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

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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

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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 educational programs 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 (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. The MPC research program theme, "Preserving the Existing Transportation System" will focus on: (1) cost-effective preservation and maintenance practices for highways and freight rail lines; (2) tools to evaluate the effects of tolling and highway investments; (3) inspecting, evaluating, and designing bridges to promote longevity and cost-effective maintenance; (4) the resilience of highway infrastructure to wildfires, floods, earthquakes, and other natural disasters; and (5) workforce development and capacity building. In addition, some related safety research will be conducted to address regional needs.

MPC projects that have been selected since the award of this grant include MPC-533 through MPC-582 which can be found on the Mountain-Plains Consortium website.

b. What was accomplished under these goals?

i. Project Selection

Forty-nine research projects have been selected and have undergone a rigorous peer review process which is required to meet the requirements for selection. 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.

Note: Some MPC projects relate to more than one USDOT Strategic Goals. These projects will be listed more than once.

Table 1: MPC Research Projects Most Directly Correlated with Safety

1. MPC-534 — Traffic Performance Assessment of Disrupted Roadway Networks Following Earthquakes
2. MPC-535 — Development of Unmanned Aerial Vehicle (UAV) Bridge Inspection Procedures
3. MPC-537 — Quantifying Mountain Basin Runoff Mechanisms for Better Hydrologic Design of Bridges and Culverts
4. MPC-540 — Updating and Implementing the Grade Severity Rating System (GSRS) for Wyoming Mountain Passes
5. MPC-545 — Self-Centering Bridge Bent for Accelerated Bridge Construction in Seismic Regions
6. MPC-547 — Infrastructure Safety Support System for Smart Cities with Autonomous Vehicles
7. MPC-549 — Benefit Cost Analysis of Railroad Track Monitoring Using Sensors On-Board Revenue Service Trains
8. MPC-550 — Safety Support System for Highway-Rail Grade Crossing
9. MPC-551 — Automated Track Geometry Monitoring System
10. MPC-552 — The Effects of Autonomous Vehicles on Safety and Safety Culture in Freight Operations
11. MPC-556 — Forging a Path to Vision Zero in the US: A Critical Analysis of Road Safety in Australia
12. MPC-557 — Reassessing Child Pedestrian Mode Choice & Safety via Perceived Parental Risk
13. MPC-561 — Reliability-Based Assessment of Landslide Risk Along Roadways

14. MPC-563 — Optimized Adhesive Performance in Electronic Transportation Sign Construction
15. MPC-564 — Quantifying the Range of Variability in the Flexural Strength of Fiber Reinforced Concrete using Monte Carlo Simulation
16. MPC-565 — Study on Structural Performance Evaluation of Double-Tee Bridges
17. MPC-566 — Supporting Tribal Crash Data Utilization and Strengthening Institutional Capacity for Effective Traffic Safety Programs
18. MPC-567 — Assessing Teen Driver Safety Interventions: Graduated Driver Licensing and Parent Advisory Letters
19. MPC-568 — Mitigation of Flooding-Related Traffic Disruptions with Green Infrastructure Storm Water Management
20. MPC-569 — Traffic Performance Modeling and Planning of Emergency Medical Response in Rural Areas
21. MPC-570 — Experiments and Modeling for Infrastructure Data-Derived Fuel Economy and Safety Improvements
22. MPC-572 — Incorporating Tourism Data in Traffic Estimation on Wyoming Low-Volume Roads
23. MPC-573 — Proposing the Super DDI Design to Improve the Performance of Failing Service Interchanges in Mountain-Plains Region
24. MPC-574 — Proposing New Speed Limit in Mountainous Areas Considering the Effect of Longitudinal Grades, Vehicle Characteristics, and the Weather Condition
25. MPC-576 — Sustainable Alternative to Structurally Deficient Bridges
26. MPC-582 — Safety Culture, Leadership & Fatigue in Transportation Operations

Table 2: MPC Research Projects Most Directly Correlated with State of Good Repair

1. MPC-533 — Use of Life Cycle Cost Analysis to Enhance Inspection Planning for Transportation Infrastructure
2. MPC-534 — Traffic Performance Assessment of Disrupted Roadway Networks Following Earthquakes
3. MPC-536 — Development of Age and State Dependent Stochastic Model for Improved Bridge Deterioration Prediction
4. MPC-537 — Quantifying Mountain Basin Runoff Mechanisms for Better Hydrologic Design of Bridges and Culverts
5. MPC-538 — Representative Testing of Expansive Soil Treatment Technologies for Transportation Earthworks
6. MPC-539 — Ultra-accelerated Method to Evaluate Recycled Concrete Aggregate in New Construction
7. MPC-541 — Assessing Road Conditions for Wyoming County Gravel Roads
8. MPC-544 — Lifecycle Assessment Using Snowplow Trucks' Automatic Vehicle Location Data
9. MPC-545 — Self-Centering Bridge Bent for Accelerated Bridge Construction in Seismic Regions
10. MPC-546 — Field Performance of Asphalt Pavements at Low and Intermediate Temperatures
11. MPC-548 — Development of Models for the Prediction of Shear Strength of Swelling Clays
12. MPC-549 — Benefit Cost Analysis of Railroad Track Monitoring Using Sensors On-Board Revenue Service Trains
13. MPC-550 — Safety Support System for Highway-Rail Grade Crossing
14. MPC-551 — Automated Track Geometry Monitoring System
15. MPC-554 — Composite-based Rehabilitation of Constructed Bridge Girders with Grooved Geometrics
16. MPC-561 — Reliability-Based Assessment of Landslide Risk Along Roadways
17. MPC-562 — Evaluation of Durability and Structural Performance of Concrete with Embedded Inductive Coils
18. MPC-563 — Optimized Adhesive Performance in Electronic Transportation Sign Construction
19. MPC-565 — Study on Structural Performance Evaluation of Double-Tee Bridges
20. MPC-571 — Monitoring Transportation Structure Integrity Loss and Risk with Structure-From-Motion
21. MPC-577 — Uses and Challenges of Collecting LiDAR Data from a Growing Autonomous Vehicle Fleet
22. MPC-581 — Structural Fiber Reinforcement to Reduce Deck Reinforcement and Improve Long-Term Performance

Table 3: MPC Research Projects Most Directly Correlated with Economic Competitiveness

1. MPC-535 — Development of Unmanned Aerial Vehicle (UAV) Bridge Inspection Procedures

2. MPC-540 — Updating and Implementing the Grade Severity Rating System (GSRS) for Wyoming Mountain Passes
3. MPC-542 — Exploratory Modeling and Analysis for Automated Vehicles in Utah
4. MPC-543 — Big Transportation Data Analytics
5. MPC-544 — Lifecycle Assessment Using Snowplow Trucks' Automatic Vehicle Location Data
6. MPC-547 — Infrastructure Safety Support System for Smart Cities with Autonomous Vehicles
7. MPC-552 — The Effects of Autonomous Vehicles on Safety and Safety Culture in Freight Operations
8. MPC-554 — Composite-based Rehabilitation of Constructed Bridge Girders with Grooved Geometrics
9. MPC-555 — Testing Irrationality in Metered Parking Payment Compliance
10. MPC-558 — Optimal Deployment of Dynamic Charging Lanes for Plug-in Hybrid Trucks
11. MPC-560 — Rapid Set Cement for Precast Pre-stressed Bridge Girder Applications
12. MPC-564 — Quantifying the Range of Variability in the Flexural Strength of Fiber Reinforced Concrete using Monte Carlo Simulation
13. MPC-572 — Incorporating Tourism Data in Traffic Estimation on Wyoming Low-Volume Roads
14. MPC-573 — Proposing the Super DDI Design to Improve the Performance of Failing Service Interchanges in Mountain-Plains Region
15. MPC-575 — Characterization of the Plant-Based Bio-Asphalt Binder and Bio-Additives
16. MPC-577 — Uses and Challenges of Collecting LiDAR Data from a Growing Autonomous Vehicle Fleet
17. MPC-578 — Integrated Strategic and Operational Planning for a Fast-Charging Battery Electric Bus System
18. MPC-581 — Structural Fiber Reinforcement to Reduce Deck Reinforcement and Improve Long-Term Performance
19. MPC-582 — Safety Culture, Leadership & Fatigue in Transportation Operations

Table 4: MPC Research Projects Most Directly Correlated with Livable Communities

1. MPC-542 — Exploratory Modeling and Analysis for Automated Vehicles in Utah
2. MPC-543 — Big Transportation Data Analytics
3. MPC-553 — Multi-Business Commute Optimization System: System Development and Pilot Case Study
4. MPC-555 — Testing Irrationality in Metered Parking Payment Compliance
5. MPC-556 — Forging a Path to Vision Zero in the US: A Critical Analysis of Road Safety in Australia
6. MPC-557 — Reassessing Child Pedestrian Mode Choice & Safety via Perceived Parental Risk
7. MPC-569 — Traffic Performance Modeling and Planning of Emergency Medical Response in Rural Areas
8. MPC-579 — Developing Scales to Measure Multidimensional Travel-Related Subjective Well-Being

Table 5: MPC Research Projects Most Directly Correlated with Environmental Sustainability

1. MPC-538 — Representative Testing of Expansive Soil Treatment Technologies for Transportation Earthworks
2. MPC-539 — Ultra-accelerated Method to Evaluate Recycled Concrete Aggregate in New Construction
3. MPC-553 — Multi-Business Commute Optimization System: System Development and Pilot Case Study
4. MPC-558 — Optimal Deployment of Dynamic Charging Lanes for Plug-in Hybrid Trucks
5. MPC-559 — Identifying Effective Travel Behavior Change Strategies for Poor Air Quality Events in Northern Utah
6. MPC-560 — Rapid Set Cement for Precast Pre-stressed Bridge Girder Applications
7. MPC-562 — Evaluation of Durability and Structural Performance of Concrete with Embedded Inductive Coils
8. MPC-568 — Mitigation of Flooding-Related Traffic Disruptions with Green Infrastructure Storm Water Management
9. MPC-570 — Experiments and Modeling for Infrastructure Data-Derived Fuel Economy and Safety Improvements
10. MPC-571 — Monitoring Transportation Structure Integrity Loss and Risk with Structure-From-Motion
11. MPC-575 — Characterization of the Plant-Based Bio-Asphalt Binder and Bio-Additives
12. MPC-576 — Sustainable Alternative to Structurally Deficient Bridges
13. MPC-578 — Integrated Strategic and Operational Planning for a Fast-Charging Battery Electric Bus System
14. MPC-580 — Implementation of Precast Concrete Segments for Electrified Roadway

ii. Programmatic Milestones

In addition to the programmatic milestones described below, several milestones embedded within individual projects have been achieved. Most of the research projects call for literature reviews. The literature reviews for those projects with the earliest starts are substantially complete. Interim reports are not required after the literature review stage. At this time, all projects are on schedule to be completed as planned during the grant period. The program accomplishments to date are summarized in Table 6 by reference to milestones.

Table 6: Program Milestones

Milestone Event	Description	Start Date	End Date
Execution of Grant Agreement	The grant was received from RITA and executed by NDSU's Sponsored Programs office. All of the necessary internal accounting and financial procedures were established, including subcontract agreements with consortium universities. Ongoing as we receive contract amendments each year.	11/30/2016	09/30/2022
Primary Focus	MPC's proposal targets the following FAST Act research and technology deployment objectives under the goal of Preserving the Existing Transportation System. Our research program will focus on: (1) cost-effective preservation and maintenance practices for highways and freight rail lines; (2) tools to evaluate the effects of tolling and highway investments; (3) inspecting, evaluating, and designing bridges to promote longevity and cost-effective maintenance; (4) the resilience of highway infrastructure to wildfires, floods, earthquakes, and other natural disasters; and (5) workforce development and capacity building. In addition, some related safety research will be conducted to address regional needs.	11/30/2016	09/30/2022
Call for Proposals	Proposals are being solicited from each MPC university using guidelines developed by the MPC director.	12/1/2016	10/01/2021
Peer Review of Proposals	All project proposals are being subjected to external and internal peer review.	02/15/2017	10/01/2021
Selection of Projects	Projects are being selected from the proposals received which are peer reviewed by industry experts, academia, and stakeholders. Projects are awarded to the principal investigator and their respective University based on available funding.	05/15/2017	10/01/2021
Posting of Projects	Selected projects are being posted on the MPC website and added to the Research in Progress database as directed in the Grants and Deliverables document.	05/15/2017	10/01/2021
Site Visit	A site visit to all MPC universities are being conducted annually by the MPC Director.	11/30/2016	09/30/2022
UTC/CUTC Meeting	The director and administrative staff attended the UTC/CUTC meeting at TRB and received guidance from RITA regarding the forthcoming grant.	11/30/2016	09/30/2022

iii. Educational Accomplishments

The transportation and transportation-related courses offered during this reporting period are listed in Table 7, organized by major subject area. In some cases, courses with the same titles were offered at more than one MPC university.

Table 7: Transportation and Transportation-Related Courses Offered This Period

Engineering & Design (45 courses)	
• CIVE 507 Transportation Engineering • CEE 106/106L Elementary Surveying and Lab • CEE 311 Structural Material Lab • CEE 340/340L Geology and Lab • CEE 443 Matrix Structural Analysis • CEE 446/546 Advanced Geotechnical Engineering • CEE 456 Concrete Theory and Design • CEE 467/567 Transportation Engineering • CEE 765 Pavement Design • CVEN 4602 Highway Engineering • CVEN 5602 Advanced Street & Highway Design • CVEN 5682 Pavement Design • URPL 3000 Planning the Built Environment • CVEEN 1400 Computer-Aided Design • CVEEN 2010 Statics • CVEEN 2140 Strength of Materials • CVEEN 3210 Structural Loads and Analysis • CVEEN 3310 Geotechnical Engineering I • CVEEN 3410 Hydraulics • CVEEN 3510 Civil Engineering Materials • CVEEN 4221 Concrete Design I • CVEEN 4222 Steel Design I	• CVEEN 5210 Structural Analysis II • CVEEN 5220 Concrete Design II • CVEEN 5230 Steel Design II • CVEEN 5240 Masonry/Timber Design • CVEEN 5305 Introduction to Foundations • CVEEN 5420 Open Channel Flow • CVEEN 6250 Structural Dynamics • CVEEN 6310 Foundation Engineering • CVEEN 6340 Advanced Geotechnical Testing • CVEEN 7250 Structural Earthquake Engineering • CVEEN 7310 Advanced Foundation Engineering • CE 2070 Surveying Engineering • CE 3500 Transportation Engineering • CE 3600 Soil Mechanics • CE 4620 Soil & Rock Slope Engineering • CE 5590 Pavement Materials • CE 5660 Soil & Rock Slope Engineering • CEE 3080 Design of Reinforced Concrete • CEE 5100 Infrastructure Renewal • CEE 5190 GIS Civil Engineers • CEE 6040 Structural Reliability • CEE 3020 Structural Analysis • CEE 5100 Infrastructure Evaluation and Renewal
Freight & Logistics (13 courses)	
• TRAN 4010 Introduction to Transportation Systems • TRAN 4330 Principles of Supply Chain: Management and Technologies • TRAN 4080 Transportation Law and Regulation: Domestic and International • CVEEN 2300 Engineering Economics • CVEEN 7410 Flood Modeling	• TL 711 Logistics Systems • TL 715 Introduction to ERP • TL 782 Highway Planning and Logistics • TL 788 Research in Transportation and Logistics • TL 811 Modeling for Logistics Research • TL 729 Adaptive Planning in Logistics Systems • TL 731 Logistics Decision Analysis • TL 725 ERP Configuration
Planning & Environment (31 courses)	
• URPL 5050 Urban Development • URPL 6350 Form and Formation of Cities • URPL 6355 Urban Redevelopment Strategies • URPL 6365 Parks and Public Spaces • URPL 6400 Community Development • URPL 6399 Introduction to Sustainable Urban Infrastructure • URPL 6410 Social Justice in Planning • URPL 6600 Regional Planning	• CVEEN 3610 Environmental Engineering I • CVEEN 5410 Hydrology • CVEEN 5500 Sustainable Materials • CVEEN 5560 Transportation Planning • CVEEN 5605 Treatment Design • CVEEN 5610 Water Chemistry and Laboratory Analysis • CVEEN 6470 Surface Water Quality Prediction • CVEEN 6600 Solid Hazard Waste Engineering

• URPL 6560 Transit, Bicycle & Pedestrian Planning • TRAN 4710 Transportation Finance (Module 1 of 2) • TRAN 4020 Transportation Economics (Module 2 of 2) • TRAN 4060 Transportation Marketing and Sales Tools • TRAN 4330 Principles of Supply Chain: Management and Technologies • CVEEN 3100 Technical Communication for Engineers	• CVEEN 6920 Groundwater Hydrology • CVEEN 7430 Advanced Subsurface Modeling • CVEEN 7460 Hydro informatics • CVEEN 7660 Water Reuse • CVEEN 7920 Environmental Processes • TL 885 Geospatial Information Systems for Transportation • TL 723 Advanced Supply-Chain Planning Across the Enterprise • TL 789 Leadership, Ethics, and Academic Conduct in Transportation • TL 823 Contemporary Supply Chain Research
Public Transportation (13 courses)	
• URPL 6560 Transit, Bicycle & Pedestrian Planning • TRAN 4080 Transportation Law and Regulation: Domestic and International • TRAN 4320 Transportation Management, Leadership, and Values • TRAN 4800 Analysis of Freight & Passenger Transportation Business Segments • TRAN 4840 Multimodal Passenger-Freight Transportation Systems	• CVEN 5800 Transit Design • CVEEN 1000 Introduction to Civil and Environmental Engineering • CVEEN 5710 Cost Estimating/Proposal Writing • CVEEN 5720 Project Scheduling • CVEEN 5830 Project Management/Contract Administration • TL 786 Public Transportation • TL 756 Transportation and Land Use Integration • TL 757 Intelligent Transportation Solutions
Traffic & Operations (8 courses)	
• CIVE 507 Transportation Engineering • CVEN 4612 Traffic Impact Assessment • CVEN 5612 Traffic Impact Assessment • CVEEN 5110 GIS in Civil Engineering	• CVEEN 6530 Quantitative Methods for Transportation Operations • CVEEN 7545 Transportation Modeling • CE 5575 Intelligent Transportation System • CEE 3210 Intro to Transportation Engineering
Transportation Safety (11 courses)	
• CIVE 303 Infrastructure and Transportation System • CVEN 5611 Transportation Engineering Statistics • CVEEN 5510 Highway Design • CVEEN 5570 Pavement Design • CVEEN 7920 Infrastructure Sensing and Health Monitoring	• CEE 6250 Transport Safety • CEE 5930 Transportation Data/Safety • TL 781 Programs Evaluation • TL 755 Context Sensitive Solutions • TL 719 Courses: Crisis Analysis and Homeland Security • TL 754 Urban Transportations Systems Analysis
Transportation Systems (8 courses)	
• CVEN 5633 Sustainable Transportation Systems • URPL 6555 Transportation, Land Use, and the Environment • TRAN 4010 Introduction to Transportation Systems • TRAN 4050 Intermodal Transportation Systems	• TRAN 4850 International Transportation & Supply Chain Management Analysis • CVEEN 2310 Probability/Statistics • CVEEN 3520 Transportation Engineering • CVEEN 6790 Advanced Computer Aided Construction

Altogether, 110 transportation and transportation-related courses were offered this reporting period, for a total of 194 transportation courses offered since the beginning of this grant. In addition to the courses listed in Table

7, foundational courses in engineering materials, mechanics, structural analysis, and geotechnical engineering were offered at most MPC universities.

c. What opportunities for training and professional development has the program provided?

i. Workforce Development Accomplishments

Altogether, 59 training sessions were offered this reporting period, for a total of 125 offered under this grant 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 (on-site) 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 – (on-site) 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 - Wells, Ransom, McKenzie Counties (3)
- Guardrail Selection, Installation, Maintenance & End Treatments
- HDPE/PP Pipe
- Heavy Equipment
- Heavy Equipment Operation (Hands On)
- Heavy Equipment Operations (Classroom)
- Heavy Equipment Preventative Maintenance
- High Strength Bolt Installation
- Hot-In-Place Recycling - On site 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 Earth Wall Construction Inspection
- MnRoad - Research that Pays
- Motor Grader Training - Cass, Dunn, Sheridan, Stark, Stutsman, Ward, Williams Counties (7) and the City of West Fargo

d. 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 social media postings.

e. 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 different technology transfer means before the end life of the grant. Typically, a project is completed in 12-18 months with dissemination of results 18-24 months from the start of the research. We continue to monitor very closely the progress of the work plans as reported for each project in the semi-annual PPPRs. Also, monthly communication, at a minimum are made with each MPC University director to ensure the success of our investigators.

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 principal investigators have been consolidated into Appendix A through D.

a. Conferences & Workshops can be found in Appendix A
i. This period MPC faculty and investigators have attended and/or sponsored 31 conferences and workshops. Since the beginning of the grant, we have attended and/or sponsored 62 events in support of MPC research.

b. Publications can be found in Appendix B
i. During this period MPC faculty and investigators have published 30 peer-reviewed articles or papers in scientific, technical, or professional journals. Since the beginning of this grant, we have published 46 different peer-reviewed articles or papers.

c. Conference Papers can be found in Appendix C
i. This reporting period we have published 11 conference papers and 22 total since the grant began.

d. Presentations can be found in Appendix D
i. MPC faculty and investigators have presented at 26 different scientific, technical, or professional conference this period. In total, we have had 49 presentations on MPC research, results and outcomes.

e. What else has been produced during this rating period?
i. The MPC website is fully operational at: https://www.mountain-plains.org/
ii. The MPC Key Personnel can be found at: https://www.mountain-plains.org/personnel/
iii. Colorado State University is using cell-phone cameras (photogrammetry) to measure swelling of expansive soils and shrinkage limit of clays. Work is being prepared for a technical publication in the Geotechnical Testing Journal.

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

a. What organizations have been involved as partners?
As projects are selected and work plans completed the timing of match funding and the commitments of collaborators will vary widely throughout the life of the grant. During this period, we had 29 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.

- Bay Area Transportation Commission, San Francisco, CA, in-kind consultation, consultation on workforce development activities
- City of Fort Collins, Fort Collins, CO, provide data and access to local bridges
- 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 Dam Safety, Pueblo, CO, technical support
- Colorado Department of Transportation, Denver, CO, provide data and access to bridges
- Colorado Water Conservation Board, Denver, CO, financial support
- CTS Cement, Anaheim, CA, in-kind support

- Daktronics, Brookings, SD, in-kind and financial support
- Driver License Division, North Dakota Department of Transportation, Bismarck, ND, in-kind support
- Forterra Precast, Salt Lake City, UT, in-kind support, provides concrete and formwork for building the specimens
- Mineta Transportation Institute, San Jose, CA, in-kind consultation, consultation on workforce development activities
- MnROAD facility, Minnesota Department of Transportation, Monticello, MN, in-kind support and collaborative research
- Mountain Land Association of Governments, Orem, UT, technical advisory committee
- 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
- Port of Oakland, Oakland, CA, in-kind consultation, survey completion
- RSG, Inc., Salt Lake City, UT, collaborative research
- Safety Division, North Dakota Department of Transportation, Bismarck, ND, in-kind support
- SELECT Center, Logan, UT, collaborative research
- South Dakota Department of Transportation, Pierre, SD, field testing collaboration
- South Dakota State University, Brookings, SD, in-kind support
- University of Sydney, Sydney, Australia, in-kind use of facilities
- Utah Department of Transportation, Salt Lake City, UT, financial support
- Wasatch Front Regional Council, Salt Lake City, UT, technical advisory committee
- Wyoming Department of Transportation, Cheyenne, WY, financial support
- Wyoming Technology Transfer Center, Laramie, WY, collaborate in the research

The above list of collaborators in research shows a strong federal, state, local, and private industry support of MPC research.

b. Have other collaborators or contacts been involved?

USDOT's continued support with the award of this grant has allowed us to encourage and support 50 principal investigators, faculty, and administrators at eight universities in Region 8. In addition, we have been able to support, mentor, and develop research skills and knowledge in transportation for 69 students from the U.S. and countries around the world.

i. The principal investigators, faculty, administrators, and students listed below, who work within the MPC Universities have participated in MPC research projects this reporting period.

Twelve principal investigators, faculty, and administrators participated in MPC projects at **Colorado State University** to include: Rebecca Atadero, Mehemet Ozbek, Suren Chen, Yanlin Guo, John W. van de Lindt, Gaofeng Jia, Jeffrey Niemann, Thomas Bradley, Joseph Scalia, Chris Bareither, Aditi Bhaskar and Paul Heyliger. In addition, the following twelve students worked on MPC research projects: Abdelrahman Abdallah, Guangyang Hou, Kaisen Yao, Brandon Perry, Min Li, Douglas Woolridge, Zana Taher, Katie Knight, Yangyang Wu, Qiling Zou, David Trinko and Chao Jiang.

Ten principal investigators, faculty, and administrators participated in MPC projects at **North Dakota State University** to include: Ying Huang, Pan Lu, Raj Bridgelall, Dinesh Katti, Kalpana Katti, Denver Tolliver, NeTia Bauman, Sharma Kshitij, Kimberly Vachal and Laurel Benson. In addition, the following fourteen students worked on MPC projects: Mu'ath Al-Tarawneh, Mohanad Alshandah, Liu Hu, Xinyuan Yang, Xinyi Yang, Gina Blazanin, Keshab Thapa, H M Nasrullah Faisal, Neeraj Dhingra, Bhavana Bhardwaj, Amin Keramati, Bukola Bakare, Xiaoyi Zhou and Leonard Chia.

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

Seven principal investigators, faculty, and administrators participated in MPC projects at the **University of Colorado Denver** including the following: Wesley Marshall, Moatassem Abdallah, Caroline Clevenger, Yail Jimmy Kim, Meng Li, Carolyn McAndrews and Bruce Janson. In addition, ten students are working on MPC research projects: Nick Ferenchak, Shahryar Monghasemi, Ahmed Ibrahim, Mallory Redmon, Shalini Mahanthege, Alayna Truong, Ricardo Gonzalez, Brady Heath, Manze Guo, and Molly North.

One principal investigator, faculty, and administrator participated in MPC projects at the **University of Denver**: Patrick Sherry. In addition, two students worked on MPC research projects: Sree Sinha and Emma Porter.

At the **University of Utah** there are three principal investigators, faculty, and administrators participated in MPC projects: Xiaoyue Cathy Liu, Chris Pantelides and Pedro Romero. In addition, the following eight students worked on MPC research: Zhuo Chen, Nima Haghighi, Roghayeh Zoleikani, Zhiyan Yi, Dipendra Thapa, Faramarz Safazadeh, Abu Sufian Mohammad Asib and Shuanli Bao.

Five principal investigators, faculty, and administrators participated in MPC projects at the **University of Wyoming** including: Jennifer Tanner, Khaled Ksaibati, Promothes Saha, Er Yue and Amirarsalan Mehrara Molan. In addition, seven students worked on MPC research projects: Md. Tarik Hossain, Fayez AlMutawa, Mustaffa Raja, Mohammed Mahdi Rezapour Mashhadi, Waleed Aleadelat, Mutasem Alzoubaidi and Milhan Moomen.

At the **Utah State University,** eight principal investigators, faculty, and administrators participated in MPC project research: Ziqi Song, Patrick Singleton, Marc Maguire, Andrew Sorensen, Robert J. Thomas, John Rice, James Bay and Marv Halling. In addition, the following ten students worked on MPC research: Zhaocai Liu, Prasanna Humagain, Ferdousy Runa, David Christensen, Peter Gilbert, Adam Pack, Seth Thompson, Joshua Ward, Nicholas Markosian and Pilaiwan Vaikasi.

c. Were there any collaborators from outside the UTC?
i. Aly Tawfik, California State University, Fresno

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

Colorado State University MPC's projects help significantly on improving the understanding of structural engineering related to bridges and transportation systems. These include advanced simulation techniques, data collection methodology, experimental approaches and new findings.

New explorations into systemic safety, data mining, intelligent transportation, and sensor technology innovations and solutions at **North Dakota State University** presented opportunities for improved incident prediction, preventative countermeasures, and system monitoring that will assure a safe, reliable and agile transportation system.

University of Colorado Denver's MPC projects all progressed well over the last project period and with several papers now under review, we expect to see additional peer-reviewed results soon. This work also impacted the students working on the MPC project by providing an opportunity for research and the various research-related skill development.

The MPC research underway at the **University of Denver** will contribute to a further understanding of the role of safety culture on the safety of transportation employees and the public at large. This will be done by establishing a significant link between safety culture and autonomous vehicles and indirectly with attention and vigilance, the two major factors in accident prevention.

The MPC research carried out at the **University of Utah** impacts the following areas within civil and environmental engineering: (a) analytical methods to estimate traffic volumes and reliability for short-duration traffic count sizes; (b) data envelopment analysis methods to evaluate the lifecycle of snowplow trucks and improve their operational efficiency; (c) methods for constructing resilient bridges in areas of high seismicity that will remain operational immediately after a large earthquake; (d) test methods to screen or eliminate asphalt mixtures that result in poor cracking performance of the road surface at low and intermediate temperatures.

The MPC research that the **Utah State University** performs is adapted for use inside and outside of the classroom which means that students are receiving a state-of-the-art education which is shaping how they are viewing the future of the discipline. Civil engineering can sometimes be viewed by the students as a mature field of study where there is not a lot of innovation. The research that USU performs allows us to bring new ideas, techniques and tools to the classroom to show the students that the field is rapidly evolving and new technology is constantly being utilized. It has been a very positive experience.

University of Wyoming MPC projects conducted under this contract are all advanced and they will produce tangible results. As an example, MPC-572 will result in models the will accurately estimate traffic volumes on low volume roads in the state of Wyoming. The developed methodology can be easily adopted by other DOTs nationwide.

b. What is the impact on other disciplines?

Colorado State University's MPC research is expected to contribute to the state-of-the-art skills and knowledge of several other disciplines, such as public health, vehicle engineering, material engineering, hydrology/hydraulics engineering, and data science.

University of Colorado Denver's MPC projects are beginning to have multi-disciplinary impacts such as with the business community, the bridge construction industry, and the Vision Zero community.

The research carried out at the **University of Utah** impacts the following disciplines: (a) statistical modeling and/or machine learning for estimating/predicting traffic conditions; (b) mathematical optimization to solve linear programming models to maximize operational efficiency of snowplow trucks; (c) finite element modeling for post-tensioning in concrete columns under cyclic and earthquake loads; (d) new materials and methods to optimize development of asphalt mixtures.

For **Utah State University,** MPC-562 has a direct tie with the Electrical and Mechanical Engineering Departments at USU. It also has parallel ties with work being performed at Purdue University and Colorado State University.

At the **University of Wyoming**, the new initiatives in the connected vehicles technologies and the advancements in ITS technologies resulted in utilizing faculty members from other disciplines to participate in their MPC research. As an example, faculty members and researchers from the electrical engineering department are now part of University of Wyoming research teams, developing advanced transportation technologies. In addition, faculty members from mechanical engineering are helping in the reduction of data collected with advance imaging techniques to evaluate dust in gravel roads. Faculty members from the psychology department are helping in identifying human factors in transportation studies as well.

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

Colorado State University's MPC projects offer opportunities for graduate and undergraduate students to get involved in research and teaching, preparing them for their future career.

North Dakota State University has strong participation by doctoral students. Currently, 16 students are contributing to research underway within the current grant. The students are from a range of fields including transportation & logistics, engineering, information technology, and statistics.

University of Colorado Denver's 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.

The MPC research carried out at the **University of Utah** involves undergraduate and graduate research assistants. Many of the research activities encourage 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 government agencies. A few of the 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.

The MPC research underway at the **University of Denver** will contribute to the safety and security of the transportation workforce. Safety Culture influences almost every aspect of the day to day operations of a transportation organization. In addition, autonomous vehicles will be implemented in major transportation in the coming years. By establishing a link between the two, and expanding safety culture to include fatigue issues, the workforce will be even more prepared to work safely.

Utah State University
In addition to the direct impact of the ten funded students on the projects, we have also worked with contractors and other companies that expand their market into the transportation workforce. For exampleMPC-560 involves CTS Cement and Olympus Precast both of which are very interested in expanding their markets to include the research findings.

The MPC research studies conducted at the **University of Wyoming** will provide the needed support for the transportation workforce. MPC-540, for example, will help traffic engineers set up speed limits on downgrades. On the other hands, MPC-541 will help county engineers in identifying the conditions of their gravel roads.

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

North Dakota State University 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.

University of Colorado Denver's MPC projects 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.

Colorado State University' MPC projects use advanced computational and experimental facility at CSU, including high performance computers and field testing facilities and equipment (e.g. vehicle on-board testing, UAV, etc.). The usage of these facilities from these projects help keep the facilities running in a sustainable way. These projects will lead to the presentations made in different annual conferences and committee meetings of professional societies. These will also help build better institutional interactions, through events like, Transportation Research Board, Engineering Mechanics Institute, American Society of Engineers, and the Structural Engineering Institute.

The MPC research carried out at the **University of Utah** has impacted the following resources: (a) machine learning algorithms for estimating and predicting vehicle miles travelled; (b) real-time automatic vehicle location data from snowplow trucks are used for future lifecycle analysis and truck deployment optimization; (c) post-tensioning in precast concrete columns advances our ability to construct self-centering columns thus improving seismic resilience of bridges; (d) AASHTO approved test methods are used to evaluate cracking potential of road surfaces resulting in a performance-based specification.

Utah State University worked very hard to deliver more workshops online then they ever have. This has been a good thing for UTU as they try to increase the effectiveness of their delivery to regions that typically would not be able to attend due to travel costs.

The MPC program at the **University of Wyoming** has increased the research activities related to transportation. As a result, the University of Wyoming has invested a significant amount of resources to established a high-tech transportation laboratory in a new engineering building.

e. What is the impact on technology transfer?

North Dakota State University researchers continue to seek opportunities to present MPC research 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.

Colorado State University works closely with government stakeholders, such as Colorado DOT, the city of Fort Collins, and the city of Denver. Some new techniques are expected to be adopted as new practices, such as bridge design, bridge inspection, emergency transportation response and ITS.

University of Colorado Denver's MPC projects remain ongoing, so the technology transfer thus far has focused on more traditional outlets such academic journals and conference presentations. They look forward to expanding these outlets in the next reporting period, such as piloting MPC-553 with the local business community.

MPC technology transfer activities at the **University of Utah** are being used to optimize impact in the following manner: (a) incorporate analytics into UDOT Asset Management and Planning Functions and present results to TRB Managed Lane, Freeway Operations, and Highway Capacity and Quality of Service committees; (b) present results to FHWA Office of Operations and TRB Committee on Maintenance and Operations Management; (c) present results regarding seismic resilience of bridges to the UDOT Annual Conference and TRB Committee on Seismic Design and Performance of Bridges; (d) present results to highway agencies, materials testing laboratories, and the TRB Annual Meeting.

The MPC program at **University of Wyoming** is producing a significant number of published research. In addition, they are getting lots of publicity for our research by presenting at professional meetings. UW will have more than 15 presentations at the upcoming Transportation Research Board meeting in 2019.

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

University of Colorado Denver's MPC projects will help lay the foundation for improving the built environment and extending the longevity of the existing infrastructure. The intent is also to help make our roads safer and more efficient, and the results will help do so.

MPC projects at **Colorado State University** help gain public awareness of needs and significance of transportation infrastructures (e.g. bridges and pavements), transportation management under natural disasters, (e.g. earthquakes, and flooding) and how people can achieve better knowledge and apply effective intervention measures using new techniques of health monitoring, simulation and experiments.

The implications of the MPC research at the **University of Denver** on public safety and safety culture extend beyond transportation alone. For example, following a public awareness safety campaign in Minnesota about sleep and fatigue, the Minneapolis public school system changed the start times for high-school students. Similarly, we can hope to see the transfer of our results to the broader society.

The MPC research carried out at the **University of Utah** has the following impact on society: a network-wide real-time performance monitoring system to transform traffic management; optimization of operational efficiency and recommendation for snowplow truck replacement strategy; enhance seismic resilience of bridges by making them operational immediately after an earthquake; performance-based asphalt mixture specification will improve the longevity of road surfaces and minimize the lifecycle costs.

University of Wyoming's MPC research is relevant to the whole society. Establishing appropriate speed limit will enhance the safety of the motorist.

5. Changes/Problems

At the Colorado State University:
MPC-533 — Use of Life Cycle Cost Analysis to Enhance Inspection Planning for Transportation Infrastructure - This project was delayed due to the difficulty in finding a suitable graduate student. Now that a quality student has been found, the project will move forward quickly.

MPC-571 — Monitoring Transportation Structure Integrity Loss and Risk with Structure-From-Motion - There has been some attrition of students so we are trying to find a new student to work on this project.

At the North Dakota State University:
MPC-566 — Supporting Tribal Crash Data Utilization and Strengthening Institutional Capacity for Effective Traffic Safety Programs - The lead PI in the project has resigned. A search is currently being conducted to fill the position. The project timeline will be adjusted as that search is completed.

At the University of Wyoming:
MPC-539 — Ultra-accelerated Method to Evaluate Recycled Concrete Aggregate in New Construction - There has been a delay in getting the RCA. Our year-long testing will start in November 2018. Recent testing has been completed to standardize a smaller concrete prism with a shorter duration. If possible, this will be included.

At the Utah State University:
MPC-561 — Reliability-Based Assessment of Landslide Risk Along Roadways - Lack of qualified students last academic year slowed progress on this project.

5A. Additional Information Regarding Products and Impacts

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

Some important research outcomes are expected by **Colorado State University** from their MPC projects, which will be reflected in technical presentations and published technical papers like the following:

1) new methodology to assess the impact of traffic disruption caused by flooding and new measures to mitigate such impact through storm water management

2) development of new techniques to model and plan the traffic performance for EMS vehicles following natural hazards

3) new approach to develop next generation fuel-efficient and safe vehicles, improved approach to inspect bridges using UAV techniques

4) predict bridge deterioration with modeling and experimental investigation of treatment of expansive soil to support transportation infrastructures.

North Dakota State University's research and outreach is planned with the guidance of the USDOT Strategic Goals and the associated regional needs are used to select projects for transportation system improvement in a peer review process. NDSU research into intelligent railroad track monitoring, clay shear strength modeling, and systemic predictive risk modeling for highway-rail crossings will provide results that can be transitioned into enhanced field practices. Risk reduction strategies in safety are also an area of research interest. The highway-rail crossing study, rail track monitoring, tribal crash reporting, smart cities autonomous infrastructure and teen driver studies all contribute knowledge needed in delivering a safer public transportation system. Materials research is designed to improve knowledge regarding the underlying infrastructure condition and management. Freight demand modeling will contribute to the planning tools to enhance freight movement in rural and small urban environments.

Rail crossing, large truck safety, and tribal crash reporting research supports USDOT Strategic Goals in to improve safety on all public roads.

South Dakota State University's MPV efforts are focused on improving the durability and extending the life of transportation infrastructure. Additionally, research being done on preserving the environment and Preserving the existing transportation system.

Under the primary theme of improving and preserving the existing transportation system, the **University of Colorado Denver** has several successful MPC projects that will enhance the efficiency, effectiveness, and safety of the current infrastructure. Their projects will also have a positive impact on the USDOT theme of improving safety.

At the **University of Denver** safety culture research conducted in their projects is directly related to the USDOT Secretary Strategic Goal, Safety. Measuring safety culture in the transportation industry is an essential tool to developing, maintaining, managing and continuously improving safety culture.

The MPC research carried out at the **University of Utah** has the following outcomes: analytical methods will leverage existing historical data to reveal methods for estimating traffic with the potential to reduce the burden on the annual traffic count program; Utah DOT's strategy of "Keeping Utah Moving" will be supported by having an optimal age snowplow fleet; bridges constructed with the proposed research recommendations should not require expensive repairs after large earthquake and should remain operational; performance-based asphalt mixture specifications could possibly extend the life of a road surface which will reduce maintenance and replacement costs.

The MPC projects conducted at the **University of Wyoming** concentrate on upgrading and enhancing the performance of transportation It is anticipated that the studies conducted at UW will enhance the safety of the driving public. In addition, it will make it easier for transportation engineers to perform their job duties efficiently.

Utah State University has a wide range of research interests and scopes in their projects. Which align with the five USDOT Secretary's strategic Goals, Region 8, and also local needs. We have tried to focus our research on these goals and insure that we are being responsive and true to the intent of the grant.

6. SPECIAL REPORTING REQUIREMENTS: None