TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Nebraska Department of Roads

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)* TPF-5(193) Suppl. #86	**Transportation Pooled Fund Program - Report Period:** ☐ Quarter 1 (January 1 – March 31) ☐ Quarter 2 (April 1 – June 30) ☑ Quarter 3 (July 1 – September 30) ☐ Quarter 4 (October 4 – December 31)	
Project Title: Phase II Conceptual Development of an Impact Attenuation System for Intersecting Roadways		
Name of Project Manager(s): Bielenberg, Faller, Reid	**Phone Number:** 402-472-9064	**E-Mail** rbielenberg2@unl.edu
Lead Agency Project ID: 2611211118001	**Other Project ID (i.e., contract #):**	**Project Start Date:** 7/1/2015
Original Project End Date: 12/31/16	**Current Project End Date:** 12/31/16	**Number of Extensions:** 0

Project schedule status:

☑ On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Percentage of Work Completed to Date
$256,184	$23,786	25%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
	$13,523	

Project Description:

The Nebraska Department of Roads (NDOR) funded the first phase of this effort (M332 – New Conceptual Development of an Impact Attenuation System for Intersecting Roadways). This Phase I effort consisted of development of design concepts, analysis of those concepts, and recommendations as to their feasibility. The project was proposed as an initial conceptual design effort, allowing NDOR to limit the research funds for this phase until a viable design was identified and a more substantial investment could be made toward compliance testing.

Following the Phase I study, a hybrid end terminal/crash cushion and net attenuator system was for additional research that had several areas in need of further development. First, dynamic component testing of the proposed Dragnet attenuator found that the current force levels were insufficient to maintain stopping distances near the desired length of 30 ft. In fact, component testing with three standard Dragnet energy absorbers on each side of the system resulted in deflections over 40 ft. Thus, redesign of the net attenuator system will be required to increase the resistive force and shorten the stopping distances. This will likely require redesign of the energy-absorbing drums, the capture net, and the anchorage of the energy absorbers. Additionally, it was desired that the hybrid end terminal/crash cushion and net attenuator attempt to accommodate moderate slopes. Thus, additional research is needed to determine what slopes can be safely used with the revised net attenuator. The first phase of the research considered a variety of end terminal and crash cushion systems, but additional research is needed to determine what other systems are optimal based on their geometry and shielding of the bridge rail end. Finally, additional research is needed to determine the exact layout of the hybrid end terminal/crash cushion and net attenuator system in order to ensure that the two systems function properly when used together.

Thus, the current research results indicated a potential for an alternative design to meet the MASH safety criteria. However, further research is needed to complete the design and prepare it for full-scale crash testing and evaluation to MASH TL-3.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

In this quarter of the research project, MwRSF tested the high-capacity energy absorber prototype and capture net supplied by Impact Absorption in late March of 2016.

In test no. DBT-1, MwRSF impacted the net attenuator with one high-capacity energy absorber on each side of the net mounted near the center of the net height on rigid frames. The 4,908 heavy bogie vehicle impacted the center of the net at an angle of 90 degrees and a speed of 56.5 mph. The net attenuator captured the bogie and brought it to a controlled stop approximately 34 ft from impact. Peak deceleration forces were 23.6 kips, which correlated to a peak deceleration of 4.81 g's. The longitudinal OIV and ORA values were calculated to be 5.8 m/s and 4.7 g's, respectively. Lateral OIV and ORA values were negligible.

The tape feed length on the left and right side were 148.25 in. and 153.75 in., respectively. MwRSF also ran an analysis to check the estimated deceleration levels for the 1100C small car vehicle. Estimated longitudinal OIV and ORA values were calculated to be 7.5 m/s and 8.5 g's, respectively. These values are well within the MASH limits.

The results from the test showed that the high capacity absorber and net had promise, but that higher force levels were needed. In addition, future versions must be ground mounted to work in the hybrid end terminal/crash cushion and net attenuator system while meeting stub height requirements of 4" or less.

For the next step, MwRSF plans to evaluate the system with higher force levels and ground mounted to determine if the system can be setup and function properly when mounted at grade. Impact Absorption is working on supplying an energy absorber with 17 kip sustained pull force. Additionally, MwRSF is working on mounting the system at ground line and low enough to meet stub height requirements. A subsequent test is planned to evaluate the increased capacity energy

Anticipated work next quarter:

In the upcoming quarter, MwRSF will develop the ground mount for the revised high-capacity energy absorber and attempt to perform a dynamic component test of the high-performance net attenuation system at the 1/4 offset point. Progress will also continue on the summary report and investigation of the Zodiac Aerospace net attenuator alternatives.

Significant Results:

Fabrication of high-performance energy absorber for feasibility testing and development of a second potential energy absorber concept. A dynamic component test was conducted on the initial version of the high-performance energy absorber, and the results were used to push for a revised energy absorber design that will be evaluated next in a subsequent bogie test.

A literature search of existing terminal and crash cushion designs was completed and preliminary review of the available system was done to consider potential options for use with the hybrid end terminal/crash cushion and net attenuator system. Further recommendations on potential systems will be based on NDOR input and will be dependent on the parameters of the final net attenuator design.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

Due to complications arising from the timing and response of the private industry partners in this effort, the development of the new treatment for intersecting roadways is currently behind schedule. This was discussed with the TAC in the October 2016 meeting and it was agreed that it was worthwhile to extend the research effort to allow for further net attenuator development and the use of potential Zodiac Aerospace technologies. Thus, a no-cost time extension will be requested for this project prior to the current end date.

Potential Implementation:

Currently, no safety treatment has been successfully crash tested using TL-3 conditions under NCHRP Report No. 350 or MASH to resolve the problems posed when intersecting roadways are located near a bridge railing. A design that can safely treat this situation along high-speed roadways is sorely needed. In addition, the development of a new design concept for an attenuation system for intersecting roadways will focus on the site and space restraints associated with intersecting roadways and adapt a design that best meets those constraints.

MwRSF will work closely with NDOR engineers and the TAC committee members throughout the concept development of a new attenuation system for intersecting roadways in order to ensure that the system is practical. This focus should ensure that the system is viable for NDOR as well as other state DOT's.

Once the new, TL-3 attenuation system for intersecting roadways has been crash tested, evaluated, and accepted by FHWA, NDOR and other State DOTs can implement the new design into its Standards and/or Special Plans for intersecting roadways. At the conclusion of this research project, it is recommended that NDOR designate an intersecting roadway location that will use this new technology in order to evaluate a "real-world" installation and make any necessary improvements.

Finally, the publication and dissemination of the research results and demonstration program, in the form of newsletters, research reports, and refereed journal papers, will aid the rapid transfer of this new technology to all interested