AI DECODED

Artificial intelligence (AI) is poised to bring immense safety, efficiency, equity, resiliency, and sustainability benefits to the transportation sector. As we continue to see increased deployments of AI tools, knowledge gaps have emerged. The Intelligent Transportation Society of America (ITS America) has developed AI Decoded to help explain AI in a practical, non-technical way for transportation practitioners and non-practitioners alike. Bringing greater awareness to AI use cases and demystifying its capabilities will help the industry continue to make strides in deployment. Education on new technologies, like AI, is key to deployment and realizing the transformational benefits of this technology.

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ITS America AI Decoded

AI Decoded provides an in-depth exploration of the branches of artificial intelligence (AI) and their impact on the transportation industry. This document covers widely used AI models and their specific applications, including Machine Learning (ML), Neural Networks, Deep Learning, Computer Vision, and Generative AI.

Through detailed case studies and practical examples, we illustrate how AI transforms transportation systems, optimizing traffic management, enhancing safety, and improving overall efficiency. Additionally, we address the distinction between true AI technologies and other advanced systems, highlighting the benefits and potential risks associated with AI deployment. This comprehensive overview aims to demystify AI and showcase its transformative potential in modern transportation.

ITS America also developed our companion *AI Policy Principles*, which will help guide the regulation, development, and deployment of AI technologies and applications in our transportation system so that these new tools are used safely, transparently, and effectively.

Both of these documents can be accessed at the ITS America website – www.itsa.org.

What is AI?

Artificial intelligence (AI) refers to the capability of software or a program to imitate intelligent human behavior, essentially giving computers the ability to think, act, and learn like humans. AI algorithms can analyze data, recognize patterns, and make decisions with minimal to no human intervention, all through code written and created by humans.

AI is a broad term covering an entire ecosystem of branches, as shown in Figure 1, that have been developed to tackle various tasks and challenges across different domains. The following sections provide an overview of widely used AI models and how they are applied to the transportation industry.

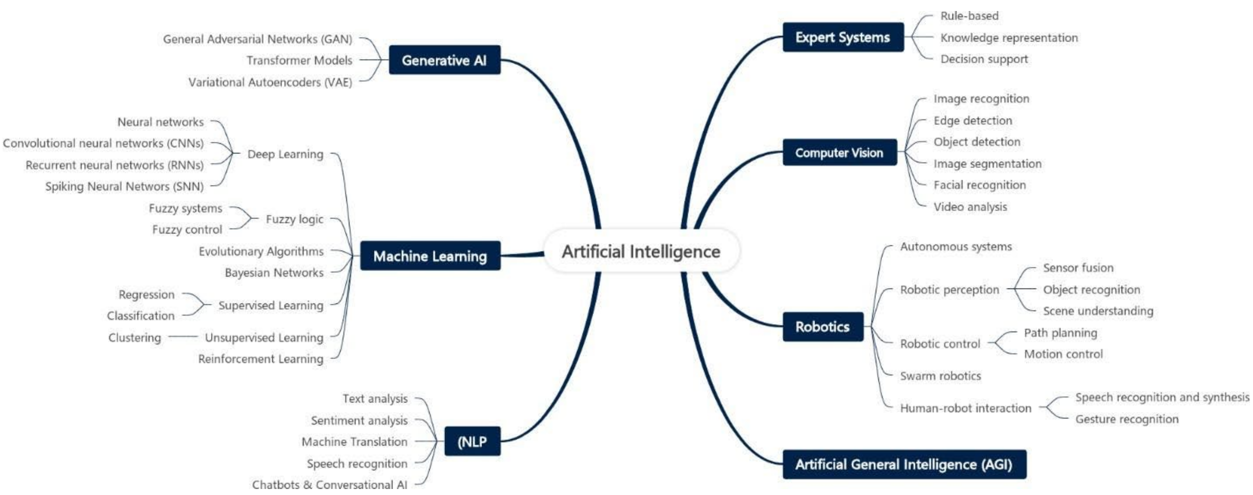

Figure 1: Branches of Artificial Intelligence (AI)

Machine Learning (ML)

Machine Learning is considered the biggest and most prominent area of AI today. It involves creating programs that find patterns and make decisions based on past data, allowing computers to learn from the data without needing specific instructions for every task.

There are multiple ***methods*** of machine learning that define the process by which the program learns from the data and how it receives feedback to get better answers. Common methods include:

- **Supervised Learning:** The program is trained with labeled data, where input data is paired with correct output data. This means that for each piece of input data, the correct answer is already known. The goal is for the program to learn how to map new input data to the correct output based on this training. ***Example:*** *Predicting traffic flow at different times of the day to optimize traffic light timings.*
- **Unsupervised Learning:** The program is given data without specific instructions on what to do. The model analyzes the data to find patterns, similarities, or differences among the data points

and uses algorithms to group the data, making it easier to interpret or visualize. ***Example:*** *Grouping (or clustering) urban areas by traffic patterns to help with city planning.*

- **Reinforcement Learning:** The program learns to make decisions by performing actions and receiving rewards or penalties. The agent seeks to maximize rewards over time by learning the best strategies using trial and error. ***Example:*** *Training autonomous delivery robots to find the best delivery routes while avoiding obstacles.*

There are multiple **algorithms and models** used in machine learning - these are the programs that perform the learning task. An algorithm could be as simple as a linear regression algorithm which determines the line of best fit on a dataset to predict on outcome based on an input.

Neural Networks

The most prominent algorithms or models today are **neural networks**. These are inspired by the human brain and consist of layers of interconnected nodes (like neurons) that process and analyze data. Neural networks are popular because they offer high accuracy, versatility, and scalability for complex tasks.

Deep Learning

Deep learning is a type of neural network that uses many layers of neurons, as shown in Figure 2, and enables more effective learning and modeling of complex patterns and representations in data. This depth also enables deep learning models to handle large amounts of unstructured data, like images and speech, and achieve higher accuracy in tasks such as image recognition, natural language processing, and many other applications. ***Example:*** *Autonomous vehicles use deep learning to process sensor data, such as images from cameras and LIDAR, to recognize objects like pedestrians, other vehicles, and road signs, enabling safe navigation.*

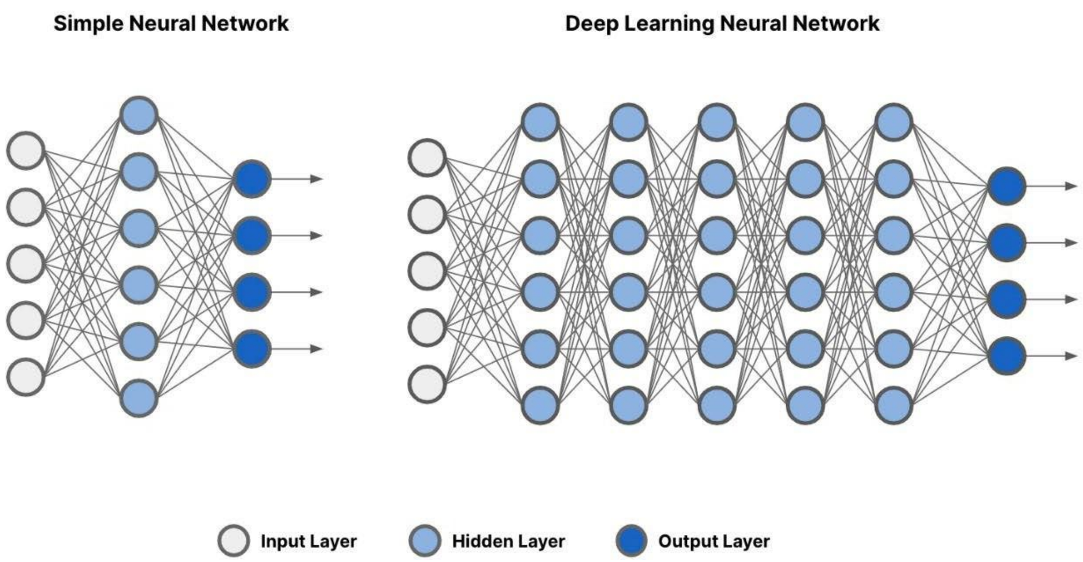

Figure 2: Deep Learning

Computer Vision

Computer vision is a multidisciplinary field focused on enabling computers to interpret, understand, and process visual information from the real world. It involves developing algorithms and techniques to extract meaningful insights from images or videos. Computer vision tasks include image classification, object detection, image segmentation, facial recognition, scene understanding, and more. Traditionally, computer vision relied on handcrafted features and classical machine learning algorithms like Support Vector Machines (SVM) or Random Forests, which merge the outputs of numerous decision trees to produce a single one. However, with the advent of deep learning, the field has experienced significant advancements, particularly in areas like object detection and image classification.

Over the past years, deep learning has become the dominant approach in computer vision due to its ability to automatically learn complex patterns and features from raw visual data. Convolutional Neural Networks (CNNs), a type of deep neural network designed for processing grid-structured data like images, have become the cornerstone of modern computer vision systems. ***Example**: Computer vision algorithms take video footage from cameras and detect wrong-way driving on a highway entrance, alerting authorities before 9-1-1 is even dialed.*

Generative AI

Generative AI (GenAI) focuses on creating new content based on existing data. This can include generating images, text, audio, or even synthetic data. Generative AI holds significant promise for the transportation sector by enhancing and innovating various aspects of the industry. Large Language Models (LLM), very large deep learning models that are pre-trained on vast amounts of data, have increased the exposure of GenAI to the public with the advent of tools such as ChatGPT and Gemini. These LLMs have been trained on large bodies of text and specialize in generating text and code using transformer models. Expansion of these models has led to GenAI usage for image generation, creating music, and many other applications.

What Isn't AI?

As AI becomes increasingly integrated into transportation systems, it is crucial to distinguish between true AI technologies and other advanced systems that do not qualify as AI. Here are some key differences:

- **Basic Automation**: Basic automation refers to simple machines or software that follow pre-set rules to perform tasks. An example of this is an automatic toll collection system that charges vehicles without manual intervention. While sophisticated, this system does not adapt or learn from the data it processes.
- **Standard Algorithms**: Standard algorithms are traditional computer algorithms that solve problems using a fixed sequence of steps. These do not involve learning or adapting over time. An example is a traffic signal controller that changes traffic lights based on pre-defined rules and the traffic demand detected by the system. This approach, while effective in managing traffic flow, lacks the ability to improve or change its decision-making process based on new data.
- **Statistical Analysis**: Statistical analysis involves basic statistical methods that analyze data without learning or adapting. An example is calculating average travel times on different routes

using historical data. While this can provide useful insights, it does not involve the adaptability or learning that characterizes AI.

By understanding these distinctions, we can better appreciate the unique advancements that AI brings to transportation. AI technologies offer adaptability, as they can adjust to new data and changing conditions in real time. They incorporate learning, enabling them to make more accurate predictions and decisions over time. Moreover, AI systems possess autonomous decision-making capabilities, allowing them to optimize traffic flow and enhance safety without human intervention. These adaptability, learning, and decision-making abilities make AI a powerful tool for developing more efficient, safe, and responsive transportation solutions.

AI in the Modern Era

While AI is increasingly prevalent in the modern technology era and in popular media, it is not a new concept; its roots can be traced back to the mid-20th century.

A Brief History of AI

The history of AI can be categorized into several waves, each marked by periods of optimism, significant breakthroughs, and subsequent challenges that led to temporary setbacks. These phases, shown in Figure 3, highlight the evolving nature of AI and the persistent quest to achieve human-like intelligence.

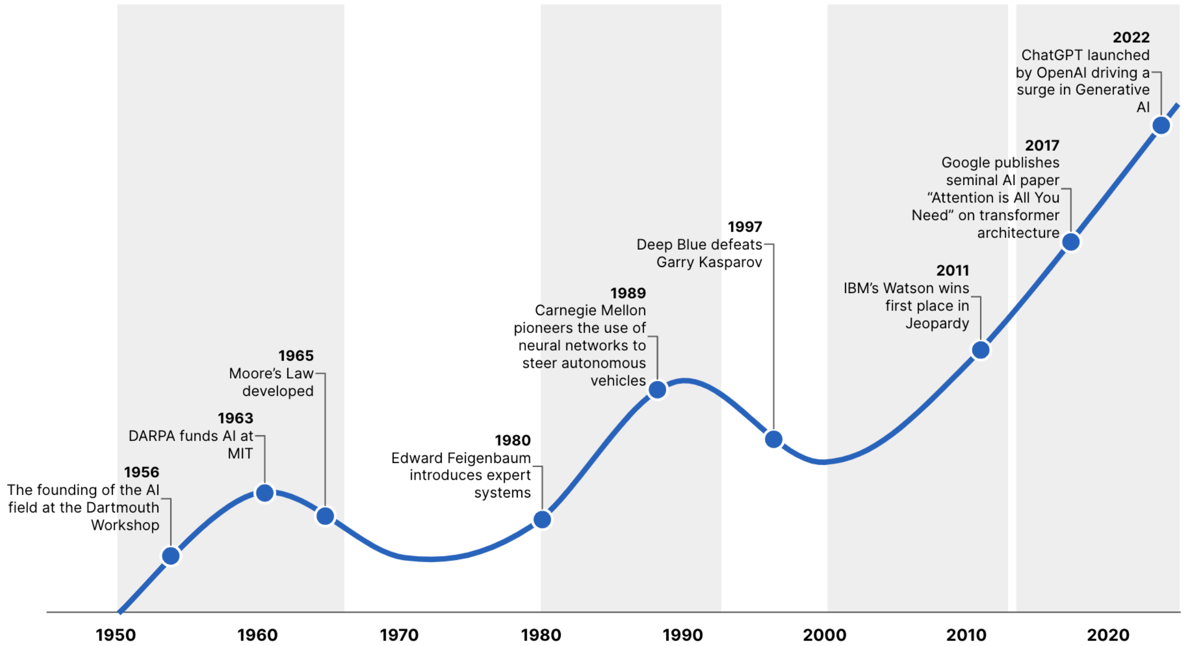

Figure 3: History of Artificial Intelligence (AI) Evolution

1. First Wave (1950s - 1960s): The birth of AI as an academic discipline saw Alan Turing, who proposed the Turing Test, and John McCarthy, who coined the term "Artificial Intelligence." However, limited computational power and scalability led to an "AI Winter," a period of reduced funding and interest.

2. Second Wave (1980s): The rise of expert systems and an influx of government funding characterized this era. These systems used large databases and inference rules to simulate the decision-making abilities of human experts. Expert systems required extensive manual input and struggled to adapt to new or unexpected situations, leading to skepticism and reduced investment.

3. Third Wave (1990s - Early 2000s): This period focused on machine learning, where systems learned from data rather than relying on predefined rules. Statistical methods, neural networks, and the availability of large datasets spurred progress in tasks like image recognition and natural language processing. However, AI systems were still limited by data availability, computational power, and the complexity of real-world environments.

4. Fourth Wave (2015-now): What's different now?

In recent years, AI has experienced a resurgence, driven by several key factors that distinguish the current wave from previous ones:

- **Increased Data Availability:** The proliferation of Internet of Things (IoT) devices, social media, and digital platforms has generated vast amounts of data. Advances in networking and communication technologies have made it easier to collect, share, and analyze this data, enabling AI systems to learn and generalize more effectively.
- **Lower Compute Costs and Advanced Hardware:** Reductions in hardware costs and the advent of specialized processors, such as Graphics Processing Units (GPUs) and Tensor Processing Units (TPUs), have significantly enhanced computational capabilities. This allows for the efficient training of complex AI models, unlocking new levels of performance and accuracy.
- **Workforce Development:** The growing demand for AI expertise has led to an increase in educational programs and resources dedicated to training software engineers, data scientists, and machine learning engineers. A larger and more skilled workforce is driving innovation and accelerating the development and deployment of AI technologies across various industries.
- **Better Infrastructure:** The development of open-source frameworks (e.g., TensorFlow, PyTorch) and comprehensive documentation has made AI tools more accessible and user-friendly. Cloud computing platforms offer scalable infrastructure for AI experimentation and deployment, enabling researchers and practitioners to build, test, and deploy AI models more rapidly and cost-effectively.
- **Investments and Research:** The other key factors both influenced and are enabled by the large funding investments by both private companies and universities. This funding has also contributed towards research advancements in neural networks and transformer models.

These advancements have collectively transformed AI from a field characterized by isolated breakthroughs and setbacks into a dynamic and rapidly evolving discipline. For example, traffic signals have developed substantially over the last 50 years. With improvements in connectivity and sensing capabilities, traffic signals have become more intelligent than ever before with the capability to adjust signal timings in response to changing traffic patterns through AI-driven technologies. The convergence of abundant data, powerful computing resources, a skilled workforce, robust infrastructure, and money to research and implement solutions has set the stage for AI to make significant and lasting impacts on intelligent transportation systems (ITS) and beyond.

Transportation Applications of AI

Every transportation application requires information and data to drive decision-making. AI is now a central technology behind data-intensive applications, and it is quickly becoming more prevalent in transportation. New technologies are enabling AI to be used in increasingly more complex application areas. Amidst the buzzwords and media hype it can be difficult to identify what the maturity level of different applications and technologies are, and we outline a general framework splitting technologies and applications into different categories:

1. Experimental: These are applications where the applications and technologies are in their infancy – they may be simply theoretical (i.e., exploratory research) or tested within simulated or controlled environments rather than in the real-world.

2. Emerging: These are applications and technologies which have been introduced into real-world environments through small-scale pilot projects where little is known yet about impacts and benefits.

3. Growth: These are applications or technologies where pilots have successfully demonstrated positive impacts and the technology is being actively used in uncontrolled environments and are being scaled up.

4. Mature: These are applications and technologies which are well-proven, benefits are positive and are well documented and understood, and are adopted at scale by multiple organizations.

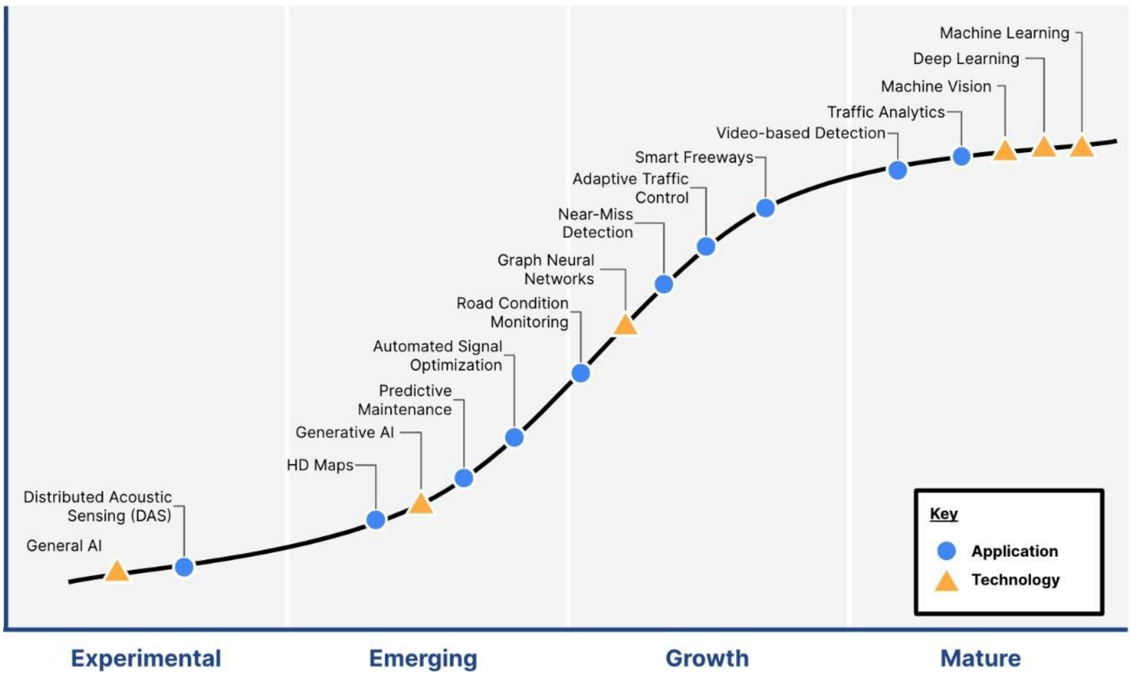

Figure 4: Status of AI technologies and applications

AI is diverse in maturity at both the technology and application level. Understanding the relative maturity of each can help identify suitable approaches for implementation and identify opportunities for further technical development. For example, Experimental and Emerging applications carry risks, but often potentially high rewards which can be mitigated by small-scale, lower cost deployments (where feasible). Practitioners should be cognizant of the risks of technological failure and be prepared that success may just mean lessons learnt.

Benefits of AI

AI stands out for its potential to revolutionize how we manage and interact with our transportation infrastructure. AI-driven solutions promise to address many of the challenges faced by modern transportation systems, from traffic congestion to safety concerns.

- **Improved Traffic Management:** AI can optimize traffic signals, reduce congestion, and manage traffic flow more efficiently. Real-time data analysis helps in dynamic traffic control, reducing delays and improving road safety.
    - **Enhanced Public Transportation:** AI can optimize routes, schedules, and passenger loads for buses and trains. Predictive maintenance can reduce downtime and improve the reliability of public transport.
    - **Reduced Crashes and Improved Safety:** AI systems can analyze data from various sources (e.g., cameras, sensors) to predict and prevent crashes. Autonomous vehicles, powered by AI, can reduce human error, a leading cause of and/or factor in many crashes.
    - **Environmental Benefits:** AI can optimize routes for fuel efficiency, reducing emissions and pollution. Intelligent traffic management can reduce idle times and unnecessary fuel consumption.
- **Enhanced User Experience:** Personalized travel recommendations and real-time updates can improve the user experience. AI-driven apps can provide accurate ETAs, alternative routes, and transport options.
- **Cost Savings:** Efficient management of transportation systems can lead to significant cost savings for both operators and users, including reducing fuel consumption and maintenance costs through predictive analytics.
- **Data-Driven Decision Making:** AI can process vast amounts of data to provide actionable insights for city planners and policymakers. This can lead to better infrastructure planning and investment based on predictive models and trends.

Risks and Challenges of AI

However, with these advancements come significant considerations and potential risks. For AI to be used effectively, ethically, and responsibly, a few key risks must be considered and accounted for in any implementation.

- **Privacy Concerns:** The extensive use of data, including personal travel patterns, raises privacy issues as there is a higher risk for potential misuse of data by third parties or for surveillance. In addition, the increased connectivity and reliance on digital systems make the systems vulnerable to cyber-attacks and it is necessary to enable strong and robust security protocols to protect the systems from cyber threats. Strong protections and a data governance framework should be implemented to ensure data is protected, as is data privacy through anonymization and aggregation, and that it cannot be accessed by unauthorized people.
- **Job Displacement:** Automation and AI could lead to job losses in sectors such as driving, traffic management, and public transportation. This accelerates the need for retraining and reskilling workers whose jobs may be displaced. It is important to assess the talent impact across organizations to proactively plan for and support upskilling efforts.
- **Technical Challenges:** There are numerous challenges in the deployment of AI technologies including (1) ensuring the accuracy, explainability and reliability of AI systems in complex and unpredictable traffic environments can be challenging, (2) integrating AI with existing infrastructure and systems and (3) the ongoing maintenance of AI solutions as new data sources are available. All of these could result in potential failures of AI systems which could disrupt transportation services significantly. In the event of an AI system failure organizations rely on backup systems, manual intervention, and human oversight to ensure continuity and mitigate the impact of the failure. Fail-safe procedures are necessary in critical infrastructure applications to help ensure the safety and efficiency of those systems even in adverse circumstances. AI systems need to be tested and checked using recognized measures to make sure they operate effectively, especially when used for decision-making and in high-risk areas.
- **Ethical and Legal Issues:** Decision-making by AI in critical situations, such as crash scenarios, raises ethical questions. Liability and accountability in the case of AI system failures or crashes involving autonomous vehicles also raises legal questions. Determining the inherent bias of a system can be difficult unless you know how and by whom it was trained.
- **Dependency on Technology:** Over-reliance on AI could lead to complacency and reduced human vigilance. AI technologies should be viewed as a complement to human effort, not a replacement, and it is important to continue to train the workforce and users on traditional methods alongside training them on AI-based tools. Furthermore, building AI systems as a human-in-the-loop process, where possible, can ensure that users are always involved in any critical workflow. For example, many AI-based signal timing plan optimization systems require manual review of timing plans before being deployed in traffic signals. Adjusting the workforce's dependency on AI involves a strategic approach to balance automation with human capabilities. To do so effectively, we must encourage skills development and training on how to work collaboratively with AI tools and identify tasks best suited for AI automation. We must also identify tasks that require human judgement, creativity, and emotional intelligence, while transparently communicating the

role AI plays in the workforce so that we can strike the balance between efficiency and dependency.

Balancing these benefits and risks requires careful planning, robust security measures, ethical considerations, and a focus on inclusivity and sustainability in the deployment of AI in intelligent transportation systems.

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Specific Applications and Case Studies

Spotlight on Tennessee DOT: Using AI to Operate Smarter Corridors

The Tennessee Department of Transportation (TDOT) implemented an AI-Based Decision Support System along the I-24 Smart Corridor to improve traffic management and safety.

TDOT faced the challenge of reducing accidents and enhancing traffic flow on the busy I-24 highway. To address this, they utilized data from traffic detectors and cameras, combined with deep learning algorithms, to dynamically generate variable speed limits and diversion routing. These AI-driven decisions aim to smooth traffic flow and reduce the need for abrupt braking, thus minimizing the likelihood of crashes.

The benefits of this system have already become evident. Since its deployment, there has been an 8.5% decline in crashes involving injuries or fatalities.[1] While the initial impact on travel times has been limited, TDOT anticipates significant improvements once diversion routing is fully integrated. This feature coordinates traffic signal systems on alternate routes, aiming to reduce travel times during incidents and alleviate congestion.

By employing cutting-edge AI technology, TDOT is making strides in creating a safer, more efficient highway system. The success of the I-24 Smart Corridor serves as a promising example of how technology can enhance traffic management and safety.

[1] State of Tennessee - https://www.tn.gov/tdot/news/2022/3/25/i-24-smart-corridor-phase-2-gantry-construction-to-begin.html

Spotlight on Hawaii DOT: Enhancing Safety with AI-Driven Analytics

To improve infrastructure safety, the Hawaii Department of Transportation (HDOT) has implemented a cutting-edge Safety Analytics platform powered by artificial intelligence. This innovative approach moves beyond traditional methods of evaluating past performance metrics and aims to proactively forecast potential problem areas on roadways.

HDOT faced a significant challenge with conventional safety analysis techniques that rely on historical data and crash modification factors. While these methods help understand past issues, they fall short in predicting future hazards. To address this, HDOT adopted an AI-driven platform that integrates predictive modeling, decision-support systems, and data visualizations.

This advanced technology provides practitioners with actionable insights and recommendations for roadway improvements. By analyzing diverse data sets, the AI platform suggests effective strategies and devices such as rumble strips, raised pedestrian beds, pavement markings, enhanced signage, improved lighting and reflectivity, enforcement techniques, or even complete facility redesigns.

The benefits of this approach are substantial. The AI platform forecasted 18,100 potential crashes and estimated that implementing the recommended countermeasures could save 6.9 lives over a three-year period.[2] These AI-driven insights not only enhance strategic decision-making but also help justify funding requests to lawmakers, ensuring that the necessary resources are allocated to improve road safety.

HDOT's adoption of AI for safety analytics marks a significant advancement in proactive infrastructure management, setting a new standard for roadway safety and exemplifying the potential of technology to save lives.

[2] Hawaii Department of Transportation - https://safety-tool-hidot.hawaii.gov/#back-to-top-anchor

Spotlight on Caltrans: Enhancing Safety and Mobility Insights using GenAI

Caltrans, in collaboration with other state agencies, is conducting exploratory pilots to test the potential of GenAI in enhancing safety and mobility across California. These initiatives aim to leverage advanced AI technologies to protect vulnerable road users and improve traffic flows throughout the state.

One notable project is the Proof of Concept (POC) for Vulnerable Roadway User (VRU) Safety. This pilot tests a GenAI solution designed to identify high-risk crash locations based on specific criteria and user vulnerabilities. The AI-driven approach aims to recommend strategies to enhance safety at critical hotspots, develop a prioritized list of improvement locations, and guide Caltrans' infrastructure decisions. The focus is on deploying field personnel and mobile infrastructure more effectively, particularly in underserved areas. The system is intended to be scalable, capable of incorporating new data sets as they become available.

Another significant POC involves Traffic Mobility Insights. This project tests a GenAI solution for developing traffic insight models that process and integrate varied traffic data formats, adapt to real- time traffic patterns, and provide proactive recommendations to mitigate safety issues throughout the California's highway system. Additional aspects being tested include predictive analytics for incident management, strategies for reducing greenhouse gas emissions, and optimizing freight mobility and safety.

The pilots also aim to identify critical areas for investment in active transportation infrastructure, such as biking and walking paths. Developing user-friendly GenAI tools is a priority, ensuring enhanced operator decision-making support and incorporating feedback from end-users. By integrating multimodal transportation data, the project seeks to support an inclusive and equitable transportation approach. Additionally, integrating and analyzing transit and ride-sharing data aims to create a unified view of the state's transportation network, facilitating more cohesive and efficient system management.

These exploratory efforts use a pilot approach to develop and test promising emerging technologies, with the potential to revolutionize state transportation management.

AI for Traffic Signal Optimization (Multiple Locations)

Traffic signals are crucial for managing the flow of vehicles and pedestrians at intersections. However, optimizing these signals is a labor-intensive and costly process, often requiring dozens of hours per intersection and expensive data collection. Consequently, signal updates typically occur only every three to five years, leading to outdated and inefficient signal timings that reduce signal performance.

To address this challenge, digital twin technologies have been developed capturing data from multiple sources including traffic signals, detection devices, and connected vehicles to generate accurate models of signal and corridor operations. By combining these models with machine learning approaches, it becomes possible to optimize signal timing plans and predict performance outcomes. The deployment of these technologies in real-world pilot projects and initial deployments have achieved impressive results:

- **Flow Labs:** Demonstrated a decrease in travel time, emissions, and crash risk by 24%, 21%, and 51% respectively.
- **CCAT:** Demonstrated a decrease in delay and stops at signalized intersections by up to 20% and 30%, respectively.

These advancements not only improve traffic flow, but also reduce the labor and costs associated with signal optimization. The automation and data-driven nature of these technologies enable more frequent updates, resulting in better overall traffic management and a more efficient transportation system.

AI for Predictive Asset Maintenance (New York City)

Maintaining over 350,000 street lighting poles in New York City presents a major challenge as traditional inspection processes are time-consuming and labor-intensive.

To address this challenge, the department has integrated AI into their maintenance workflow, enhancing efficiency and preparing for future smart city initiatives. The department developed a publicly accessible portal that allows the public and partner agencies to report issues and concerns in real-time, streamlining the process of placing and opening work orders. To further improve efficiency, an AI-based pole inspection module was added to the system. This module analyzes the condition of each part of the pole, identifying and reporting issues automatically using advanced image recognition and machine learning algorithms. This automation saves an estimated 160,000 hours of manual inspection work per year, allowing the department to allocate resources to other critical safety and maintenance needs.

The AI system provides real-time analysis and immediate reporting of issues, enabling swift and efficient maintenance responses. This not only frees up valuable human resources but also ensures the street lighting infrastructure remains in optimal condition, improving roadway visibility and safety.

Succeeding with AI

AI is a transformational technology, but its successful implementation in the transportation industry requires a multi-faceted approach. This includes robust data and AI governance to ensure data accuracy, compliance, and ethical use, alongside workforce development to deploy and utilize AI effectively.

Technological Enablers

With recent advancements in technology that have made it easier for organizations to adopt AI-based approaches and succeed with them, AI adoption is now feasible for many organizations. AI requires a combination of software, hardware, and data to function effectively, and these components have become more accessible and affordable in recent years:

- **Cloud Adoption:** Provides scalable and flexible computing resources, reducing the need for physical infrastructure and offering access to powerful AI tools and services. Cloud platforms enable organizations to leverage collective intelligence and innovations in AI.
- **Data Availability:** The explosion of available data enhances AI model accuracy and effectiveness. Specialized data companies can supply crucial information, while improved data storage and processing technologies support AI needs.
- **Lower Compute Costs:** Decreased computational expenses make running complex AI algorithms more affordable, lowering the barrier for AI experimentation and innovation, and facilitating the development of sophisticated AI models.

Data & AI Governance

AI solutions are reliant on their underlying data to provide accurate information, predictions, and recommendations. Therefore, transportation organizations that want to take full advantage of AI must build the underlying data estate and governance structure.

- **Clear Guidelines and Governance Body:** Establishing clear guidelines for AI use within an organization and setting up a governance body for ongoing oversight ensures that AI is implemented ethically and effectively. This body should adapt the guidelines as technology and organizational needs evolve, providing necessary oversight. It will be critical to define the values of the organization related to AI, to ensure policies, guidance and governance structure are all aligned towards common goals. A robust governance structure is required for a successful AI policy and achieving the vision for the organization.
- **Data Privacy and Security:** Implementing stringent data privacy and security rules ensures that the organization's data handling practices meet compliance requirements. This helps maintain transparency and security, building trust and avoiding costly cyberattacks and data breaches.
- **Data Ownership and Stewardship:** Defining clear roles for data ownership and stewardship ensures accountability for data accuracy, privacy, and usage. This approach is essential for maintaining data integrity and ensures that there are designated individuals responsible for managing data assets.
- **Data Standards and Sharing:** Establishing standards for data formatting, tagging, classification, and interoperability ensures consistency and reliability across the organization. Clear data sharing and permissions facilitate the appropriate flow of information, enabling the workforce to leverage AI tools effectively while safeguarding sensitive data.

Workforce Development

As AI is infused into the tools used by transportation organizations, enabling the workforce to use those tools effectively is an important part of an AI-enabled transportation ecosystem.

- **AI Ethics and Governance Training:** Training employees on AI ethics and governance helps them understand data usage, regulatory compliance requirements, and ensures AI applications align with ethical principles and legal standards. This training mitigates potential risks and harms associated with AI.
- **Enhancing Data Literacy:** Providing data literacy education enables employees to understand how data sources inform AI outputs, interpret AI results, and communicate data needs and issues effectively. This foundational knowledge is crucial for effective AI utilization.
- **Continuous Learning and Development:** A commitment to continuous learning ensures that the workforce stays updated as AI technology evolves. This fosters a culture of innovation and adaptation, supporting the development and adoption of new AI solutions.
- **Leadership and Communication:** Leadership adoption of AI tools and clear communication about AI’s impact and expectations from the top of the organization empower the workforce to

embrace AI solutions. This top-down approach demonstrates the strategic vision for AI use and encourages employees to leverage AI in their workflows.

By focusing on these areas, transportation organizations can effectively adopt AI, leveraging its transformative potential to enhance performance, competitiveness, and achieve safer, greener, and smarter mobility for all.

APPENDIX

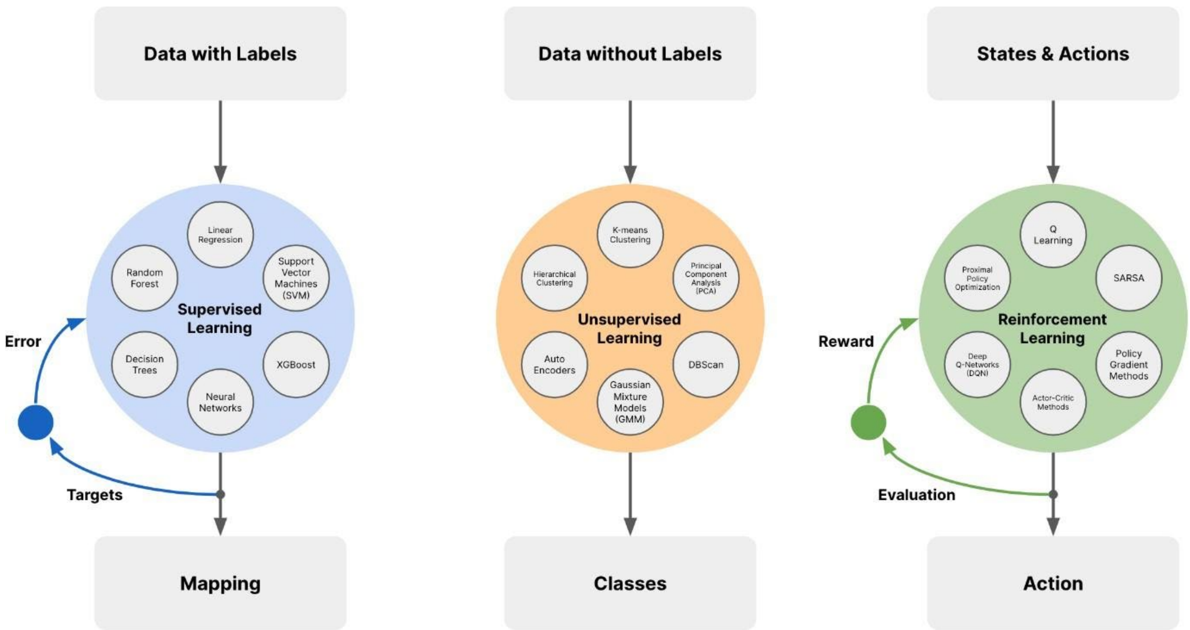
Natural Language Processing (NLP)

Natural Language Processing (NLP) focuses on the interaction between computers and human (natural) languages. The goal of NLP is to enable machines to read, understand, and write human language in a meaningful and useful way. Whilst NLP is considered an independent subset of AI, in many cases, NLP systems use a combination of computational linguistics, machine learning, and deep learning to process and analyze large amounts of natural language data.

An NLP system includes several components such as text processing, breaking down text into smaller units, identifying the grammatical parts of speech, determining the sentiment or emotion expressed and generating coherent and contextually relevant text based on a given input. Examples of NLP applications in transportation include:

- **Voice-activated Assistants**: for example, in-car voice assistants like Apple's Siri, Google Assistant
- **Chatbots for Customer Service**: for example, DOTs use chatbots to receive residents' complaints and feedback on traffic signal issues and road hazards or ask for information.
- **Predictive Maintenance:** for example, analyzing maintenance logs and technician reports using NLP can help identify common issues and predict potential equipment failures.

Methods and Algorithms in Machine Learning



Application & Technology Maturity Levels

Stage	Applications	Technologies
Experimental Research	- Distributed Acoustic Sensing (DAS) for traffic monitoring	- General AI
Emerging	- Automated Signal Optimization - Predictive Maintenance - HD Maps - Autonomous Vehicles - Vulnerable Roadway User (VRU) Safety - Traffic Mobility Insight	- Generative AI - Reinforcement Learning
Growth	- AI Simulation - Near-Miss Cameras - Road Condition Monitoring - Smart Freeway - Adaptive Traffic Control	- Graph Neural Networks
Mature	- Video / Lidar based Detection - Traffic Data Analytics - Integrated Corridor Mobility (ICM)	- Machine Vision - Deep Reinforcement Learning - Deep Neural Networks

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