A. PROJECT NO. & TITLE: NETC 14-4 Optimizing Future Work Zones in New England for Safety and Mobility

B. PRINCIPAL INVESTIGATOR(s) & UNIVERSITY(s): Yuanchang Xie, Nathan H. Gartner and Chronis Stamatiadis, University of Massachusetts Lowell

C. START DATE (Per NETC Agreement): 07/06/2015

D. END DATE (Per NETC Agreement): 07/05/2017 (Requested to be extended to 12/31/2017)

E. PROJECT OBJECTIVES

Given the aging infrastructure and the anticipated growing number of work zones in New England, it is of utmost importance to optimize their layouts to improve safety and to mitigate their impact on mobility. This study aims to use the Transportation Research Board’s SHRP2 Naturalistic Driving Study (SNDS) data for investigating driver behavior in work zones under different traffic, lighting and weather conditions. In addition, data from the smart work zones (SWZs) in Massachusetts (and other New England states if available) to validate the findings obtained from the analysis of the SNDS data is also proposed. Based on the analysis of the SNDS and SWZs data, improved work zone Temporary Traffic Control Plans (TTCPs) will be developed. These TTCPs will be evaluated using an advanced driving simulator and a microscopic traffic simulation tool. The main objectives of this study include:

- **Literature Review**: A focused review on work zone safety will be conducted.
- **SNDS Data Analysis**: Critical factors that may potentially affect (either positively or negatively) driver behavior in work zones under various conditions will be reviewed and analyzed based on the SNDS data. These factors may include traffic signs, variable message signs, law enforcement, work zone layout, etc.
- **Identify and Quantify Strategies**: The identified factors will be further examined and tools will be developed to quantify these factors’ impacts on three key aspects of improving work zone safety: reducing speed, maintaining safe distances and preventing driver distraction. In addition, the impacts of these factors on reducing near crash events will be studied. Investigating near crash events and driver behavior/maneuvers immediately prior to them will allow us to better understand how work zone crashes occur.
- **Proposed Work Zone Control Plans**: Based on the SNDS data analysis results and a review of work zone control strategies, new and improved work zone TTCPs will be developed.
- **Validate the Results**: Field data collected from smart work zones (SWZs) in Massachusetts (and other New England states if available) will be used to evaluate the performance of certain work zone TTCPs. If there is a match between the SWZs and the work zones in the SNDS data, the corresponding data sets will be compared both quantitatively and qualitatively. In addition, an advanced driving simulator and a microscopic traffic simulator will be used to evaluate the safety and mobility performance of various work zone layouts and controls. Extensive driving simulator studies will be conducted to evaluate how drivers respond to different work zone layouts and controls.

F. REPORT PERIOD: 4/1/2017 ~ 6/30/2017

G. ACCOMPLISHMENTS THIS PERIOD:
A total of seven tasks have been identified for the proposed study, which are 1) literature review; 2) development of Temporary Traffic Control Plan (TTCP) metrics; 3) development of methodology for testing and analyzing TTCPs; 4) development of new TTCPs; 5) evaluation of new TTCPs through simulation; 6) project meetings; and 7) reporting. During the 7th quarter, the team has been focusing on Tasks 3, 5, 6, and 7. The accomplishments during this quarter are detailed in the following sections.

**Task 3 – Development of Methodology for Testing and Analyzing TTCPs**

*Naturalistic Driving Study Data*

The team received the 2nd set of NDS data set on April 7, 2017 and started to analyze it in this quarter. We focused on the following data elements: 1) speed time series data, 2) acceleration/deceleration time series data, and 3) crash and near-crash events.

Analyzing the speed time series data was to identify traffic control strategies that have a major impact on vehicle speed in work zone. We found that presence of police vehicles can effectively reduce vehicle speed, while variable message signs and traffic cones are ineffective. Narrow lanes may help reduce vehicle speed. However, more NDS samples are needed to further confirm this conclusion. The team also analyzed the acceleration/deceleration time series data. Compared to the speed data, the acceleration/deceleration data was noisier and the corresponding analysis did not lead to definitive conclusions.

The analysis of the crash and near-crash events suggests that speeding may not be a major contributor to crashes in work zone, which is contrary to what people typically believe. The NDS data suggests that distraction, fatigue driving, sudden stop/deceleration of lead vehicle, and unsafe merging behavior were the major causes for the identified crash and near-crash events.

The team wanted to use the NDS speed time series data to validate the virtual reality driving simulator. From the 2nd NDS data set, we were unable to find enough runs with the same or similar work zone set up. For a single run of a particular NDS driver, it is probably unreasonable to expect driving simulation to generate very similar results due to driver heterogeneity. Therefore, no further validation attempts were taken.

**Driving Simulator**

A no-cost extension request has been submitted to the project advisory committee, in which the team proposed to reallocate funds to purchase a motion simulator and an eye tracking device. The motion simulator will further improve the fidelity of the driving simulator and give participating drivers’ even more realistic driving experience. The eye tracking device will allow us to detect driver distraction, which is one of the major contributors to work zone crashes and near-crash events.

**Task 5 – Evaluation of New TTCPs**

In the 7th quarter, the team continued to evaluate the six speed control scenarios described in the 6th quarterly report using the Virtual Reality (VR) driving simulator. The evaluation results have been summarized in a paper entitled "Modelling Highway Work Zone Traffic Safety and Driver Behaviours Using a Virtual Reality Driving Simulator", which has been accepted for presentation at the 2017 Road Safety & Simulation International Conference.

In addition to the speed control strategies, the team also finished evaluating merge strategies using VISSIM. We considered the following merge strategies: conventional merge (i.e., no control), early and late merges, merge with priority rule, and signalized merge. For early and late merges, we developed custom code to force vehicles to merge at a specific location, which ranges from 200ft to 2500ft.
upstream of the beginning of a work zone with an increment of 100ft. We carefully reviewed the simulation animations of the early and late merges and observed long queues in the closed lane and fast-moving traffic in the open lane(s). In practice, vehicles in the open lane typically will also slow down due to vehicles in the closed lane trying to merge into the open lane(s). Therefore, we proposed a merge with priority rule strategy, which requires vehicles in the adjacent open lane to yield to vehicles in the closed lane when there are queues in the closed lane. We tested the performance of the above merge strategies under various traffic demands. We also considered two work zone scenarios: (1) two lane highway with the right lane closed, and (2) three lane highway with the right most lane closed. The detailed merge strategy evaluation results will be reported during the upcoming 7th quarterly meeting.

**Task 6 – Project Meetings**
The team held the 6th quarterly meeting on April 26, 2017. We plan to have the 7th quarterly meeting within the next 10 days depending on the schedules of project technical committee members.

**Task 7 – Reporting**
The team submitted the 6th quarterly report on April 17, 2017.

**H. PROBLEMS ENCOUNTERED:**

No problems were encountered in the 7th quarter.

**I. TECHNOLOGY TRANSFER ACTIVITIES:**

- 7th Quarterly Report – The report is submitted to NETC on July 15, 2017 for review.
- A paper entitled “Modelling Highway Work Zone Traffic Safety and Driver Behaviours in the United States Using a Virtual Reality Driving Simulator” has been accepted by the 2017 Road Safety & Simulation Conference to be held in The Hague, Netherland in October 2017.

**J. STATUS BY TASK**

<table>
<thead>
<tr>
<th>TASK</th>
<th>% COMPLETE</th>
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<tbody>
<tr>
<td>1 – Literature Review</td>
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<tr>
<td>2 – Development of TTCP Metrics</td>
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<tr>
<td>3 – Development of Methodology for Testing and Analyzing TTCPs</td>
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<tr>
<td>4 – Development of New TTCPs</td>
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<tr>
<td>5 – Evaluation of New TTCPs through Simulation</td>
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<tr>
<td>6 – Project Meetings</td>
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<tr>
<td>7 – Reporting</td>
<td>63%</td>
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**K. PERCENT COMPLETION OF TOTAL PROJECT: 75%**

**L. ACTIVITIES PLANNED FOR NEXT QUARTER:**

The project team will continue working on Tasks 3, 5, 6 and 7.

**M. FINANCIAL STATUS:**

As of: July 17, 2017
Total Project Budget: $ 200,000
Total Expenditures: $ 110,590