Integrating Data and Physics for Assessing Maintenance Strategies to Enhance Winter Road Resilience

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Center Name: Pacific Northwest Transportation Consortium (PacTrans)

Research Priority: Improving the Mobility of People and Goods

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Project Partners: Xianming Shi (WSU) and Chuang Chen (WSU)

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Project Start and End Date: 8/16/2023 – 8/15/2025

Project Description: Winter road maintenance (WRM) operations are critical to nearly 70% of the roads and more than 70% of the population located in cold regions of U.S. In light of climate change, the frequency and intensity of extreme weather events such as snowstorms are increasing. Transportation agencies are under increasing pressure to provide a high level of service (LOS) and to improve safety and mobility in a fiscally and environmentally responsible manner.

Currently, there is an urgent demand for more effective solutions to address the resilience challenges on roadways enduring extreme winter weather. However, there is a lack of investigation on how to quantify the effects of various maintenance strategies on winter road resilience. By definition, resilience is the ability of a roadway to bounce back to a performance level before a disruptive event or other disturbances, and it can be characterized by metrics such as robustness, adaptability, agility, redundancy, response time, recovery time, level of recovery, and performance loss. For instance, the recovery of traffic speed and traffic volume could be used as a resilience index for the effectiveness of WRM operations, whereas vulnerability is one of the most explored indexes in transportation system resilience studies.

In addition to resilience index, it is imperative to investigate the appropriate model type for quantifying the effects of maintenance strategies. In previous research, regression analysis and path analysis have been conducted on exploring the relations between winter weather variables, road condition and maintenance operations. With the advancements in data analysis and modeling techniques, such as machine learning (ML), it is valuable to explore a model type that can effectively capture the maintenance process and its impact on road resilience. This investigation can provide insights into the dynamic relationship between maintenance activities and road resilience, enhancing the understanding in this area.

US DOT Priorities: This project fits well under the research priority “Sustainable and Resilient Infrastructure” by assessing the impact of winter weather on road resilience and the effect of maintenance activities for mitigation. The goal of this project is to “build more resilient and sustainable transportation systems to benefit and protect communities.” This project will collect and process data of

various types and from diverse sources. Advanced analytical tools will be employed to provide a data-driven insight.

Outputs: This project will develop and demonstrate the methodology for evaluating the influence of current WRM strategies for road network resilience, especially during extreme winter weather. The PI will deliver webinars to state DOT personnel and consulting engineers on the use of the tools developed.

Outcomes/Impacts: The outcomes of this work include an enhanced understanding of road resilience from the perspective of traffic mobility, as well as a comprehensive analysis of the dynamic nature of maintenance operations. Moreover, the quantification of maintenance effects facilitates optimal decision-making processes to improve resilience and mobility in transportation systems. The outputs of this study include an evaluation framework, including its various components such as models, algorithms, and methods for quantifying maintenance effects. These techniques can be directly applied to analyze and model panel data pertaining to traffic and road performance. In addition to optimizing winter maintenance operations, the impacts of this research extend to climate change adaptation and natural disaster mitigation. The evaluation framework can be incorporated with predicted future weather variables and events to inform corresponding strategies in these areas.

Final Research Report: *will provide upon completion of the project*