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

Grant No. DTRT13-G-UTC38
Mod 1, 2, & 3
Mountain-Plains Consortium, North Dakota State University
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North Dakota State University
Upper Great Plains Transportation Institute
NDSU Dept. 2880, P.O. Box 6050, Fargo, ND 58108-6050

Grant period: October 1, 2013 – September 30, 2019

Reporting Period End Date: September 30, 2018
Semi-Annual PPPR#10

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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, 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 and modifications 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. Due to space constraints, Tables 1 through 5 (which list MPC's selected projects) are linked to the U.S. DOT Secretary's strategic goals, by category in Appendix E.

ii. Educational Accomplishments

The transportation and transportation-related courses offered during this rating period are listed in Table 6, organized by major subject area. In some cases, courses with the same titles were offered at more than one MPC university.

Table 6: Transportation and Transportation-Related Courses Offered This Period

Major Subject Area	Course Title
Engineering & Design	1. CIVE 507 Transportation Engineering
	2. CIVE 303 Infrastructure and Transportation System
	3. CEE 106/106L Elementary Surveying and Lab
	4. CEE 311 Structural Material Lab
	5. CEE 340/340L Geology and Lab
	6. CEE 443 Matrix Structural Analysis
	7. CEE 446/546 Advanced Geotechnical Engineering
	8. CEE 456 Concrete Theory and Design
	9. CEE 467/567 Transportation Engineering
	10. CEE 765 Pavement Design

	11. CVEN 4602 Highway Engineering
	12. CVEN 5602 Advanced Street & Highway Design
	13. CVEN 5682 Pavement Design
	14. URPL 3000 Planning the Built Environment
	15. CVEEN 1400 Computer-Aided Design
	16. CVEEN 2010 Statics
	17. CVEEN 2140 Strength of Materials
	18. CVEEN 3210 Structural Loads and Analysis
	19. CVEEN 3310 Geotechnical Engineering I
	20. CVEEN 3410 Hydraulics
	21. CVEEN 3510 Civil Engineering Materials
	22. CVEEN 4221 Concrete Design I
	23. CVEEN 4222 Steel Design I
	24. CVEEN 5210 Structural Analysis II
	25. CVEEN 5220 Concrete Design II
	26. CVEEN 5230 Steel Design II
	27. CVEEN 5240 Masonry/Timber Design
	28. CVEEN 5305 Introduction to Foundations
	29. CVEEN 5420 Open Channel Flow
	30. CVEEN 6250 Structural Dynamics
	31. CVEEN 6310 Foundation Engineering
	32. CVEEN 6340 Advanced Geotechnical Testing
	33. CVEEN 7250 Structural Earthquake Engineering
	34. CVEEN 7310 Advanced Foundation Engineering
	35. CE 2070 Surveying Engineering
	36. CE 3500 Transportation Engineering
	37. CE 3600 Soil Mechanics
	38. CE 4620 Soil & Rock Slope Engineering
	39. CE 5590 Pavement Materials
	40. CE 5660 Soil & Rock Slope Engineering
	41. CEE 3080 Design of Reinforced Concrete
	42. CEE 5100 Infrastructure Renewal
	43. CEE 5190 GIS Civil Engineers
	44. CEE 6040 Structural Reliability
	45. CEE 3020 Structural Analysis
	46. CEE 5100 Infrastructure Evaluation and Renewal
Freight & Logistics	47. TRAN 4010 Introduction to Transportation Systems
	48. TRAN 4330 Principles of Supply Chain: Management and Technologies
	49. TRAN 4080 Transportation Law and Regulation: Domestic and International
	50. CVEEN 2300 Engineering Economics
Planning & Environment	51. URPL 5050 Urban Development
	52. URPL 6350 Form and Formation of Cities
	53. URPL 6355 Urban Redevelopment Strategies
	54. URPL 6365 Parks and Public Spaces

	55. URPL 6400 Community Development
	56. URPL 6399 Introduction to Sustainable Urban Infrastructure
	57. URPL 6410 Social Justice in Planning
	58. URPL 6600 Regional Planning
	59. TRAN 4710 Transportation Finance (Module 1 of 2)
	60. TRAN 4020 Transportation Economics (Module 2 of 2)
	61. TRAN 4060 Transportation Marketing and Sales Tools
	62. TRAN 4330 Principles of Supply Chain: Management and Technologies
	63. CVEEN 3100 Technical Communication for Engineers
	64. CVEEN 3610 Environmental Engineering I
	65. CVEEN 5410 Hydrology
	66. CVEEN 5500 Sustainable Materials
	67. CVEEN 5560 Transportation Planning
	68. CVEEN 5605 Treatment Design
	69. CVEEN 5610 Water Chemistry and Laboratory Analysis
	70. CVEEN 6470 Surface Water Quality Prediction
	71. CVEEN 6600 Solid Hazard Waste Engineering
	72. CVEEN 6920 Groundwater Hydrology
	73. CVEEN 7430 Advanced Subsurface Modeling
	74. CVEEN 7460 Hydroinformatics
	75. CVEEN 7660 Water Reuse
	76. CVEEN 7920 Environmental Processes
	77. CVEEN 7410 Flood Modeling
Public Transportation	78. CVEN 5800 Transit Design
	79. URPL 6560 Transit, Bicycle & Pedestrian Planning
	80. TRAN 4080 Transportation Law and Regulation: Domestic and International
	81. TRAN 4320 Transportation Management, Leadership, and Values
	82. CVEEN 1000 Introduction to Civil and Environmental Engineering
	83. CVEEN 5710 Cost Estimating/Proposal Writing
	84. CVEEN 5720 Project Scheduling
	85. CVEEN 5830 Project Management/Contract Administration
Traffic & Operations	86. CIVE 507 Transportation Engineering
	87. CVEN 4612 Traffic Impact Assessment
	88. CVEN 5612 Traffic Impact Assessment
	89. CVEEN 5110 GIS in Civil Engineering
	90. CVEEN 6530 Quantitative Methods for Transportation Operations
	91. CVEEN 7545 Transportation Modeling
	92. CE 5575 Intelligent Transportation System
	93. CEE 3210 Intro to Transportation Engineering
Transportation Safety	94. CVEN 5611 Transportation Engineering Statistics
	95. CVEEN 5510 Highway Design
	96. CVEEN 5570 Pavement Design
	97. CVEEN 7920 Infrastructure Sensing and Health Monitoring

	98. CEE 6250 Transport Safety
	99. CEE 5930 Transportation Data/Safety
Transportation Systems	100. CIVE 303 Infrastructure and Transportation System
	101. CVEN 5633 Sustainable Transportation Systems
	102. URPL 6555 Transportation, Land Use, and the Environment
	103. TRAN 4010 Introduction to Transportation Systems
	104. TRAN 4050 Intermodal Transportation Systems
	105. CVEEN 2310 Probability/Statistics
	106. CVEEN 3520 Transportation Engineering
	107. CVEEN 6790 Advanced Computer Aided Construction

Altogether, 107 transportation and transportation-related courses have been offered this reporting period, for a total of 773 total transportation courses offered this grant period. In addition to the courses listed in Table 6, foundational courses in engineering materials, mechanics, structural analysis, and geotechnical engineering were offered at most MPC universities.

iii. Workforce Development Accomplishments: The 97 training events listed below were provided for transportation professionals during this reporting period. Multiple training sessions are annotated by ( ) and the appropriate number of sessions.

- Accelerated Bridge Construction
- Air Conditioning Maintenance For Shop Personnel
- Asphalt Pavement Mgmt. – Roadway Fatigue & Treatments
- ATSSA Flagger Certification
- ATSSA Traffic Control Design Specialist
- ATSSA Traffic Control Supervisor
- ATSSA Traffic Control Technician (2)
- Autonomous, Connected Vehicles & Smart Highways – Technology and Policy Implications
- Backing Safety & Blind Spot Awareness
- Bridge 101 - Onsite in Grand Forks, Williams Counties (2)
- Bridge Paint Inspection
- Bridge Preservation by Design - Consideration of Zinc Coated Rebar
- Bridge Preservation: Development of a Cost-Effective Concrete Bridge Deck Preservation Program
- Chain Saw Operation & Safety
- Chainsaw Basics - Onsite in Burleigh County
- Chainsaw Basics - Onsite Field Training in Burleigh County
- Coaching and Counseling
- Construction Project Mgmt/Contract Admin
- Construction Site SWPPP Compliance, Tools, Tricks, & Tips (2)
- Corrugated Steel Pipe
- Diverging Diamonds
- Down with Stress!
- Drilled Shaft Foundations
- e-Construction Roundtable
- Enhanced Culvert Inspections Best Practices: MnDOT Guidebook
- Ethics (Engineering & Business)
- Glue for Gravel Roads - Onsite in Wells, Ransom, McKenzie Counties (3)
- Guardrail Selection, Installation, Maintenance & End Treatments
- HDPE/PP Pipe
- Heavy Equipment
- Heavy Equip. Operation (Hands On)
- Heavy Equipment Operations
- Heavy Equipment Preventative Maintenance
- High Strength Bolt Installation
- Hot-In-Place Recycling - Onsite in Valley City
- Human Factors - Road User Needs, Capabilities & Limitations
- Hydraulic Systems on Maintenance Equipment

- Improving Gravel Roads -- Understanding Design Criteria
- Intelligent Compaction
- Intelligent Work Zones
- Introduction to Highway Lighting
- Legal Aspects of Traffic Control on Highway Work Zones (Tort Liability)
- Maxwell: 17 Indisputable Laws of Teamwork
- Maxwell: Put Your Dreams to the Test
- Mechanically Stabilized EarthWall Construction Inspection
- MnRoad - Research that Pays
- Motor Grader Training - Onsite in Cass, Dunn, Sheridan, Stark, Stustsmam, Ward, West Fargo, Williams Counties (8)
- MPC Research: A Comprehensive Safety Analysis of Diverging Diamond Interchanges
- MPC Research: Cell Phone Use Diminishes Self-Awareness of the Adverse Effects of Cell Phone Use on Driving
- Nature Tales: Clues to Help in Roadway Design & Maintenance
- Navigating the Landscape of Conflict
- ND Asphalt Conference
- OSHA - Workplace, Equipment and Jobsite Safety
- OSHA 10-hr
- Pavement Striping
- PE Exam Preparation (2)
- Personal Protective Equipment
- Pile Driving Operations for Inspectors
- Pipe Repair & Lining Strategies
- Polyvinyl Chloride (PVC) Pipe
- Presenting with Impact
- Prof Communication in Today's Electronic Workplace
- Registered Stormwater Inspector
- Reinforced Concrete Pipe
- Roundabouts -- State of the Practice
- Sheet Piling and Cofferdam Design
- Smart Work Zones
- Snow Fences
- Street Sweeper
- Succession Planning for All Managers
- Technical Writing
- The Power of Positive Language
- Tier IV Regeneration & Diesel Exhaust Fluid for Mechanics
- Tractor Mower Safety
- Trenching Safety & Confined Spaces
- Ultra High Performance Concrete
- Ultra Violet Cured in Place Lining
- Uncovering Leadership Blind Spots
- Welding 101
- Workzone and Flaggers ATSSA certification
- WYDOT Aggregate Certification
- WYDOT Asphalt Certification
- WYDOT Concrete Certification
- Wyoming Transportation and Safety Congress

iv. Research Accomplishments

The following eighteen 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-452	Calibration of the Highway Safety Manual's Safety Performance Functions for Rural Two-Lane Highways with Regional Considerations for the Rocky Mountains and Plain Regions	Mar 2018	MPC-18-344
MPC-446	A Modified Approach for Predicting Fracture of Steel Components Under Combined Large Inelastic Axial and Shear Strain Cycles	Apr 2018	MPC-18-345
MPC-466	First and Last Mile Assessment for Transit Systems	May 2018	MPC-18-347

MPC-491	A Self-Centering Buckling Restrained Braces for Curved Bridges	May 2018	MPC-18-348
MPC-494	Statistical Analysis and Sampling Standards for Maintenance Management Quality Assurance	Jun 2018	MPC-18-350
MPC-469	Improving Efficiency and Reliability of Bus Rapid Transit	Jun 2018	MPC-18-349
MPC-527	Strategic Planning and Design for Electric Bus Systems	Jul 2018	MPC-18-355
MPC-449	Methodology for Uncertainty-Based Inspection Planning of Concrete Bridge Decks Using Mechanistic Models of Crack Formation and Propagation	Jul 2018	MPC-18-346
MPC-378	MEMS Sensors for Transportation Structures	Jul 2018	MPC-18-343
MPC-478	Long-Term Behavior of Precast Concrete Bridges	Jul 2018	MPC-18-352
MPC-492	Early-Age Fiber-Reinforced Concrete Properties for Overlays	Jul 2018	MPC-18-353
MPC-480	A Comprehensive Safety Assessment Methodology for Innovative Geometric Designs	Jul 2018	MPC-18-357
MPC-513	Optimal Deployment of Wireless Charging Facilities for an Electric Bus System	Aug 2018	MPC-18-359
MPC-499	Reuse of Aqueous Waste Streams in Transportation Related Applications	Sep 2018	MPC-18-363
MPC-305	Reuse of Aqueous Waste Streams in Transportation Related Applications	Sep 2018	MPC-18-364
MPC-357	Railroad Investment in Track Infrastructure	Sep 2018	MPC-18-365
MPC-414	Quantifying Sustainability Metrics for Trunk Line Bridges in the Mountain Plains Region	Sep 2018	MPC-18-360
MPC-476	Highway-Rail Grade Crossing Traffic Hazard Forecasting Model	Sep 2018	MPC-18-354

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 (7) 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 conferences and workshops; publications; conference papers; and presentations from MPC primary investigators have been consolidated into Appendix A through D.

- **a. Conferences and Workshops** can be found in Appendix A
- **b. Publications** can be found in Appendix B
- **c. Conference Papers** can be found in Appendix C
- **d. Presentations** can be found in Appendix D

e. What else has been reported during this rating period?

- 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/
- An MPC technology transfer plan was submitted and accepted
- Two Colorado State University students defended their graduate degrees:
    - Moden, K. (2018). Laboratory Evaluation of a Post-Fire Ground Treatment to Mitigate Soil Erosion and Runoff, MS Thesis.
    - Peterson, K. (2018). Slope Erodibility Analyses on Reinforced Soil Surfaces Under Hydraulic Loading Using the Discrete Element Method, PhD Dissertation.
- CSU researchers explored photogrammetry using cell-phone cameras to measure the swelling of expansive soils and the shrinkage limit of clays. This work is being prepared for a technical publication in the Geotechnical Testing Journal.
- A webpage has been developed for project MPC-500 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
- A webpage has been developed for project MPC-501 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/alternative-to-dt-bridges
- A webpage has been developed for project MPC-511 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
- A webpage has been developed for project MPC-523 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.
- A master's thesis was completed by R. Achariya at South Dakota State University entitled "Evaluation of the Moisture-Induced Damage Potential of Asphalt Mixes and Asphalt Binder-Aggregate Systems." An acknowledgement of federal support was made.
- By extending the MATSIM transport simulator, University of Colorado Denver has developed a transport simulator that can be used to evaluate system-optimal route planning solutions.
- UCD researchers have developed two families of solutions for efficient system-optimal route planning at city-scale based on "approximation" and "parallelization."

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 varied widely throughout the life of the grant. During this period, we had sixty-five committed collaborators, who provided different support such as financial, in-kind, equipment, supplies, software, or data support. In addition, many collaborators provide direct links for collaboration in research, survey mechanisms, and project activities.

- AAA Foundation for Traffic Safety, Washington, DC, financial support
- Ajou University, Suwon, South Korea, in-kind support
- Bay Area Transportation Commission, San Francisco, CA, in-kind consultation, consultation on workforce development activities
- California State Fresno, Fresno, CA, collaborate in the research

- Campbell County Road and Bridge Department, Gillette, WY, collaborate in the research
- Campbell Scientific, Bridge Diagnostic Inc. (BDI), Logan, UT, sensors, data acquisition, programming of the software, and equipment (weather tower)
- Campbell's Scientific, Logan, UT, data loggers and sensors
- City of Brookings, SD, collaborative research
- City of Watertown, Watertown, SD, collaborative research
- CMA-CGM Maritime, Inc., Washington, DC, in-kind consultation, survey completion
- Colorado Associate of Geotechnical Engineers, Denver, CO, provided materials (soil) and recommendations for representative testing conditions
- Colorado Department of Transportation, Denver, CO, collaborate in the research data, financial, input of research topics
- Converse County Road and Bridge Department, Douglas, WY, collaborate in the research
- Crook County Road and Bridge Department, Sundance, WY, collaborate in the research
- Digital Glove Foundation, Longmont, CO, in-kind sharing of data
- East Dakota Water Development District, Brookings, SD, financial support
- Fehr & Peers, Salt Lake City, UT, collaborative research
- FHWA, Wyoming Division, Cheyenne, WY, feedback and instructions for the study
- Geneva Rock, Salt Lake City, UT, provided concrete for building the walls
- Headed Reinforcement Corporation, Fountain Valley, CA, in-kind support in terms of headed steel bars for the seismic retrofit
- Headed Reinforcement Corporation, Fountain Valley, CA, provided the headed steel bars for the seismic retrofit
- Indian Highway Safety Program, BIA, Albuquerque, NM, SME contribution
- James River Water Development District, Huron, SD, financial support
- Keolis Commuter Services, Boston, MA, in-kind consultation, survey completion
- Lincoln County Road and Bridge Department, Kemmerer, WY, collaborate in the research
- Mandan Hidatsa Arikara Nation, Fort Berthold Reservation, ND, SME contribution
- Mineta Transportation Institute, San Jose, CA, in-kind consultation, consultation on workforce development activities
- Missouri Department of Transportation, Columbia, MO, advising on damaged transportation structures
- National Renewable Energy Laboratory, Golden, CO, use of facilities, equipment, and data
- NDDOT Safety Division, Bismarck, ND, in-kind crash data contribution
- New Jersey City University, Jersey City, NJ, in-kind support
- Nibley City, Nibley, UT, Provided access to the bridge and permanent electricity that we can use.
- North Carolina Pedestrian and Bicycle Information Center, Chapel Hill, NC, collaborate in the research
- Northern Plains TTAP (No longer active), Bismarck, ND, SME contribution
- Pacific Earthquake Engineering Research Center, University of California at Berkeley, Berkeley, CA, collaborate in research
- Port of Oakland, Oakland, CA, in-kind consultation, survey completion
- Sika Corporation USA, Lyndhurst, NJ, in-kind support in terms of the carbon fiber reinforced polymer for the seismic retrofit
- Sisseton Wahpeton Oyate Reservation, Agency Village, SD, collaborate in the research
- South Dakota Department of Environment and Natural Resources, Pierre, SD, collaborative research
- South Dakota Department of Transportation, Pierre, SD, financial support
- South Dakota State University, Brookings, SD, in-kind support

- Spirit Lake Nation, Fort Totten, ND, SME contribution
- Standing Rock Sioux Tribe Indian Reservation, Fort Yates, ND, collaborate in the research
- Standing Rock Sioux Tribe, Standing Rock Reservation, ND & SD, SME contribution
- StarSeismic LLC, Park City, UT, financial support and construction guidance
- Structural Technologies Inc., Columbia, MD, provided matching support and composite materials
- Teton County Road and Bridge Department, Jackson, WY, collaborate in the research
- University of California at Los Angeles, Los Angeles, CA, supplying data basing support
- University of Colorado Boulder, Boulder, CO, collaborate in the research
- University of Nebraska-Lincoln, Lincoln, NE, collaborate in the research
- University of Utah, Salt Lake City, UT, financial support through student salary and equipment purchase
- USDA Forest Service, Fort Collins, CO, land access for sampling
- Utah Department of Transportation, Salt Lake City, UT, financial support
- Utah Department of Transportation, Taylorsville, UT, financial support
- Utah Transit Authority, Salt Lake City, UT, financial support
- Wasatch Front Regional Council, Salt Lake City, UT, technical advisory committee
- Wyoming Department of Transportation, Cheyenne, WY, data, financial, materials and supplies that include: crushed base aggregates, equipment for resilient modulus experiments, standard properties of these crushed base aggregates, and AASHTOWare software which all include support of research
- Wyoming Technology Transfer Center, Laramie, WY, collaborate in the research
- Yankton Sioux Tribe, Wagner, SD, collaborate in the research

The above list of collaborators provided match—either in-kind, financial, or equipment. Their collaboration in research shows strong federal, state, local, and private industry support of MPC research.

b. What individuals have worked on the program?

Following are the principal investigators, faculty, administrators, and students participating in MPC research projects this period:

For **Colorado State University** eleven principal investigators, faculty, and administrators are participating in MPC projects: Mehmet Ozbek, Suren Chen, Jeffrey D. Niemann, Scott Glick, Paul Heyliger, Rebecca Atadero, Christopher Bareither, Hussam Mahmoud, Bolivar Senior, John W. van de Lindt, and Joseph Scalia. In addition, sixteen students are working on MPC research projects: Huajie Wen, Kirsten Peterson, Kayla Moden, David Turner, Luke Chen, Guangyang Hou, Almotasem Maamon, Kelsey Czyzyk, Aliena Debelak, Luke Chen, Karly Rager, Aura-Lee, Trai Nguyen, Xin Huang, Mehrdad Memari and Zana Taher.

Nine principal investigators, faculty, and administrators are participating in MPC projects at **North Dakota State University** are: Eunsu Lee, Kimberly Vachal, Raj Bridgelall, Brenda Lantz, Pan Lu, Denver Tolliver, Zhibin Lin, Dinesh Katti, and Kalpana Katti. In addition, eleven students are working on MPC project: Ali Rahim Talegani, Zijian Zheng, Mingli Li, Xingyu Wang, Leonard Chia, Bhavana Bhardwaj, Neeraj Dhingra, Keshab Thapa, H M Nasrullah Faisal, Erik Johnson and Bukola Bukare.

Ten principal investigators, faculty, and administrators are participating in MPC projects at **South Dakota State University** are: Nadim I. Wehbe, Allen L. Jones, Christopher Schmit, Kyungnan Min, Mostafa Tazarv, Rouzbeh Ghabchi, Michael Pawlovich, Ilgin Guler, Junwon Seo and Francis Ting. In addition, sixteen students are working in MPC research projects: Jason Weber, Ghaem Hooshyari, Peng Dai, Jason Neville, Gregory Hansen, Lucas Bohn, Michael Mingo, Zachary Carnahan, Puskar Kumar Dahal, Thomas

Cook, Samundra Thapa, Buddhika Prasad, Chamika Prashan Dharmarathna, Sandip Rimal, Rajan Acharya and Chamika Prashan Dharmarathna.

Ten principal investigators, faculty, and administrators are participating in MPC projects at the **University of Colorado Denver** are: Wesley Marshall, Bruce Janson, Austin Troy, Matthew Cross, Moatassem Abdallah, Caroline M. Clevenger, Mehmet E. Ozbek, Carolyn McAndrews, Yail Jimmy Kim and Farnoush Banaei-Kashani. In addition, twelve students are working on MPC research projects: Nick Ferenchak, Aaron Johnson, Nick Coppola, Yaneev Golombek, Shahryar Monghasemi, Duygu Kalan, Alejandro Henao, Justin Shapiro, Ibrahim Bumadian, Ahmed Ibrahim, Robert Fitzgerald and Zohreh Raghebi.

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: Madeline Bremer, Sree Sinha and Emma Porter.

Thirteen principal investigators, faculty, and administrators are participating in MPC projects at the **University of Utah** are: Chris Pantelides, Milan Zlatkovic, Tiffany Hortin, Richard J. Porter, David Sanbonmatsu, David Strayer, Joel Cooper, Pedro Romero, Xiaoyue Cathy Liu, Amanda Bordelon, Juan Medina, Steven Bartlett and Ran Wei. In addition, twenty-nine students are working on MPC research projects: Jem Locquaio, Jeff Taylor, Kiavash Fayyaz, Mingde Lin, Arwen Behrends, Zhenghui Yu, Joseph Herkimer, Kyle Strayer, Sean Strayer, Donald Godfrey, Jeffrey Orrego, Shuanli Bao, Yu Song, Catalina Arboleda, Linkun Li, Anurag Upadhyay, Ruoyang Wu, Min Ook Kim, M. Scott Shea, Fahmid Hossain, Faramarz Safazadeh, Massoud Hosseinali, Taylor Adams, Bhaskar Kunwar, McEntee Vanessa, Yi Ou, Zhuo Chen, Jafar Allahham and Avinash Rishi.

Eight principal investigators, faculty, and administrators are participating in MPC projects at the **University of Wyoming** are: Khaled Ksaibati, Bart Evans, Mohamed Ahmed, Rhonda Young, Dennis Trusty, Kam Ng, Promothes Saha, and Milan Zlatkovic. In addition, fourteen students are working on MPC research projects: Waleed Al Eadelat, Nikolai Greer, Sandeep Thapa, Trenna Terrell, Sahima Nazneen, Melake Brhanemeskel, Marwan Hafez, Nicole Peterson, Sherif Gaweesh, Rachael Larson, Irfan Ahmed, Dawit Mebrahtom, Muhammad Tahmidul Haq and Andalib Shams.

Six principal investigators, faculty, and administrators are participating in MPC projects at **Utah State University** are: Anthony Chen, Jim Bay, John Rice, Paul Barr, Marv Halling and Ziqi Song. In addition, nine students are working on MPC research projects: Yi He, Zhaocai Liu, Jen Ostrowski, Phillip Powelson, Ethan Pickett, Hossein Nasr-Isfahani, Holly Llyod, James Broderick and Justin Pace.

USDOT's support throughout this grant period has allowed us to encourage and support sixty-five primary investigators and faculty at eight Universities in Region 8. In addition, we have been able to support, mentor, and develop research skills and knowledge in transportation for 110 students from the U.S. and countries around the world.

c. Have other collaborators or contacts been involved?

At **South Dakota State University,** two primary investigators have left for other universities: Vikash Gayah and Guanghui Hua.

4. Impact/ Expected Impacts

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

Colorado State University's projects have proposed a modified approach to advance current techniques in fracture prediction of steel components and established a novel risk-based inspection and management technology for current bridges. These advances will help build safer and more sustainable transportation

infrastructures. Recent research findings from new explorations into data mining and sensor technology in railroad transportation at **North Dakota State University** offer opportunities for improved incident prediction and preventative countermeasures to improve railroad safety.

Research at **South Dakota State University** has enabled the development of new methods and technologies to extend the life of existing bridges on local roads, design fully precast new bridge systems for accelerated bridge construction on local roads, select the best suitable technique for compaction testing of granular material, mitigate environmental damage from harmful highway stormwater runoff, recycle dairy processing byproducts for use as deicing agents on highways, generate databases of rebar couplers for use in bridge columns for accelerated bridge construction, develop software for optimizing access management, increase the durability of asphalt pavements, enhance the reliability and efficiency of bridge ratings for loads, and develop decision tools for enhanced predictions of bridge scour. The impact of SDSU's research on bridge engineering for local roads will extend the life of existing bridges, improve the design and planning processes needed for accelerated bridge construction, and enhance the reliability and efficiency of bridge load ratings. The overall effects are to increase the knowledge, efficiencies, and communications among practicing engineers.

The **University of Colorado Denver's** projects have provided the Civil Engineering discipline with new approaches for proactively assessing pedestrian and bicyclist safety and estimating the vehicle-miles of travel (VMT) impact of ride-hailing services, and have changed the narrative about the impact of street trees on safety in urban areas. These projects have been innovative and impactful in terms of the research itself and the positive impacts on workforce development. UCD's students are simultaneously gaining expertise in transportation engineering and broader experiences and skills.

The **University of Denver** continues its efforts to develop and validate a measure of corporate safety culture for the transportation industry. The current instrument (developed through MPC research) shows promise of being a useful measure of corporate culture, with some additional refinement and scale reconstruction. Results of the on-going study have demonstrated the validity of the measurement instrument, in that there is a relationship between scores and safety outcome indices such as the number of reported injuries, number of reported accidents, and number of reported near misses. The results strongly suggest that the risks of accidents decrease significantly when members of an organization perceive senior leaders as having high levels of commitment to safety. According to the University of Denver's research, the odds of having and or reporting an accident are five times more likely if there is a perception that senior members do not have a strong commitment to safety. Near miss reporting has become much more prevalent over the past 10 years. The impact of University of Denver's study shows that perceived senior management and immediate or front-line supervisory commitment to safety contribute to a reduction in reported near misses.

Research carried out at the **University of Utah** will enable engineers and transportation professionals to compute transit station accessibility based on publicly available open datasets. This tool can be used by transit agencies to evaluate their network performance. A sampling technique for asset sampling will assist state, region, and station levels in maintenance budget allocations. Optimal deployment strategies for electric bus systems have been developed to achieve specified planning goals. In addition, a software tool has been created to assist transit engineers. Analytical models were developed for the design of new bridges with self-centering buckling restrained braces to improve seismic resilience and reparability. Finally, experiments were carried out to determine the hardened properties of fiber-reinforced concrete using two different synthetic fiber types and three different fiber contents.

A significant number of publications have resulted from the various research studies being conducted at the **University of Wyoming**. These publications are advancing the knowledge and the ability of transportation professionals in the U.S. and globally. Specific mitigation strategies were developed for WYDOT, the trucking industry, and Wyoming Highway Patrol to reduce truck crashes on highways.

The impact that MPC research at **Utah State University** has had on the program and students has been significant. The primary disciplines impacted have been Civil Engineering (Transportation, Structural and Geotechnical) and Electrical Engineering (Electric Vehicles). The work done by USU faculty outside of the classroom is brought into the class through examples and stories. This helps students receive state-of-the-art knowledge concerning the work that is being done. This directly impacts the students. It enhances their education. The most valuable outcome of the research is that it allows students to think of things outside of the code, which facilitates critical thinking of why things are done the way they are in design and practice.

b. What is the impact on other disciplines?

Research at **Colorado State University** has improved the state-of-the-art of several engineering disciplines other than traditional transportation and structural focuses, such as material engineering, hydrology/hydraulics engineering and construction management by contributing to advanced optimization algorithms and data analysis techniques.

South Dakota State University researchers have worked closely with the mechanical bar splices manufacturing industry on the development of unified testing methods for identifying design parameters for different bar splicing systems. Additionally, SDSU researchers have demonstrated the financial and environmental benefits of transforming aqueous waste streams from food and beverage processing into pavement de-icing agents. Through their outreach and research efforts, SDSU faculty are continually working with other disciplines and industry professionals.

Research carried out at the **University of Utah** has impacted the following disciplines: (a) psychological science by increasing their knowledge of the dynamics of human performance from research on cellphone use and driver performance; (b) mechanical engineering by developing formulations for fiber reinforced polymers used in the repair of concrete wall piers; (c) electrical engineering by developing a strategic plan for optimal design of electric bus systems – also by measuring dielectric constants using electromagnetic permittivity to develop an in-situ water-cement meter for concrete; (d) geography by expanding geographic information systems (GIS) using data from mobile devices regarding maintenance management quality assurance – also using Lidar topographical surveys and remote sensing techniques such as synthetic aperture and interferometric synthetic aperture radar; (e) health science by developing photo-catalytic coatings for concrete surfaces to mitigate harmful air polluting chemicals; and (f) statistical methods by determining sampling frequency, number of samples, and resampling to ensure maintenance quality.

University of Colorado Denver has strived for a more multi-disciplinary approach and has been successful in integrating with both the Urban and Regional Planning and Computer Science departments. These collaborations bring innovative techniques and a broader mindset to transportation research questions. In the collaboration between Engineering and Computer Science, for instance, big data are being harnessed by applying data science techniques to transportation data.

At **Utah State University,** Civil Engineering has collaborated with Electrical Engineering and the Select Center on the advancement of electrical vehicles. The collaborative research has impacted the engineering department through the advancement of new skills and knowledge of electric vehicles. A conference on Sustainable Electrified Transportation Center 2018 is being co-sponsored at the Annual Meeting and Technology Showcase to discuss collaboration and advancement with academia and industry professionals in this area. The conference information can be found at: https://conference.usu.edu/selectshowcase/.

The University of Denver's research impacts other disciplines in the areas of Psychology, Organizational Behavior and Business with respect to the topics of organizational culture, leadership and fatigue. For example, one of the more popular undergraduate minors is the Pioneer Leadership Program and the Executive Education program. Findings and results from this study will inform educators in those programs as they instruct their students in adopting best practices for leadership development and enhancing organizational culture.

The MPC center at **North Dakota State University** has reached out to the Civil Engineering, Mechanical Engineering, Computer Science, and Psychology departments and the College of Business, promoting collaboration among these groups. The MPC program has fostered a stronger transportation presence on campus and encouraged multi-department research projects.

At the **University of Wyoming**, new initiatives in connected vehicles technologies and advancements in ITS technologies have resulted in utilizing faculty members from other disciplines to participate in MPC research work. As an example, faculty members and researchers from the electrical engineering department are now part of MPC's research teams developing advanced transportation technologies. In addition, faculty members from mechanical engineering are helping in the reduction of data collected with advanced imaging techniques to evaluate dust in gravel roads. Faculty members from the psychology department are helping identify human factors in transportation research. Through these efforts, the MPC program is increasing the knowledge and promoting collaboration among many disciplines at the University of Wyoming.

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

Research projects at **Colorado State University** have provided extensive training opportunities by offering graduate research assistantships for students working on transportation studies. Some of the findings from these projects have been incorporated into several transportation courses, such as CIVE507 Transportation Engineering and CIVE 303 Infrastructure and Transportation System, and some seminars to train the next generation of engineers. These research and education opportunities are made available to a wide range of different students, including some female and underrepresented groups in the transportation work force. Finally, the presentations made at professional conferences by CSU PIs help disseminate the newest findings and advances to transportation practitioners and future engineers, thus strengthening the skills of the transportation work force.

At **North Dakota State University,** students currently learn and practice advanced analytical skills, modeling, research methods and processes of implementation. They also develop technology transfer skills and experiences which strengthen their abilities to disseminate and put research results into practice. A goal of the MPC program is to mentor and develop students to be productive transportation professionals out in society in private industry, academia, and federal, local, or state entities. NDSU has an active Association of Transportation and Logistics student organization. The students have expressed interest in working with students from other MPC universities. The leadership development and communication opportunities in the ATL are a capacity-building resource for the future researchers in the field.

At **South Dakota State University,** 16 students were trained on conducting research in transportation-related fields. Techniques and methods have been further developed for effective use of resources to construct and maintain transportation infrastructure. Research findings have been incorporated into the educational material for undergraduate students, thus strengthening the work force of tomorrow.

MPC projects at the **University of Colorado Denver** have been instrumental in providing opportunities for several graduate students. They are 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. They will be our transportation professionals in the future.

Research carried out at the **University of Utah** involves undergraduate and graduate research assistants. Many of the research activities encourage undergraduate students to seek internships and full employment with the Utah and other State DOTs. Graduate students are sought after for their skills by local and national consulting firms, as well as by government agencies. A few University of Utah doctoral students go on to become professors at other universities in transportation-related disciplines. The Department of Civil and Environmental Engineering at the University of Utah hosts an annual week-long transportation camp targeted to students in grades 8 to 10. This past summer, it involved 17 students from different schools around the Salt Lake City school district.

Promoting a safe transportation system is the ultimate goal of research at the **University of Denver**. A measurement tool developed by University of Denver enables managers to track their progress towards a safer culture. Providing the information and the tools derived from this research effort to persons in the workforce will contribute to a safer workforce and ultimately a safer public.

A significant number of workshops at the **University of Wyoming** have been cosponsored by MPC and the Wyoming LTAP. Techniques developed in the gravel roads area are being taught in the class room for students interested in pursuing careers in the transportation area. These techniques involve not only the identification of the conditions of gravel roads but the optimization of the limited resources available for maintaining and rehabilitating gravel roads.

Utah State University offers a more comprehensive curriculum now in transportation and is finding that more and more students are selecting this area of study. Getting more students into transportation courses makes a direct impact on the workforce. More students from USU are graduating with backgrounds in Transportation Engineering. USU’s efforts are increasing the number of graduate students in this field that are selected for federal, state, and local transportation jobs.

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

Projects at **Colorado State University** are helping better utilize advanced computational and experimental facilities at CSU. The usage of these facilities as a result of MPC projects helps keep the facilities running in a sustainable way. Presentations made in different annual conferences and committee meetings of professional societies also help build better institutional interactions, such as TRB and ASCE STI, EMI and SEI etc.

MPC research at **South Dakota State University** has enhanced the research infrastructure of the asphalt and the structures laboratories through acquiring state-of-the-art equipment. Additionally, webpages have been developed for disseminating research briefs to the public.

MPC projects at the **University of Colorado Denver** have been instrumental in helping expand the university's transportation research capabilities. This has impacted both faculty and students in terms of providing research and educational experience. This has led to high-quality peer-reviewed research as well as employment opportunities for the students that have worked on these projects.

The MPC research carried out at the **University of Utah** has complemented the capabilities of its laboratories to carry out research in materials, transportation, structures and geotechnical engineering. In the area of transportation, the existing driving simulator has been used to generate relevant data. In the area of materials, fiber reinforcement expertise has improved our capability to develop fiber reinforced concrete mix designs. In the area of structural and geotechnical engineering, experiments carried out have improved our capacity to develop more robust models of the seismic performance of bridges.

MPC research undertaken at the **University of Denver** will primarily enhance its institutional credibility and reputation, thus enabling the University to contribute information in a timely way to other organizations. For example, by conducting MPC research the University of Denver's faculty have developed expertise that enhances their overall view of the University. MPC funding provides the University of Denver with needed expertise that then enables UD faculty to engage the business community and public agencies in discussions regarding policy issues.

The **University of Wyoming** will have the grand opening of a new engineering building on campus. Some of the Transportation Engineering faculty will be moved to the new building which will house the state of the art transportation laboratories. MPC support, project selection and funding have provided a long term justification and proven need for a state of the art transportation laboratory.

Utah State University has just welcomed a new transportation faculty member(Dr. Michelle Mekker) to the program. Dr. Mekker graduated from Purdue University and joined USU's faculty in the fall of 2018. USU would not have been able to successfully hire in this area if it had not been for the MPC program and the research success that USU faculty have been experiencing in the field of transportation. The MPC program is having a positive impact on personnel hiring and assignment decisions.

e. What is the impact on technology transfer?

Colorado State University's PIs have worked closely with government stakeholders, such as the Colorado DOT and the City of Fort Collins, to introduce new techniques that could be potentially adopted in new design practices for the design of bridges and foundations. Moreover, the **University of Denver's** Safety Culture Instrument is available to the public and members of the transportation community.

North Dakota State University researchers continue to seek opportunities to present research of interest in webinars, conferences, and workshops. Each completed research project is summarized in a research brief that is broadcast in email and newsletter formats. Each project is required to have a technology transfer component to ensure that findings are actively shared with potential user groups. Through the use of technology transfer it is anticipated that **South Dakota State University's** research results will be adopted by the South Dakota DOT, and potentially by other neighboring states, for design and maintenance of transportation infrastructure.

In terms of technology transfer, MPC projects at the **University of Colorado Denver** have led to improvements in practices, both in the private and public sectors. For example, methods from MPC-510 have been applied to the commute optimization results for an existing business. Improved patterns have been identified for the business. Although it is difficult to show causation in this instance, the results of MPC-455 have coincided with a reemergence of bicycling and bicycling facilities in cities. Another paper has been derived from MPC-489, which will provide cities with evidence regarding street trees and road safety.

Dr. Song of **Utah State University** has been working with Park City on research and as a result has electric bicycles that are placed in the city to help with the transportation and logistics of people. While this was not a UTC project, it has been part of the overall collaborative electric vehicle research effort at USU and could be a positive opportunity. In addition, USU has produced a video on its work in earthquake resistance, which has direct ties to transportation. **Meanwhile, University of Wyoming** has concentrated its technology transfer efforts on submitting the results of research findings to various refereed journals and professional conferences. In 2017, UW faculty had 20 published journal articles.

Technology transfer activities at the **University of Utah** are being used to optimize impacts in the following manner: (a) liquefaction-induced lateral spread will result in software development that will be widely disseminated to State DOTs; (b) research on cell phone use and driver performance will aid in the development of educational programs and communications to promote safe driving and will be made

available to governmental agencies such as the National Highway Transportation Safety Administration; (c) methods to rehabilitate existing concrete wall piers in bridges before or after major earthquakes will be presented at local and national bridge conferences and the TRB Seismic Design and Performance of Bridges Committee; (d) Utah Transit Authority (UTA) is testing electric buses and considering their integration into its future fleet; research on electric buses is helping UTA evaluate capital and operational cost, greenhouse-gas emission reduction and fuel cost savings associated with the integration of electric buses; (e) the TRB Highway Capacity and Quality of Service and TRB Maintenance and Operations Management committees will be updated on the results of hotspot and sampling analysis for effective maintenance management and performance monitoring; (f) University of Utah presentations and journal papers have made an impact regarding seismically resilient bridges using damping devices that improve safety and community resilience; (g) University of Utah research on early use of fiber reinforced concrete properties will be presented to Utah DOT and the American Concrete Pavement Association; (h) results of the University of Utah's maintenance costs in highway design decisions project will be presented at the UDOT Engineering Conference and TRB Annual Meetings; (i) there have been interactions between University of Utah researchers and UDOT, FHWA's Office of Operations, and TRB's Committees on Maintenance and Operations Management, Highway Capacity and Quality of Service, and Freeway Operations regarding University of Utah's project on statistical analysis and sampling standards; (j) with respect to University of Utah project on first-last mile strategies, the following agencies are involved in technology transfer: UTA, UDOT, Federal Transit Administration, TRB Transit Management and Performance Committee, and TRB Rail Transit Systems Committee.

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

MPC projects at **Colorado State University** have helped the general public understand the importance of transportation infrastructures (e.g. bridges and pavements), risks under natural disasters, such as earthquakes, flooding and fire hazards, and how people can mitigate such risks and develop safer and more resilient infrastructure and community. MPC research at **South Dakota State University** has focused on promoting efficient use of limited financial resources for improving transportation infrastructure and fostering environmental stewardship, which benefits the environment and communities.

The **University of Wyoming's** research on road dust issues has quantified the effects of dust on human health, cattle health, and crops production. Meanwhile, MPC projects at the **University of Colorado Denver** have helped lay a foundation for improving the built environment and extending the longevity of the existing infrastructure. The intent is to also help make our roads safer and more efficient. The results are helping to do so for the citizens of Colorado.

University of Denver's research ultimately benefits society as a whole by contributing to a safer environment. UD's research has an impact on the workforce and the traveling public and contributes to the improvement of occupational safety practices, both nationally and worldwide. The fact that UD faculty have been invited to present their research on this topic at international conferences speaks highly of the importance of the topic, the results, and the ultimate benefit to the global society.

The impacts of **Utah State University's** research on society beyond science and technology are wide ranging. USU's electric vehicle work has environmental implications, as well as safety implications with regard to connected vehicle aspects. The transportation research that is being performed has economic implications with respect to moving goods and services quicker and cheaper. Moreover, it has policy implications. The research results improve the economy and the safety and well-being of citizens.

MPC research carried out at the **University of Utah** has had significant impacts on society by showing that damage in liquefaction-induced ground failures can be mitigated in major earthquakes; drivers may be overconfident about their abilities to drive safely while being distracted; and the safety of existing

bridges can be enhanced before and after major earthquakes, therefore improving community resilience. In addition, MPC research and technology transfer have impacted society by:

- Providing transit agencies with cost-and-benefit analyses comparing electric, diesel, and CNG bus fleets
- Developing methods of identifying defect hotspots on a GIS platform that can be used to guide road segmentation
- Developing a device to determine water-cement ratio that can be used in the field as a fast in-situ concrete quality assurance and control tool.
- Identifying ways of reducing cracks in asphalt pavements that result in significant savings in maintenance and rehabilitation costs.
- Developing methods to inform how transportation systems and project level design decisions will impact long-term maintenance costs.
- Conducting performance-based analysis of operational and safety trade-offs associated with left-turn phasing alternatives.
- Showing that concrete surfaces with titanium oxide coatings can be used to remove atmospheric polluting chemicals from the air.
- Improving patch repair mixtures for roadways utilizing fiber reinforced concrete.
- Developing innovative intersections/interchange designs developed that will improve the safety and quality of life of nearby communities.
- Offering recommendations for first-last mile strategies that will increase transit ridership and maximize mobility options, thereby reducing auto usage.
- Exploring human factors and processes that will significantly affect transportation safety.
- Developing recommendations for highway surface treatments of primary roads.

5. Changes/Problems

Colorado State University

- **MPC-507 – Automating Inspection and Damage Assessment of Transportation Infrastructure with Photographic Imaging –** Several of the geometries had to be changed because of poor imaging results.
- **MPC-509 – Expansive Soil Mitigation for Transportation Earthworks by Polymer Amendment –** Delay to allow for development of representative testing equipment, and procurement of materials, as part of MPC-538 Representative Testing of Expansive Soil Treatment Technologies for Transportation Earthworks.

North Dakota State University

- **MPC-518 – Tribal Crash Reporting in ND: Practices, Perceptions, and Systematic Implementation.** The primary traffic contact with the SRST resigned. The NDDOT discontinued funding crash data reporting support for tribes in the state - MHA had received funds in FY18. All eligible tribes had received funds prior to FY18. Arden Boxer (a key collaborator) is no longer involved in the project since the TTAP was dissolved. Turnover in local tribal contacts and changes in the national TTAP program have created unforeseen delays and challenges in project continuity.

University of Colorado Denver

- **MPC-517 – Route Planning for Enhanced Transportation Network Utilization: A System Optimization Approach for Route Planning in Advanced Traveler Information Systems –** During the previous reporting period, we discussed the possibility of using CDOT OD data to perform our evaluation of the proposed algorithms with our CDOT collaborators. We also received affirmative response from CDOT. After further discussion with our CDOT collaborators, we decided to use DRCOG OD model instead of the CDOT OD data for

experimentation, as it was claimed that DRCOG OD model better represents the type of workload we expect to handle with our route planning algorithms.

University of Utah

- **MPC-490 – Longevity of Air Pollution Mitigating Photo-Catalytic Coatings on Transportation Infrastructure –** PI has left the university
- **MPC-493 – Incorporating Maintenance Costs and Considerations into Highway Design Decisions –** Significant progress has been accomplished in the project. A new Project Manager from Utah DOT and the Technical Advisory Committee (TAC) have been involved in follow-up meetings to prioritize goals and continue moving forward with data collection and analysis. A significant change in the approach to analyze drainage structures and related long-term maintenance costs shifted this task from a qualitative analysis collecting anecdotal experience from standard structures, to a quantitative analysis similar to that initially proposed for barrier systems. This change will enhance the outcomes of the project and result in hard numbers to draw conclusions and recommendations on drainage expenses.
- **MPC-529 – Alternative in-situ Water-Cement Meter Using a Parallel-Plate Capacitor Concept –** Project may need a new PI on record. The existing PI has left the university, the former student who worked on it has graduated, and the "new" student who is working on the project is planning to graduate soon before the project has ended.

Utah State University

- **MPC-512 – Pre-stress Losses and Development of Short-Term Data Acquisition System for Bridge Monitoring –** The use of the strain data took us in a slightly different direction that we originally thought we would go but that was part of the research process. The bridges that were selected for the drone study were different from the original ones but the change was made to improve the study.

5a. Additional Information Regarding Products and Impacts

What are the impacts, outcomes, outputs of MPC research in relation to the National Goals expressed in the Secretary's Strategic Goals?

Colorado State University's MPC projects (including the findings) considerably contribute to the strategic goals of the USDOT, specifically safety and state of good repair. Some important research outcomes have been achieved based on the research conducted at CSU, as evidenced by several important technical presentations and published technical papers. Moreover, novel methodologies and techniques have been developed such as: a new methodology to assess seismic risks of curved and skewed bridges and improve their current designs, new techniques to use timber bridge decks as a sustainable option for future bridge repair, the feasibility of improvements in foundation performance in areas of expansive soils, improved approaches to predicting fracture risks in some steel components of bridges, and new approaches to reducing flood risks at existing bridges.

North Dakota State University's MPC research and outreach are planned with the guidance of the USDOT's strategic goals, particularly safety, state of good repair, and mobility. NDSU's ITS research is designed to expand the capacity to monitor infrastructure conditions and improve system reliability through enhanced technology and applications. Materials research is designed to improve knowledge regarding the underlying infrastructure condition and management. Freight demand modeling contributes to the planning tools needed to enhance freight movements in rural and small urban environments. Railroad crossing, large truck safety, and tribal crash reporting research supports U.S. DOT's strategic safety goal.

South Dakota State University's MPC research continues to focus on Safety, State of Good Repair and Environmental Sustainability, three of the USDOT's Strategic Goals. SDSU continues to pursue projects that fit these strategic goals and needs of Region 8 and South Dakota.

Under the primary theme of improving and preserving the existing transportation system, **University of Colorado Denver** has completed several successful projects that will enhance the efficiency, effectiveness, and safety of the current infrastructure. UCD projects will also have a positive impact on the USDOT theme of improving safety. During this reporting period, we made strides in the area of research on the impact of technologies that are disrupting mobility such as Uber and Lyft. We also shed light on conventional thinking and urban clear zones with respect to street trees and safety. Other research work has contributed greatly to the bridge materials area, which is key for infrastructure longevity.

University of Denver's safety culture research is directly related to the U.S. DOT Secretary's Strategic Goals. Specifically, the goal of Safety - Strategic Objective 1 - Systemic Safety Approach - Strategy - "Leadership: Establish a Departmental commitment to continually improve transportation safety by fostering a positive transportation safety culture across the transportation sector." (see USDOT 2018-2022 Strategic Plan, page 7). Measuring Safety Culture in the transportation industry is an essential tool to developing, maintaining, managing and continuously improving safety culture.

MPC research carried out at the **University of Utah** complies with the U.S. DOT's strategic goals of safety, infrastructure, innovation and accountability. Specifically, the completed projects address the safety and security of transportation operations, mobility and global connectivity, traffic management, infrastructure renewal, and improvement in the state of good repair. Specifically, University of Utah's

- **Safety**: MPC research on the human factors of driving will aid in the development of government programs and policies to promote safe driving. The discovery that drivers persist in using cell phones because they are unaware of the adverse effects of multi-tasking on their driving will lead to informed outreach programs. Moreover, safety can be improved through innovative intersection and interchange designs. The improved safety of protected/permitted left-turn phases for different intersection conditions will reduce conflicts and crashes.
- **State of Good Repair:** University of Utah research has shown that proper highway surface treatments can reduce the impact caused by construction delays while improving the overall condition of highways. The minimization of cracking of asphalt pavements can extend the life of a highway by three to five years, which results in a 20% reduction in maintenance cost. Ensuring that the concrete used at the jobsite corresponds to the specified quality will improve initial highway designs. Mitigation of potential liquefaction-induced damage from major earthquakes will preserve the transportation infrastructure. Self-centering devices can reduce bridge residual displacements after an earthquake, which improves community resilience. Rapid strengthening and repair methods of seismically deficient bridge wall piers is feasible using fiber reinforced polymer materials that are light and durable. Cost-effective solutions for delivering highway projects can minimize operational and maintenance resources needed to sustain system effectiveness and functionality. Concrete surface coatings can remove air pollutants affecting public health.

Most of the studies being conducted at the **University of Wyoming** are related to Safety and State of Good Repair. Research findings and results continually educate transportation professionals and provide new technologies to implement throughout the Region.

All MPC projects at **Utah State University** are directly tied to the USDOT Secretary's strategic goals. There is nothing that USU researchers work on that is not in direct response to the Secretary's priorities. The USDOT lists Safety, Infrastructure, Innovation and Accountability as the four strategic goals on their website. USU do not have a project that fails to touch something in each of these areas. USU has made contributions in the areas of electric vehicles and transportation planning. These are good areas to

highlight. USU has also contributed in the materials area which is important for the infrastructure preservation and maintenance.

6. SPECIAL REPORTING REQUIREMENTS: None