



Implementation of Artificial Intelligence to Improve Winter Maintenance

Exploratory Advanced Research...Next Generation Transportation Solutions



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The union of technology and transportation is leading to advancements in how decisions are made and deployed for winter maintenance activities. Federal Highway Administration (FHWA) is investigating the use of artificial intelligence (AI) to collect and analyze data that could dramatically improve winter maintenance operations, safety, and mobility, as well as reduce costs and labor hours and enhance pavement design and management. Data-Driven MDSS (Dr. MDSS) looks to AI to provide next-level analysis of real-world situations in real time, addressing the risks and challenges of conducting onsite assessments. Dr. MDSS is a type of MDSS that focuses on the access to and handling of internal and external data to make decisions. FHWA's Exploratory Advanced Research (EAR) Program is supporting research on the potential development of a Dr. MDSS prototype for State departments of transportation (DOTs). Researchers from the Michigan Technological Institute are conducting the research project, "Autonomous Winter Road Maintenance Decision Making Enabled by Boosting Existing Transportation Data Infrastructure with Deep and Reinforcement Learning."

The Impacts of Winter Weather and the Benefits of AI

Each year, winter weather affects millions of Americans across more than 30 States. State DOT and local transportation departments' winter maintenance budgets for materials, labor, and other activities continue to rise, with Federal, State, and local governments collectively spending billions of dollars in an average year.¹ Major, widespread storms can drive up costs substantially and can shut down roadways for prolonged periods of time, causing a domino effect of challenges for State and local DOTs. Attention to safety becomes even more critical when transportation crews conduct snow removal and salting activities for several consecutive days in their respective regions of the country.

The implementation of AI-driven tools could produce near-immediate, positive results for State and local DOTs when planning for weather

events through improved data processing, predictive road condition methods, and computer-supported decisionmaking.

Innovative Concepts: Where AI Can Take Us

The research team homed in on four distinct opportunities from AI that could prove promising for the successful development of the prototype for winter maintenance decisionmaking:

- Recurrent Neural Networks and Road Condition Predictions—Recurrent neural networks (RNN) are an artificial network that use speech and language processing to predict patterns. Using that predictive approach, RNNs could prove beneficial to help predict data such as salt concentrations and surface temperatures—conditions currently predicted by standard empirical models.
 - Deep Reinforcement Learning and Decisionmaking—Machine learning has become increasingly more prevalent both in use over the last decade for its ability to analyze data without any human intervention and with deep reinforcement learning (DRL) programs making the decisions. For example, DRL was featured in the news in 2017 when the program learned—without human game data—to master chess, Go (an ancient Chinese strategy game), and shogi (a Japanese chess-like game of strategy) in 24 hours.² Although much of DRL is advanced in simulation scenarios, the high-level of DRL programs can translate to making winter maintenance decisions about salting, for instance, in a real setting but based on autonomous decisionmaking capability: the "object" ([learning] agent or engineer) is put into an environment (roadways) in which its decision to act (maintenance decisions) can impact the environment (road conditions). In this scenario, the agent would make decisions based on traffic conditions and cost savings with a cost-benefit analysis tool while "learning" which action to take in the future.
- While RNN makes the predictions, it is DRL that takes those predictions and puts them into practice.
- Visuals to See Road Conditions—The integration of AI applications with more traditional visual tools, such as surveillance

¹ Minnesota Department of Transportation. 2015. Benefit-Cost of Various Winter Maintenance Strategies. Bozeman, MT: Western Transportation Institute. http://clearroads.org/wp-content/uploads/dlm_uploads/FR_CR.13-03_Final.pdf, last accessed April 20, 2021.

² Silver, D. et al. 2017. Mastering the Game of Go Without Human Knowledge. Macmillan Publishers Limited, part of Springer Nature. <https://faculty.washington.edu/jwilker/559/2018/go.pdf>, last accessed September 29, 2021.



Implementation of AI Framework to Improve Winter Maintenance Decisionmaking

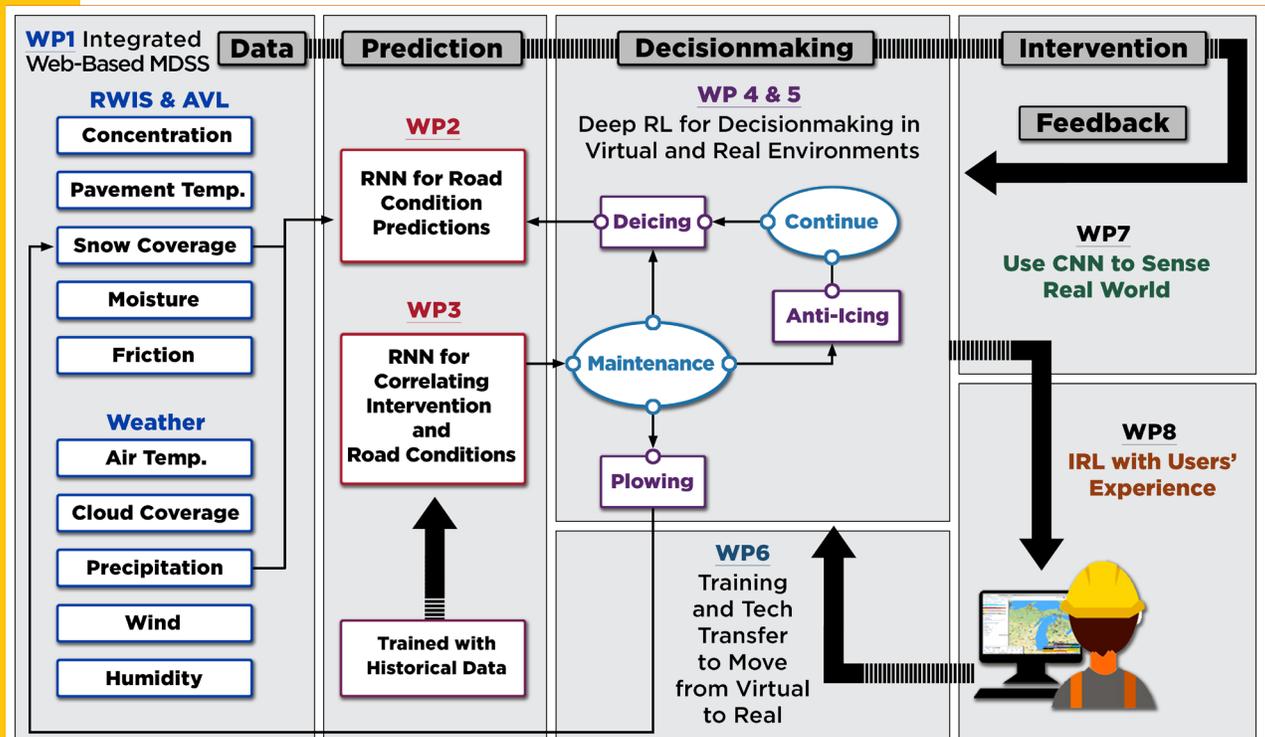
cameras or truck-mounted automatic vehicle location (AVL) cameras, can lead to an enhanced method of detecting road conditions in real time, including pavement, traffic, and weather conditions. From an AI perspective, all of these can become learned conditions an application can begin to predict.

Convolutional neural networks (CNN) act as the “eyes” of the AI application. During an assessment, data collected through CNN are fed back to the AI program, where the application analyzes data with spatial patterns (videos and images) that will support winter maintenance decisionmaking from a live, visual standpoint. The data collected through CNN can surpass in volume and accuracy data collected from weather stations, Road Weather Information System (RWIS) stations, and traffic data providers.

- Holistic, Closed-Loop Approach—To reach AI’s maximum capability, all components would work together as one cohesive, closed loop. A closed loop is an automatically controlled system where data are fed to the system to start a process or operation—a process that continues throughout the life of the event until the event is complete and then begins again. Using each innovation

as a standalone tactic can offer benefits to winter maintenance; however, combining each innovation into a holistic system would prove most beneficial for safety, operations, and mobility improvements, as well as offering cost savings and pavement maintenance support. Further, as part of a closed-loop system, each innovation advances data, tactics, and processes that prove mutually beneficial for the entire system and continually feeds information back to the decisionmaking point that originated the event. Figure 1 details the research team’s approach to proof of concept development, identifying the various components including data, prediction, decisionmaking, intervention, and feedback—ultimately forming the closed-loop approach. The research team will aim to design the system to collect the various types of data and process the data through RNN for DRL to automatically make the maintenance decisions. The results from road and traffic conditions will be analyzed through CNN to verify those outcomes and enhance decisionmaking in the future. Once complete, the closed-loop approach for winter maintenance activities would start again for another condition or scenario, with continuous improvement imbedded in the process as a core principle.

Figure 1. Overview of proposed research, forming a closed-loop approach.



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Three-Phased Approach to Research

The research team identified an approach to the project that would advance the work in three defined phases:

- Phase 1: The team will look to create a Dr. MDSS that explores winter maintenance activities and is informed by similar research developed for an open-source MDSS prototype that focused on seasonal load restrictions—restrictions on vehicle weight and speed during specific times of the year when conditions are not safe or suitable for the posted speed or weight limits. The team aims to create a functional model-based MDSS and develop the RNN to support predicting conditions with and without human involvement. The team plans to release the prototype created in Phase 1 during Phase 2. The release will include an open-source, functional app for winter maintenance decisionmaking and the creation of a GitHub repository for tool development and to provide public access to the app.
- Phase 2: In this stage of the project, the research team will begin using the Dr. MDSS and DRL-enabled application prototype in various test environments, including virtual and real world.
- Phase 3: Taking what was learned and developed during the first two phases, in

EXPLORATORY ADVANCED RESEARCH

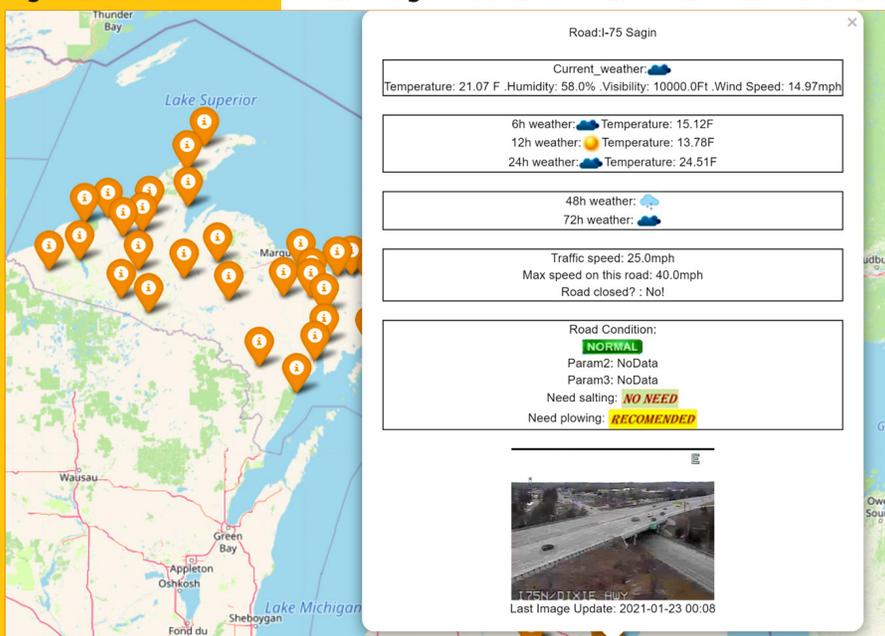


What Is the EAR Program?

The EAR Program addresses the need for longer term, higher risk research with the potential for transformative improvements to transportation systems. The EAR Program seeks to leverage advances in science and engineering that could lead to breakthroughs for critical, current, and emerging issues in highway transportation by experts from different disciplines who have the talent and interest in researching solutions and might not do so without EAR Program funding.

To learn more about the EAR Program, visit <https://highways.dot.gov/research/exploratory-advanced-research>. The website features information on research solicitations, updates on ongoing research, links to published materials, summaries of past EAR Program events, and details on upcoming events.

Figure 2. Road and weather conditions generate data for winter maintenance activities.



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Phase 3, the research team will incorporate real-world data and feedback into the Dr. MDSS prototype to enhance and improve its capabilities. Data and feedback will include human-generated information; information and road engineers' experience and best practices; roadway sensors; and images, videos, and AVLs of pavement, weather, and traffic conditions. The data collected will enable the Dr. MDSS prototype to improve upon itself without human intervention.

The research team anticipates releasing the following results from this project: the open-source Dr. MDSS tool, publication of significant findings, and raw data, which will be made available either through a permission-based system (for data developed with collaborators) or public access (for data identified as free of copyright restrictions).

Learn More

For more information about this EAR Program project, contact Morgan Kessler at 202-493-3187 (email: morgan.kessler@dot.gov).