Semi-Annual Progress Report for University Transportation Centers

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- **Program Director (PD) Name, Title, and Contact Information**
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  Semi-annual

- **Signature of Submitting Official (signature shall be submitted in accordance with agency- specific instructions)**

L.R. Rilett, Director, Mid-America Transportation Center

1. ACCOMPLISHMENTS

What are the major goals of the program?

The major goals of the Mid-America Transportation Center (MATC), which were outlined in the MATC proposal, are indicated in the table below. Activities related to research, education, technology transfer, and USDOT requirements are well underway. Please refer to the table below for an update on the status of each activity.

Table 1: Status of MATC's Research, Educational, and Technology Transfer Activities and Reporting Requirements

Research Activities	**Status**	**Percent Completed for Years 1-4**
Call for Problem Statements	On Schedule	100%
Request for Proposals	On Schedule	100%
Final Proposal Ranking & Selection	On Schedule	100%
Data Management Plan (DMP) - Overarching Plan for MATC	On Schedule	100%
Collect DMPs from PIs for Individual Research Projects	On Schedule	85%
Collect ORCIDs from all MATC Researchers	On Schedule	98%
Submit Project Descriptions to TRB's RiP Database	On Schedule	95%
Submit Final Research Reports	On Schedule	95%
Collect & Store Final Data in UNL Data Repository	On Schedule	100%
Education and Outreach Activities		
Grad/Undergrad MATC Course Development & Implementation	In Process	25%
MATC Undergraduate Summer Internship Program	On Schedule	100%
MATC Scholars Program	On Schedule	100%
MATC/UTC Outstanding Student of the Year	On Schedule	100%
MATC Roads, Rails, and Race Cars After-School Program	On Schedule	100%
MATC/NCIA Sovereign Native Youth STEM Leadership Academy	On Schedule	100%
MATC Summer Institute	In Process	75%
MATC Research Experience for Undergraduates (REU) Program	On Schedule	100%
MATC Joint Activities with Student Chapters	On Schedule	100%
Technology Transfer Activities		
Technology Transfer Plan – Overarching Plan for MATC (Approved October 19, 2018)	On Schedule	100%
Collect Tech Transfer Plans from PIs for Individual Research Projects	On Schedule	40%
Technology Transfer Tech Briefs, Webinars & Presentations on Research Results	On Schedule	100%

Roadside Safety Short Course (UNL)	On Schedule	100%
Roadside Safety Workshop (UNL)	On Schedule	100%
Traffic Safety Classes (KU)	On Schedule	100%
Structural Condition Assessment Short Course (MS&T)	On Schedule	20%
LTAP Workshop	On Schedule	100%
USDOT OST-R Reporting Requirements:		
Federal Financial Reports	On Schedule	100%
Post Research Project Descriptions on MATC Website	On Schedule	100%
UTC Program Progress Performance Reports (Semi-annually)	On Schedule	100%
Annual Performance Indicators Reports	On Schedule	100%
Additional USDOT OST-R Requirements:		
Establish and Maintain Center Website	On Schedule	100%
Directory of Key Center Personnel	On Schedule	100%
Attendance at UTC Grantees' Meetings	On Schedule	100%

What was accomplished under these goals?

Research Activities

Although hindered by the COVID-19 Pandemic, all research activities have continued and the following research activities were accomplished during the reporting period of October 1, 2020 – March 31, 2021.

Principal Investigators (PIs) have either submitted or are in the process of completing Data Management and Technology Transfer Plans for their individual research projects, which are in accordance with USDOT requirements and the Center's overarching plan.

In January 2021, MATC sent out the call for internal research proposals. Four (4) University of Nebraska-Lincoln (UNL) MATC research projects were reviewed by an External Review Committee; of which, three (3) were selected for funding.

UNL/UNO/UNMC currently has fifteen (18) new and ongoing USDOT-MATC funded projects, supported by twenty-nine (29) PI's and Co-PI's. The University of Iowa (UI) currently has five (5) ongoing USDOT-MATC funded projects, supported by nine (9) PI's and Co-PI's. The University of Kansas (KU) and University of Kansas Medical Center (KUMC) currently have five (5) ongoing USDOT-MATC funded projects, supported by ten (10) PI's and Co-PI's. The Missouri University of Science & Technology (MS&T) currently has fifteen (15) ongoing USDOT-MATC funded projects, supported by ten (10) PI's and Co-PI's.

Throughout the reporting period, individual project PIs from Nebraska, Iowa, Kansas, and Missouri submitted quarterly reports detailing the progress, activities, and outcomes of their individual research projects. Some of the accomplishments reported by PIs are outlined below.

University of Nebraska-Lincoln (UNL)/University of Nebraska-Omaha (UNO)/University of Nebraska Medical Center (UNMC)

Research conducted on existing and ongoing projects included:

Project Title: Assessing Performance of Geosynthetic Reinforced Pavement with a Large-Scale Track Wheel Test and Nondestructive Testing Tools

- During the project period, the team had a kick-off meeting and established the detailed schedule.
- The team is designing the large-scale track wheel (LSTW) testing apparatus, and had a meeting with the engineers at the regional machine shop to discuss the applicability and details of the design. Also, the team had a meeting with the structural lab manager to identify the resources and schedule to build the apparatus in the PKI structural lab.
- A new graduate student was hired and he stated his literature review for the project.

Project Title: Evaluation of the Driveway Assistance Device (DAD) Systems in One-Lane Two-Way Work Zone

There have been further discussions with the Nebraska Department of Transportation on potential DAD test beds for the studies. NDOT is to seek FHWA approval to install DAD work zone configuration for data collection.

Project Title: Development of New Generation of Portable Concrete Barriers

The major activity completed this quarter was the continued refinement of LS-DYNA models created last quarter for each of the five portable concrete barrier design concepts. Additions to the models from last quarter included material assignment and contact definitions. Simulations for all five design concepts were conducted in LS-DYNA with a Silverado pickup model to represent MASH TL-3 impacts (MASH 3-11). The results from these simulations were used to determine both necessary and possible improvements to the models. The simulations were analyzed to identify the pros and cons of each concepts and evaluate the effects of alternative design modifications on barrier or vehicle safety performance. A summary report on literature review and design concept brainstorming activity is under ongoing internal review.

Project Title: LIDAR-Based Vibration Monitoring for Assessing Safety of Damaged Bridges

A code was developed using the software development kit of the FARO laser scanner to acquire dynamic displacement data along the surface of a structure. The system can acquire data in a single line at a point-to-point spacing of approximately 1 mm in under 1 second.

All materials for testing have been purchased and set-up is ongoing. Testing should begin in January 2021. While this experimentation is associated with dynamically loaded bridge decks, it presents an opportunity to test the LIDAR data acquisition system and compare to traditional sensors. Physical test setup occurred in January and February with testing commencing in March. The specimens consist of full-scale bridge deck sections, which are excited dynamically. By the end of March, one specimen had been dynamically tested and monitored. While this experiment allows for the comparison with traditional sensors on a realistic structure, additional experimental planning is underway for benchscale testing. Benchscale testing will involve specimens with variable frequencies and mode shapes to allow the limitations of the proposed method to be tested. The specimen for the benchscale testing has been acquired and testing will commence at the end of next quarter. All testing activities are conducted day-to-day by the Graduate Student Researcher (Khalid Al-Kady) with oversight by the faculty PIs. In addition, one undergraduate researcher has been added to the project to assist with day-to-day laboratory activities.

The team has outlined several approaches for the development of the analysis algorithm along with pros and cons for each.

Project Title: Resilience of Rural Communities and Transportation Networks to Hazards
During the reporting period, the PI and graduate student primarily focused on Tasks 1 and 2:

Task #1 (Literature Review). As part of this review, previous surveys of transportation officials regarding functionality of bridges were identified and catalogued. Very few surveys of this type have been conducted and available data is limited. However, one survey tool has been disseminated that is available for use and modification.

Task #2 (Survey of Bridge Inspectors). A previously disseminated survey tool has been identified as the starting point. The survey has been iterated upon internally to best incorporate rural bridges and county inspectors. The methodology for survey dissemination has also been discussed to maximize the response rate.

Project Title: Crashworthy Foundations for Soil-Embedded Roadside Safety Hardware
The major activities this quarter were (1) literature review, and (2) preliminary modeling. The bulk of activity focused on the literature review. Sources were identified and reviewed to characterize soil conditions from field sampling logs. Field samples are typically characterized using SPT blow counts, as well as general soil gradation and moisture content. The literature review also focused on identifying soil modeling methods and formulations applicable to nonlinear dynamic finite element analysis (FEA) studies in LS-DYNA, and methods to correlate field sampled values to reasonable ranges of FEA modeling parameters. Additionally, state standards addressing light pole foundations were reviewed and synthesized, along with states' guidance for estimation of soil mechanical properties and parameters from SPT values. Preliminary models were initiated to investigate the behavior of concrete foundations embedded in soil and impacted by a bogie.

Project Title: Protecting Critical Civil Infrastructure against Impact from Commercial Vehicles – Phase II

- Onboarded new Ph.D. student for project (Qusai Alomari).
- Student completed advanced LS-DYNA training.
- Student created replicative models of former Ph.D. student Fang's validation analyses:
    - A drop hammer impact test on reinforced concrete (RC) beams.
    - A blast test on a central RC column in reduced-scale building frame.
- Student successfully replicated model 3(a).
- Initiated planning and literature review for:
    - Blast behavior and mechanisms.
    - Bridges and bridge piers subjected to air blast.
    - Fire/heat influence on bridge pier column behavior.
- Continued development of publications from former Ph.D. student Fang's work.
    - Student created replicative model of former Ph.D. student analyses of a circular prototype single pier column subjected to Ford F800 single-unit truck impact, and air blast.

Project Title: Incorporating Snow Processes in the Iowa Flood Information System (IFIS) and Evaluating its Applicability for Nebraska

- Procurement of sensors initiated.
- A graduate student started working on the project, but unfortunately, the student had to quit the program in December for personal reasons.
- The bridge locations were finalized.
- The sensor setup configuration was discussed.
- NDOT completed survey for 3 bridge locations.

Project Title: Virtual Barriers for Mitigating and Preventing Run-Off-Road Crashes – Year 4

Project planning was conducted and graduate students capable of supporting the visual programming effort for the CSE research conducted with Dr. Ashok Samal were pursued and offered. MwRSF continued map level planning indicating the segmentation of data, road attribute overlays, and back end data population efforts. Feasibility of porting data to visualization programs including ArcGIS were demonstrated. Further analysis demonstrated that road and lane data were conducive to identifying the maximum safe travel speed dependent on a global and locally-defined safe tire friction value, which could be linked to environmental conditions and speed limits. Further augmentation of the effect of elevation on vehicle stability and reactions were performed, results were summarized, and two journal papers were prepared discussing the application of the virtual road barrier, currently named the "Midwest Virtual Road Corridor" or MVRC.

Project Title: Bio-Inspired Reusable Crash Cushions with Superior Energy-Absorbing Capacity

Recruited two undergraduate research assistants to work on the project, one is Mr. Arman Moussavi and the other is Ms. Hushvini Palaniappan. We have weekly meetings every Monday. Mr. Arman Moussavi will pursue a master's degree at UNL after graduation and he will be responsible for all the experimental and numerical work associated with this grant.

Project Title: MATC Smart Barrier

A finalized map framework was developed which contained critical information about the virtualized "road corridor", including curvature, elevation, travel direction, and segment lengths. Discretization algorithms were developed which allowed data of arbitrary density to be collected and used to form a cohesive road network. Final results were collected and summarized in a technical research report, and a conference paper and journal paper describing key findings were prepared.

Project Title: Investigation and Development of a MASH Test Level 6, Cost-Effective, Barrier System for Containing Heavy Tractor Tank-Trailer Vehicles and Mitigating Catastrophic Crash Events – Year 3

The major activities accomplished this quarter were the completion of the suite of simulations evaluating the TL-6 vehicle impact with barriers of different heights, determinations of the shear and moment loads applied by the vehicle and estimation of the required barrier capacities to support a TL-6 impact, and evaluation of vehicle stability after impact with the barrier. Results were tabulated and compared for different heights and against results of the Year 1 simplified model. Recommendations were provided for the barrier capacity. Results were documented in a technical research report.

Project Title: Real-Time Emergency Communication Systems for HAZMAT Incidents (REaCH)

- Draft of professional driver behavior and health monitoring attitudes survey completed.
- Completed coding of dashboard main page for laboratory test to test heat index sensor. This includes alert notification.
- Began coding and constructing technology to capture heat index data real-time from sensor and sent to REaCH database and displayed on dashboard in real time. We are close to completing this functionality and preparing for a laboratory experiment – from sensor to dashboard on April 26th.
- Prepared research methods/design and checklist for laboratory experiment.
- Completed study of appropriate thresholds values and entered into test system.
- Completed in-depth test plan for the REaCH Application including test scenarios, test plan and test data, and inserting data analytics approaches to visualize health trends. We plan to automate benchmark testing when feasible.
- Wearable devices and NDA agreements
    - Kestrel Drop – Nielsen-Kellerman – Boothwyn, PA
    - S-patch – Wellysis – Seoul, Korea
    - Biobeat – Biobeat Technologies Ltd. – Petach-Tikva, Israel
- External meeting with wearable vendors
    - Mor Hershkovitz – Biobeat Technologies Ltd.
    - Young Juhn – Wellysis Corp.
    - Joe Racosky – Nielsen-Kellerman
- Finalized the NDA with Nielsen-Kellerman and received the communication protocol from them. We will be able to communicate with the Kestrel DROP device from the command line and read temperature, heat stress, etc. over the bluetooth protocol, without having to rely on the phone app.
- Planning for internal College of Public Health grant, PI, Achutan, C., Co-Is, Medcalf, S., Yoder, A, Fruhling, A, Lynden, E., Integrating wearable sensors in firefighter suits to prevent heat-related illnesses, $25K. Extended to April 1, 2021. A student was hired in August to work on this project. Survey is under development.

On March 12, 2020 students working in the lab were asked to begin working remotely due to the COVID 19 epidemic. Likewise, some of the faculty on project were asked to work remotely by the University if possible. Two of the four are working remotely. One faculty member was reassigned from the project to work on the front line to support the Medical Center's preparation and response to COVID 19 and to care for patients. This status continues to be the situation.

The COVID-19 pandemic and business responses play a factor in ongoing and future efforts. The research team has not been shut down and is working, but much of the personnel has transitioned to working remotely, as has much of the country during this time of social distancing. This major shift in regular work operations may lead to delays and inefficiencies may prevent in-person meetings between the research team. These are unprecedented times. As such, it is difficult to predict how long it will last and how it will affect the project moving forward.

University of Iowa (UI)

During this reporting period, research conducted on existing and ongoing projects included:

Project Title: Infrastructure Inspection During and After Unexpected Events – Phase III:
The damage-detection and model-updating modules were tested using experimentations. First, a bridge prototype in Iowa was selected as a representative of a common bridge model in the state of Iowa. After acquiring the as-built blueprints of the bridge, its small-scale physical model and its finite element (FE) model were constructed based on the laws of similarities. The physical model was constructed based on geometry as well as flexural stiffness similarity conditions. Added masses and rotational springs were introduced to replicate bridge bearing supports. The physical small-scale model's material strength and boundary conditions were initiated based on the available data. The FE model of this small-scale model was simulated in the numerical simulation software Abaqus®. As expected, the initial physical model and its FE model did not match due to the uncertainties of material strength and boundary conditions. In structural model updating, the structural features (natural frequency and transmissibility-based mode shapes) of the physical model and its numerical model must be matched. In performing the feature-extraction process, both impact testing and shaker excitation methods were deployed to generate dynamic responses. After extracting reliable structural responses, the FE model was calibrated until preselected features in the FE model and the physical model matched with a good degree of accuracy. After the initial model-updating process, it can be assumed that the resulting FE is a good representation of the physical model. To test the damage-detection algorithm, several damage scenarios at the translational as well as rotational supporting springs were simulated. This was done by changing the springs at the hinges and dashpots at the bridge's supports. Then, a new set of testing was conducted on the damage model using the impact hammer and shaker excitations. The goal was to investigate whether the damage-detection algorithm and model-updating schemes could detect which uncertain system parameters had been changed and required updating. It was found that the proposed damage-detection algorithm was able to detect the damages that were previously generated with accepted resolution, except in complex cases when all rotational as well as translational boundary conditions were changed simultaneously. The latter could be related to the small number of sensors (two) used in the experimentations. A comprehensive explanation of all steps required to execute the new structural model-updating, damage-detection, and BLCP approaches will be presented in the final report.

Project Title: Infrastructure Inspection During and After Unexpected Events – Phase IV
The goal during this reporting period was to develop a computational fluid dynamics (CFD) module to predict forces imposed on bridges by water during river flooding.
A representative bridge superstructure was selected, and its geometric properties were inserted in a CFD code. The aim of this process was to estimate the full 6D imposed forces and moments from the flood/fluid domain on the bridge/solid domain based on CDF modeling. Three different flood types of incremental stages, from the lower level of the bridge up to the fully inundated stage. A CFD code/software REX and a high-performance computing (HPC) system were used to simulate various flood incidents on the representative bridge model. The CFD Rex code integrates the pressure at the fluid-solid interface and estimates the overall imposed force/moment from the fluid on the solid model of the bridge. For validation purposes, the result of the CFD REX code will be compared in a future work with the commercial code ANSYS as well as AASHTO guideline values. This will ensure the validity of the numerical simulation and build trust in this process. Since REX just returns the imposed forces from the fluid domain and treats the solid domain as a rigid body, the resulting strain/stress

field cannot be investigated. Therefore, future developments will consider using a full coupled fluid-structure interaction module for the analysis.

Project Title: Reducing Flammability for Bakken Crude Oil for Train Transport

Experiments were completed and data analysis is in progress for the study on settling characteristics of jet fuel and carbon-based nanomaterial (Carbon dot) using the settling characteristics experiment setup and; Combustion data from jet fuel colloidal suspensions, made using carbon-based nanomaterial (Carbon dot) using the droplet combustion setup. Preliminary results will be presented at the 12th U.S. National Combustion Meeting, May 24 – 26, 2021, virtual conference.

Experiments are in progress for combustion data from Jet-A/Water and Ethanol blended Jet-A/Water emulsified fuels generated using the droplet combustion setup; stability of multi-component emulsified fuel investigations using settling characteristics experimental setup and; study of settling characteristics of jet fuel and carbon-based nanomaterial (carbon dot) using the settling characteristics experiment setup. Results will be presented at IMECE 2021, November 1 – 5, 2021, virtual conference.

Project Title: Transportation Planning with Floods

We are working with a new graduate student on the project since August. Vahid Eghbal Akhlaghi is a PhD student in the Department of Business Analytics. He is well versed in Gurobi, which is the software needed to solve the optimization problems we are modeling. We are working in modeling the problem of choosing which bridges and road to upgrade in advance of a flooding event. We are focused on identifying the ones that allow all citizens the ability to reach hospitals. Vahid has also solved these problems for small cities. We also submitted one paper to a journal.

We started modeling small cities such as Charles City and Fort Dodge. We moved from Fort Dodge to Coralville to model larger communities in road networks. We started solving some preliminary instances as well as analyzing the results and visualizing the solutions on ArcGIS. The visualization was designed to better understand the optimal location of mitigated roads and investigate the optimal solutions. We reviewed the literature on road and bridge mitigation to develop models that are more realistic and find the main difference between this project and the literature.

We have improved our proposed model's efficiency to solve larger-size instances with a larger number of population centers. The developed improvements correspond to both model's build-time and its solution-time. Pruning the network by eliminating unnecessary and redundant arcs (roads) was one of our main proposed improvements. Some of these arcs represent the ones that are far from both population centers and hospitals and are not being used in connecting them. Another improvement applied to our model takes advantage of the problem's data structure. We first find the clusters in the network. A cluster in a network is a set of We are working with a new graduate student on the project since August. Vahid Eghbal Akhlaghi is a PhD student in the Department of Business Analytics. He is well versed in Gurobi, which is the software needed to solve the optimization problems we are modeling. We are working in modeling the problem of choosing which bridges and road to upgrade in advance of a flooding event. We are focused on identifying the ones that allow all citizens the ability to reach hospitals. Vahid has also solved these problems for small cities. We also submitted one

paper to a peer reviewed journal.

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Project Title: Development of New Design Guidelines for Protection against Erosion at Bridge Abutments and Embankments

- Continued running spill-through abutment simulations in a curved channel.
- Started using the data from the simulations to try to extend the formula proposed for spill through abutments in straight channels for curved channels.
- Generated a new mesh that will be used to test the volume of fluid module needed to conduct simulations with a deformable free surface in a channel containing a wing-wall abutment. The main goal will be to use VOF to conduct simulations for cases when the bridge deck supported by the abutment becomes submerged.

Experiments have experienced delays due to COVID-19 as university labs remain temporarily closed and work is being conducted remotely.

University of Kansas (KU)/University of Kansas Medical Center (KUMC)

During this reporting period, research conducted on existing and ongoing projects included:

Project Title: Modeling Driver Behavior and Aggressiveness Using Bio-Behavioral Methods: Phase III

- Data analysis and statistical testing of data that were collected.
- Calibration of car-following model (Intelligent Driver Model) to incorporate the research findings.

Low Cost 3-D LIDAR Development for Transportation

Generation (gen) 3 of the MATC 3-D LIDAR project did not reach completion last year following complications from the COVID-19 pandemic. However, progress that was made on gen 3 was carried over in the development of the current gen 4 LIDAR system. On the design side, most of the effort for the third and fourth generation LIDAR systems have been in the pursuit of upgrading the existing Arduino microprocesser (gen 2) to a Raspberry Pi (RPi). The advantages of the RPi are primarily in computing power offering faster data acquisition resulting in quicker execution. Changing the computer platform requires the sweep and data acquisition program to be rewritten for the RPi.

The LIDAR turret (everything above the horizontal motor) has been completely redesigned to accommodate bearings. These bearings reduce the degrees of freedom between the motors and the components that they drive. A potentiometer has also been added that is driven off the horizontal motor to address problems in the gen 2 system.
Obtained a few point clouds from the PI's group requiring significant processing before being applied into Co-PI's application. Dr. He's team first initialized and introduced point cloud processing problems that could potentially be seen during the development process, such as: Point cloud saving format, point cloud coordinate system transformation, outliers filtering, and upsampling (super-resolution). The team has focused on two goals: 1/ Filtering noises and outliers from raw point clouds in real-time system with appropriate evaluation method; 2/ Building and applying super-resolution models for vacancy filling, with an attempt to boost up the scanning process.

This has been implemented in programs to tackle the first goal, including Coordinate transformation (Spherical to Cartesian), point cloud filtering, and point cloud smoothing.

Project Title: Assessing and Improving the Cognitive and Visual Driving Fitness of CDL Drivers

- Meetings: Our research team continues to meet monthly, virtually since March 2020, to review current and future goals. We continue to have five second year medical students to replace the three outgoing third-year medical students, since they began their clerkships. In sum, we have five medical students, one research assistant, one co-investigator and one PI.
- IRB Status: Dr. Bhattacharya submitted a modification to add additional incentive to pay for a CDL renewal if the license is to expire within the subsequent 60 days of the study visit. All IRB documentation is up to date.
- Collaboration: We continue to build on our existing collaborations. We have worked with KUMC Frontiers and Durham Buses to finish recruitment of our year 1 subjects.
- Recruitment: Due to COVID, it has been challenging to recruit subjects since our lab was closed from March 16th until June 30th, 2020. All testing was halted "indefinitely" impeding our ability to schedule subjects. We have restarted testing since July 1st. To date, we have tested all of our year 1 subjects and have begun our year 2 testing. Sources of recruits were the Kansas Department of Transportation, local grocery stores, waste companies, WalMart, Costco, Amazon, truck stops, Durham school buses, and the Owner Operated Independent Driver's Association.

Missouri University of Science & Technology (MS&T)

During this reporting period, research conducted on existing and ongoing projects included:

Project Title: Performance of Earthquake-Damaged Reinforced Concrete Bridges with Repaired Columns

The research team is continuing to perform and validate the incremental dynamic analysis (IDA) on the 3-span concrete bridge system with combinations of unrepaired and repaired columns. Work on the final report and journal manuscript is currently underway. The research team has reached out to Dr. Yang (University of Hartford), who has expertise and experience in this subject area. Dr. Yang has agreed to collaborate with the research team on the analysis and the journal manuscript.

Project Title: Performance of Earthquake-Damaged Reinforced Concrete Bridges with Repaired Columns – Phase II

Work on this project (Phase II) initiated during this reporting period. The graduate student (Ph.D. student in Civil Engineering) working on Phase II of the project is the same student who worked on Phase I of the project, and as such, he is familiar with the topic and the simulation. During the reporting period, the research team has been building the model and performing the incremental dynamic analysis (IDA) in Phase I of this project that will be utilized in Phase II. In addition, the literature is being surveyed to select retrofitted and repaired columns that will be used for the Phase II simulations. Potential candidates for the retrofitted and repaired columns have been selected from the literature for the Phase II simulations. Within the next reporting period, the model developed to analyze the seismic response of an RC bridge with repaired columns will be extended to the case of retrofitted columns.

Project Title: Investigation of Wind Effects on Bridges Induced by Tornadoes for Tornado-Resistance Design – Phase II

The research in this period is to simulate wind field using computational fluid dynamics (CFD) simulation and to investigate the pressure on the bridge surface induced by tornadic winds.

Project Title: Development of ATMA/AIPV Deployment Guidelines Considering Traffic and Safety Impacts

During the reporting period, the research team has completed a literature review, and is working on traffic flow modeling, and data collection and model calibration.

Project Title: Deep Learning for Unmonitored Water Level Prediction and Risk Assessment

The kick-off meeting was held to start the project. A historical data analysis has been conducted to determine any available data or approaches that would be relevant to the current work. We have also prepared a survey instrument to solicit information from first responders, state emergency officials and other stakeholders to identify areas of interest where flooding commonly occurs.

Project Title: Optimization of Transportation Infrastructure System Performance with Autonomous Maintenance Technology in Work Zones

During the reporting period, Missouri S&T OSP officially set up this project on 3/29/2021 therefore, the team has begun working on task 1 literature review.

Project Title: SMART Shear Keys for Multi-Hazards Mitigation of Diaphragm-Free Girder Bridges – Phase II

The research team discussed a SMART shear key test plan with Drs. Higgins and Lomonaco from Oregon State University. The potential test was scheduled to be carried out in July and August 2021.

Literature review was done on the element model of a bridge using OpenSees simulation platform. Simulation on the Opensees model began recently.

Project Title: Sensor-Assisted Condition Evaluation of Steel and Prestressed Concrete Girder Bridges Subjected to Fire – Phase II

First, steel plates with dimensions of 0.0359 inch (thickness), 0.784 inch (width) and 23.622 inch (length) were instrumented with distributed fiber optic sensors (DFOS) by bond adhesives.

These steel plates were tested under high temperatures. Each plate passed through a furnace and was loaded at both ends when temperature was raised to a target value of 100 ℃, 200 ℃, 300 ℃, 400 ℃ or 500 ℃. Three types of DFOS were used: the fiber with coatings, the fiber with a buffer, and the fiber with a sheath. The last one was used for temperature compensation and the previous two were used for strain measurement. Three types of bond adhesives were used with varying temperature resistances.

Second, concrete specimens with a cross section of 20 mm × 20 mm and a length of 600 mm were tested at the previous temperatures. Like the steel plate specimens, each concrete specimen was instrumented with three kinds of embedded DFOS sensors. Another three DFOS were bonded on the surface of the concrete specimen using high temperature adhesives to get more information (such as strain on the surface) for evaluation of the heated specimens.

Due to the COVID-19 impact, progress in the lab was quite slow due to lab closures/restricted access to campus and social distance requirements. Delays experienced in starting new projects due to local understaffing. MoDOT and CDOT were not able to perform field testing, and were not able to collect data for our research purpose.

Specific Objectives

University of Nebraska-Lincoln (UNL)/University of Nebraska-Omaha (UNO)/University of Nebraska Medical Center (UNMC)

During this reporting period, specific objectives addressed on new projects included:

Project Title: Assessing Performance of Geosynthetic Reinforced Pavement with a Large-Scale Track Wheel Test and Nondestructive Testing Tools

- The team initiated the project.
- During the project period, the team had a kick-off meeting and established the detailed schedule.
- The team anticipated to fabricate the apparatus by Spring and setup the apparatus before 2021 summer.
-

Project Title: Evaluation of the Driveway Assistance Device (DAD) Systems in One-Lane Two-Way Work Zone

Nothing to report.

Project Title: Development of New Generation of Portable Concrete Barriers

The first objective “analysis of the candidate PCB design concepts” was complete, and good progress were made to develop LS-DYNA computer simulations for selected concepts. The preliminary models were prepared and meshed. LS-DYNA simulations were conducted on each concept. Two objectives including (1) Analysis and development of PCB design concepts, and (2) LS-DYNA Simulation of Preferred Design Concept were complete, and good progress were made to develop LS-DYNA computer simulations for modifications to the selected concepts.

Project Title: LIDAR-Based Vibration Monitoring for Assessing Safety of Damaged Bridges

Research Task #1: Literature Review (Completed in Q1)

Research Task #2: Acquisition Methodology (Completed in Q3)

Research Task #3: Experimental Assessment (ONGOING)
Research Task #4: Algorithm Development (ONGOING)

Project Title: Resilience of Rural Communities and Transportation Networks to Hazards
Task #1: Literature Review (Completed in previous quarter)
Task #2: Survey of Bridge Inspectors (ongoing)
Task #3: Functionality Analysis (not yet started)
Task #4: Baseline Rural Resilience Model (not yet started)
Task #5: Final Reporting and Dissemination (not yet started)

Project Title: Crashworthy Foundations for Soil-Embedded Roadside Safety Hardware
The review of state DOT guidance and related literature were effectively completed in this quarter. Additional literature review may be performed as necessary as modeling progresses. Computer simulations of bogie tests were initiated and are in-progress.

Project Title: Protecting Critical Civil Infrastructure against Impact from Commercial Vehicles – Phase II
The ultimate goal of this research is to explore and, if needed, develop and recommend viable retrofitting techniques along with exploring, developing and recommending viable analysis and design procedures. The objectives have been accomplished during the reporting period:

- Initiate investigations into effects of fire/temperature on performance of bridge system subjected to impact and blast into supporting units.

Project Title: Incorporating Snow Processes in the Iowa Flood Information System (IFIS) and Evaluating its Applicability for Nebraska
Significant portion of Task 1 was completed during this period. We finalized the eight locations for sensor installation. NDOT already surveyed three of these locations. We were not able to make significant progress on Task 2 yet since the graduate student who started working on the HLM model left the program in December. The student also stared working on a review paper which would be a part of Task 6. A new student has started in Spring 2021 and is already working with the model equations.

Project Title: Virtual Barriers for Mitigating and Preventing Run-Off-Road Crashes – Year 4
Further background development was performed supporting the data collection and segmentation process. The analysis procedure is intended to support the data collection during the visual survey and data population phase to follow. Data collection needs were determined and are being summarized for concise database creation.

Project Title: Bio-Inspired Reusable Crash Cushions with Superior Energy-Absorbing Capacity
A bio-inspired approach is used in this study to develop innovative lightweight reusable crash cushions. First, three biological role models, i.e., coconut endocarp, sea urchin spines, and bovid horns, are picked out from nature due to their low density, high strength, and remarkable impact-resistant and energy-absorbing capacities. Then, the two students conducted a comprehensive structural and mechanical analysis to understand the mechanisms underlying their superior mechanical properties.

Project Title: MATC Smart Barrier
Further exploration of road data acquisition techniques was conducted. Segmentation, noise

evaluation, and "remapping" functions applied to road data to improve numerical modeling and fit. Completeness of the data was investigated by applying different road data densities to the mapping algorithm.

Project Title: Investigation and Development of a MASH Test Level 6, Cost-Effective, Barrier System for Containing Heavy Tractor Tank-Trailer Vehicles and Mitigating Catastrophic Crash Events – Year 3

Determination of barrier shear and moment capacities and vehicle stability after impact. Documentation of final results in a technical report and recommendations for the next phase, as well as future modeling improvements.

Project Title: Real-Time Emergency Communication Systems for HAZMAT Incidents (REaCH)

- Bi-weekly team meetings – meeting minutes available upon request
- Grothe, J., Blake, A., Yoder, A., Achutan, C., Medcalf, S., Fruhling., A., "Exploring First Responders' Use and Perceptions on Continuous Health and Environmental Monitoring, draft under review by all co-authors, target journal Safety. – no additional progress
- Sharon Medcalf, PhD1, Matthew L. Hale, PhD2, Chandran Achutan, PhD, CIH1, Aaron M. Yoder, PhD1, Stanley W. Shearer3, FF/EMT-P, Ann Fruhling, PhD2, , Requirements Gathering Through Focus Groups for a Real-Time Emergency Communication System For Hazmat Incidents (REaCH), submitted to Safety and decided to withdraw and send to Emergency Management journal.
- Development of REaCH prototype in-progress.

University of Iowa (UI)

During this reporting period, specific objectives addressed on existing and ongoing projects included:

Project Title: Infrastructure Inspection During and After Unexpected Events – Phase III:

Nothing to report.

Project Title: Infrastructure Inspection During and After Unexpected Events – Phase IV

Nothing to report.

Project Title: Transportation Planning with Floods

Optimize mitigate options with different objectives/constraints for communities in Iowa.

Project Title: Reducing Flammability for Bakken Crude Oil for Train Transport

- Experimental settling data for jet fuel-nanomaterial (carbon dot) colloidal suspension data will be generated, which will help to explore the stability of such suspensions. Experiments are completed. Data analysis is on progress.
- Experimental combustion data for jet fuel/carbon dot colloidal suspensions will be generated. Experiments are completed. Data analysis is on progress.
- A review on droplet combustion is on progress which will help to understand the effect of carbon-based nanomaterials and polymers on combustion characteristics of different fuels.
- Some schedule has been altered due to COVID-19 situation

Project Title: Development of New Design Guidelines for Protection against Erosion at Bridge

- Propose a new multi-parameter new design formula that can be used for riprap design at spill through abutments placed in straight channels.
- Check if existing design formulas recommended in HEC 23 (Lagasse et al. and Pagan-Ortiz) are conservative enough especially for channels with very wide floodplains. Propose modifications to existing formulas, if needed.
- Incorporate the effect of the relative abutment length La/Bf and abutment width in a modified design formula for riprap sizing at spill-through abutments placed in a straight channel.
- Investigate how channel curvature affects the critical Froude number for riprap failure for spill-through abutments.
- Extend the design formula for spill-through abutments placed in a curved channel.

University of Kansas (KU)/University of Kansas Medical Center (KUMC)

During this reporting period, specific objectives addressed on existing and ongoing projects included:

Project Title: Modeling Driver Behavior and Aggressiveness Using Bio-Behavioral Methods: Phase III

Further testing of car-following models and optimization based on the biobehavioral data.

Low Cost 3-D LIDAR Development for Transportation

PI's Group: The graduate student has put together the gen 4 LIDAR system and is currently debugging the hardware and software. In the next quarter, it is envisioned that the student will be able to generate initial point clouds.

Co-PI's Group: The student involved has made significant progress on achieving the two main tasks of the group: 1/ Designing and evaluating real-time filtering and denoising algorithms, to detect outliers existing in the raw point clouds; 2/ Boosting up scanning process by integrating a super-resolution model for resampling the point cloud.

Project Title: Assessing and Improving the Cognitive and Visual Driving Fitness of CDL Drivers

Tasks that were met during this quarter are the following:

- Coordinate with the Kansas Department of Transportation and Kansas Department of Health and Environment to work with trucking companies to recruit subjects.
- Conduct the battery of cognitive and visual tests on a target goal of 85 subjects (40 to date).
- Request driving record data annually for all subjects, without risk of penalty.
- Collect baseline data on the task-evoked pupillary response (TEPR) reflex.
- Contact the appropriate subjects for rehabilitation of cognitive, visual and TEPR tasks performed sub-optimally. This protocol was submitted during the last quarterly report.
- Perform rehabilitative tasks as appropriate.
- Collect Year 2 data of cognitive and visual testing and correlate with driving performance.
- Provide subjects options for rehabilitation of cognitive, visual and TEPR tasks performed sub-optimally.
- Present work at University of Kansas School of Medicine's Student Research Forum.
- Begin writing a publication.

For the collection of baseline data mentioned above, we created a check-out sheet that we give each participant at the end of each assessment. The goal is to create a summary table with the results of their tests and recommendations for each participant. Also, in the protocol we mentioned that we will have a self-assessment questionnaire to give to all of our participants when they come in for their second and third assessments. We have explored the literature and have created an appropriate self-assessment questionnaire that began distribution from October 19th for year 2 and 3 participants.

Missouri University of Science & Technology (MS&T)

During this reporting period, specific objectives addressed on existing and ongoing projects included:

Project Title: Performance of Earthquake-Damaged Reinforced Concrete Bridges with Repaired Columns
The finite element analysis code previously developed to simulate the seismic response of an RC bridge has been paired with MATLAB script to perform incremental dynamic analysis (IDA). The MATLAB script is currently being debugged.

Project Title: Performance of Earthquake-Damaged Reinforced Concrete Bridges with Repaired Columns – Phase II
In Phase I of this project, a finite element analysis (FEA) code was developed to simulate the seismic response of an RC bridge. This FEA model, developed using OpenSees software framework, will be adapted and implemented in Phase II of this project.

Project Title: Investigation of Wind Effects on Bridges Induced by Tornadoes for Tornado-Resistance Design – Phase II
This addresses the wind effects on the bridge, proposed in the research proposal.

Project Title: Development of ATMA/AIPV Deployment Guidelines Considering Traffic and Safety Impacts
Finished work on task 1 literature review, and started to work on task 2 traffic flow modeling, and task 3 data collection and model calibration.

Project Title: Deep Learning for Unmonitored Water Level Prediction and Risk Assessment
Task 0: Kick-off Meeting with Project Stakeholders was held, including all stated stakeholders (S&T researchers, MoDOT, and SEMA) to select survey participants to provide information on test locations. Task 1: Historic Data Analysis was conducted to identify any new and relevant information related to flooding and flash flooding that could contribute to the project. Task 2: First responders survey instrument was created based on the information from the kick-off meeting and considering the results of earlier MATC projects by the team. This instrument has been shared with both MoDOT and SEMA stakeholders to identify early test subjects prior to rolling it out to a broad audience of first responders and emergency management personnel.

Project Title: Optimization of Transportation Infrastructure System Performance with Autonomous Maintenance Technology in Work Zones
Kicked off this project, and start to work on task 1 literature review.

Project Title: SMART Shear Keys for Multi-Hazards Mitigation of Diaphragm-Free Girder Bridges – Phase II

The first step aims to: 1) investigate and summarize the current element model of bridge members, 2) evaluate the performance of brittle and ductile models for smart shear keys during simulations.

The second step aims to: 1) simulate and investigate the effect the SMART shear key on a simplified bridge under earthquake and tsunami loading, 2) experimentally verify the model of SMART shear key installed on a reduced scale bridge under tsunami loading through the large flume on the Oregon State University campus.

Project Title: Sensor-Assisted Condition Evaluation of Steel and Prestressed Concrete Girder Bridges Subjected to Fire – Phase II

The aim of the study is to investigate the feasibility of using distributed fiber optic sensors to measure the strain of steel or concrete specimens under high temperatures. The effect of the steady state and transition state on the measurement results will be uncovered. The effect of the high temperature adhesives on the measurement results will be investigated. The strain transfer under the high temperatures will be investigated.

Significant Results, including major findings, developments, or conclusions (both positive and negative)

University of Nebraska-Lincoln (UNL)/University of Nebraska-Omaha (UNO)/University of Nebraska Medical Center (UNMC)

During this reporting period, significant results for new projects included:

Project Title: Assessing Performance of Geosynthetic Reinforced Pavement with a Large-Scale Track Wheel Test and Nondestructive Testing Tools

- The team started to design of a large-scale track wheel (LSTW) testing apparatus.
- A new graduate student was hired and he started literature review for the project.

Project Title: Evaluation of the Driveway Assistance Device (DAD) Systems in One-Lane Two-Way Work Zone

Nothing to report.

Project Title: Development of New Generation of Portable Concrete Barriers

Preliminary simulations in LS-DYNA were completed for Concept 1, Concept 2, Concept 17, and Concept 19. The simulations for Concept 2 and Concept 17 terminated prematurely due to instabilities, and it was found that these two concepts required modifications to the connection design to provide a sufficient transfer load and moment between barrier segments and reduce potential concern for vehicle snag. Using the results and insight gained from the preliminary LS-DYNA simulations completed in the last quarter, more simulations were completed for Concept 1, Concept 2, Concept 17, and Concept 19. The goal of these simulations was to refine the barrier models and investigate both necessary and possible modifications.

Necessary modifications were made to the connection designs in Concept 2 and Concept 17 to enable sufficient moment transfer between barrier segments and alleviate vehicle snag issues

encountered in the preliminary simulations. For Concept 2, this involved simply adding a second connection pin on each side of the joint, so that the connection now consists of 4 total connection pins with two connection plates. This modification proved adequate to transfer moment between barrier segments, which the previous design did not. For Concept 17, the feet brackets were enlarged from 36 inches long and 6 inches tall to 60 inches long and 10 inches tall. Simulations with this connection terminated prematurely due to instabilities caused by vehicle snag, for impacts at 51 inches and 75 inches upstream of the joint. However, the simulation with impact at 112.5 inches upstream of the joint did not terminate prematurely. Thus, the results of this simulation were used for comparison with the other PCB concepts. Secondary simulations were conducted to investigate possible modifications to the barrier designs for Concept 1 and Concept 19. An investigation of a lateral versus longitudinal connection pin arrangement was completed for Concept 1 and found no significant difference in vehicle safety performance or barrier displacement between the two pin arrangements. Additional simulations were conducted for Concept 19 to investigate the use of an inverted slope of the barrier face. The inverted slope variant featured identical barrier mass and similar barrier geometry, with the only difference being the inverted slope on the face of the barrier. Compared to the original version of Concept 19, vehicle safety performance and barrier displacement were similar, but the inverted slope exhibited a 22% reduction in vehicle roll and a 41% reduction in vehicle climb. The second variant of Concept 19 tested a revised shape of the shear key connection between top and bottom barrier segments. The revised shear key variant featured nearly identical barrier mass and identical exterior geometry. However, the shear key width was reduced and the horizontal gap on either side of the shear key was increased from ¼ inches to ½ inches. Also, simulation was completed for Concept 18, which is the only PCB concept out of steel. Concept 18 was not selected for further evaluation as it did not provide desired reduction in barrier deflection and was found relatively expensive.

Project Title: LIDAR-Based Vibration Monitoring for Assessing Safety of Damaged Bridges
This quarter primarily consisted of fine-tuning the acquisition methodology and the final aspects of experimental planning. A significant accomplishment is the final, deployable, and testable version of the dynamic data acquisition system. This system consists of a commercial laser scanner, an adapter to prevent rotation of the scanner, and a control software (developed in-house) that commands the system to acquire a single line of data rapidly over a set amount of time.

Project Title: Resilience of Rural Communities and Transportation Networks to Hazards
Nothing to report.

Project Title: Crashworthy Foundations for Soil-Embedded Roadside Safety Hardware
The state DOT standards review indicated that cylindrical light pole foundations were typically 24 to 36 inches in diameter, and typically 6 to 8 feet deep. Important soil parameter ranges with respect to SPT N values were identified for coarse- and fine-grained soils, respectively. A preliminary LS-DYNA model was developed and initial analyses were performed with embedment depths of 2, 4, 6, and 8 ft.

Project Title: Protecting Critical Civil Infrastructure against Impact from Commercial Vehicles – Phase II
Nothing to report.

Project Title: Incorporating Snow Processes in the Iowa Flood Information System (IFIS) and Evaluating its Applicability for Nebraska
Nothing to Report.

Project Title: Virtual Barriers for Mitigating and Preventing Run-Off-Road Crashes – Year 4
Elevation results were linked to vehicle stability and augmented to the quasi-planar geological data. Safety parameters including maximum operating safe speed, based on parameters recommended in the AASHTO Green Book and vehicle stability concerns, were correlated with road data collected in the Virtual Corridor database.

Project Title: Bio-Inspired Reusable Crash Cushions with Superior Energy-Absorbing Capacity
Throughout this quarter, progress has been made on this project in the form of literature and past research investigations. A focus was placed on each of the three biological role models, i.e., coconut endocarp, sea urchin spines, and bovid horns. Useful information from past research was analyzed and noted for additional future use. Once a comprehensive literature review including data analysis is complete, one or two of these biological role models will be selected to conduct further testing and research on.

The focus of reviewed works of literature was the endocarp which is the thinner woody inner layer of the coconut. One study reviewed the different structure and mechanical properties of young vs old coconut shells. This study found that old coconut showed sclerification and improved load transfer to nanostructure. Overall, old coconut shells showed more damage tolerant behavior than young shells (Gludovatz et al., 2017). This analysis shows an additional level to testing the strength of this material that this research may note for further investigation. Another study focuses on the crashworthiness design of composite materials of the coconut. This study focused on the bio-mystery of coconuts that were theoretically derived and validated through the use of numerical calculations (Lu et al., 2020). Additionally, a bio-inspired template was provided for functional composite material design. This information will aid in the current study by providing an idea of the validity of the coconut in crash-applied uses.

One of the more useful papers reviewed analyzed the strength-size relationships in both coconut endocarp and the second biological model of this study, sea urchin spines. The importance of this study was to answer the question- Can Weibull theory (which predicts that brittle fracture strength is a function of size, stress distribution, and stress state) can be applied to the coconut endocarp and sea urchin spines to model their size/volume/property-relations? The element of porosity throughout tested samples seemed to be of great importance throughout many of the papers reviewed when dealing with the higher strength and Young's Modulus of the samples. Additionally, Mg concentrations were noticed in various studies.

The third and last biological model reviewed was the bovid horn. Previous research involving this material has a very wide scope. A few studies incorporated electron microscopy technology to better understand the elements of the horns such as fracture surface. The studies reviewed also focused on energy absorption with different conditions such as sampling conditions. These additional ideas for further information gathering could be useful throughout this study as they will guide this research in a meaningful direction.

The upcoming plan for this research is to focus on the study of the testing of one or two of these biological models. Right now, this study is leaning towards the path of focusing on the

coconut endocarp and sea urchin spines. This is due to some similarities noted throughout literature already published in this field such as the Weibull theory defined in one of the papers reviewed. However, as the analysis of past publications on this topic proceeds, a final decision on what material or materials will be focused on for this project will be made.

Project Title: MATC Smart Barrier
The virtual road corridor data.

Project Title: Investigation and Development of a MASH Test Level 6, Cost-Effective, Barrier System for Containing Heavy Tractor Tank-Trailer Vehicles and Mitigating Catastrophic Crash Events – Year 3
Large truck ZOI extensions were plotted for comparison with the TL-6 simulations. TL-6 evaluation simulations were completed and results were summarized, plotted, and compared with the TL-5 and Year 1 simplified vehicle model results. Impact loads compared favorably with the available data for calibration, and overall trends matched expectations for vehicle behaviors. Specific barrier heights were associated with distinctive, surprising transitions in load and moment behavior.

Project Title: Real-Time Emergency Communication Systems for HAZMAT Incidents (REaCH)
Nothing to report.

University of Iowa (UI)

During this reporting period, significant results from ongoing projects included:

Project Title: Infrastructure Inspection During and After Unexpected Events – Phase III:
Nothing to report.

Project Title: Infrastructure Inspection During and After Unexpected Events – Phase IV
Nothing to report.

Project Title: Transportation Planning with Floods
For our basic mitigation model, we found it can solve instances on small cities in about 1 second! Thus, we have added more details to the model to better capture the different costs and constraints. We started scaling the model for solving larger networks and communities. We are using cost of mitigation and number of amenities as criteria to optimize accessibility to amenities based on population. One of our model's main advantages compared to the literature is the consideration of the mitigation cost instead of the number of mitigated roads. We also developed a variation of the model that includes the road's capacity as model's constraints to ensure that the number of people using each road does not exceed that road's maximum capacity.

The highest impact of these improvements was a significant reduction in the number of constraints and variables, leading to a smaller search space that significantly reduced the problems' solution time. After applying the improvements, we could achieve some preliminary results that provide more detailed information about the required amounts of budget for mitigation. More importantly, utilizing these improvements helped us cover 93% of Coralville's population in our model and assure their accessibility to the hospitals by finding an optimal set of roads that need to be mitigated to minimize the network's total travel time. For experiments with more than 93% of the population, we could still achieve high-

quality solutions with less than a 1% optimality gap. Still, we have decided to develop some heuristic solution approach for these problems, which is planned to be done in the next quarter.

Project Title: Reducing Flammability for Bakken Crude Oil for Train Transport

- Two conference papers are accepted for publication (IMECE 2020). Both papers were presented in the IMECE 2020.
- A review paper on droplet combustion is on progress.
- Schedule has been changed due to COVID-19 situation.

Project Title: Development of New Design Guidelines for Protection against Erosion at Bridge

Simulations were conducted for four values of the floodplain width Bf/Href = 5, 10, 14 and 20. These series of simulations conducted with a constant value of Bf/Href are denoted Case I, Case II, Case III and Case IV. For each case, simulations were conducted with two different values of the median diameter of the riprap stone, D50/Href = 0.2 and 0.4, three values of the radius of curvature measured along the centreline of the main channel, R/Href = ∞ (straight channel) and R/Href = 400 and 200 (R/Bm = 20 and 10). The relative abutment length, La/Bf, was varied between 0.35 and 1.0. As for the straight channel simulations, the discharge was varied until the maximum bed shear stress value over the rip-rap apron protecting the outer-bank abutment reached the critical value corresponding to the mean riprap diameter.

Using the database generated using the numerical simulations, a design formula for riprap size selection in aprons protecting spill-through abutments is proposed. As for wing-wall abutments (Wu et al., 2020), the formula is expressed as:

$$D50/y = (Ks/(Ss-1))0.5\alpha*Fr\alpha = C0.5\alpha*Fr\alpha \quad (1)$$

where D50 is the mean diameter of the riprap stone, y is the flow depth, Ks is a constant called the shape factor and Fr is the Froude number calculated with y and the mean velocity in the section containing the abutment. The two model parameters are □ and and C = Ks/(Ss-1). The design equations of Pagan-Ortiz (1991) and Lagasse et al. (2001) for spill-through abutments are obtained by choosing Ks = 0.89, C = 0.324, α = 2.0 and Ks = 0.535, C = 0.54, α = 2.0 (Fr < 0.8) in eqn (1), respectively. As for wing-wall abutments, the question is if a design equation of the form given by eqn. (1) but with variable C and α will approximate well the present data set for spill-through abutments. Our analysis shows that this is indeed the case and that α is mainly a function of the floodplain width for test cases with La/Bf < 1. For the Case II simulations conducted with Bf/Href = 10 and La/Bf≤0.7. One can see that the variation of D50/y with Fr is linear in log-log scale for each value of La/Bf. Moreover, the lines corresponding to cases with La/Bf = 0.5 and 0.7 are parallel, which means that α is not a function of La/Bf. By contrast, the model parameter C is a function of Bf/Href, La/Bf and R/Href, that report the best-fit values for all the test cases considered in the present investigation. One can see that C increases monotonically with La/Bf for constant channel curvature if La/Bf < 1 and C increases with increasing floodplain width for constant La/Bf < 1 and channel curvature. Meanwhile, α decreases monotonically with increasing floodplain width, e.g., from 1.95 for Bf/Href = 10 to 1.8 for Bf/Href = 14 to 1.75 for Bf/Href = 20. The other finding is that for spill-through abutments with La/Bf = 1, α is independent of the floodplain width (Table 3). This is illustrated in Fig. 2b that shows results for Bf/Href = 10 and La/Bf = 1. The variation of D50/y with Fr is linear in log-log scale and the lines are parallel with a slope α = 1.85.

The new design formula predictions of the critical Froude number are close to the numerical results for all the cases conducted with La/Bf = 0.7. The qualitative trends are the same for the test cases conducted with a different value of La/Bf, as long as La/Bf < 1. For brevity, these results are not included. As expected, the critical Froude number corresponding to riprap shear failure of the apron protecting the outer-bank abutment decreases with increasing channel curvature. As α is not dependent on the channel curvature, this means that C decreases with decreasing R/Href (see Table 2). Though a value of R/Bm = 10 (R/Href = 200) corresponds to a small-to-moderate channel curvature for natural streams, the effect on the critical Froude number is important. For example, in the Bf/Href = 20, La/Bf = 0.7, D50/Href = 0.4 simulations, Fr decays from 0.97 for a straight channel to 0.85 for a curved channel with R/Href = 200. The other effect illustrated in Fig. 8 is that for constant La/Bf < 1 and constant channel curvature, Fr decreases with increasing floodplain width.

University of Kansas (KU)/University of Kansas Medical Center (KUMC)

Project Title: Modeling Driver Behavior and Aggressiveness Using Bio-Behavioral Methods: Phase III

The proposed bio-behavioral Intelligent Driver Model was compared to the base IDM. The proposed model was found to better predict the car-following speeds and trajectories.

Low Cost 3-D LIDAR Development for Transportation

PI's Group: Extensive testing on the gen 2 prototype allowed for a thorough evaluation of its accuracy throughout all the rangefinder's six configurations. This benchmarking effort should be an ideal comparison for the fourth generation 3-D LIDAR system. Though gen 4 will run an updated version of Garmin's LIDAR Lite V3 (V3-HP), the configurations remain the same.

Co-PI's Group: The first implementation of the LIDAR software improvement addresses Spherical Coordinate→ Cartesian Coordinate transformation, and chooses PLY as standard point cloud representation format for post processing. The first version of filtering and smoothing algorithms are developed, and applied on a collected point cloud from the PI's group. The filtering process showed that the majority of outliers have been eliminated, while still keeping the essential information from original version. However, the team has not found the appropriate evaluation method to measure and compute the efficiency of the algorithms. Evaluation is essential to optimize and perform a comparison with difference techniques. The team will investigate this further. Additionally, the current algorithm is not able to be implemented in real-time because it requires a completed point cloud of significant size (>120k points). For real-time filtering and smoothing, Bayesian-based approaches may be considered.

Project Title: Assessing and Improving the Cognitive and Visual Driving Fitness of CDL Drivers

Nothing to report.

Missouri University of Science & Technology (MS&T)

During this reporting period, significant results from ongoing projects included:

Project Title: Performance of Earthquake-Damaged Reinforced Concrete Bridges with Repaired Columns

The developed numerical model is capable of performing incremental dynamic analysis to study the collapse of the simulated bridge.

Project Title: Performance of Earthquake-Damaged Reinforced Concrete Bridges with Repaired Columns – Phase II

As demonstrated in Phase I of this project, the developed numerical model is capable of predicting the response of RC bridge columns (unrepaired and repaired) under cyclic lateral loading conditions. Within the next reporting period, the base model of the column will be extended to retrofitted columns.

Project Title: Investigation of Wind Effects on Bridges Induced by Tornadoes for Tornado-Resistance Design – Phase II

The research in this period is to conduct simulation to find the wind effects of straight-line winds on the cable-stayed bridge. This cable-stayed bridge holds two traffic lanes, with a width of 12.19m and a length of 274.32m.

The model design software, Pointwise, is employed to build and mesh the bridge model.

In order to investigate the wind effects on this cable-stayed bridge, this bridge is placed into the tornadic wind field and its equivalent straight-line wind field. In the equivalent straight-line wind field, the velocity-inlet and pressure-outlet boundaries are more than 5H and 15H away from the bridge, respectively, where H is the height of the bridge. And the blockage ratio is 1.4%. The velocity input is based on a power-law profile and 0.14 is taken as the exponent which is to simulate the urban/suburban terrain. The maximum resultant velocity (the resultant velocity of tangential and radial velocities) at a certain height (H_r= 6.85 m) is 81.1 m/s in the tornadic wind field. Therefore, the velocity profile applied to velocity input is expressed as below

$$V_s=81.1(Z/H_r)^{0.14} \quad (4)$$

where V_s denotes the velocity at different heights, H_r denotes the reference height (H_r = 6.85 m), and Z denotes the height above ground.

The black lines on the two sides are the streamlines of the flow, which keep straight on the horizontal plane except the region close to the cable-stayed bridge. This means that the wind flow is not disturbed by the boundary of the wind field, indicating that the design of the straight-line wind field is acceptable. The maximum positive velocity occurred near the cable-stayed bridge, because the wind flow has to accelerate to pass the cable-stayed bridge to keep constant quantity of flow. The maximum negative velocity is observed at the corners near the pylons on the windward side, where vortices are formed.

Pressure coefficient is adopted to represent the pressure distribution on the bridge surface. In this study, the pressure coefficient is calculated based on Eq. (5)

$$C_p = \frac{P-P_r}{\frac{1}{2}\rho_r V_r^2} \quad (5)$$

where $P - P_r$ denotes the relative static pressure at the point where the pressure coefficient is evaluated. In both of the two cases, P_r, V_r, and ρ_r denote the reference pressure, reference wind velocity and air density, respectively, which are $P_r = 101{,}325$ Pa, $V_r = 81.1$ m/s and $\rho_r = 1.225$ kg/m3 in this study according Li and Yan (2019).

The pressure distribution is homogeneous on the plane except the regions near the cable-stayed bridge. The maximum positive pressure is obtained on the windward side of the cable-stayed bridge. Because the velocity of flow becomes zero at the stagnation point on the windward side and the pressure increases due to the decrease in velocity, according to the Bernoulli equation. The maximum negative pressure is obtained at the two corners of the pylon on the windward side of the cable-stayed bridge. Two big vortices are observed behind the pylon on the leeward side of the bridge. Small vortices can also be observed on the windward side of the cable-stayed bridge and between the diaphragms plates which are below the bridge deck. So the regions below the bridge deck is dominated by negative pressure, which induces suction.

On the most parts of the cable stayed bridge, the surface is dominated by negative pressure. The positive pressure is only observed on the windward side of the deck and the pylons. The maximum positive pressure is obtained on the top region of the pylons which is marked by the red circle. This is similar with the results from Erdem (2010). Erdem concluded that the maximum pressure distribution occurred on vertical surface of the tower and it increases in direct proportion to the height of the tower. The maximum negative pressure is obtained on the sides of the pylons due to that fact that wind has to accelerates to pass the pylons, and pressure decreases due to the increase in velocity according to the Bernoulli equation.

Project Title: Development of ATMA/AIPV Deployment Guidelines Considering Traffic and Safety Impacts

A paper resulted from the research of this project, titled “Identification of Operational Design Domain for Autonomous Truck Mounted Attenuator System on Multilane Highways” was submitted to the Journal of Transportation Research Record for the consideration of publication.

Project Title: Deep Learning for Unmonitored Water Level Prediction and Risk Assessment

Methods for soliciting information from stakeholders using GIS software and online survey tools were developed.

Project Title: Optimization of Transportation Infrastructure System Performance with Autonomous Maintenance Technology in Work Zones

Nothing to report.

Project Title: SMART Shear Keys for Multi-Hazards Mitigation of Diaphragm-Free Girder Bridges – Phase II

Bridge and model selection.

Project Title: Sensor-Assisted Condition Evaluation of Steel and Prestressed Concrete Girder Bridges Subjected to Fire – Phase II

Nothing to report. The collected data is processing now.

Key Outcomes or Other Achievements

University of Nebraska-Lincoln (UNL)/University of Nebraska-Omaha (UNO)/University of Nebraska Medical Center (UNMC)

During this reporting period, key outcomes and other achievements included:

Project Title: Assessing Performance of Geosynthetic Reinforced Pavement with a Large-Scale Track Wheel Test and Nondestructive Testing Tools
Nothing to report.

Project Title: Evaluation of the Driveway Assistance Device (DAD) Systems in One-Lane Two-Way Work Zone
Nothing to report.

Project Title: Development of New Generation of Portable Concrete Barriers
The key outcome for this quarter was refinement of candidate concepts, creation of 3-D models, development of preliminary LS-DYNA models, conduct LS-DYNA simulations with pickup truck model, analysis of barrier and vehicle performance, and evaluate necessary and possible modifications for selected concepts. These PCB concepts were determined to meet the MASH TL-3 safety requirements with reduced free-standing barrier deflections as well as increased vehicle stability as compared to existing, widely used PCB systems. One concept, Concept 19 was found the most promising design with 90% reduction in barrier deflection.

Project Title: LIDAR-Based Vibration Monitoring for Assessing Safety of Damaged Bridges
During this reporting period, the key outcome has been the development of a dynamic data acquisition system that can be remotely operated and requires no contact with the structure. This reporting period also involved dynamic testing of bridge slabs, which were monitored for vibration. The dynamic excitation was imparted to mimic phased (staged) construction with the excitation occurring during the concrete pour and curing. This is the first time that phased construction cracking was able to be observed in a laboratory setting to confirm the degradation seen in real bridges. This unique dynamic behavior enables us to study our platform in a unique and complex scenario that is routinely encountered in the field.
Project Title: Resilience of Rural Communities and Transportation Networks to Hazards
Nothing to report.

Project Title: Crashworthy Foundations for Soil-Embedded Roadside Safety Hardware
Results are too preliminary to warrant stating as an outcome at this stage.

Project Title: Protecting Critical Civil Infrastructure against Impact from Commercial Vehicles – Phase II
Nothing to report.

Project Title: Incorporating Snow Processes in the Iowa Flood Information System (IFIS) and Evaluating its Applicability for Nebraska
Nothing to report.

Project Title: Virtual Barriers for Mitigating and Preventing Run-Off-Road Crashes – Year 4
The development of maximum safe speeds was correlated with the curvature and elevations. Some vehicle parameters were correlated with geological data which can support

electronically-communicated variable speed limits.

Project Title: Bio-Inspired Reusable Crash Cushions with Superior Energy-Absorbing Capacity
Nothing to report.

Project Title: MATC Smart Barrier
A technical paper was submitted to the WCX SAE World Congress and was approved for presentation in April, 2020. NOTE: due to COVID-19 outbreak, the SAE World Congress was cancelled, although paper publication is anticipated as planned. Three webinars were conducted in cooperation with external agencies not supporting this project but which were highly related to automated vehicle transportation.

Project Title: Investigation and Development of a MASH Test Level 6, Cost-Effective, Barrier System for Containing Heavy Tractor Tank-Trailer Vehicles and Mitigating Catastrophic Crash Events – Year 3
The objective of this project is to redesign a TL-6 barrier to safely contain and redirect a tank-trailer vehicle. To evaluate the capacity of the new TL-6 barrier, LS-DYNA finite element analysis software was used to analyze the barrier. A detailed vehicle model is necessary to obtain more accurate model results, such as forces applied to the barrier. Final simulations are in progress to verify barrier capacity and vehicle containment.

Project Title: Real-Time Emergency Communication Systems for HAZMAT Incidents (REaCH)

- Draft of professional driver behavior and health monitoring attitudes survey completed.
- Completed coding of dashboard main page for laboratory test to test heat index sensor. This includes alert notification.
- Began coding and constructing technology to capture heat index data real-time from sensor and sent to REaCH database and displayed on dashboard in real time. We are close to completing this functionality and preparing for a laboratory experiment – from sensor to dashboard on April 26th.
- Prepared research methods/design and checklist for laboratory experiment.
- Completed study of appropriate thresholds values and entered into test system.
- Updated technical documentation
- Preparing to move from Box to O365
- Purchased Raspberry PIs – 4,SD cards, power supplies, battery packs and notebook computer to be our survey and portable test system.

University of Iowa (UI)

During this reporting period, key outcomes and other achievements included:

Project Title: Infrastructure Inspection During and After Unexpected Events – Phase III:
Nothing to report.

Project Title: Infrastructure Inspection During and After Unexpected Events – Phase IV
Nothing to report.

Project Title: Transportation Planning with Floods

We can quickly determine the roads and bridges that must be mitigated (i.e. increase elevation, set up flood wall, etc.) for all citizens to have access to a hospital if a flooding event occurs.

Project Title: Reducing Flammability for Bakken Crude Oil for Train Transport

Nothing to report.

Project Title: Development of New Design Guidelines for Protection against Erosion at Bridge

As part of the present research project, a general methodology based on 3-D non-hydrostatic RANS numerical simulations was developed to determine the conditions for riprap shear failure for cases when a riprap apron is placed close to an abutment.

Based on data from the numerical experiments, the performance of existing design formulas (Pagan-Ortiz,1991 and Lagasse et al., 2001) used for riprap protection at bridges containing wing-wall abutments was checked for a wide range of conditions, outside of the range that was used to calibrate these design formulas. A main finding was that the two design formulas are not conservative enough for cases when the floodplain width is large even for the case of a straight channel. The other finding was that the two design formulas were not conservative enough for channels of sufficiently large curvature. This result was somewhat expected given that the increased acceleration of the flow around the outer-bank abutment with increase channel curvature should also result in an increase of the maximum bed shear stress over the riprap region.

Another main contribution of the present research was to propose new design formulas that retain the same functional relationship as that of Pagan-Ortiz (1991) and Lagasse et al. (2001) formulas in which the nondimensional riprap diameter, D50/ym, is proportional to the critical Froude number at a power □ ($D50/ym=C^{\alpha/2}*Fr^{\alpha}$). They can use to make predictions for abutments placed in curved channels. This significantly enlarges the range of practical conditions where the new formula can be applied, as many bridges are built in regions where the channel curvature is not negligible. Rather than using constant values for the two model parameters, C and α, as was the case for the previously mentioned formulas, C and α may be a function of the main nondimensional geometrical parameters (e.g., Bf/W, R/W, La/Bf) in the new design formulas. The two-parameter formulas can be used to predict the critical value of the Froude number, or equivalently the mean channel velocity or the discharge, at which riprap stone will start being entrained in straight and curved channels with or without a floodplain.

In the case of wing-wall abutments, one major finding is that α is not a function of the channel curvature but increases monotonically with increasing Bf/W. The predicted range $1.62< \alpha <1.84$ was in between the values used by Pagan-Ortiz (1991) formula ($\alpha =1.62$) and Lagasse et al. (2001) formula ($\alpha =2$). The variation of C with increasing Bf/W is not monotonic because larger C values are predicted for channels with no floodplain compared to channels with a narrow floodplain. Meanwhile, C increases monotonically with decreasing R/W (e.g., with increasing curvature). The rate of increase is the largest for channels with no floodplain. Present data suggests that C is not a function of channel curvature for channels with very wide floodplains.

In the case of spill-through abutments placed in a straight channel α is independent of La/Bf and C increases with increasing La/Bf. The predicted range of α was 1.7-1.95, slightly lower than $\alpha =2$ for Lagasse et al. and Pagan-Ortiz formulas. It is found that existing design formulas

are not sufficiently conservative even for some of the test cases conducted with straight channels (e.g., cases with relatively large La/Bf). A two parameter, design formula for riprap size selection in aprons protecting spill-through abutments of the form $D50/y=C^{0.5\alpha}*Fr^{\alpha}$ is proposed for spill-through abutments placed in straight or curved channels, where y is the flow depth next to the toe of the abutment. While α is only a function of the floodplain width for abutments that do not extend until close to the main channel and α =1.85 for abutments extending over the whole width of the floodplain, the second parameter C is a function of La/Bf, R and Bf. The new design formula was found to fit quite well all the data set generated via numerical simulations.

University of Kansas (KU)/University of Kansas Medical Center (KUMC)

During this reporting period, key outcomes and other achievements included:

Project Title: Modeling Driver Behavior and Aggressiveness Using Bio-Behavioral Methods: Phase III

The proposed bio-behavioral Intelligent Driver Model is very promising as it can better simulate driver behavior and therefore, replicate more realistically the traffic flow phenomena.

Low Cost 3-D LIDAR Development for Transportation

PI's Group: Systemic problems were identified that have driven design improvements for the fourth generation of the MATC 3D LIDAR Project. These include using a potentiometer to measure the horizontal angle of the device, minimizing the free play in the rangefinder position using bearings, and updating the rangefinder. Additionally, data was taken so that the fourth generation LIDAR system can be directly compared to the gen 2 prototype once gen 4 has been completed. Among the data collected was the run time of roughly 2.5 hours for gen 2 that should be significantly reduced by the increased computing power of the latest generation.

Co-PI's Group: Nothing to report.

Project Title: Assessing and Improving the Cognitive and Visual Driving Fitness of CDL Drivers

In total, from the beginning of our study until September 30, 2020, we have spoken to 244 potential participants from over 30 CDL companies, of which 31 subjects have completed their first assessments. We have begun year 2 and 3 assessments for the 3 year follow-up period. The participants have had a good experience and they have recommended us to other CDL drivers as well. Since COVID began, we reopened our lab in July 2020, recruited four new medical students, oriented them to our study via zoom, and have revised our phone triage and protocol systems.

Missouri University of Science & Technology (MS&T)

During this reporting period, key outcomes and other achievements included:

Project Title: Performance of Earthquake-Damaged Reinforced Concrete Bridges with Repaired Columns

Nothing to report.

Project Title: Performance of Earthquake-Damaged Reinforced Concrete Bridges with Repaired Columns – Phase II

Nothing to report.

Project Title: Investigation of Wind Effects on Bridges Induced by Tornadoes for Tornado-Resistance Design – Phase II
Our simulation presents the wind effects of a cable-stayed bridge under straight-line winds.

Project Title: Development of ATMA/AIPV Deployment Guidelines Considering Traffic and Safety Impacts
Nothing to report.

Project Title: Deep Learning for Unmonitored Water Level Prediction and Risk Assessment
We are conducting research to gather information from a broad group of Missouri first responders to identify areas that need better predictive tools to improve public safety and save lives.

Project Title: Optimization of Transportation Infrastructure System Performance with Autonomous Maintenance Technology in Work Zones
Nothing to report.

Project Title: SMART Shear Keys for Multi-Hazards Mitigation of Diaphragm-Free Girder Bridges – Phase II
Nothing to report.

Project Title: Sensor-Assisted Condition Evaluation of Steel and Prestressed Concrete Girder Bridges Subjected to Fire – Phase II
Nothing to report.

Education and Outreach Activities

MATC has implemented several educational outreach programs in support of USDOT's Strategic Plan and the center's mission to increase the number of students from underrepresented groups in STEM education and transportation-related careers. Descriptions of each educational program and the activities that took place during October 1, 2020 – March 31, 2021 are detailed below.

MATC After-School Program - Road, Rails, and Race Cars (RRRC)
MATC's after-school program combines the talents of 4-12th grade teachers, engineering graduate and undergraduate college and university student mentors, and professional and industry partners to educate the diverse leaders of tomorrow about STEM principles. Each participating school offers the club for an hour every week. Mentors present on an engineering or transportation-related topic and lead students in an interactive activity that encompasses the concepts of the lesson. Examples of activities include constructing bridges and conducting strength tests, creating towers that can withstand simulated earthquakes, and building race cars powered by potential energy stored in a rubber band.

The reporting period of 10/1/2020 – 3/31/2021 coincides with the Covid-19 pandemic. The pandemic has caused school closures and restrictions on access to school sites at most of our 9 locations in 4 cities across Nebraska. However, a limited number of sites implemented RRRC utilizing online lessons and materials supplied by MATC staff. The programming details are as follows.

Fall 2020 Programming

During the reporting period, preparations were completed to develop online lessons and activities that on-site teachers can implement, with MATC support. Three (3) sites in Lincoln, NE offered RRRC during this period: Culler Middle School, Mickle Middle School, and Park Middle School. Clubs began during Lincoln Public School's 2nd Quarter, beginning October 19, 2020.

For the Fall 2020 semester, RRRC at Culler Middle School was offered on Thursdays from 3:15 p.m. to 4:15 p.m., beginning on October 28, 2020, and ending on December 16, 2020. A total of three (3) implementation dates were completed during the fall iteration, with the total attendance being 5 by 4 students. The typical weekly participation was approximately 2 students. The curriculum included activities under the topics of civil engineering, structural engineering, mechanical engineering, railway safety, city planning, physics, and material science.

For the Fall 2020 semester, RRRC at Mickle Middle School was offered on Wednesdays from 3:15 p.m. to 4:15 p.m., beginning on October 21, 2020, and ending on December 9, 2020. A total of seven (7) implementation dates were completed during the fall iteration, with the total attendance being 30 by 7 students. The typical weekly participation was approximately 4 students. The curriculum included activities under the topics of civil engineering, structural engineering, mechanical engineering, railway safety, city planning, physics, and material science.

For the Fall 2020 semester, RRRC at Park Middle School was offered on Wednesday from 3:15 p.m. to 4:15 p.m., beginning on October 21, 2020, and ending on December 9, 2020. A total of seven (7) implementation dates were completed during the fall iteration, with the total attendance being 101 by 33 students. The typical weekly participation was approximately 12 students. The curriculum included activities under the topics of civil engineering, structural engineering, mechanical engineering, railway safety, city planning, physics, and material science.
For the Fall 2020 programming, RRRC employed: one (1) Education and Outreach Coordinator, and three (3) on-site teachers. Additional RRRC tasks completed included revising existing lessons and activities, developing an online curriculum of lessons and activities, and coordinating with teachers and CLC staff.

Spring 2021 Programming

The spring semester portion of RRRC was implemented at three (3) sites in Lincoln, NE: Culler Middle School, Mickle Middle School, and Park Middle School. Weekly implementation was the same as Fall 2020, with on-site teachers leading clubs with MATC support.

For the Spring 2021 semester, RRRC at Culler Middle School was offered on Thursdays from 3:15 p.m. to 4:15 p.m., beginning on January 14, 2021, and ending on February 25, 2021. A total of seven (7) implementation dates were completed during the spring iteration, with the total attendance being 27 by 11 students. The typical weekly participation was approximately 4 students. The curriculum included activities related to several topics in transportation safety.

For the Spring 2021 semester, RRRC at Mickle Middle School was offered on Wednesdays from 3:15 p.m. to 4:15 p.m., beginning on January 13, 2021, and ending on February 24, 2021. A total of seven (7) implementation dates were completed during the spring iteration, with the total attendance being 19 by 5 students. The typical weekly participation was approximately 3 students. The curriculum included activities related to several topics in transportation safety.

For the Spring 2021 semester, RRRC at Park Middle School was offered on Wednesday from 3:15 p.m. to 4:15 p.m., beginning on October 21, 2020, and ending on December 9, 2020. A total of five (5) implementation dates were completed during the spring iteration, with the total attendance being 14 by 14 students, though complete attendance records were not kept. The typical weekly participation was approximately 14 students. The curriculum included activities related to several topics in transportation safety.

For the Spring 2021 programming, RRRC employed: one (1) Education and Outreach Coordinator, and four (4) on-site teachers. Additional RRRC tasks completed included revising existing lessons and activities, developing an online curriculum of lessons and activities, and coordinating with teachers and CLC staff.

MATC Scholars Program

The MATC Scholars Program is a multi-day conference that brings students from underrepresented groups together with diverse faculty. MATC's Scholars Program fills an existing gap for minority students by encouraging them to attend graduate school and teaching them necessary skills to succeed in obtaining graduate degrees in their chosen STEM-related fields. Students from historically black colleges and universities, tribal colleges, and other minority-serving institutions across the country are given the valuable opportunity to network and attend seminars led by experienced faculty members and educational administrators at the University of Nebraska-Lincoln campus.

The Fall 2020 Scholars Program for Tribal College and University (TCU) students was scheduled October 9, 2020 through October 30, 2020, and provided seminars, panels, and workshops that inform and inspire Native American students on their educational journeys. Seven (7) students from Nebraska Indian Community College, and one (1) student from Pawnee Nation College registered. Due to restrictions due to the COVID-19 pandemic, the MATC Scholars Program for TCU students was held virtually. In this manner, each of the regularly scheduled sessions were instead offered in video or zoom formats. There were 11 videos posted during the period of October 9 to October 30, 2020. There were also two live Zoom sessions for a total of 13 sessions . Scheduled video content included topics such as Choosing a 4-Year Institution that is Right For You, Funding your Success, A Look Into a Journalism Major and Native American Journalism, Study Skills in a 4-Year Institution, and Native Experiences in a 4-year institution, just to name a few.

The Spring 2021 program was held virtually during the period March 29, 2021 – April 9, 2021. The program provided seminars, panels, workshops, and expos that informed and inspired students from Historically Black Colleges & Universities and Hispanic-serving institutions on their educational journey. The program was held from 9:00 am – 4:00 pm CST on Fridays and Saturdays during the program period. All sessions were initiated by MATC via Zoom. Sessions focused on topics including *The Why and How of Graduate School, Strategies for Succeeding in Graduate School*, a *Career Expo,* and a *Graduate Expo.*

Spring 2021 program presenters virtually came together from the A.O. Maki & Associates, LLC., Bucknell University, Cummins, JEO Consulting Group, Inc., Michigan Department of Transportation, Missouri University of Science and Technology, the National GEM Consortium, New Mexico State University, North Carolina Agricultural and Technical State University, Prairie View A&M University, Southern University A&M College, Tennessee State University, The Princeton Review, US Department of Transportation, University of Iowa, University of Maryland Eastern Shore, University of Nebraska, University of Texas at Arlington, Lincoln University, and Werner Enterprises.

The twenty-five (25) undergraduate students who attended were represented from seven (7) institutions including Lincoln University, New Mexico State University, North Carolina A&T State University, Prairie View A&M University, Southern University A&M College, Tennessee State University, and University of Maryland Eastern Shore.

The full agenda flipbook for the Spring 2021 program can be viewed at https://matc.unl.edu/education/scholars-program2021.php.

MATC Intern Program

The MATC Intern Program partners with private companies, local government, and academia to provide undergraduate students with paid summer internship opportunities in the transportation and engineering fields. During this 12-week program, students gain hands-on experience in their area of interest under the mentorship of a professional. Students work 40 hours per week while experiencing the day-to-day tasks and responsibilities of their desired career. The program culminates in a written paper and presentation detailing the student's internship experience.

Summer 2020 internships were conducted remotely, offering students the opportunity to assist faculty researchers with data analysis, literature reviews, and familiarize themselves with various hardware and software platforms required for transportation research. It is anticipated that Summer 2021 internships will be conducted as a hybrid of remote and in-person based on sponsor availability. Currently, MATC has five (5) private firm sponsors offering seven (7) Summer 2021 internship positions, to which six (6) University of Nebraska students have applied.

NCIA/MATC Sovereign Native Youth STEM Leadership Academy

The NCIA/MATC Sovereign Native Youth STEM Leadership Academy is a six-day summer program held on the University of Nebraska-Lincoln campus. The mission is two-fold: (1) to provide an extended learning opportunity in science, technology, engineering, and math (STEM) subjects, and (2) explore a wide-range of education and career options after high school. The academy offers a broad range of hands-on activities that build leadership skills and interest in STEM subjects and transportation-related careers while engaging with Native American history and culture. The curriculum is developed and implemented by Native American faculty, students, and leaders from across the country. Attendees have the unique opportunity to build a professional network with Native American guest speakers and panelists, who provide mentorship by sharing their education and career success.

The 2020 NCIA/MATC Sovereign Native Youth STEM Leadership Academy was originally scheduled for May 31 to June 5, 2020 on the campus of the University of Nebraska-Lincoln. Registration was anticipated to be 40 high-school students, primarily from reservation and rural schools in the state of Nebraska, with a smaller number anticipated from urban schools. Due to the university shut-down and general safety precautions during the Covid-19 pandemic, it was decided to reconfigure the program from in-person to online. A six-week program in which students would participate in weekly modules was developed and was scheduled to begin on June 29 and finish on August 7, 2020. Four students enrolled in the online version of the summer academy (3 from Winnebago, 1 from the city of Omaha), and partially completed the six-week program.

For Summer 2021, it was decided to postpone the Summer Academy due to ongoing Covid-19 concerns and restrictions. An in-person program is being planned for Summer 2022.

MATC Summer Institute

MATC is actively working to expand the MATC Summer Institute, which unites transportation professionals and K-12 educators to develop classroom materials based on transportation research at the member institutions. Teachers work closely with both MATC faculty and graduate students to develop grade-level-appropriate transportation-oriented lesson plans. These lesson plans meet all state curriculum standards, and are available on the MATC website for any interested teacher to utilize. MATC is committed to working with middle- and high-school math, science, and industrial technology teachers from schools that have significant populations of underrepresented groups.

MATC Research Experience for Undergraduates (REU)

MATC was not able to support an REU student during this reporting period. We are reviewing undergraduate options to support a Summer 2021 MATC REU student.

How have the results been disseminated?

MATC staff maintained project records on the Transportation Research Board's Research in Progress (RiP) database and on MATC's online database at: http://matc.unl.edu/research/research_search.php. Links to the RiP records are provided on each project page in the MATC research database.

MATC projects are committed to having a sustained impact on the transportation system through technology transfer and workforce development efforts. MATC PIs are developing Technology Transfer Plans for their individual projects to ensure transferability of their research to other regions. For example, recent Technology Transfer plans include projects focusing on infrastructure inspections during and after unexpected events, and protecting critical civil infrastructure against impact from commercial vehicles.

University of Nebraska-Lincoln (UNL)/University of Nebraska-Omaha (UNO)/University of Nebraska Medical Center (UNMC)

Project Title: Assessing Performance of Geosynthetic Reinforced Pavement with a Large-Scale Track Wheel Test and Nondestructive Testing Tools

Nothing to report.

Project Title: Evaluation of the Driveway Assistance Device (DAD) Systems in One-Lane Two-Way Work Zone

Nothing to report.

Project Title: Development of New Generation of Portable Concrete Barriers

Results have been disseminated within the research team and other UNL faculty. Furthermore, we plan to present the results at the Midwest Pooled Fund Program mid-year meeting with sponsoring State DOTs scheduled for April 22, 2021 to collect their feedback.

Project Title: LIDAR-Based Vibration Monitoring for Assessing Safety of Damaged Bridges

An abstract was submitted for consideration at Structures Congress 2021, a conference sponsored by the Structural Engineering Institute at American Society of Civil Engineers). This was submitted in June 2020. However, the organizing committee has decided to cancel this

conference. Alternative venues are being discussed in the group.

A journal manuscript has been drafted and is in the final stages preparing for submission. This journal paper is targeting the ASCE Journal of Bridge Engineering. Planned submission is January 2021.

The graduate student, Khalid Al-Kady, presented the research at the UNL COE Graduate Student Symposium.

Project Title: Resilience of Rural Communities and Transportation Networks to Hazards
Nothing to report.

Project Title: Crashworthy Foundations for Soil-Embedded Roadside Safety Hardware
Results have not progressed sufficiently to warrant dissemination at this stage.

Project Title: Protecting Critical Civil Infrastructure against Impact from Commercial Vehicles – Phase II
Nothing to report.

Project Title: Incorporating Snow Processes in the Iowa Flood Information System (IFIS) and Evaluating its Applicability for Nebraska
Nothing to report.

Project Title: Virtual Barriers for Mitigating and Preventing Run-Off-Road Crashes – Year 4
During this reporting period, two journal papers were submitted for review. One journal paper previously submitted for review in the previous reporting period was accepted, regarding the fundamental applications of the MVRC concept.

Project Title: Bio-Inspired Reusable Crash Cushions with Superior Energy-Absorbing Capacity
Nothing to report.

Project Title: MATC Smart Barrier
A technical summary of the results of the MATC Year 3 effort, combined with a summary of the results of the Years 1 and 2 projects, was drafted and is in review. One conference paper draft was completed and submitted to the 4th International Workshop on Intelligent Transportation and Autonomous Vehicles Technologies (ITAVT 2021. Two additional journal paper drafts were begun but have not yet been submitted. Additionally, conference calls were held with the Nebraska DOT and the Midwest States Pooled Fund program to denote findings to date.

Project Title: Investigation and Development of a MASH Test Level 6, Cost-Effective, Barrier System for Containing Heavy Tractor Tank-Trailer Vehicles and Mitigating Catastrophic Crash Events – Year 3
A technical summary report draft has been submitted to MATC describing results of the Year 3 research effort.

Project Title: Real-Time Emergency Communication Systems for HAZMAT Incidents (REaCH)
Ng, R., Rogers, J., Yachamaneni, K., Baysa, K., Li, D., Suwondo, T., Yoder, A., Ghersi, D., Fruhling, A. (2021). Wireless Sensor Integration into System's Network for Real-time Data Streaming:

Lessons Learned. UNO Student Creativity and Research Fair, March, 2021. Poster. Ru Ng presented. A. Fruhling Advisor.

University of Iowa (UI)

Project Title: Infrastructure Inspection During and After Unexpected Events – Phase III:
Nothing to report.

Project Title: Infrastructure Inspection During and After Unexpected Events – Phase IV
Nothing to report.

Project Title: Transportation Planning with Floods
We submitted a paper about our year 1-2 work on path finding during flooding events. We are working on the second paper.

Project Title: Reducing Flammability for Bakken Crude Oil for Train Transport
Two conference publications are accepted for publication and presented. Experiments are completed on nanofuel with Carbon dot nanomaterial. A review on droplet combustion is going on which will be published into a journal publication.

Project Title: Development of New Design Guidelines for Protection against Erosion at Bridge
A journal paper is in press in the J. Hydraulic Research. It reports the main results for wing-wall abutments placed in straight and curved channels and proposed modifications of the riprap design formula. We also presented our work at the February MATC Workshop and will present a MATC seminar in October 2020. In the long term, we will work with the Transportation Research Board (TRB) committees related to bridges (e.g., TRB-AFB60) and FWHA such that the main findings and the improved formulas will be considered for adoption as a Technical Brief of HEC-23.

University of Kansas (KU)/University of Kansas Medical Center (KUMC)

Project Title: Modeling Driver Behavior and Aggressiveness Using Bio-Behavioral Methods: Phase III
We presented at a webinar organized by MATC.

Low Cost 3-D LIDAR Development for Transportation
PI's Group: MS Teams site has been set up for the project through which the progress and results generated to date have been shared.

Co-PI's Group: Filtered data and smoothed data have been shared with the PI in the MS Teams site. Algorithm for filtering and smoothing will be shared once cleaned up carefully by a team member.

Project Title: Assessing and Improving the Cognitive and Visual Driving Fitness of CDL Drivers
The medical students formed two teams and submitted two posters to the University of Kansas School of Medicine's Student Research Forum in April 2021. We received 2nd place for one of them!

We also submitted a proposal to the Road Safety and Simulation Conference 2021 correlating simulation performance to cognitive and visual measures of our year 1 participants. We were accepted and are writing our paper to present. The conference has been postponed to June 2022.

Missouri University of Science & Technology (MS&T)

Project Title: Performance of Earthquake-Damaged Reinforced Concrete Bridges with Repaired Columns
Nothing to report.

Project Title: Performance of Earthquake-Damaged Reinforced Concrete Bridges with Repaired Columns – Phase II
Nothing to report.

Project Title: Investigation of Wind Effects on Bridges Induced by Tornadoes for Tornado-Resistance Design – Phase II
Nothing to report.

Project Title: Development of ATMA/AIPV Deployment Guidelines Considering Traffic and Safety Impacts
Nothing to report.

Project Title: Deep Learning for Unmonitored Water Level Prediction and Risk Assessment
Nothing to report.

Project Title: Optimization of Transportation Infrastructure System Performance with Autonomous Maintenance Technology in Work Zones
Nothing to report.

Project Title: SMART Shear Keys for Multi-Hazards Mitigation of Diaphragm-Free Girder Bridges – Phase II
Nothing to report.

Project Title: Sensor-Assisted Condition Evaluation of Steel and Prestressed Concrete Girder Bridges Subjected to Fire – Phase II
Nothing to report.

MATC Research Webinars

The webinars listed below were hosted by MATC during this reporting period. Closed captioned recordings of each webinar were uploaded to the MATC YouTube channel (https://www.youtube.com/user/MidAmericaTrans/videos) with full research briefs and presenter bios available on the MATC website (http://matc.unl.edu/webinarseries.php).

Date	Title	Presenters
10/23/2020	Development of New Design Guidelines for Protection Against Erosion at Bridge Abutments	Dr. George Constantinescu

12/8/2020	Reducing Flammability for Bakken Crude Oil for Train Transport	Dr. Albert Ratner Mr. Sazzad Parveg (GRA)
2/15/2021	Deep Learning Techniques for Flash Flood Management	Dr. Steven Corns

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

University of Nebraska-Lincoln (UNL)/University of Nebraska-Omaha (UNO)/University of Nebraska Medical Center (UNMC)

Project Title: Assessing Performance of Geosynthetic Reinforced Pavement with a Large-Scale Track Wheel Test and Nondestructive Testing Tools
The team will finish the design and order of fabrication for a large-scale track wheel (LSTW) testing apparatus in coming the reporting period. Also, the team will have a plan to promote the apparatus to the Geosynthetic industries and other regional media.

Project Title: Evaluation of the Driveway Assistance Device (DAD) Systems in One-Lane Two-Way Work Zone
Continue to discuss with NDOT and other Midwest DOTs to identify potential test beds.

Project Title: Development of New Generation of Portable Concrete Barriers
The plan for the next period is to continue development of the LS-DYNA models for candidate PCB design concepts. Additional revisions/modifications to the models will be investigated. The performance of each concept will be evaluated under various MASH impacts with pickup truck. Along simulation efforts, a progress report will be prepared on literature search and concept selection activity.

Project Title: LIDAR-Based Vibration Monitoring for Assessing Safety of Damaged Bridges
Primary activities during the reporting period will focus on experimentation and evaluation of the limitations of the acquisition system. Specifically, 6 bridge slabs will be poured and tested in the Omaha PKI Structures Lab. During the pour, the slabs will be dynamically excited mimicking traffic induced vibration during construction. The lidar-based assessment technology developed as part of this project will be utilized to monitor the motion of the bridge slab and will be compared with traditional sensors. Additionally, we will focus on Tasks #3 and #4. Dynamic bridge slab tests will continue through the beginning of the next quarter. Benchscale tests will begin towards the end of the next quarter. Each of these tests will enable validation and analysis of the prototype monitoring system. Given this data, algorithm development to aid decision-making will also continue.

Project Title: Resilience of Rural Communities and Transportation Networks to Hazards
The primary activities for the next reporting period will focus on gathering the results of the survey and beginning to analyze and interpret resulting functionality curves. The survey will be disseminated broadly within the region to include county-level bridge engineers. Results of the survey are expected by June. Upon receiving the survey results, data will be cataloged and stored anonymously. Provided this information, initial functionality analyses will be conducted which will lead the way to the fourth task (baseline rural resilience model).

Project Title: Crashworthy Foundations for Soil-Embedded Roadside Safety Hardware
Model development will continue, including limited modeling validation using available test

data for soil-embedded hardware. Bogie testing embedded foundation configurations will be selected and test planning (drafting) will begin.

Project Title: Protecting Critical Civil Infrastructure against Impact from Commercial Vehicles – Phase II

In the next reporting period, onboarding of the new Ph.D. student will continue along and model replication studies will be completed. Planning and literature review for expanded blast students to examine bridges system response to blast, impact and fire/temperature will continue. Publication development of publications from former Ph.D. student Fang's research will continue and publications submitted. Expanded numerical studies focusing on the effects of fire accompanying blast and impact will continue, with studies leveraging Fang's research. Modeling activities will center on identifying appropriate constitutive models.

Project Title: Incorporating Snow Processes in the Iowa Flood Information System (IFIS) and Evaluating its Applicability for Nebraska

We will try to complete sensor installations. We also plan to make some progress on the snow modeling part of the project.

Project Title: Virtual Barriers for Mitigating and Preventing Run-Off-Road Crashes – Year 4

During the next reporting period, the graduate student responsible for performing the visual survey, mapping road and lane data to geodetic markers, and generating the road digitization application will conduct work. Further review of the photographic "tiling" system used by aerial satellite and photography which is linked to GNSS data (latitude & longitude) will be explored to ensure excellent corroboration of photographically-identified lane edges and actual GNSS coordinates of lane boundaries.

Project Title: Bio-Inspired Reusable Crash Cushions with Superior Energy-Absorbing Capacity

We will continue having weekly meetings on Monday. The experiments should start, and the experimental data will be summarized and presented at conference meetings

Project Title: MATC Smart Barrier

Submit Year 3 final report. Note that a subsequent Year 4 project was approved regarding the implementation of findings from the Years 1 through 3 effort, using machine vision and artificial intelligence to build the virtual road corridor network. Future progress updates will reflect progress on that research project.

Project Title: Investigation and Development of a MASH Test Level 6, Cost-Effective, Barrier System for Containing Heavy Tractor Tank-Trailer Vehicles and Mitigating Catastrophic Crash Events – Year 3

A phase 4 proposal has been submitted to MATC regarding the full-scale crash testing of the high-capacity, MASH TL-6 barrier system.

Project Title: Real-Time Emergency Communication Systems for HAZMAT Incidents (REaCH)

- Work with Dr. Rilett on introductions to the State Patrol.
- Continue coding the functionality of main Dashboard page. Add threshold validation code as needed to the REaCH system.
- Conduct laboratory experiment testing sensor and thresholds for heat index.
- Research POLAR open source SDK on Github.

- Survey professional drivers on attitudes towards being monitored.
- Submit manuscript of the First Responders Wearable Technology survey to Safety journal. (Dr. Yoder, et al)
- Submit manuscript of the Needs Assessment to Emergency Management journal. (Dr. Medcalf, et al)
- Dr. Fruhling and team to meet with NSRI National Strategic Research Institute and NCITE to discuss DoD interests in the project.
- Look for federal grant RFPs and write application.
- Develop a website.

University of Iowa (UI)

Project Title: Infrastructure Inspection During and After Unexpected Events – Phase III:
A final report, containing all tasks and the BLCP algorithm in a straight flowchart applicable for DOT authorities will be written. A journal paper is under preparation.

Project Title: Infrastructure Inspection During and After Unexpected Events – Phase IV
In the next step, the CFD results will be integrated via the full fluid structure interaction approach to investigate bridge response and stress fields to capture its potential response mechanism.

Project Title: Transportation Planning with Floods
Vahid is reviewing the existing literature on road and bridge mitigation to develop more realistic models of the costs and constraints involved.

Updating some of the problem's datasets is another activity we are planning for the next quarter. Previously, each road segment's mitigation cost was based on its number of lanes, length, and speed limit. However, by locating each bridge's specific location and length, we could differentiate the costs between roads and bridges. A third set of arcs includes the ones labeled as roads but contain a small bridge on them. Accordingly, the costs of these particular arcs will be also updated. Another update in the data will be done by including more realistic capacities for the hospitals.

Project Title: Reducing Flammability for Bakken Crude Oil for Train Transport

- Research efforts will focus on combustion properties of renewable jet fuel droplets to aid in eventual combustion modeling of crude oil.
- Research efforts will focus on combustion properties of jet fuel droplets to aid in eventual combustion modeling of crude oil.
- Research efforts will focus on combustion properties of ethanol and methanol droplets to aid in eventual combustion modeling of crude oil.
- Research efforts will also focus on modification of droplet splashing properties of crude oils by adding nanomaterials.
- A review on droplet combustion will be formalized into a journal publication.

Project Title: Development of New Design Guidelines for Protection against Erosion at Bridge
A main direction of future research is to extend the present formula for cases when the flow regime beneath the bridge deck connecting the two spill-through abutments changes from free surface flow to orifice flow or to fully-pressurized flow. Such a regime change induces very

complex changes in the velocity and bed shear-stress distribution inside the pressurized-flow region and downstream of it. A similar numerical approach based on 3-D, nonhydrostatic RANS simulations and using the Volume of Fluid method to track the free surface can be used to understand the effects of increasing the flow depth in the channel on the distributions of the bed shear stress around the abutments and to determine the extent of the region that needs to be protected using riprap stone. A similar approach to the one documented over the first three years of research can be then used to propose a riprap sizing formula for spill-trough abutments that can be applied for all possible flow regimes at the bridge site.

We will continue testing the performance of the volume of fluid module needed to perform simulations with a deformable free surface. This capability is essential to perform simulations for cases when the free surface elevation is situated above the bridge deck and the flow becomes pressurized in the vicinity of the abutments and of the bridge deck. Our main goal will be to validate this approach during the next quarter.

We also plan to write and submit a paper to the Journal of Hydraulic Engineering summarizing our research that led to proposing a new design formula for riprap sizing at spill-through abutments.

University of Kansas (KU)/University of Kansas Medical Center (KUMC)

Project Title: Modeling Driver Behavior and Aggressiveness Using Bio-Behavioral Methods: Phase III

- Conduct further testing through microscopic simulation of the proposed bio-behavioral IDM.
- Expand the methodology to include data collection with automated vehicles.
- Develop driver training and assessment material using the research findings.

Low Cost 3-D LIDAR Development for Transportation

PI's Group: Over the next three months, wiring will leave the breadboard stage to be finalized and soldered. The power source will be selected and implemented. The program will approach finalization along with the packaging of the finalized gen 4 prototype. Data collection will continue to suggest areas for improvement up until the prototype is completed.

Co-PI's Group: In the next phrase, team members will focus on finding evaluation metrics and experimenting more on filtering/smoothing algorithms, accomplishing some comparisons, and providing conclusions and summarization of the findings. The prototype for super-resolution will start to be developed, including choosing model type, training method, and collecting data.

Project Title: Assessing and Improving the Cognitive and Visual Driving Fitness of CDL Drivers

We will continue to have monthly team meetings. The lab is now open, which will help with testing. We plan to continue year 2 and 3 data collection. Since the project is slated to end in the spring of 2022, we ended recruitment of year 1 participants after November 2020.

In addition, we have begun looking at the year 1 data for scholarly presentations to TRB and local research seminars.

Missouri University of Science & Technology (MS&T)

Project Title: Performance of Earthquake-Damaged Reinforced Concrete Bridges with Repaired Columns

During the next report period, the PI and the graduate student will finish debugging the MATLAB script to preform the IDA. The results of the IDA will be analyzed, and a draft of a journal paper will be prepared for submission.

Project Title: Performance of Earthquake-Damaged Reinforced Concrete Bridges with Repaired Columns – Phase II

During the next reporting period, the PI and the graduate student will finalize the selection of the repaired and retrofitted columns that will be simulated in Phase II of this study. In addition, the base model of the RC bridge column member will be extended to retrofitted columns, and the repaired and retrofitted column member responses will be simulated. The IDA will also be initiated.

Project Title: Investigation of Wind Effects on Bridges Induced by Tornadoes for Tornado-Resistance Design – Phase II

Simulation will be conducted to find the total forces/moments induced by winds on the cable-stayed bridge.

Project Title: Development of ATMA/AIPV Deployment Guidelines Considering Traffic and Safety Impacts

Finish working on task 2 traffic flow modeling. Make progress on task 3 data collection and model calibration. Due to the COVID-19 impact, MoDOT and CDOT are not able to perform field testing, and were not able to collect data for our research purpose. So this is slower than expected.

Project Title: Deep Learning for Unmonitored Water Level Prediction and Risk Assessment

We will gather information from the first test group and evaluate how well the survey instrument gathers the desired information and how easy it is for the survey takers to use. This will include written comments and possibly interviews with members of the test group. Once these areas are identified, we will plan the locations for predictions using deep learning algorithms and for taking manual water level information.

Project Title: Optimization of Transportation Infrastructure System Performance with Autonomous Maintenance Technology in Work Zones

Finish working on task a literature review.

Project Title: SMART Shear Keys for Multi-Hazards Mitigation of Diaphragm-Free Girder Bridges – Phase II

Four SMART shear keys will be cast. The facilities used to help install the shear key on the bridge candidate will be fabricated.

The performance of SMART shear key under both earthquake and tsunami loading will be numerically investigated.

Project Title: Sensor-Assisted Condition Evaluation of Steel and Prestressed Concrete Girder Bridges Subjected to Fire – Phase II

During the next reporting period, prestressed (pretensioned or posttensioned) concrete specimens will be designed and fabricated. Variables such as specimen dimensions, concrete strength, prestressing level, and instrumentation will be considered. Meanwhile, the anchor system and hydraulic jack to apply a prestressing force will be checked in the lab.

2. PARTICIPANTS & COLLABORATING ORGANIZATIONS

What organizations have been involved as partners?

During the reporting period, the Mid-America Transportation Center worked with 42 organizations to develop and implement research, education, and technology transfer activities. Each organization and its location are listed in Table 2 along with information describing the specific area or capacity in which the respective organization is committed to supporting the center.

MATC's education programs have an especially strong history of forming strong partnerships with professionals from a wide range of disciplines across the public and private sectors. MATC's partnership with the Nebraska Commission on Indian Affairs (NCIA) and tribal schools across Nebraska has led to several expansions of the STEM Academy, RRRC, and Scholars Program. Initial collaboration with NCIA on the first MATC/NCIA STEM Academy led to MATC's introduction with Umó^{N}ho^{N} Nation Public School, Santee Community School, and Winnebago Public School. RRRC was implemented at each of these schools following the participation of STEM teachers in the Academy. A representative from Little Priest Tribal College also served on a panel during the 2019 Academy. MATC continued collaborating with Little Priest through recruitment efforts for the 2019 Scholars Program. This year will be the first time Little Priest students participated in the program.

Table 2: MATC Partners and Type of Collaboration

MATC Program Affiliation	Organization Name	City	State	Financial	In-Kind Support	Contribution Facilities	Collaborative Research	Personnel Exchanges
All Programs	University of Nebraska-Lincoln	Lincoln	NE	X	X	X	X	X
All Programs	Nebraska Transportation Center	Lincoln	NE		X	X	X	X
Roads, Rails, and Race Cars Program (RRRC)	Culler Middle School	Lincoln	NE		X	X		
RRRC	Lefler Middle School	Lincoln	NE		X	X		
RRRC	Mickle Middle School	Lincoln	NE		X	X		
RRRC	Goodrich Middle School	Lincoln	NE		X	X		

RRRC	Dawes Middle School	Lincoln	NE		X	X		
RRRC	Park Middle School	Lincoln	NE		X	X		
RRRC	UmóNhoN Nation Public School	Macy	NE	X	X	X	X	
RRRC	Community Learning Center	Lincoln	NE				X	
RRRC; Academy	Lincoln Public Schools	Lincoln	NE	X			X	
RRRC; Academy	Winnebago Public School	Winnebago	NE	X	X	X	X	
RRRC; Academy	Santee Community School	Santee	NE	X	X	X	X	
RRRC; Academy	Nebraska Indian Community College	Macy	NE	X			X	
Academy	Union Pacific	Omaha	NE	X				
Academy	University of Nebraska Medical Center	Omaha	NE	X		X		
Academy	Little Priest Tribal College	Winnebago	NE				X	
Academy	Claire M. Hubbard Foundation	Omaha	NE	X				
Academy	Lincoln Bike Kitchen	Lincoln	NE	X				
Academy	National Institutes of Health (Worlds of Connections)	Lincoln	NE	X				
Academy; Scholars	Nebraska Commission on Indian Affairs	Lincoln	NE				X	
Scholars	Encompas Architects, P.C.	Lincoln	NE				X	
Scholars	Kansas Office of the Governor	Topeka	KS			X		
Intern Program	City of Lincoln Public Works	Lincoln	NE		X	X		
Intern Program	City of Omaha Public Works	Omaha	NE		X	X		
Intern Program	Nebraska Department of Transportation	Lincoln	NE	X	X	X		
Intern Program	Felsburg Holt & Ullevig	Omaha	NE		X	X		
Research	KUMC Research Institute	Kansas City	KS	X				
Research	Durham Buses	Kansas City	KS	X				X

Research	Wichita State University	Wichita	KS				X	
Research	Alaska DOT & Public Facilities	Juneau	AK					
Research	Iowa DOT	Des Moines	IA	X				
Research	Kansas DOT	Kansas City	KS	X				
Research	Missouri DOT	Jefferson City	MO	X	X		X	
Research	Virginia DOT	Richmond	VA			X		
Research	Utah DOT	Salt Lake City	UT			X		
Research	National Institute of Standards and Technology	Gaithersburg	MD				X	
Research	U.S. Geological Survey	Rolla	MO		X	X	X	
Research	National Weather Service	Springfield	MO		X	X	X	
Research	MicroSystem Inc.	Fort Walton Beach	FL				X	
Research	Iowa Flood Center	Iowa City	IA		X	X	X	
Research	University of Iowa Computer Science Department	Iowa City	IA			X	X	
Research	University of Iowa Hydroinformatics Lab	Iowa City	IA			X	X	
Research	United States Army Corps of Engineers	Kansas City	MO		X	X	X	
Research	United States Army Corps of Engineers	Washington	DC				X	
Research	Santa Catarina State University	Florianópolis	Brazil		X			
Research	Marshall University	Marshalltown	WV		X			
Research	Liquid Bulk and Tank, Inc.	Omaha	NE		X	X		
Research	Nebraska State Patrol	Lincoln	NE		X	X	X	
Research	National Instruments	Austin	TX			X		
Research	Velodyne Lidar	Mill Valley	CA			X		
Research	OGRA	Ontario	Canada			X		
Research	MACAVO	Ontario	Canada			X		
Research	FARO Technologies, Inc.	Lake Mary	FL		X			
Research	Hunt Transport Services, Inc.	Lowell	AR		X			
Tech Transfer	Florida Atlantic University	Boca Raton	FL			X		

Tech Transfer	Tran-SET at Louisiana State University	Baton Rouge	LA				X	

Have other collaborators or contacts been involved?

University of Nebraska-Lincoln (UNL)/University of Nebraska-Omaha (UNO)/University of Nebraska Medical Center (UNMC)

Project Title: Assessing Performance of Geosynthetic Reinforced Pavement with a Large-Scale Track Wheel Test and Nondestructive Testing Tools
Nothing to report.

Project Title: Evaluation of the Driveway Assistance Device (DAD) Systems in One-Lane Two-Way Work Zone
Nothing to report.

Project Title: Development of New Generation of Portable Concrete Barriers
Nothing to report.

Project Title: LIDAR-Based Vibration Monitoring for Assessing Safety of Damaged Bridges
Nothing to report.

Project Title: Resilience of Rural Communities and Transportation Networks to Hazards
Nothing to report.

Project Title: Crashworthy Foundations for Soil-Embedded Roadside Safety Hardware
Nothing to report.

Project Title: Protecting Critical Civil Infrastructure against Impact from Commercial Vehicles – Phase II
Nothing to report.

Project Title: Incorporating Snow Processes in the Iowa Flood Information System (IFIS) and Evaluating its Applicability for Nebraska
Nothing to report.

Project Title: Virtual Barriers for Mitigating and Preventing Run-Off-Road Crashes – Year 4
Nothing to report.

Project Title: Bio-Inspired Reusable Crash Cushions with Superior Energy-Absorbing Capacity
Nothing to report.

Project Title: MATC Smart Barrier
An additional proposal was developed in partnership with the UNL College of Law and UNL Computer Science and Engineering Department, through the Nebraska Transportation Research Council. This proposal was not accepted but was encouraged to reapply in future

years. The PI, Dr. Cody Stolle, is a member of the Nebraska Governance and Technology Center (NGTC) and will host an informational discussion on the role of governance and technology on connected and automated vehicles. In addition, a grant is being pursued to augment student research on transportation policy governing CAVs.

Project Title: Investigation and Development of a MASH Test Level 6, Cost-Effective, Barrier System for Containing Heavy Tractor Tank-Trailer Vehicles and Mitigating Catastrophic Crash Events – Year 3
Andy Zickler from Virginia DOT and Shawn Debenham from Utah DOT both provided some correspondence useful to the project.

Project Title: Real-Time Emergency Communication Systems for HAZMAT Incidents (REaCH)
Nothing to report.

University of Iowa (UI)

Project Title: Infrastructure Inspection During and After Unexpected Events – Phase III:
Nothing to report.

Project Title: Infrastructure Inspection During and After Unexpected Events – Phase IV
Nothing to report.

Project Title: Transportation Planning with Floods
Vahid Eghbal Akhlaghi – PhD student in the Department of Business Analytics
Yazeed Alabbad, PhD student at the UI Hydroinformatics Lab, University of Iowa

Project Title: Reducing Flammability for Bakken Crude Oil for Train Transport
Nothing to report.

Project Title: Development of New Design Guidelines for Protection against Erosion at Bridge
We had some discussions with Prof. Melville from Auckland University who is one of the top scientists working in this area and whose experiments were used by many groups doing work related to riprap design formulas, including by ours as part of the research performed during the 1st year of this project. Dr Constantinescu visited Univ Auckland in May 2019 and discussed results of the study with Prof. Melville. Dr Constantinescu also visited ETH Zurich in March 2021 and presented some of the main results and findings of this project to the researchers at the Hydraulics, Hydrology and Glacialogy Lab at ETH and got lots of feedback.

University of Kansas (KU)/University of Kansas Medical Center (KUMC)

Project Title: Modeling Driver Behavior and Aggressiveness Using Bio-Behavioral Methods: Phase III
Nothing to report.

Low Cost 3-D LIDAR Development for Transportation
Jarod Bennett, Mather Saladin, Daniel Sizoo, Spencer Stewart, and Graham Wood are undergraduate mechanical engineering students at the University of Kansas who are working

on a parallel 3-D LIDAR project as a capstone design project. They are providing useful help and information to this project.

Project Title: Assessing and Improving the Cognitive and Visual Driving Fitness of CDL Drivers
Nothing to report.

Missouri University of Science & Technology (MS&T)

Project Title: Performance of Earthquake-Damaged Reinforced Concrete Bridges with Repaired Columns
Nothing to report.

Project Title: Performance of Earthquake-Damaged Reinforced Concrete Bridges with Repaired Columns – Phase II
Nothing to report.

Project Title: Investigation of Wind Effects on Bridges Induced by Tornadoes for Tornado-Resistance Design – Phase II
Nothing to report.

Project Title: Development of ATMA/AIPV Deployment Guidelines Considering Traffic and Safety Impacts
Nothing to report.

Project Title: Deep Learning for Unmonitored Water Level Prediction and Risk Assessment
Nothing to report.

Project Title: Optimization of Transportation Infrastructure System Performance with Autonomous Maintenance Technology in Work Zones
Nothing to report.

Project Title: SMART Shear Keys for Multi-Hazards Mitigation of Diaphragm-Free Girder Bridges – Phase II
Nothing to report.

Project Title: Sensor-Assisted Condition Evaluation of Steel and Prestressed Concrete Girder Bridges Subjected to Fire – Phase II
Nothing to report.

3. OUTPUTS

In the center's overarching Technology Transfer Plan, MATC identified three performance measures and three corresponding goals related to the outputs, or products, resulting from research and development activities. Table 3 contains a description of each performance measure, the associated goal, and the center total for the reporting period.

Table 3: Performance Measures, Goals, and Totals for MATC Outputs

	Performance Measure	Description	Goal	Center Total for October 1, 2020 – March 31, 2021
Output 1	Products and Processes	Quantity of new or improved processes, practices, technologies, software, training aids, or other tangible products.	Thirty (30) new products and processes by the end of the grant period.	Zero (0) MATC is on schedule to develop new and improved processes, practices, technologies, and other products by the end of the grant cycle.
Output 2	Technical Communications	Number of technical communications (journal papers, conference papers, final reports, etc.)	Fifteen (15) technical communications each year of the grant period.	Fifteen (15) During the reporting period, 4 final reports and 8 peer reviewed journal papers and 3 conference papers were published.
Output 3	Outreach Activities	Number of outreach activities (webinars, social media, workshops, newsletters, and presentations, etc.)	Fifteen (15) outreach activities for each year of the grant period.	Sixteen (16) During the reporting period, 6 presentations, and 3 webinars occurred; 7 websites and social media platforms were utilized.

Publications, conference papers, and presentations

Journal Publications

1. Al-Kady, K., Wittich, C.E., Wood, R.L., and Morcous, G. (202x). "Field Monitoring of Traffic-Induced Vibration during Phased Construction of Bridges." Status: In Preparation for Submission to: Journal of Bridge Engineering. Acknowledgment: Yes.
2. Jacome, R.O., Stolle, C.S., Faller, R.K., and Grispos, G., "A Dynamically-Concise Roadmap Framework for Guiding Connected and Automated Vehicles", 4th International Workshop on Intelligent Transportation and Autonomous Vehicles Technologies (IM2021-ITAVT), Accepted January 13, 2021.
3. Fang, C., Yosef, T.Y., Linzell, D.G, and Rasmussen, J.D., "Computational Modeling and Simulation of Isolated Highway Bridge Columns Subjected to Vehicle Collision and Air Blast," Journal of Engineering Failure Analysis. Accepted 3/21/2021.
4. Fang, C., Yosef, T.Y., Linzell, D.G., and Rasmussen, J.D., "Residual Axial Capacity Estimates for Bridge Columns Subjected to Vehicle Collision and Air Blast," ASCE Journal of Bridge Engineering. Accepted 3/3/2021.
5. Wu, H., Zeng, J. and Constantinescu, G. (2020). A multiparameter design formula for riprap size selection at wing-wall abutments, Journal Hydraulic Research, to be published in the June issue.
6. Kummetha, V.C., A. Kondyli, "Evaluating Driver Comprehension in Various Simulated Environments

by Using Performance, Total Gaze Duration, and Probe Questions". Submitted to Transportation Research Part F
7. Yanping Zhu, Matthew Klegseth, Yi Bao, Matthew S Hoehler, Lisa Choe, and Genda Chen. Distributed Fiber Optic Measurements of Strain and Temperature in Long-Span Composite Floor Beams with Simple Shear Connections Subject to Compartment Fires. Fire Safety 121 (2021) 103275.
8. Jacome, R., Stolle, C.S., Faller, R.K., and Grispos, G., "A Dynamically-Concise Roadmap Framework for Guiding Connected and Automated Vehicles", 4th International Workshop on Intelligent Transportation and Autonomous Vehicles Technologies (ITAVT 2021), IEEE.

Conference Papers

1. Al-Kady, K., Wittich, C.E., Wood, R.L., and Morcous, G. (2021). "Impacts of Traffic-Induced Vibration on Phased Construction Bridges: Field Monitoring." ASCE Structures Congress, April 2021. Status: Conference Cancelled.
2. ASM Parveg, G Singh, A Ratner. "Experimental investigation of effect of Graphene Nano particles (GNP) on the combustion behavior of renewable jet fuel droplets". ASME IMECE 2020, Portland, Oregon, USA, 16-19 November 2020, Final paper presented. Acknowledgement of Federal support: Yes.
3. N Hentges, G Singh, A Ratner. "Experimental Investigation of the Settling Characteristics of carbon-based nanoparticle in renewable jet fuel". ASME IMECE 2020, Portland, Oregon, USA, 16-19 November 2020, Final paper presented. Acknowledgement of Federal support: Yes.

Presentations

1. Al-Kady, K. (2021). "Impacts of Traffic-Induced Vibration on Phased Construction Bridges." COE Graduate Student Symposium, University of Nebraska-Lincoln, Lincoln, NE, February 2021. Status: Presented/Completed.
2. Ng, R., Rogers, J., Yachamaneni, K., Baysa, K., Li, D., Suwondo, T., Yoder, A., Ghersi, D., Fruhling, A. (2021). Wireless Sensor Integration into System's Network for Real-time Data Streaming: Lessons Learned. UNO Student Creativity and Research Fair, March, 2021. Poster. Ru Ng presented. A. Fruhling Advisor.
3. Constantinescu, G. (2020) "Development of new design guidelines for protection against erosion at wing-wall and spill-through abutments," Mid-America Transportation Center, Research Seminar, Univ. Nebraska, October 2020.
4. Constantinescu, G. (2021) "A new design formula for riprap sizing at spill-through and wing-wall bridge abutments," Hydraulics, Hydrology and Glaciology Laboratory VAW, ETH Zurich, Switzerland, March 2021.
5. Branstetter, Chase, Lemke, Corinna, Kranick, Mathew (2021) "Assessing the Driving Fitness of CDL Drivers in the Midwest" Mentor: Shelley Bhattacharya, DO. MPH
6. Jenkins, Rachel, Gibson, Robert, Rooker, Jake, Patel, Nidhi, Devos, Hannes, Akinwuntan, Abiodun, Bhattacharya, Shelley (2021) "Association of CDL Drivers' Self-Reported Tickets & Accident History with Cognitive Function Testing" **2nd place winner

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

MATC maintains five online sites that distribute information utilizing the internet. Links to each site as well as report period information can be found below.

MATC Website

By clicking the following link, http://matc.unl.edu, you will be directed to MATC's website. Below is highlighted information from Google Analytics about the website's traffic from October 1, 2020 – March 31, 2021. By understanding and capitalizing this knowledge, we are able to make our homepage engaging, relevant, and resourceful to our viewers. Since our last progress report, the total number of site visits increased by 5,948.

Visits: 18,650	Page views: 39,415	Pages per visit: 2.11	Average visit duration: 00:00:29

SlideShare

The top 5 countries that viewed our SlideShare presentations during the reporting period are: the United States, Germany, Netherlands, India, and Brazil. Below is a snapshot of MATC's SlideShare activity and the link to view the page: https://www.slideshare.net/matcRegion7UTC/presentations/. MATC's SlideShare views have increased by 2,656 since the last progress report.

Total Views: 2,408	New Uploads: 0	Downloads: 6	Favorites: 1

Facebook

Metrics for the MATC Facebook page can be viewed below, and the page can be accessed by clicking on the following link. MATC's reach decreased by 1,448 since the last reporting period. https://www.facebook.com/pages/Mid-America-Transportation-Center-MATC/141238439284182.

Total Page Likes: 416	Reach: 844	Total Countries (of Followers): 10

Twitter

MATC's Twitter handle is @MATCNews. The page can be viewed by clicking the following link: https://twitter.com/MATCNews. The highlighted numbers for MATC's Twitter activity can be seen below. The number of tweets MATC produced decreased by 0 since the last reporting period. The number of profile visits increased by 52.

New Followers: 0	Tweet Impressions: 1,009	Profile Visits: 123	Tweets: 0

YouTube

MATC's YouTube feed can be viewed by clicking the following link: http://www.youtube.com/user/midamericatrans?feature=results_main. MATC uploaded 9 more videos compared to the last reporting period.

New Videos: 18	Views: 2,110	Minutes Watched: 298	New Subscribers: 7

Additional Partner Websites

Several MATC Principal Investigators created websites to share information about their research projects. The links to these websites are provided in Table 4 along with the corresponding MATC project.

Table 4: Websites for Individual MATC Research Projects Created by Principal Investigators

Project Title	Principal Investigator	Website Link
Transportation Planning with Floods	Ann Campbell and Ibrahim Demir	http://iihr-vl01.iihr.uiowa.edu/dev/routing/
Crash Prediction and Avoidance by Identifying and Evaluating Risk Factors from Onboard Cameras	Ruwen Qin	https://sites.google.com/view/yuli1102/projects/matc?authuser=0.
Assessing and improving the cognitive and visual driving fitness of CDL drivers	Shelley Bhattacharya	http://www.kumc.edu/landon-center-on aging/research/truck-safety-study.html.
Real-time Flood Forecasting for River Crossings	Witold Krajewski	http://siihr50.iihr.uiowa.edu/smap/demo/

7. OUTCOMES

MATC identified three performance measures and three corresponding goals related to program outcomes in the center's Technology Transfer Plan. Table 5 contains a description of each performance measure, the associated goal, and the center total for the reporting period.

Table 5: Performance Measures, Goals, and Totals for MATC Outcomes

	Performance Measure	Description	Goal	Center Total for October 1, 2020 – March 31, 2021
Outcome 1	Commercialized Products	Quantity of invention disclosures, patent disclosures, patents issued, cooperative research and/or user agreements, and new business entities created.	Ten (10) products that are commercialized or in the commercialization process by end of grant period.	Zero (0) MATC is on schedule to develop commercialized products by the end of the grant period. This process is reflected in each PI's individual tech transfer plan.
Outcome 2	Output Adoption	Number of changes made to the transportation system (including regulations, legislation, standard plans, technical guides, or policy) resulting from MATC research.	Ten (10) that have been adopted or in the process of adoption by the end of grant period.	Zero (0) MATC is on schedule to implement changes to the transportation system by the end of the grant period.
Outcome 3	Product Utilization	Number of MATC products utilized (including citations, references, views, report	Forty (40) by the end of the grant period.	One-hundred ten (110) Including unique downloads of MATC

		downloads, and report requests).		research reports and unique clicks on the links to final data.

8. IMPACTS

MATC identified three performance measures and three corresponding goals related to program impacts in the center's Technology Transfer Plan. Table 6 contains a description of each performance measure, the associated goal, and the center total for the reporting period.

Table 6: Performance Measures, Goals, and Totals for MATC Impacts

	Performance Measure	Description	Goal	Center Total for October 1, 2020 – March 31, 2021
Impact 1	Public Stakeholder Participation	Number of public organizations serving as sponsors of research and T2 programs.	Five (5) public sector external partners providing support to MATC activities for each year of the grant period.	Forty-Seven (47) MATC partnered with 47 public organizations on research, education, and technology transfer activities. See Table 2 for the complete list.
Impact 2	Private Stakeholder Participation	Number of private organizations serving as sponsors of various research and T2 programs.	Five (5) private sector external partners providing support to MATC activities for each year of the grant period.	Ten (10) MATC partnered with 10 private organizations on research, education, and technology transfer activities. See Table 2 for the complete list.
Impact 3	Transportation Professional Participation	Number of transportation professionals who participate in MATC T2 activities.	One hundred (100) transportation professionals for each year of grant period.	One-Hundred Sixty-Nine (169) MATC partnered with 169 transportation professionals participated in MATC activities during the reporting period.

What is the impact on the effectiveness of the transportation system?

Ongoing MATC research projects will have a wide variety of impacts on the effectiveness of the transportation system.

University of Nebraska-Lincoln (UNL)/University of Nebraska-Omaha (UNO)/University of Nebraska Medical Center (UNMC)

Project Title: Assessing Performance of Geosynthetic Reinforced Pavement with a Large-Scale Track Wheel Test and Nondestructive Testing Tools

This project is directly related to focus areas of the Mid-America Transportation Center in enhancing the safety of road conditions and reducing the negative effects of crashes. The Nebraska Department of Transportation (NDOT) fully supports this project. In addition to the participating UNL Civil Engineers, two NDOT engineers will participate as a monitor in this project. Through a supplementary combination with the NDOT research, the team will have a synergistic effect on the current project.

Project Title: Evaluation of the Driveway Assistance Device (DAD) Systems in One-Lane Two-Way Work Zone

The project is expected to provide a guide to improve the safety and efficiency of driver assistance devices on access points within work zones on two-way highways with one lane closed.

Project Title: Development of New Generation of Portable Concrete Barriers

The impact of this MATC project will be developed design concept(s) for new MASH TL-3 portable concrete barriers, and full-scale crash testing recommendation. LS-DYNA simulation will be used to fully develop PCB that meet the design criteria (collected from state DOTs. This new high-performance portable barrier should be capable of meeting the MASH TL-3 safety requirements with reduced free-standing barrier deflections as well as increased vehicle stability as compared to existing, widely used PCB systems. Once the barrier is full-scale crash tested and with an anticipated lower dynamic deflection, transportation agencies will be able to use the barrier to shield more work-zones that previously had limitations on using portable barriers that deflected significantly. Utilization of this barrier would allow for more construction worker protection in more areas as well as be a safe option for errant motorists.

Project Title: LIDAR-Based Vibration Monitoring for Assessing Safety of Damaged Bridges

This project aims to develop a novel algorithm and methodology for dynamic characterization of bridges using commercially available laser scanners. This is expected to be an advancement with respect to current practice by increased resolution, accuracy, and speed of acquisition. Given that many state DOTs and sub-contracted firms that assess bridges already own and operate laser scanners, this will be a cost-effective solution to assess bridge health. In addition, this will be a non-contact sensing solution which will enhance safety for all personnel and the traveling public.

Project Title: Resilience of Rural Communities and Transportation Networks to Hazards

This project aims to understand the restoration of functionality for bridges and transportation networks in rural areas following various hazards. This understanding is expected to impact decision-making regarding repair and replacement of critical routes to enhance the resilience of transportation systems in rural areas.

Project Title: Crashworthy Foundations for Soil-Embedded Roadside Safety Hardware

Current luminaire pole foundation design standards are non-optimal, such as requiring drilled shafts socketed into bedrock, and generally restricted to medium to dense or stiff soils and

where the installation does not encounter the water table. Foundations for site conditions consisting of soft clays, silts, organic silts, or peat are typically designed with significantly more costly approaches, such as designing the foundation to "float" above the very soft compressible soils, replacing in-situ soils with higher quality material, or constructing very deep foundations. This project will allow luminaire pole foundations to be more cost-effectively designed, thereby freeing resources for redistribution to improve safety elsewhere in state agencies' transportation networks.

Project Title: Protecting Critical Civil Infrastructure against Impact from Commercial Vehicles – Phase II

The overall purpose of the research study is to improve the resiliency and robustness of bridge pier columns in the event of intentional or accidental vehicle collision coupled with a possible event, such as an explosion.

Project Title: Incorporating Snow Processes in the Iowa Flood Information System (IFIS) and Evaluating its Applicability for Nebraska

The expected impacts involve improved transportation safety due to accurate early flood warning.

Project Title: Virtual Barriers for Mitigating and Preventing Run-Off-Road Crashes – Year 4

The research result to be produced at the end of this project is a stand-alone software tool to autonomously extract critical road data using visual and geodetic data. The purpose of the data is to provide highly-accurate, visually-based data from satellite and aerial photography, which can be adjusted or corrected using survey data or in-vehicle GPS data for minor deviations related to the process of aerial image tiling. The result will be a highly-accurate, concise representation of road data that can autonomously acquire and process critical road shape data in expansive regions. This data is critical for the analytical backbone of the MVRC system.

Project Title: Bio-Inspired Reusable Crash Cushions with Superior Energy-Absorbing Capacity

Nothing to report.

Project Title: MATC Smart Barrier

Research is still in development. No impacts have yet been experienced on the transportation system. It is anticipated that implementation of this externally-sourced guidance reference system will improve driver awareness functionality in "smart" vehicles, and could be used as a foundational tool in future vehicle guidance applications. Current progress has been reaffirmed in discussions with state DOTs and international agencies in Canada.

Project Title: Investigation and Development of a MASH Test Level 6, Cost-Effective, Barrier System for Containing Heavy Tractor Tank-Trailer Vehicles and Mitigating Catastrophic Crash Events – Year 3

The biggest impact will be the tank-trailer model that will be used further for simulation in LS-DYNA, which will help to design a new roadside containment barrier for tractor-tank trailer vehicles. Upon successful completion, the new barrier could be used to mitigate the effects of hazardous crash events from tank trailers carrying hazardous materials. The tank model could also be used by other transportation agencies to study other topics related to tank trailer vehicles.

Project Title: Real-Time Emergency Communication Systems for HAZMAT Incidents (REaCH)
Nothing to report.

University of Iowa (UI)

Project Title: Infrastructure Inspection During and After Unexpected Events – Phase III:
Nothing to report.

Project Title: Infrastructure Inspection During and After Unexpected Events – Phase IV
Nothing to report.

Project Title: Transportation Planning with Floods
Better understanding of the optimum location of mitigation for different parts of road networks, such as bridges, during flooding can help planning and management activities for transportation systems.

When this phase is more developed, we would like to schedule meetings with representatives from the DOT.

Project Title: Reducing Flammability for Bakken Crude Oil for Train Transport

- This research will result in making transportation of highly inflammable crude oil by rail safer.
- This is expected to increase the effectiveness of the transportation system by preventing fires resulting from crude oil train derailments, which in the past have caused several fatalities and serious damage to property and infrastructure.

Project Title: Development of New Design Guidelines for Protection against Erosion at Bridge
The main impact of the present research will be to get a better understanding of why existing riprap design formulas are not conservative enough in some cases and on ways to improve the performance of these formulas in order to reduce the risk of a serious bridge failure due to flood-induced scour .

University of Kansas (KU)/University of Kansas Medical Center (KUMC)

Project Title: Modeling Driver Behavior and Aggressiveness Using Bio-Behavioral Methods: Phase III
We expect to establish a more complete car-following model that considers human bio-behavioral factors such as workload, situation awareness, and level of activation by capturing bodily changes such as pupil diameters, blink frequency, gaze fixations, and heart rate. This will provide a platform to refine existing car-following models and provide key insights to how behavior affects traffic and performance.

Improving the prediction capabilities of car-following models can have a significant positive impact on traffic mitigation and planning strategies, as prediction models can be refined to a greater accuracy.

Low Cost 3-D LIDAR Development for Transportation

Fast 3-D LIDAR systems have the potential to aide in the development of autonomous vehicles by allowing for object detection that is often more accurate than conventional camera systems. It has the advantage of requiring light to reflect back in order to be detected, which reduces the risk of closer objects being mistaken for larger, further objects behind them. A system sufficiently fast could also monitor for obstacles such as curbs, potholes, and road debris. In addition, an inexpensive system could be widely distributed within the transportation system fostering a greater ability to monitor threats to safety.

Project Title: Assessing and Improving the Cognitive and Visual Driving Fitness of CDL Drivers
Nothing to report.

Missouri University of Science & Technology (MS&T)

Project Title: Performance of Earthquake-Damaged Reinforced Concrete Bridges with Repaired Columns
The results of this project will lead to a better understanding of the effect of a local repair of an RC column to the global behavior of the repaired bridge. This is expected to lead to safer and more cost-effective decisions on repair of earthquake-damaged bridges.

Project Title: Performance of Earthquake-Damaged Reinforced Concrete Bridges with Repaired Columns – Phase II
The results of this project will lead to a better understanding of how to optimize combined levels of (pre-earthquake) retrofit and (post-earthquake) rapid repair in order to maintain service to a bridge shortly after an earthquake occurs, while reducing initial costs and uncertainties.

Project Title: Investigation of Wind Effects on Bridges Induced by Tornadoes for Tornado-Resistance Design – Phase II
The expected results and products will include: 1) A high-fidelity CFD model to obtain the wind pressure distribution on flexible bridges induced by tornadoes and straight-line winds; 2) A modified equation for calculating the design wind pressure towards tornado-resistance design for bridges. The PI will contact AASHTO to promote this to be included in AASHTO Bridge Design Specifications.

Project Title: Development of ATMA/AIPV Deployment Guidelines Considering Traffic and Safety Impacts
This proposed project furthers year-2 research on developing and testing autonomous vehicle technology to reduce work zone fatalities and injuries. This project focuses on the modeling of the impacts of ATMA system to traffic operation, including the queue length and traffic delay, with the goal of answering a question of how should DOT develop deployment strategies with those aspects taken into consideration.

Project Title: Deep Learning for Unmonitored Water Level Prediction and Risk Assessment
This research will expand the information available to make predictions on flooding that impacts road networks. While previous studies were associated with areas with instrumentation installed, this work will broaden the number of areas that can be monitored to better inform the travelling public and emergency personnel relying on ground transportation.

Project Title: Optimization of Transportation Infrastructure System Performance with

Autonomous Maintenance Technology in Work Zones
This proposed project furthers year-2 and year-3 research on developing and deploying autonomous vehicle technology to reduce work zone fatalities and injuries. This project aims to support DOT decision-makers to determine which road segment to prioritize for maintenance, with the goal of maximizing transportation system performance.

Project Title: SMART Shear Keys for Multi-Hazards Mitigation of Diaphragm-Free Girder Bridges – Phase II
Nothing to report.

Project Title: Sensor-Assisted Condition Evaluation of Steel and Prestressed Concrete Girder Bridges Subjected to Fire – Phase II
Nothing to report.

What is the impact on the adoption of new practices, or instances where research outcomes have led to the initiation of a start-up company?

University of Nebraska-Lincoln (UNL)/University of Nebraska-Omaha (UNO)/University of Nebraska Medical Center (UNMC)

Project Title: Assessing Performance of Geosynthetic Reinforced Pavement with a Large-Scale Track Wheel Test and Nondestructive Testing Tools
Nothing to report.

Project Title: Evaluation of the Driveway Assistance Device (DAD) Systems in One-Lane Two-Way Work Zone
As part of the technology transfer component, this project will develop the necessary background material to have the MUTCD approve the use of DAD systems in work zones within region 7 DOTs.

Project Title: Development of New Generation of Portable Concrete Barriers
The final PCB design with improved crash performance, once tested, will be installed on roadside, work zones throughout the country and the world, resolving safety concerns of roadways accidents.

Project Title: LIDAR-Based Vibration Monitoring for Assessing Safety of Damaged Bridges
It is expected that state DOTs and private engineering firms that are contracted to inspect or assess bridges will adopt the advanced technology developed as part of this project.

Project Title: Resilience of Rural Communities and Transportation Networks to Hazards
It is expected that knowledge gained in this project will benefit government agencies in decision-making regarding post-hazard conditions of transportation components.

Project Title: Crashworthy Foundations for Soil-Embedded Roadside Safety Hardware
Light pole foundation designs in weak and potentially saturated soils will be more easily installed without unnecessary depth or socketing into rock. More broadly, validated modeling practices for soil-embedded roadside safety hardware will enable more flexible design practices with less stringent soil requirements.

Project Title: Protecting Critical Civil Infrastructure against Impact from Commercial Vehicles – Phase II
The research study is accomplished to help understand the response of bridge column subjected to vehicle collision and explosion and provide recommendations related to acceptable column design and retrofit damage mitigation schemes.

Project Title: Incorporating Snow Processes in the Iowa Flood Information System (IFIS) and Evaluating its Applicability for Nebraska
Nothing to report.

Project Title: Virtual Barriers for Mitigating and Preventing Run-Off-Road Crashes – Year 4
The stand-alone software tool is a multi-source tool, meant to be used by state DOTs but which could be called by any mapping software or entity (e.g., Google, Apple, etc). The intent of the data collection tool is to provide an expansive data collection that serves as a correctable "baseline" for road data, which is later portable to a visualization program using an API.

Project Title: Bio-Inspired Reusable Crash Cushions with Superior Energy-Absorbing Capacity
Nothing to report.

Project Title: MATC Smart Barrier
Nothing to report.

Project Title: Investigation and Development of a MASH Test Level 6, Cost-Effective, Barrier System for Containing Heavy Tractor Tank-Trailer Vehicles and Mitigating Catastrophic Crash Events – Year 3
The more detailed model is anticipated to be more accurate and would be used for further simulations as needed. Also, the final barrier, once tested, would be able to be installed on roadsides throughout the country and world, thus increasing safety of the roadways.

Project Title: Real-Time Emergency Communication Systems for HAZMAT Incidents (REaCH)
Nothing to report.

University of Iowa (UI)

Project Title: Infrastructure Inspection During and After Unexpected Events – Phase III:
Nothing to report.

Project Title: Infrastructure Inspection During and After Unexpected Events – Phase IV
Nothing to report.

Project Title: Transportation Planning with Floods
The real-time web platform can be utilized by DOT for decision making and planning.

Project Title: Reducing Flammability for Bakken Crude Oil for Train Transport

- Splashing and associated fluid behavior is expected to make an impact on the science

behind combustion and ignition of crude oil and other organic solvents.
- Modifying crude oil properties by additives to change viscosity and thereby drag is of obvious interest in the discipline of crude oil transportation by pipeline.
- Finding optimum concentrations of additives at which combustion and splashing substitutes are most stable would save costs during eventual industry technology implementation.

Project Title: Development of New Design Guidelines for Protection against Erosion at Bridge
Based on the results of the research conducted as part of this study, recommendations will be made for implementing modifications in the methodology used to calculate variables in existing design formulas for riprap based protection of spill-through and wing-wall bridge abutments against erosion and/or for inclusion of additional factors of safety or modified versions of the formulas to account for cases not covered by existing design formulas. In particular, we are focusing on quantifying the effect of channel curvature on the maximum bed shear stress around the abutment situated at the outer bank of the curved channel. We envision to have the recommendations and revised guidelines for protection of abutments against erosion implemented in future updates (e.g., via a Technical Brief) of HEC-23. HEC-23 is the main standard used by state and government agencies for implementing measures against erosion at bridge sites and in natural channels. Such new recommendations will enhance the capabilities of state DOTs to develop more reliable approaches to protect small bridges against possible failure induced by severe erosion associated with flood events. A second maingoal of this project is to extend the design formulas developed for bridge abutments with open channel flow at the bridge site for cases when the flow regime beneath the bridge deck connecting the two abutments changes from free surface flow to orifice flow or to fully-pressurized flow. Most of the scour occurs at high flow conditions and basically no design formulas are available for cases when the flow at the bridge site becomes pressurized.

University of Kansas (KU)/University of Kansas Medical Center (KUMC)

Project Title: Modeling Driver Behavior and Aggressiveness Using Bio-Behavioral Methods: Phase III
Nothing to report.

Low Cost 3-D LIDAR Development for Transportation
LIDAR is best suited for measuring precise distances as a means of calculating distance to collision; whereas, cameras can only approximate distance based on the objects position in the field of view. Cameras are more frequently used in vehicular applications due to their ability to detect lane position and other vehicles, however, cameras are subject to misinterpretation where LIDAR rangefinders are not.

Project Title: Assessing and Improving the Cognitive and Visual Driving Fitness of CDL Drivers
We expect our data will show what specific clinical tests can make CDL drivers safer behind-the-wheel, which should help the DOT give guidance to clinicians of what tests to administer for their DOT physicals.

Missouri University of Science & Technology (MS&T)

Project Title: Performance of Earthquake-Damaged Reinforced Concrete Bridges with Repaired Columns
Nothing to report.

Project Title: Performance of Earthquake-Damaged Reinforced Concrete Bridges with Repaired Columns – Phase II
Nothing to report.

Project Title: Investigation of Wind Effects on Bridges Induced by Tornadoes for Tornado-Resistance Design – Phase II
The obtained design tornadic wind loads can be used to evaluate the vulnerability of existing bridges, and to develop a reinforcing strategy for existing bridges to achieve a continuous load path. This research will eventually advance the design theory of highway or railroad bridges based on the in-depth understanding of tornadic wind effects.

Project Title: Development of ATMA/AIPV Deployment Guidelines Considering Traffic and Safety Impacts
Through studying the ATMA technology operation domain and the deployment guideline, this project helps state DOT and industry vendor paves the foundation for autonomous vehicle development and promotion. The proposed technology is jointly funded by a pool fund of 12 state DOT and has the potential of being widely adopted national-wide and internationally.

Project Title: Deep Learning for Unmonitored Water Level Prediction and Risk Assessment
Nothing to report.

Project Title: Optimization of Transportation Infrastructure System Performance with Autonomous Maintenance Technology in Work Zones
Through studying the ATMA technology operation domain and the deployment guideline, this project helps state DOT and industry vendor paves the foundation for autonomous vehicle development and promotion.

Project Title: SMART Shear Keys for Multi-Hazards Mitigation of Diaphragm-Free Girder Bridges – Phase II
Developing an innovative measure to mitigate both earthquake and tsunami/ hurricane effects could potentially save both bridge structures and the lives of travelers who drive through the affected bridges. The outcomes and benefits resulting from such an enabled measure could have direct impact on the MATC's theme on promoting safety. In addition, effective measures that can address the mitigation of multiple hazards are lacking in the literature. This study could bridge the gap between research and the growing need for multi-hazards mitigation.

Project Title: Sensor-Assisted Condition Evaluation of Steel and Prestressed Concrete Girder Bridges Subjected to Fire – Phase II
The application of distributed fiber optic sensors in fire engineering will be disseminated, once complete.

What is the impact on the body of scientific knowledge?

MATC's current and ongoing transportation research will have a wide variety of safety-related impacts on the current body of scientific knowledge.

University of Nebraska-Lincoln (UNL)/University of Nebraska-Omaha (UNO)/University of Nebraska Medical Center (UNMC)

Project Title: Assessing Performance of Geosynthetic Reinforced Pavement with a Large-Scale Track Wheel Test and Nondestructive Testing Tools

This study will develop, investigate, and refine the understanding of underlying the mechanical behavior and performance of the geosynthetic-reinforced pavement system. The mechanical performance of a geosynthetic-reinforced pavement system will be evaluated at different layers of the pavement in the controlled condition from the LSTW test installed with various sensors such as fiber optic cables, ultrasonic sensors, LVDTs, pressure cells, etc. Also, the numerical simulation will be conducted for a full-scale roadway pavement reinforced with geosynthetics at the different layers. Based on the testing and numerical modeling results, K constant and resilient and bulk modulus between reinforced and unreinforced pavement will be back-calculated to compare the performance between reinforced and unreinforced pavement.

Project Title: Evaluation of the Driveway Assistance Device (DAD) Systems in One-Lane Two-Way Work Zone

Model efficacy of the DAD systems in terms of driver's compliance or violation behaviors, as well as the time savings for both driveway and the main road traffic.

Project Title: Development of New Generation of Portable Concrete Barriers

The newly developed, non-proprietary PCB with improved crashworthiness, vehicle stability, durability, and ease of transportation and construction will provide State DOTs and roadside safety community a safer and more efficient roadside and work zone barrier, which leads to reduce fatalities and serious injuries associated with vehicle rollovers as well as saving cost of barrier installation and/or repairment. Although this would apply to roadside safety community, other transportation safety researchers and designers can utilize the PCB design. Additionally, on aspect of this research is use of alternative material including concrete additives in roadside safety barrier, which will impact this field, material science.

Project Title: LIDAR-Based Vibration Monitoring for Assessing Safety of Damaged Bridges

This project will advance civil engineering monitoring techniques by developing dynamic approaches to a primarily static system. Civil engineering often involves monitoring of various civil systems, particularly structures such as bridges. These monitoring approaches are often limited to monitoring a single point on a large system, or limited to a single point in time. This project will develop a technique to obtain data at many points over time, which will be a significant improvement.

Project Title: Resilience of Rural Communities and Transportation Networks to Hazards

This project will advance civil engineering and structural engineering as well as the broader interdisciplinary resilience community through a fundamental understanding of the functionality restoration of transportation systems. Functionality restoration is a critical aspect of resilience and the understanding generated will enable detailed studies of resilience, with particular emphasis on rural areas for which little is known with respect to resilience.

Project Title: Crashworthy Foundations for Soil-Embedded Roadside Safety Hardware

Experimental data will be generated for large-scale dynamic impact behavior of soft soils.

Information available in literature for roadside safety hardware focuses on strong soils, and soft soil experimental data has only been produced at small scales, requiring unvalidated extrapolation for large-scale application in engineering research and practice. Additionally, this research will provide insight into performance of foundations supporting breakaway features. Breakaway hardware is typically mounted to rigid or very stiff foundations in strong soil, leaving performance of foundations in weak soil as a gap in knowledge.

Project Title: Protecting Critical Civil Infrastructure against Impact from Commercial Vehicles – Phase II

Ph.D. student Fang's research advanced the body of knowledge in the following areas, all associated with the discipline of structural and, more specifically, bridge engineering:

- modeling techniques for bare and retrofitted bridge columns subjected to extreme demands;
- performance-based design and analysis methodologies for structural elements under extreme demands;
- development of damage indices to evaluate structural element performance; and
- effective retrofit techniques for structural elements under extreme demands.

Project Title: Incorporating Snow Processes in the Iowa Flood Information System (IFIS) and Evaluating its Applicability for Nebraska

The outcome from the project will advance our knowledge on snow modeling.

Project Title: Virtual Barriers for Mitigating and Preventing Run-Off-Road Crashes – Year 4

The concept of a broad, map-borne data extraction tool for critical road safety data has been proposed in scientific literature but has not had the means of broad adaptability or expansion beyond a theoretical idea. The current research demonstrates the capability of converting a theoretically-possible road data extraction into a practical database of critical road data which informs a vehicle of road coordinates and safe travel speeds. Moreover, the data remains anonymous for road users (i.e., does not track the host vehicle), but can be used by state DOTs to autonomously warn vehicles if road construction or poor travel conditions are reported. The process is intended to be wireless and therefore broadcasted from a centralized location or networked through DOT systems.

Project Title: Bio-Inspired Reusable Crash Cushions with Superior Energy-Absorbing Capacity

Nothing to report.

Project Title: MATC Smart Barrier

All existing ADAS systems rely on the vehicle interpreting and understanding the environment. No existing ADAS systems reference external markers nor obtain guidance or road profile data from external databases. Thus, this project represents the first scientific attempt to evaluate an externally-source guidance and/or trilateration system for ground transportation.

Project Title: Investigation and Development of a MASH Test Level 6, Cost-Effective, Barrier System for Containing Heavy Tractor Tank-Trailer Vehicles and Mitigating Catastrophic Crash Events – Year 3

The detailer tank-trailer model will provide a more accurate simulation of a tank-trailer impacting a TL-6 barrier, which is currently not available. This would apply to the roadside safety community, but maybe

utilized by other transportation studies (i.e. study the effect of rollover of heavy commercial vehicles such as tank-trailers).

Project Title: Real-Time Emergency Communication Systems for HAZMAT Incidents (REaCH)
Nothing to report.

University of Iowa (UI)

Project Title: Infrastructure Inspection During and After Unexpected Events – Phase III:
Nothing to report.

Project Title: Infrastructure Inspection During and After Unexpected Events – Phase IV
Nothing to report.

Project Title: Transportation Planning with Floods
This will help develop a better understanding of both how roads/bridges should be retrofitted as well as how flooding should be considered in the building of new roads/bridges.

Project Title: Reducing Flammability for Bakken Crude Oil for Train Transport

- We expect that the development of a crude oil combustion substitute, which entails original research in the field of experimental fluid mechanics, will contribute to the understanding of nanoparticle and other additives' impact on the burning properties of different organic solvents as well as crude oils.
- A crude oil substitute for combustion hasn't been identified yet in existing literature.
- We expect that the development of a crude oil splashing substitute, which entails original research in the field of experimental fluid mechanics, will contribute to the understanding of nanoparticle and other additives' impact on the fluid properties of different organic solvents.
- A crude oil substitute for splashing hasn't been identified yet in existing literature. Until now, testing suspension stability was done by visual inspection, specialized instruments, or by the "dipping rod" method, but our non-contact, non-interfering experimental setup is able to quantify the process and identify optimum additive concentrations, thereby adding to the science behind fluid properties of such suspensions.

Project Title: Development of New Design Guidelines for Protection against Erosion at Bridge
We will work with the Transportation Research Board (TRB) committees related to bridges (e.g., TRB-AFB60) and FHWA such that the main findings and the improved formulas will be published as a Technical Brief of HEC-23. Once adopted by state and federal agencies in charge of maintaining operational our bridges, the present research will increase the efficiency of scour protection measures at two main types of abutments used especially for small bridges in the US. It will also decrease the costs associated with maintaining such bridges operational after flooding events (e.g., if the flood protection measure is not effective part of the abutment can be washed away during the flood and needs to be reconstructed, a procedure that involves large costs). The present procedure based on 3D simulations can be extended to other types of abutments and also to bridge piers of complex shape, or to cases when erosion at the abutment is due to more than one factor (e.g., there is a component associated with channel curvature in the vicinity of the abutment, or pressure scour effects are important if the bridge deck becomes submerged during the flood event). Such cases are not covered by existing design

formulas which are mostly based on experiments conducted in straight channels. In the long term, the present procedure to estimate potential for erosion can provide a reliable approach to generate data needed to calibrate riprap design formulas which will complement and partially replace expensive scaled model studies conducted in the laboratory. Given that detailed information on the flow fields, turbulence and their effects on the bed shear stress distributions are available from these simulations, the present approach can lead to incorporating more physics into existing design formulas and proposing new design formulas for protection against local scour at hydraulic structures.

More reliable design formulas for protection of bridges abutments against erosion will result in significant reduction of costs to maintain roads operational during and after flood events. It will also avoid structural failure of some of the bridges and thus reduce risk for hazard associated with bridge failure during floods.

University of Kansas (KU)/University of Kansas Medical Center (KUMC)

Project Title: Modeling Driver Behavior and Aggressiveness Using Bio-Behavioral Methods: Phase III

This research could be used as a starting guideline for car-following preferences in automation. Since the sample size of the study is relatively high, the data can be used to comment on gap preferences of various drivers (classes of drivers). Insights on driver workload and its influence on following gaps/speeds can suggest preferred thresholds for autonomous driving especially where driver still plays a key role in the vehicle. The results could provide specifics on the behavior of drivers (car-following, gap acceptance, speed preference, and lane changing) in areas surrounding/neighboring Kansas and how autonomous vehicles could be initially tailored to bridge the gap between human and machine.

Project Title: Low Cost 3-D LIDAR Development for Transportation

Run time on LIDAR systems is primarily a function of computing power, rangefinder sampling rate, the total data acquisition count, and the efficiency of the program. With machine learning algorithms, LIDAR point clouds could be interpreted to differentiate and rank hazards as a means of minimizing risk to passengers and pedestrians.

The expectation of a super-resolution based method can boost the scanning process through software development (rather than optimizing performance through hardware). This approach can be helpful for fast-pace and real-time environments, where speed for collecting data from sensors becomes essential for vehicle owners.

Project Title: Assessing and Improving the Cognitive and Visual Driving Fitness of CDL Drivers

We were asked to collaborate with the University of Kansas, Lawrence on an Automated Driving Pilot study for automated vehicles in those with cognitive impairment. This will impact the improvement of current knowledge in this domain and encourage scholarly collaboration.

Missouri University of Science & Technology (MS&T)

Project Title: Performance of Earthquake-Damaged Reinforced Concrete Bridges with Repaired Columns

Nothing to report.

Project Title: Performance of Earthquake-Damaged Reinforced Concrete Bridges with Repaired

Columns – Phase II
Nothing to report.

Project Title: Investigation of Wind Effects on Bridges Induced by Tornadoes for Tornado-Resistance Design – Phase II
The obtained results will reveal the wind characteristics of tornadic wind fields and provide the information on the wind pressure, forces and moments induced by tornadoes.

Project Title: Development of ATMA/AIPV Deployment Guidelines Considering Traffic and Safety Impacts
This project will help understand how this new autonomous driving technology impact the traffic operation, including the queue length and traffic delay, and subsequently how should DOT maintain a list of roadway segments to minimize the maintenance impact.

Project Title: Deep Learning for Unmonitored Water Level Prediction and Risk Assessment
This research will create a hybrid method for using deep learning algorithms, leveraging the strengths of different deep learning algorithms to generate information vital to predicting water levels near road networks with an acceptable level of accuracy.

Project Title: Optimization of Transportation Infrastructure System Performance with Autonomous Maintenance Technology in Work Zones
This project will help quantify the impact of roadway segment maintenance with ATMA technology, and develop algorithm to solve the user equilibrium traffic assignment. Sensitivity analysis will be conducted. Last but not the least, maintenance priority will be suggested to DOT to avoid the Braess's paradox and maximize the transportation infrastructure system performance.

Project Title: SMART Shear Keys for Multi-Hazards Mitigation of Diaphragm-Free Girder Bridges – Phase II
Once validated and implemented, the proposed SMART can be a novel and efficient device for bridge hazards mitigation to prevent bridge girders from excessive displacement. In addition, the shear key will dissipate the energy from the seismic or tsunami loading to further protect the bridge.

Project Title: Sensor-Assisted Condition Evaluation of Steel and Prestressed Concrete Girder Bridges Subjected to Fire – Phase II
The capability to evaluate the condition of bridges in and after fire hazards can significantly improve the safety and reduce maintenance/repair costs associated with bridge fire accidents in highway operation. The knowledge of bridge behaviors and failure mechanisms in fire hazards can facilitate the designs of bridges with improved fire resistance. In addition, the assessment of post-fire condition of bridges supports more effective and efficient repair strategies to be implemented.

What is the impact on transportation workforce development?

MATC's research and education activities play a vital role in inspiring and preparing students to become future professionals of the transportation workforce. The MATC Scholars Program, STEM Academy, Intern Program, and After-School Program are designed to increase access and retain students from underrepresented groups in STEM and transportation-related degree granting programs and careers.

MATC research projects provide graduate students with the opportunity to gain hands-on research experience in the field of transportation. The interdisciplinary projects completed during program activities bolstered students' conceptual and practical skills in STEM subjects. Students were encouraged to reconfigure their expectations of STEM subjects and perceived barriers and extend their interest beyond classroom experiences.

University of Nebraska-Lincoln (UNL)/University of Nebraska-Omaha (UNO)/University of Nebraska Medical Center (UNMC)

Project Title: Assessing Performance of Geosynthetic Reinforced Pavement with a Large-Scale Track Wheel Test and Nondestructive Testing Tools
Nothing to report.

Project Title: Evaluation of the Driveway Assistance Device (DAD) Systems in One-Lane Two-Way Work Zone
This project is likely to provide scientific evidence to guide DAD design and placement to improve DOT workforce development on two-way highway work zones.

Project Title: Development of New Generation of Portable Concrete Barriers
The newly developed PCB would introduce a novel barrier to a broad transportation community including academic transportation researchers, contractors, manufacturers, State DOTs, and policy makers. The adoption of new barrier calls for a broad education of transportation workforce, dissemination of design information and implementation guidance, once tested. This proposed PCB offer a pathway for academic faculty, students, researchers to evaluate, analyze, and develop more application and contribute to its performance improvement. Additional aspect of new PCB is alternative concrete additives and increasingly advanced material which can affect researchers in this field.

Project Title: LIDAR-Based Vibration Monitoring for Assessing Safety of Damaged Bridges
This project is currently supporting 1 Ph.D. student and 1 Undergraduate student.

Project Title: Resilience of Rural Communities and Transportation Networks to Hazards
This project supports 1 Ph.D. student.
Project Title: Crashworthy Foundations for Soil-Embedded Roadside Safety Hardware
This project will provide insight to roadside safety engineers for how dynamic breakaway features behave, and how this differs from typical static analysis and design methods. The incongruity of expected performance from equivalent static analyses and observed dynamic behavior and performance have been noted as a source of confusion for engineers in NCHRP projects updating AASHTO specifications for railing and deck design under vehicle impacts.

Project Title: Protecting Critical Civil Infrastructure against Impact from Commercial Vehicles – Phase II
Nothing to report.

Project Title: Incorporating Snow Processes in the Iowa Flood Information System (IFIS) and Evaluating its Applicability for Nebraska
Nothing to report.

Project Title: Virtual Barriers for Mitigating and Preventing Run-Off-Road Crashes – Year 4
Multiple graduate and undergraduate students have been funded through this research project including a Hispanic Ph.D. candidate and an underprivileged Russian student performing programming. Opportunities offered to these students have been critical for advancing personal growth objectives and performing at a high level in academia and toward accomplishing personal growth objectives.

Project Title: Bio-Inspired Reusable Crash Cushions with Superior Energy-Absorbing Capacity
Nothing to report.

Project Title: MATC Smart Barrier
The project funded through the MATC UTC is supporting one student pursuing a master's degrees in mechanical engineering and one student, recently converted to a Ph.D. program to evaluate vehicle dynamics, construction, guidance, and controls. This opportunity is beneficial as the project is aligned with both students' interests in vehicle technologies, and both are interested in a career in transportation-related fields. One student is Hispanic and due in part to the work on this project, received a prestigious SAE fellowship for promising young engineers, and now serves as an inspiration to draw additional traditionally-disadvantaged and underrepresented populations to graduate University research. The other student engaged in this research project has accepted a position at the Sandia National Laboratories and will be assisting with instrumentation and intelligent vehicle implementation systems.

Project Title: Investigation and Development of a MASH Test Level 6, Cost-Effective, Barrier System for Containing Heavy Tractor Tank-Trailer Vehicles and Mitigating Catastrophic Crash Events – Year 3
It was previously thought that a TL-6 barrier would need to be 90 in. tall to contain and redirect an errant tractor-tank trailer vehicle. Preliminary results have indicated that a much shorter barrier may be able to contain and redirect an errant tractor-tank trailer vehicle. If the results with the detailed tank model and full-scale crash testing can validate that a shorter barrier is successful at containment, TL-6 barriers may be utilized more readily as they could be more cost effective. Additionally, the results of this study could be used to design TL-6 barriers for various purposes. For example, the shortest height of a TL-6 barrier was determined numerically, which could be used to save on cost when a TL-6 barrier is necessary. Additional barrier heights were also studied to determine how barrier height affects both the required barrier capacity and propensity for the impacting vehicle to extend behind the front face of the barrier, to avoid obstacles with objects behind the barrier such as bridge piers. The barrier height and roll of the trailer can also be used to explore levels of roll of the trailer that do not results in tank fluid spilling. This could impact the workforce as the information would need to get disseminated to many transportation agencies, and also could affect contractors who may installing more barriers similar to the one being developed.

Project Title: Real-Time Emergency Communication Systems for HAZMAT Incidents (REaCH)
Nothing to report.

University of Iowa (UI)

Project Title: Infrastructure Inspection During and After Unexpected Events – Phase III:
Nothing to report.

Project Title: Infrastructure Inspection During and After Unexpected Events – Phase IV
Nothing to report.

Project Title: Transportation Planning with Floods
This grant supports one PhD student in his progress towards his degree.

Project Title: Reducing Flammability for Bakken Crude Oil for Train Transport

- This research is directly related to transportation of crude oil by rail and will provide direct research opportunities in that field.
    - Specifically, undergraduate and graduate research opportunities will be provided in the University of Iowa Department of Mechanical Engineering for oil splashing, oil burning and settling experiments and fluid mechanics simulations.
    - This is expected to raise awareness about MATC and its mission in mechanical engineering undergrads/grad students entering the workforce, as well as provide them training on some of the most critical issues that MATC is currently working on solving.

Project Title: Development of New Design Guidelines for Protection against Erosion at Bridge
Nothing to report.

University of Kansas (KU)/University of Kansas Medical Center (KUMC)

Project Title: Modeling Driver Behavior and Aggressiveness Using Bio-Behavioral Methods: Phase III
Provided opportunities for graduate and undergraduate researchers to contribute towards bettering transportation knowledge in their communities.

Develop data analytics and artificial intelligence skills.

Low Cost 3-D LIDAR Development for Transportation
Developing a LIDAR system with the explicit intention to ultimately function to serve transportation needs allows students to deepen their understanding of existing technology in this space, and generate low cost solutions to aide more large scale implementation. It promotes innovation in technologies that could be implemented to improve traffic flow, and transportation safety.

Project Title: Assessing and Improving the Cognitive and Visual Driving Fitness of CDL Drivers
Nothing to report.

Missouri University of Science & Technology (MS&T)

Project Title: Performance of Earthquake-Damaged Reinforced Concrete Bridges with Repaired Columns
This project has provided training to one graduate student who is pursuing his Ph.D. degree in Civil Engineering (Structural Engineering). The student is gaining experience in numerical simulation of bridge structures, seismic behavior of bridges, and methods to repair earthquake-

damaged bridges.

Project Title: Performance of Earthquake-Damaged Reinforced Concrete Bridges with Repaired Columns – Phase II
This project has provided training to one graduate student who is pursuing his Ph.D. degree in Civil Engineering (Structural Engineering). The student is gaining experience in numerical simulation of bridge structures, seismic behavior of bridges, and methods to repair earthquake-damaged bridges.

Project Title: Investigation of Wind Effects on Bridges Induced by Tornadoes for Tornado-Resistance Design – Phase II
This related research has informed the teaching of the new graduate courses I developed: Wind Engineering and Bridge Engineering. It is used to train Structural Engineers to design tornado-resistant structures.

Project Title: Development of ATMA/AIPV Deployment Guidelines Considering Traffic and Safety Impacts
This project will help DOT engineers understand the suitable operation domain of the ATMA technology, and how to effectively deploy this technology for a safe work zone maintenance.
Project Title: Deep Learning for Unmonitored Water Level Prediction and Risk Assessment
This methodology used here will be broadly shared with the research community and can be incorporated in educational environments as an example of implementing novel approaches to deep learning and using tose techniques to solve real-world transportation system problems.

Project Title: Optimization of Transportation Infrastructure System Performance with Autonomous Maintenance Technology in Work Zones
This project will help DOT engineers maximize the transportation infrastructure system performance with ATMA maintenance technology.

Project Title: SMART Shear Keys for Multi-Hazards Mitigation of Diaphragm-Free Girder Bridges – Phase II
One Ph.D. student (Xinzhe Yuan) and one post doctoral research fellow (Dr. Haibin Zhang) are directly involved in this project under Dr. Chen's supervision.

Project Title: Sensor-Assisted Condition Evaluation of Steel and Prestressed Concrete Girder Bridges Subjected to Fire – Phase II
One Ph.D. candidate (Yanping Zhu) is directly involved in this project under Dr. Chen's supervision. He is preparing test specimens, test setup and data collection.

9. CHANGES/PROBLEMS

COVID-19 has negatively impacted the operations of all MATC institutions. Essentially all universities were closed for the majority of this reporting period except for essential services. Although some services have resumed, MATC research and outreach activities are primarily being conducted remotely.

Our summer outreach programs, including the MATC Summer Institute, the NCIA/MATC Sovereign Native Youth STEM Leadership Academy, and the MATC Intern Program were held remotely and the efficacy of these programs was negatively impacted. At this time it is unclear what the overall effect on

attendance/participation will be although we are expecting a significant drop in participation. At this time, future programs are being planned as though they will need to be held virtually as well.

10. SPECIAL REPORTING REQUIREMENTS

Nothing to report.