge load rating.
- Screening of South Dakota Asphalt Mixes for Moisture Damage using Conventional and Innovative Approaches: The study will advance the workforce development goal of the MPC through providing important experiential learning opportunity to graduate and undergraduate student research assistants (RAs), appointed on this project. Experience suggests that RAs are more likely to pursue career in transportation.
- Flood Hydrograph Generation for Predicting Bridge Scour in Cohesive Soils: One undergraduate student has conducted research on bridge scour. The student will start graduate study at South Dakota State University this summer and continue to work on this project and a related project sponsored by the MPC.

University of Colorado Denver, MPC projects have been instrumental in providing opportunities for several graduate students. They are all gaining experience in research methods, paper writing, and presenting as well

as developing new skills. This work has also provided them with the opportunity to attend conferences and interact with and share our work with other researchers and the broader transportation community.

University of Denver, research has contributed to workforce development by increasing the knowledge of transportation safety professionals. In turn, this should lead to improved performance in safety.

University of Utah, research effort is the support to graduate students as well as training in experimentation and data analysis. Undergraduates (including minority students) gained valuable research experience through their assistance with data collection. Presentations are expected to be delivered to engineers as part of organized events at the Utah Department of Transportation, while providing PDH to participants. New teaching modules will be developed in advanced transportation courses.

University of Wyoming, program provides unique opportunities for professionals to get training and certification in various areas such as materials certifications, pavement preservation, and work zone training. The cooperation between MPC and the Wyoming LTAP made this possible.

Utah State University, Portland cement project (MPC 477) has a female student that worked on it and she is pursuing a PhD. This is a significant contribution to the workforce development both in terms of degree as well as gender. We have had students on each of these projects that have graduated with their degrees. We have one that is hoping to get into the Army Corps of Engineers which would impact a lot of unique transportation projects.

e. What is the impact on technology transfer?

Researchers at South Dakota State University are making significant advances to improve the performance, reduce construction costs, and enhance safety of the transportation infrastructure in South Dakota and Transportation Region 8. They have evaluated and developed innovative testing methods, bridge systems, rehabilitation techniques, paving materials, and analytical models in the fields of bridge engineering, pavement, highway water runoff quality, and highway safety.

The University of Utah, research enhances traffic control and traffic safety. In addition, the research will impact psychological science by increasing our knowledge of the dynamics of human performance. The research enhances knowledge in asphalt pavement design, and concrete. The research will impact positively soil liquefaction principles and the seismic retrofit of bridge piers.

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

Nothing to report at this time.

5. Changes/Problems

Colorado State University

MPC-509 — Expansive Soil Mitigation for Transportation Earthworks by Polymer Amendment, project delayed to allow for development of representative testing equipment, and procurement of significantly larger masses of materials that were originally anticipated.

South Dakota State University

MPC-520 Financial Benefits of Proposed Access Management Treatments, project delayed significantly due to the original PIs departure and the current PIs initial unfamiliarity with the topic. However, this has now been rectified through an extensive literature review and interview process and project progress is being made, subject to data availability and gathering, which is now underway.

5a. Additional Information Regarding Products and Impacts: UTC's are encouraged to consider identifying program results by outputs, outcomes, or impacts and they should be linked to National goals expressed in the Secretary's Strategic Goals.

6. SPECIAL REPORTING REQUIREMENTS: None