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Driving Transportation Safety Forward with AI

Case Studies on the Application of Artificial Intelligence in Transportation

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Contents

Acknowledgements

This document, sponsored by the American Traffic Safety Services Association (ATSSA), was co-authored by Eric Perry, P.E., and Tim Lutrell, P.E. It originated from discussions among panelists during the Circle of Innovation session at the ATSSA 2024 Convention & Traffic Expo. The purpose of this document is to highlight examples of how AI can enhance roadway safety and operations, providing practitioners with insights for safer roadways.

The authors extend their gratitude to the panelists whose contributions shaped the content of this document:

- George Abcede, P.E., Hawaii Department of Transportation
- Paul Carlson, Ph.D., P.E., Automated Roads
- Greg Driskell, Limntech Scientific Inc.

ATSSA is dedicated to advancing roadway safety and mitigating injuries and fatalities through the promotion of innovative practices. ATSSA's core purpose is to advance roadway safety. ATSSA represents the roadway safety infrastructure industry with effective legislative advocacy, traffic control safety training and a far-reaching member partnership. ATSSA helps shift the focus of transportation toward saving lives and reducing injuries.

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Introduction

Transportation agencies, along with private sector partners, are looking for new ways to inject innovation into management practices and processes. These stakeholders are challenged with the need to improve efficiencies using data from a variety of transportation elements and produce results that have a positive effect on safety and mobility. From planning, designing and constructing transportation projects to efficiently maintaining an aging infrastructure, agencies use electronic applications with large amounts of data for efficiency. However, the process can be complicated and sometimes overwhelming to assess and optimize. Fortunately, advanced technology in the form of artificial intelligence (AI) is available to transform the ways agencies consume and use data to support their missions.

AI is technology that allows machines to think, learn and process data in much more efficient ways than traditional methods. Machine learning and fuzzy logic are examples of AI subsets, where these rule-based systems rely on the practical experience of the operator[1]. An example is a fuzzy logic ramp metering algorithm that uses rules to evaluate mainline freeway traffic flow to control vehicles entering from a nearby ramp to maintain acceptable conditions on the mainline. Machine learning has a more limited scope than AI overall. Both require human inputs to operate, and AI can learn and improve while processing large quantities of complex data. Practitioners see AI as an integral component in the paradigm shift from evaluating historical safety data to proactively saving lives through such technology applications.

Application of AI falls into five macro-level categories: text AI, visual AI, interactive AI, analytical AI and functional AI. Text AI is available to the user in the most basic form. As an example, through a current open-source application named ChatGPT, users can type in a question or phrase and the AI technology provides a response that might take a human several hours of research to produce. GPT stands for Generative Pre-trained Transformer, the technology that allows the tool to generate human-like text responses based on the input it receives. For example, when asked to define AI, ChatGPT[2] provides the following explanation:

> **ChatGPT**
> AI, short for Artificial Intelligence, refers to the simulation of human intelligence processes by computer systems. These processes include learning (the acquisition of information and rules for using the information), reasoning (using rules to reach approximate or definite conclusions), and self-correction. AI encompasses a broad range of techniques and approaches, including machine learning, natural language processing, computer vision, robotics, and expert systems, among others. AI systems can perform tasks that typically require human intelligence, such as understanding natural language, recognizing patterns, making decisions, and solving problems. AI has applications across various fields, including healthcare, finance, transportation, education, entertainment, and more.

Figure 1. ChatGPT Sample Output Format (Source: chat.openai.com)

[1] https://www.controleng.com/articles/artificial-intelligence-fuzzy-logic-explained/
[2] https://chat.openai.com

In the more advanced stages, the application of AI to the transportation industry includes analysis of safety data, predictive techniques and decision-support tools. The results can positively affect decisions from assessing pavement markings to developing enhanced asset management programs to more efficient maintenance programs.

As a result of research and prototype testing, agencies have asked several questions that help to consider the broader application of AI to transportation, including:

- What if AI could predict when and where traffic incidents are most likely to occur?
- Can AI be used to evaluate maintenance needs in place of time-consuming site reviews?
- Does AI have both in-vehicle and roadside or roadway technology capabilities?
- Is AI capable of running innovative pavement marking machines to maintain existing markings?
- What types of data can AI use to help with infrastructure management and maintenance?
- Can AI also communicate with in-vehicle technologies for a broader positive impact?
- Could AI provide inputs to our team that help us save lives instead of reviewing lagging statistics after lives are lost?

While some of these concepts are in the early development stages, and others are included in experimental activities and tests, some agencies are integrating AI into everyday practices. The following case studies explore ideas and concepts related to these questions and highlight how some agencies are implementing AI tools to improve transportation safety and more efficiently deliver programs.

Case Studies

Iowa Department of Transportation: AI for Traffic Incident Management

Iowa State University (ISU), in conjunction with the Iowa Department of Transportation (Iowa DOT), is developing a deep learning-based system to improve detection and support decision-making for traffic incident management. Data consists of camera feeds and traffic sensor information at intervals of less than one minute. The system uses the TensorFlow deep learning framework to assess incidents using video image data, with a future focus on predicting problems based on traffic conditions. TensorFlow (tensorflow.org) open-source software is helping Iowa DOT understand overall traffic patterns to process large amounts of data and better understand how to optimize the transportation network. The research and development work are supported by a three-year Grant from the National Science Foundation.

The system, known as Traffic Incident Management Enabled by Large-data Innovations (TIMELI), uses large-scale data analytics to reduce the number of incidents and minimize the impacts from incidents by shortening their exposure time. Using TensorFlow along with advanced graphics cards, the system analyzes existing Iowa DOT data streams to find incidents and will eventually predict problem areas. This will ultimately improve safety not only for motorists but also for incident response personnel. By shortening incident duration, the DOT can better manage non-recurring congestion and reduce the impacts from secondary crashes around the incident location. Data sources include high-definition camera feeds and traffic sensor data. AI can process the data just as a human would if humans had the ability to monitor video feeds in real-time for extended periods.

As a specific case example, a traffic management center (TMC) operator has a video feed from Interstate 235 in Des Moines. The camera is facing east in the direction of a major route serving a local high school. Personnel in the TMC, which is staffed 24 hours a day, would normally observe growing congestion and would communicate with responders and post warnings to message signs once the incident is verified. This process could take a few minutes or longer. To compound the challenge, there could be multiple locations across the state with incidents occurring at the same time. While operators would only be able to process a finite amount of data and respond, AI can handle large quantities of data and process information and response for multiple incidents at the same time. AI also becomes "smarter" after processing video and detector data to determine the conditions on the roadway, thereby improving the response and possibly reaching a point of being able to predict when conditions are more conducive to incidents. This application provides for enhanced verification and response and by shortening the incident exposure time, secondary crashes can be reduced or avoided.

Figure 2. Iowa DOT Traffic Camera Feed on I-235 in Des Moines (Source: Iowa DOT)

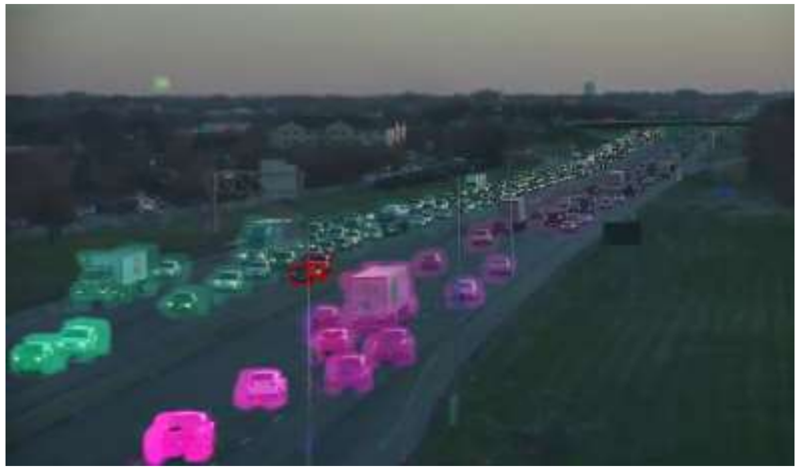

Figure 3. Stalled Vehicle Detection Using Pixel-Based Approach (Source: ISU)

For the system to work, researchers are studying methods of identifying and classifying incidents. In uncongested conditions, a vehicle trajectory-based method works to identify an incident. However, individual vehicle trajectories become more difficult to track in congested conditions; therefore, a pixel-based approach[3] works best in congested conditions. Researchers use YOLOv3 (You Only Look Once) object detector algorithms to detect vehicles and then estimate optimum flow, use motion feature extraction, and use supervised motion feature classification. Researchers also evaluate the potential for active traffic management features based on mainline incidents, such as rerouting traffic to alternate routes and the effects on—or needs of—traffic signals along the alternate route. This approach included a preliminary study on deep reinforcement learning (DRL) for adaptive signal control and traffic rerouting.

This project resulted in the creation of system architecture, tools for processing large-scale data sets and analyzing results, and a prototype software package with documentation and a user manual. Researchers plan to provide these tools to TMC operators for integration into existing software systems to make use of AI for enhanced incident management.

[3] TIMELI: Traffic Incident Management Enabled by Large-data Innovations (NSF Award ID 1632116) Final Report

Hawaii Department of Transportation: Safety Analytics Platform Using AI

The Hawaii Department of Transportation (HDOT) developed a safety analytics platform with AI, with broad plans to expand use of the technology to other areas. Traditionally, practitioners evaluate lagging performance metrics to better understand what improvements are needed. Agencies also apply safety analysis techniques such as crash modification factors based on the measured improvements from evaluated roadway safety strategies. In this case, HDOT designed the system with a proactive, positive focus through metrics such as lives saved, and speeds reduced. The desired outcome is zero fatalities, as HDOT uses advanced technologies, analytics, forecasting and visualizations to reduce safety issues and save lives.

Figure 4. HDOT's Approach to Actionable Intelligence for Safety Benefits (Source: HDOT)

In Hawaii, AI provides recommendations for improvements based on data patterns, predictions, decision-support systems and recommended countermeasures. Practitioners then use the analytics to decide on strategies and devices such as rumble strips, raised pedestrian beds, pavement markings, signage, lighting and reflectivity, enforcement techniques, or a redesign of the facility.

As an example, AI analyzed crash information across Honolulu and generated a map showing a forecasted number of crashes by location based on the analytics as shown in Figure 5. The map also includes a layer showing completed raised crosswalks and those in progress (green diamonds show completed and yellow diamonds show in progress). The varying shades of purple highlight the expected crashes as shown in the legend. AI forecasted 18,100 crashes and 6.9 lives saved during the three-year period from application of the recommended countermeasures. The outputs from the AI-driven platform are used to communicate with the public and with legislators to fund solutions to safety challenges and problem locations.

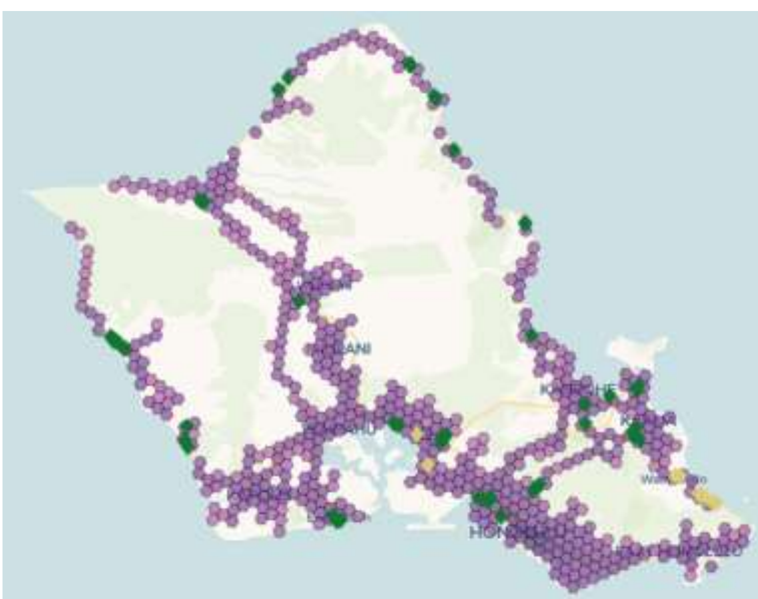

Figure 5. Oahu, Hawaii Forecast Prediction Model: 2022-2025 (Source: HDOT)

In addition to its Safety Platform, HDOT is also using AI in its Climate Resiliency Platform. Using the platform, HDOT staff can better understand the existing hazards and forecast their potential impacts. This approach allows HDOT to be more proactive than reactive. HDOT is also planning to use AI to augment its capabilities in other programs. For example, in Human Resources, HDOT plans to use AI to process data, answer inquiries from staff, assist with processing forms and even provide recommendations on possible disciplinary actions. Another potential application includes an AI call center to assist the public by processing complaints and permits including selecting the proper forms, helping fill out those forms correctly, and processing payments as needed. In addition, there is a major effort to use AI to support asset and maintenance management decisions through dashboard visualizations that use data from requested, assigned, in progress and completed asset maintenance activities.

Pavement Marking Condition Assessments Using AI

Agencies are learning how AI can be used to evaluate roadway pavement markings to determine compliance with appropriate local, state and federal standards and to predictively perform maintenance activities. One innovative source of data for evaluating pavement marking conditions is aerial imagery. Such imagery is already used in the insurance industry for damage assessment for properties, buildings and other structures, as it contains attributes needed to evaluate claims quickly and effectively. A similar approach is also being used for transportation facilities, as evidenced by recent assessments in Georgia and North Carolina.

In one example covering parts of the City of Atlanta, Ga., AI with aerial imagery has been shown to provide new ways to assess the condition of urban markings through a color-coded map of locations. The map includes green dots and red dots, where green indicates the markings are adequate and red indicates locations where markings need to be upgraded. Based on predetermined parameters the user can toggle between, AI evaluates the data and identifies the locations for improvements.

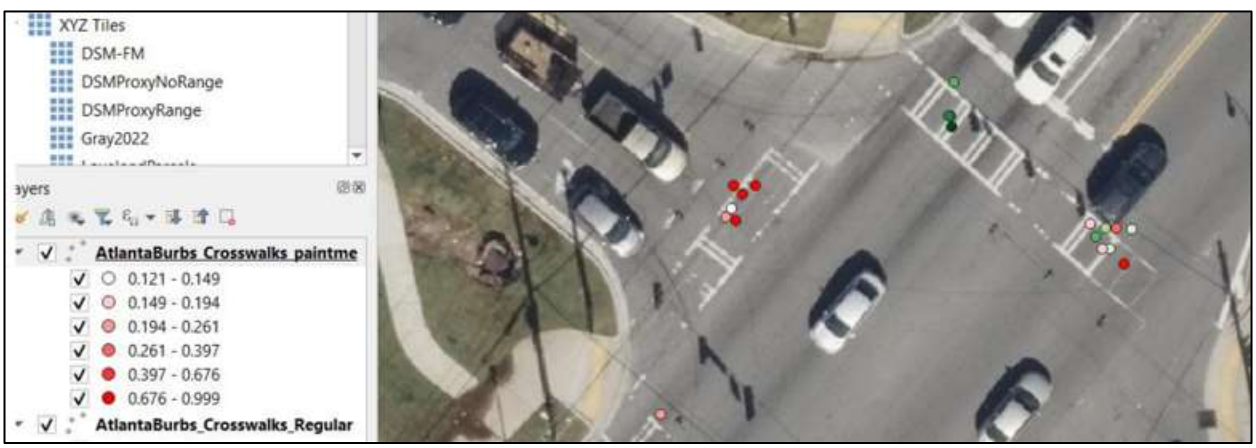

Figure 6. City of Atlanta, Ga., Example User Interface (Source: Paul Carlson)

In the City of Greensboro, N.C., AI capabilities were demonstrated to evaluate pavement markings, with expanded application to pedestrian facilities including accessibility standards compliance. In a similar format to that highlighted for the City of Atlanta, the outputs generated by AI can be used to create a maintenance and facility upgrade program. Using an AI-generated database with tags for items, the system provides a count of needs including those rated in "poor" condition (based on a quality score) and an estimate of replacement costs for the items. Based on this detail, practitioners can prioritize needs and secure funding for projects.

Item (Tag)	Count	Poor Condition Count (<=0.10)	Replacement Cost (Materials)
stopbar	4235	333	32967
straight_arrow	3848	528	78672
leftturn_arrow	5569	154	26180
rightturn_arrow	1870	81	13770
cw_diagonal	123	3	3000
cw_ladder	396	37	37000
cw_zebra	100	3	3000
handicap_symbol	856	0	0
straightleft_arrow	198	8	2592
cw_solid	219	11	8250

Figure 7. Sample AI-Supported Cost Estimates for Marking Improvements in North Carolina (Source: Paul Carlson)

There are several benefits to using aerial imagery in combination with AI for analysis of facilities. For roadway applications, aerial imagery data is less expensive than other sources, and AI and other tools are available and being expanded. The time required to obtain the data is also shorter using aerial images, and oblique and ortho images can be stitched together to minimize occlusions and provide the necessary horizontal and vertical resolution. The examples highlighted in this section are possible in large part due to the ability of AI to process the large scale data sets generated for these areas.

Research on AI Planning Data Applications

Transportation planning applications require data and models to adequately evaluate needs and develop improvement programs for transportation management areas. To support data collection and processing, researchers at The Ohio State University (OSU) are studying a novel method[4] for counting and tracking vehicles on public roadways. The technology takes advantage of existing bus security cameras to process video images and automatically count vehicles, detect objects in the roadway, and distinguish moving vehicles from those that are parked. Since the cameras are mounted inside the bus, they are mobile and therefore provide much better spatial and temporal coverage compared with fixed roadside sensors and cameras.

Figure 8. OSU Bus Equipped with AI-Connected Video Cameras (Image: OSU)

AI automates the process of identifying vehicles in the video data sets. This allows for faster and more efficient processing of video data as compared with human processing. This application uses YOLOv4 to detect and track objects. The data are currently taken from OSU campus buses, providing an existing data source for AI processing. The integration is simple and cost effective since the buses are already equipped with the cameras used for security and other needs. Researchers cite other future benefits, including intelligent traffic surveillance, enhanced roadway network mapping and asset management. For the traveling public, the benefits are reduced travel times and greater route choices via real-time information. The results of this research can be applied to other transportation agency video data collection and allow for automated processing without much human intervention. The research is supported by the United States Department of Transportation (USDOT) Mobility21 University Transportation Center Program.

[4] https://engineering.osu.edu/news/2023/07/study-taps-ai-improve-future-road-planning

Other Research on AI

ATSSA prioritized the expanded case study examples included in this report due to their direct tie to transportation safety along with the availability of information on each. Following is a list of additional examples of AI applications for transportation that are in the early stages of development.

Pothole Detection from Dash Camera Images using YOLOv5

A study by researchers at Loyola Marymount University in Los Angeles evaluated a machine learning application for accuracy in detecting potholes for repair. The approach used dash camera images along with a deep learning based object detection (You Only Look Once version 5, or YOLOv5). The solution obtained higher detection accuracy at faster speeds as compared with previous approaches. The technology could provide safety benefits as compared with user reporting or maintenance personnel observations, such as through faster repair and less vehicle damage or impacts to motorists while traveling. It could also provide greater cost savings over traditional maintenance approaches to surface repairs.

Source: https://gvejaran.intemnets.lmu.build/publications/conference/CPaper12.pdf

Category: Maintenance

Use of AI with Camera Data to Automated Pavement Marking Applications

An industry vendor created robotic technology that uses AI to evaluate and effectively maintain pavement markings. The process improves efficiency, quality and safety, reducing the risk to workers in the field. The system can be installed on existing equipment, making it adaptable to nearly any existing contractor configuration.

Source: Limntech Scientific Inc.

Category: Maintenance

Situational Awareness for Transportation Management: Automated Video Incident Detection and Other Machine Learning Technologies for the Traffic Management Center

The California Department of Transportation (Caltrans) and the University of California, Irvine, researched and created a synthesis of Automated Video Incident Detection (AID) systems along with general traffic monitoring for detection, verification and response practices. Inputs to the process include law enforcement channels, public reporting by phone and video camera systems. Past attempts with automated incident detection models have not proven as useful as originally desired, and AI can provide greater benefits. This report synthesizes techniques to characterize traffic conditions, identify incidents and improve incident detection, verification and response.

Source: https://dot.ca.gov/-/media/dot-media/programs/research-innovation-system-information/documents/final-reports/ca18-2531-finalreport-a11y.pdf

Category: Traffic Incident Management

Evaluation of a Fuzzy Logic Ramp Metering Algorithm: A Comparative Study Among Three Ramp Metering Algorithms Used in the Greater Seattle Area

The research approach included online testing to tune the controller for optimal performance, to determine the system-wide parameter defaults and to compare the behavior of the Fuzzy Logic Ramp Metering with that of the local and bottleneck ramp metering algorithms. Fuzzy logic is different from traditional AI in that it does not require complete, accurate data to make decisions. Fuzzy logic is considered a subset of AI.

Source: https://www.wsdot.wa.gov/research/reports/fullreports/481.2.pdf

Category: Traffic Operations

Artificial Intelligence for Incident Detection in Nevada and Florida

Both Nevada and Florida departments of transportation (DOTs) use proprietary software as a supplement for incident detection. The AI system fuses information from a variety of sources to detect and report suspected incidents. A Federal Highway Administration (FHWA) research study outlines some recent practices for AI including some research, testing and implemented applications.

Source: https://ops.fhwa.dot.gov/publications/fhwahop19052/chap4.htm

Category: Traffic Incident Management

Additional Construction Applications

All elements of construction have the potential to benefit from AI, including modeling of potential methods and resulting costs and resource loads up to automated creation of as-built drawings and support records retention. AI helps evaluate potential alternatives based on historical safety data and can support decisions for letting contracts that include the optimal traffic control strategies.

Source: https://blog.alicetechnologies.com/news/streamlining-road-construction-with-ai

Summary and Conclusions

The transportation agency AI applications highlighted in this document are producing several benefits as summarized in the figure below.

Example Case	AI Technologies Used	Realized/Anticipated Benefits
Hawaii DOT	AI supported resilience, climate and safety analysis platforms	• Predictive modeling that justifies decisions and supports funding requests to lawmakers • Eliminates fatal crashes and fatal incidents • Automated human resources applications, including processing communications and calls • Verifies that employee training requirements are met
Iowa DOT	Deep learning-driven video intelligence/ AI powered video content analysis	• Faster, more efficient incident verification and response • Proactive predictions when incidents are most likely to occur
Pavement Marking Condition Assessments Using AI	Custom object detection algorithms applied to high resolution aerial imagery	• Enhanced efficiency in processing aerial imagery to drive AI technologies • Greater compliance with pavement marking standards • Efficiency through automated processes for generating maintenance and improvement programs
Research by The Ohio State University	AI powered video content analysis/ existing bus camera data	• Automated analysis of video data across an existing network for vehicle count summaries • Cost-effective data sources using existing bus security camera footage for AI analysis

Figure 9. AI Technologies and Realized and Anticipated Benefits by Case Study Application

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