MACHINE LEARNING AT STATE DEPARTMENTS OF TRANSPORTATION NCHRP PROJECT 23-16

responding to dynamic conditions.

NATIONAL ACADEMIES Medicine

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What is ML? Machine Learning (ML), a subset of Artificial Intelligence (AI), involves algorithms learning patterns from data. ML models improve by retraining on new data and can make predictions, find correlations, and optimize decision-making. Techniques range from simple linear regression to complex deep neural networks, which have advanced in image, video, sound, and language processing, even surpassing human performance in some tasks.

How is ML different from other methods? ML models help in automating repetitive tasks, and they prioritize accurate predictions over understanding relationships between variables. They adapt well to nonlinear data patterns, adjust to new information, offer new insights, and handle large and complex data types effectively. This sets them apart from traditional statistical models that rely on predefined structures and assumptions.

ML Value

Transportation Example

Respond to changing conditions

Make faster and better decisions

er An ML traffic monitoring and incident management system can

An ML adaptive signal control system can improve traffic flows by

ldentify new strategies

Maximize limited staff resources

> Encode agency expertise

identify highway collisions in real-time and recommend strategies for first responders.

An ML system that supports transportation planning can craft a novel solution that would not have been previously considered by planners.

ML can streamline agency operations through automation of repetitive tasks, such as permit processing, by extracting relevant information from applications, assessing them against predefined criteria, and even recommending approval or denial.

ML can capture knowledge of highly trained maintenance personnel to detect and diagnose structural failings of equipment. Encoding agency expertise could become increasingly valuable amidst retirements.

Why use ML models? ML models have revolutionized industries like banking, healthcare, and marketing, offering new applications in chatbots and image processing. While crucial, ML requires quality data, faces explainability challenges, and demands resources. In transportation, ML solutions are popular in asset management, operations, and road safety, with high user satisfaction.

What are State DOTs doing with

ML? Despite the potential benefits of ML in transportation agencies, it is not widely used currently. A 2022 survey revealed that most agencies do not have ML applications deployed or in development, and many are not familiar with ML methods and tools. However, the map at right shows six example agency implementations of ML.

Safety Management (Washington) Identify near-crashes, detect speeding infractions, and predict crash risk from video data.

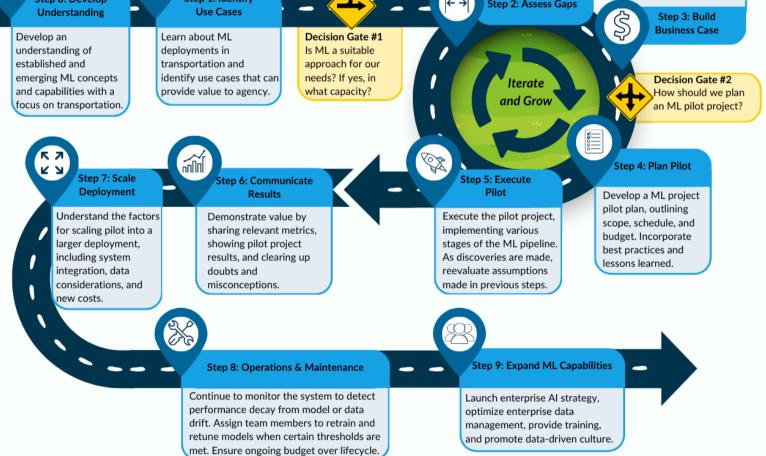
> Incident Management (Nevada) Monitor highway performance, detect incidents, and dispatch emergency personnel based on in-vehicle data, roadside detectors, apps, and other sources.

Infrastructure Monitoring (California) Detect hazards such as litter, potholes, and pavement cracks from video and other sensor data. **Operations Management** (*Delaware*) Proactively manage traffic (e.g., adjust signal timing) based on predicted speeds, travel times, and traffic flows from multi-source data fusion.

Road Weather Management (Missouri) Predict road conditions and recommend pavement treatments based on anticipated winter weather events from weather sensor, detector, and probe data.

Asset Management (Texas) Detect and inventory roadway assets (e.g., road signs) from image data, especially after major disasters like hurricanes requiring quick assessments.

Asset Data storage, Federal grant management and Utilizing existing computational, and funding could help operations are lowdata sources can software resources kickstart ML hanging fruit areas save on cost. are vital for ML programs. for ML in Common ML Building on preapplications. transportation types include ML as a service is trained models supervised learning. becoming more and open-source such as object common. tools is common detection. practice. How to implement ML successfully? Some insights from agencies pursuing ML are summarized above. ML has a promising future but may not be suitable for all problems. Agencies should understand ML's benefits, challenges, and risks to make informed decisions. A 10-step roadmap tailored to state DOTs has been developed to help transportation agencies build their ML capabilities. The roadmap is part of a broader ML guidebook based on best practices and lessons learned from research, surveys, and case studies with state DOTs. Evaluate current Highlight the value of resources and identify ML by quantifying gaps in data, storage, benefits and costs. computing, workforce, estimating business and related factors metrics, and building stakeholder buy-in. Step 0: Develop Step 1: Identify Step 2: Assess Gaps Understanding **Use Cases** Step 3: Build **Business Case** Develop an Learn about ML



What's next for ML in transportation? The ML landscape is rapidly evolving in transportation, with a rise in deep learning and generative AI models like ChatGPT. While these models offer tremendous capabilities, they also present challenges such as ethical concerns, potential inaccuracies, lack of explainability, and the need for domain expertise. As ML implementation processes in transportation advance, trends like the use of pre-trained models are expected to impact how ML solutions are acquired and utilized by transportation agencies.

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