THE EASTERN TRANSPORTATION COALITION

Transforming DOT Operations with AI

Prepared by: Rensel Consulting for TETC

Acknowledgements

The Eastern Transportation Coalition is a partnership of 18 states and the District of Columbia focused on connecting public agencies across modes of travel to increase safety and efficiency.

The Eastern Transportation Coalition is proud to work with our members to execute Special Cooperative Projects (SCOOP), like this project, as part of our programming. This program provides the opportunity to demonstrate the agility our members expect while providing value that enables both collective and individual goals to be met.

Additional information on the Coalition, including other project reports, can be found on the Coalition's website: www.tetcoalition.org

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Executive Summary

The Eastern Transportation Coalition (TETC) convened a small working group of volunteers from several member organizations to discuss the current state of artificial intelligence (AI) and generate a report for a broader dialog. This whitepaper is the result of those efforts.

The working group polled TETC membership to compile existing AI efforts and identify use cases. Fifteen agencies responded to describe their work. The working group identified eight categories to examine potential AI use cases. The table below shows the categories with descriptions and indicates which categories the fifteen members are focused on.

Transportation Agency Areas	Example Use Cases	Members Piloting Projects by Category
Business Enterprise	• Personalized customer experiences • Automation of routine tasks • Data-driven decision making • Supply chain optimization • Enhanced cybersecurity • Grant reviews	• Georgia DOT • New Jersey DOT • PennDOT
Customer Service	• AI-powered chatbots and virtual assistants • Personalized recommendations • Voice recognition and natural language processing • Real-time alerts and updates • Efficient complaint resolution	• Vermont
Safety and Mobility Services	• Automated vehicles • Smart traffic management (traffic flows and safety triggers) • Predictive maintenance • Ride-sharing • Environmental impact reduction	• Virginia DOT • Tennessee DOT
Planning	• Data analysis and prediction • Traffic management optimization • Demand-responsive transit • Accessibility and equity • Scenario analysis and simulation	• Delaware DOT • Pennsylvania Turnpike Commission • Virginia DOT • West Virginia DOT
Design	• Traffic flow optimization • Safety enhancements • Smart intersection design • Climate resilience • Integration of emerging technologies	• Delaware DOT • New Jersey DOT • West Virginia DOT
Construction	• Predictive analytics for risk and safety • Site monitoring • Autonomous construction equipment • Resource allocation	• None Identified
Maintenance	• Predictive maintenance • Condition monitoring and Asset management • Repair and rehabilitation recommendations • Workforce augmentation	• Alabama DOT • Anne Arundel County DPW Bureau of Highways • West Virginia DOT

Transportation Agency Areas	Example Use Cases	Members Piloting Projects by Category
Transportation Systems Management and Operations	• Traffic management • Fleet management • Automated vehicles • Energy efficiency and environmental sustainability • Decision support systems.	• Alabama DOT • Delaware DOT • Kentucky Transportation Cabinet • Massachusetts DOT • Pennsylvania Turnpike Commission • Rhode Island DOT • Tennessee DOT • Virginia DOT

Below are six ideas for how TETC and its members can continue to help clarify AI.

Idea 1: Reduce the Noise—With all the AI discussions occurring within and adjacent to the transportation industry, the TETC can help identify what is useful, appropriate, and trusted for members. Conversely, it can also help identify areas to avoid that may be dangerous or unhelpful. Emphasis should be placed on clarifying ethical and privacy concerns, technological and infrastructure integration challenges, regulatory and policy considerations, skill gaps, and workforce transformation.

Idea 2: Develop Evaluation Methods—A preferred analytical method or maturity evaluation process can help turn abstract ideas into practical applications and overall readiness for implementation of AI solutions in different contexts.

Idea 3: Educate—While many sources of education and training are available, and more are on the way, TETC-vetted or created training could be helpful to make sure applicability to members is achieved. TETC can focus on a specific path for developing AI capabilities in the long term. First, the training will likely need to focus on familiarity and fluency. Second, the training opportunities can progress toward policy setting. Third, the opportunities can focus on skills development for practitioners.

Idea 4: Develop Risk Management Tools and Approaches—Risk management is an overarching opportunity with current applicability. With the implementation of technology, the conversation is increasingly about risk versus reward. Common risk conventions are to avoid, accept, and manage risk. Today's practitioners can use the skills offered by an increased understanding of risk assessments.

Idea 5: Convene—Bringing members together to learn from one another is beneficial. A convened AI summit could help members 1) learn from early member implementation projects, 2) discuss the state of practice, including opportunities and gaps, and 3) continue to identify and refine member needs. Before the summit, TETC should consider updating the survey distributed as part of the research for this whitepaper.

Idea 6: Prepare—Within 12 months, the hype around AI and ongoing work may begin to normalize, allowing gaps to be identified that can focus efforts. In addition, and on the heels of the summit described above, a 5-year AI development roadmap would be helpful. The roadmap could map out the clarity of how AI will develop in the time frame so that members can develop their own strategic plans to leverage the technology.

Introduction

"AI" has become a familiar term over the past 24 months due to mainstream media coverage, the hype around ChatGPT, and the integration of "AI Tools" into some common workflows. But what exactly is AI? The general definition from the Oxford Dictionary Online is: *"The capacity of computers or other machines to exhibit or simulate intelligent behavior."* (Oxford Dictionary, 2024)

While there may not be a casual definition yet, there are plenty of ideas of what it is or at least what it could be. One thing is certain: AI is already impacting the transportation industry, and that impact is likely to increase. The velocity at which AI infiltrates all parts of general business functions creates tremendous pressure to 1) assess the opportunities, 2) understand the risks, and 3) find a responsible way to leverage what's available. As with other technological advances, transportation agencies are responsible for assessing these three elements with greater rigor due to the responsibility of keeping users safe while maximizing the integrated system's equity, capacity, and sustainability.

With these goals in mind, a team from The Eastern Transportation Coalition (TETC) has taken the initiative to develop this white paper. This agenda aims to assist all members in safely and confidently embracing AI. To embark on this journey, it is crucial to clarify some key terms within the realm of AI. ChatGPT is a **generative AI** tool that takes user queries and applies them to a large language model. Generative AI is a part of **Artificial Narrow Intelligence (Narrow AI)**. The defining characteristic of Narrow AI is its ability to handle one task at a time. Using our ChatGPT example, the software can return one set of contextualized values for every single text query offered.

Generative AI uses **natural language processing (NLP)** and **machine learning (ML)** to generate results through **large language models (LLMs)**, which are extremely large sets of data and computer code that decodes and transforms the data into query results by recognizing patterns. For example, ChatGPT was initially trained on approximately 570GB of data, including web pages, books, and other sources. Often, AI enthusiasts use ML and **deep learning** interchangeably, which can be confusing. **Figure 1** show a graphic to help develop a mental model of how different types of computing work together to create AI. As one's knowledge increases, there are many other AI terms to be familiar with. A glossary of AI terms is appended to this report to help with familiarization.

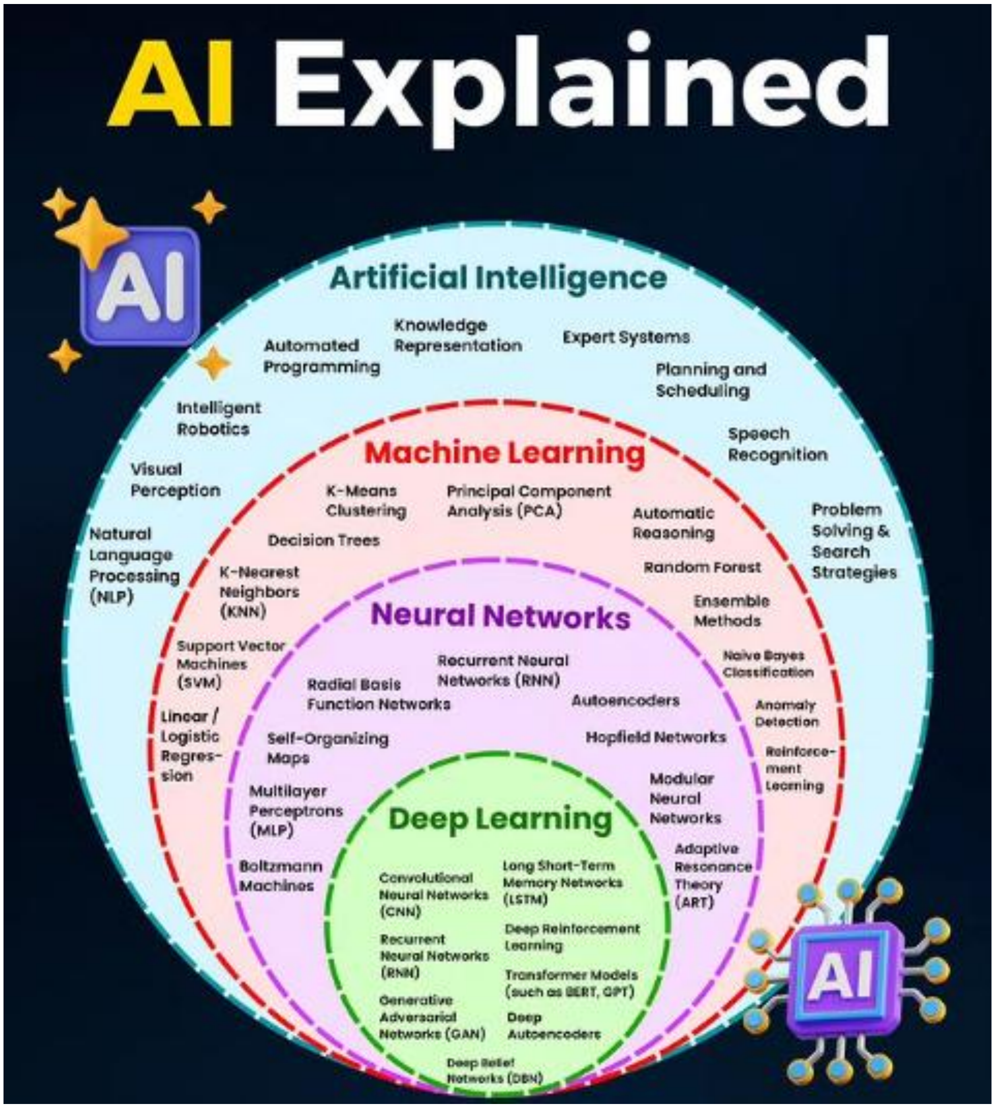

Figure 1: AI in One Graphic. Photo Credit: @ginacostag, Instagram June 8, 2024

AI in Transportation

AI in transportation is the application of artificial intelligence techniques and technologies to enhance transportation systems' efficiency, safety, reliability, and sustainability. AI can enable transportation agencies and operators to leverage data, automation, and human-machine collaboration to address current and future challenges in the transportation sector.

The transportation industry faces unprecedented demands and disruptions due to population growth, urbanization, environmental concerns, aging infrastructure, and changing customer expectations. These factors require innovative solutions to improve mobility, reduce costs, increase customer satisfaction, provide equitable outcomes, and ensure resilience. AI can offer such solutions by augmenting human capabilities, optimizing processes, and enabling new services and business models.

This white paper provides an overview of how AI can transform the transportation sector, focusing on design, maintenance, operations, planning, and customer experience. It discusses the benefits, challenges, and best practices of implementing AI in transportation and the emerging trends and opportunities for future research and development.

Historical Context and Evolution of AI in Transportation

AI has been growing in use in the broad transportation space for some time. Consider these use cases that rely on AI today.

Automated Vehicles: Researchers and developers have been developing and studying these vehicles to increase safety for many years. The technology has become more familiar to the public through commercialization and ongoing research and development.

Ride-hailing and Car-sharing Services: Companies like Waymo, Uber, Lyft, and Didi use AI to match drivers and riders, optimize pricing, and estimate arrival times. AI also enables car-sharing platforms like Zipcar and Turo to manage their fleets and offer personalized recommendations to customers.

Intelligent Transportation Systems: Cities like New York, Singapore, London, and Stockholm use AI to monitor traffic flows, adjust speed limits, and implement congestion charges. AI also helps traffic management centers coordinate emergency responses, road closures, and diversions.

Smart Parking Systems: AI-powered sensors and cameras can detect vacant parking spaces and guide drivers to them. AI also enables dynamic pricing and reservation systems for parking facilities.

Railway Automation: AI automates various aspects of railway operations, such as train control, signaling, track inspection, and fault diagnosis. It also helps railway operators optimize timetables, reduce energy consumption, and enhance customer service.

Air Traffic Control: AI assists air traffic controllers in managing complex airspace and ensuring safe and efficient flights. It also helps airlines optimize flight routes, schedules, and fuel consumption and provides personalized offers and services to passengers.

As AI matures and becomes more capable across general computing, transportation technology use cases will also grow.

Ten-Year Outlook

The research team collected the following topics and trends to watch that will impact the overall practice of using AI for problem-solving. Many of these topics contribute to the overall growth of "autonomous agents" or LLMs capable of performing several tasks in a row using memory and tools without direct human input needed. Here are 10 expected developments[1].

Advancements in Deep Learning. Deep learning has been a dominant approach in AI in recent years, and it is expected to continue to advance. This may involve the development of more efficient architectures, better optimization techniques, and an improved understanding of how to train deeper and more complex models.

Explainable AI (XAI). As AI systems are increasingly integrated into critical decision-making processes, there is a growing demand for transparency and interpretability. Research into XAI aims to develop methods that explain AI decisions, making them more understandable and trustworthy.

AI for Good. There is a growing emphasis on leveraging AI for social good, including applications in healthcare, education, environmental conservation, and disaster response. Expectations are high for AI to address pressing global challenges and contribute positively to society.

[1] OpenAI. (2024). *ChatGPT* (3.5) [Large language model]. https://chat.openai.com

Continued Improvements in NLP. NLP has seen remarkable progress in recent years, driven by advances in deep learning and large-scale language models. Over the next decade, we anticipate further improvements in language understanding, generation, and dialogue systems.

AI Ethics and Regulation. As AI technologies become more pervasive, there will likely be increased scrutiny and regulation surrounding their ethical use. This may involve mitigating bias, ensuring fairness, protecting privacy, and establishing responsible AI development and deployment guidelines.

AI and Robotics. Robotics is another field where AI plays a significant role, and we can expect continued progress in areas such as automated vehicles, industrial automation, service robots, and human-robot collaboration.

Edge AI and Federated Learning. With the proliferation of IoT devices and the increasing demand for privacy-preserving AI, edge computing and federated learning are expected to become more prominent. These approaches enable AI models to be trained and deployed locally on edge devices while preserving data privacy.

AI and Creativity. AI has shown promise in various creative domains, such as art, music, literature, and design. Over the next decade, we may see further developments in AI-generated content and collaborative creativity between humans and machines.

Quantum Computing and AI. While still in the early stages, the intersection of quantum computing and AI holds the potential for significant advancements. Quantum computing could enable more efficient optimization algorithms and lead to breakthroughs in AI research.

Interdisciplinary AI Research. AI research is becoming increasingly interdisciplinary, drawing from neuroscience, psychology, economics, and sociology. Over the next decade, expect more collaborations between AI researchers and experts from diverse domains to tackle complex challenges.

Current TETC Environment

There are varying opinions among The Eastern Transportation Coalition (TETC) members about the maturity and applicability of artificial intelligence as of spring 2024. Each member of the small group team that led this research plotted where they believed AI was on the Gartner Hype Cycle, shown with the pins below. Here is how Gartner explains their hype cycle: "*When new technologies make bold promises, how do you discern the hype from what's commercially viable? And when will such claims pay off, if at all? Gartner Hype Cycles provide a graphic representation of the maturity and adoption of technologies and applications, and how they are potentially relevant to solving real business problems and exploiting new opportunities. Gartner Hype Cycle methodology gives you a view of how a technology or application will evolve over time, providing a sound source of insight to manage its deployment within the context of your specific business goals.*" (Gartner, 2024)

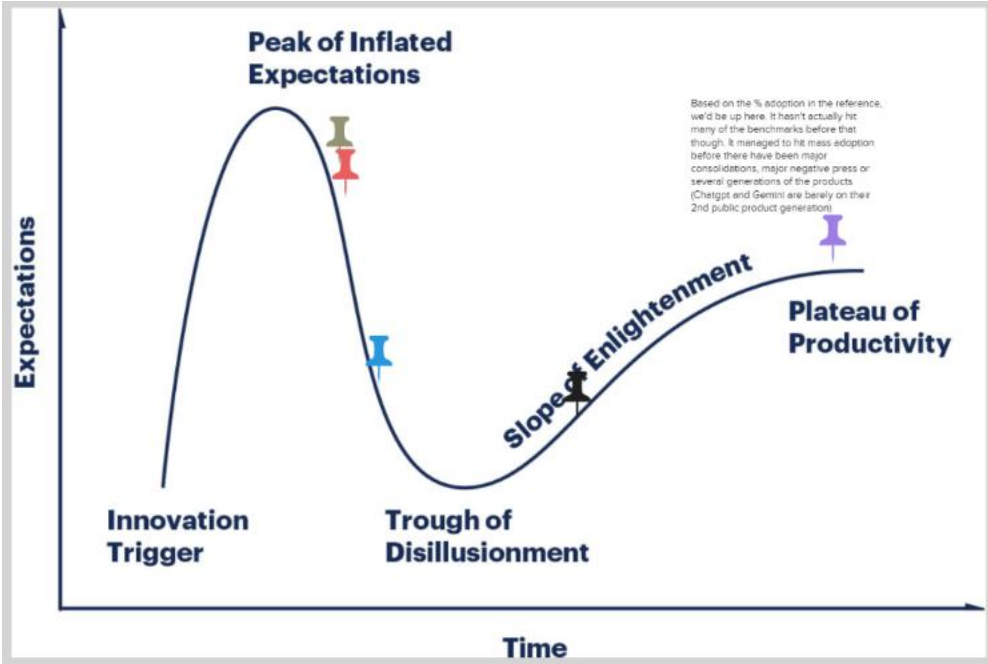

Figure 2: Where TETC Members believe AI is on the Hype Curve.

All respondents believe we are past the peak of inflated expectations, but most think we haven't crossed the trough of disillusionment. Although this is a small sample, understanding people's opinions across the coalition is essential as we seek to establish a clear roadmap for responsibly integrating this potentially beneficial technology. The research team believes that although the responses in **Figure 2** are limited, they most likely reflect the pattern that a larger sample size would follow. Therefore, the TETC AI roadmap must be sensitive to the idea that people are at different levels of awareness and bias of AI.

The working group conducted a PESTEL analysis of AI enablers and inhibitors. PESTAL stands for Political, Economic, Social, Technological, Environmental, and Legal Considerations. It is a version of a strengths, weaknesses, opportunities, and threats (SWOT) analysis approach for issues that are not immediately quantifiable, and the analysis can help clarify where respondents stand on topics and issues. **Table 1** This chart shows the enablers and inhibitors the working group sees in AI. Enablers speed up implementation and adoption, while inhibitors slow progress.

Table 1: Initial PESTEL Analysis of AI Utility.

Analysis Element	Enablers	Inhibitors
Political	• Pressure from elected officials. • Gubernatorial direction • Perception of improved employee efficiency resulting in taxpayer savings • Public support	• Power to influence elections. • Perceived reduction in labor needs and job loss • Procurement cycles/methods • Public skepticism/fear
Economic	• Potential job creation • Higher profits for private companies • Enhanced efficiencies in: • Public interactions • Local government guidance	• Significant upfront capital investment is required to develop, test, validate, deploy, mass produce, and mitigate risk for many technologies. • Unknown costs of implementation

Analysis Element	Enablers	Inhibitors
	• Administrative services • Design references. • TMC decision making	
Social	• Media/social media coverage • Momentum and expectations from the populace	• Media coverage • Concerns over "Deep fakes" and intellectual property rights (e.g., recent Hollywood labor contract). • Risk of hallucinations and mistakes with high impact • Data bias leading to inequitable outcomes. • Misinformation
Technology	• Large potential for asset management • Curated knowledge on demand • Successful task automation is demonstrated by early adopters. • Large research, development, and commercialization spends	• Upskilling needs are unknown. • No way to assess the ability of workers to upskill or what to upskill to. • Data quality and availability
Environment	• Potential to uncover new efficiencies once undetectable for the built and natural environment	• Training large AI models can require a lot of computing power and be harmful to the environment.
Legal	• Lack of standards and regulations	• Lack of standards and regulations • Privacy/Security concerns (open source) - who can access what? • Risks - How can information be used to harm an agency or its constituents? (Or the unknown of how it can be used). How can risks be managed? • Potential for privacy breaches • Governance/Oversight—who "owns" the technology, data, and output? Can we control the audience and use cases? • Policies/Procedures - Challenges with developing policies around unknown tech issues/risks

The working group disseminated an online survey to further evaluate TETC members' views on AI. 17 members responded. Most respondents were unclear about who was taking the lead on evaluating AI in their organization.

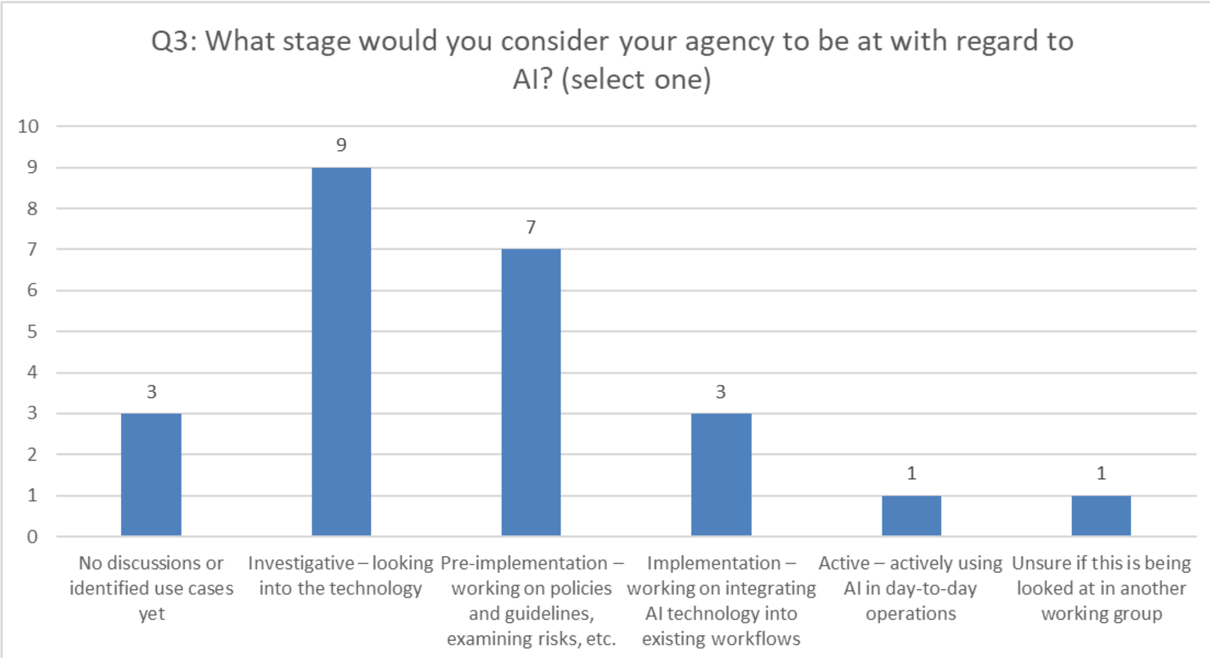

Figure 3: TETC Member Survey: What stage would you consider your agency to be at concerning AI?

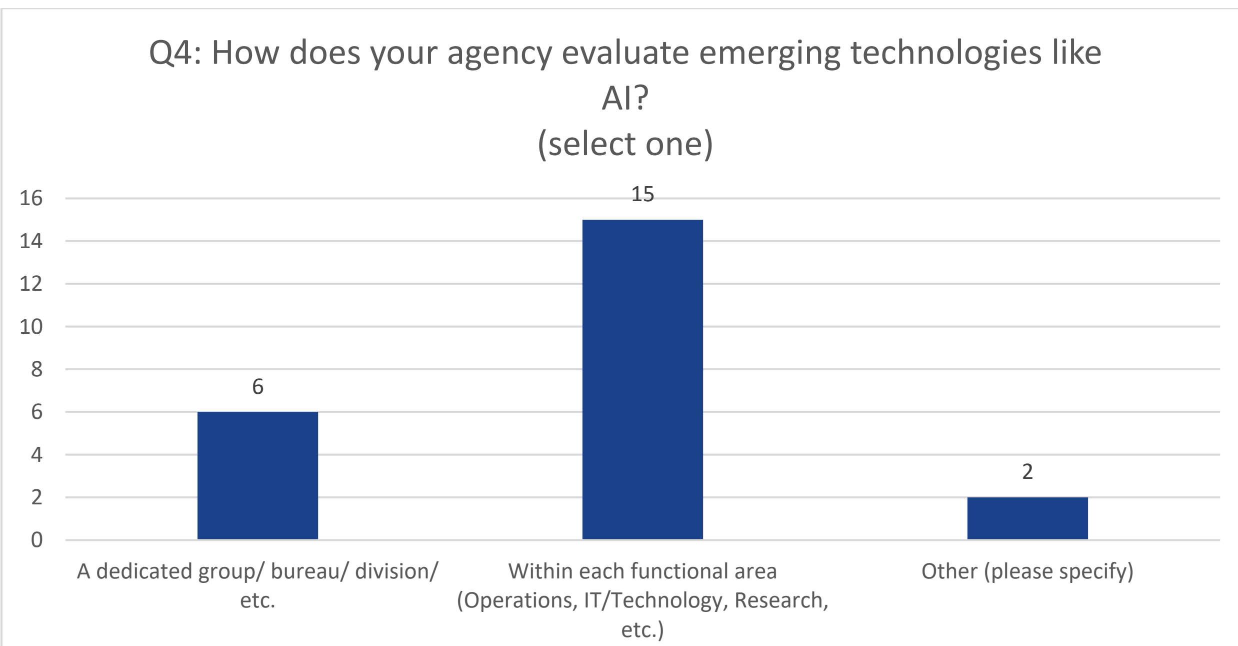

Figure 4: TETC Member Survey: How does your agency evaluate emerging technologies like AI?

The two responses of “other” in **Figure 4** indicated that individual champions did evaluations. TETC members also identified any work being completed by their organization of which they were aware. Many also noted that other parts of their organization might be doing unknown active work. This supports the idea that current work is very early and compartmentalized.

Table 2: Current AI Evaluations by TETC Members

Agency	What use cases have you implemented or thought about when using AI?
Alabama DOT	We've developed a working model that utilizes cameras on our SSP trucks to look for damaged guardrails. The idea was to automate a repair/claims process.
Anne Arundel County DPW Bureau of Highways	We are piloting AI tools in two areas: 1) Analysis of Pavement Conditions using vehicle-captured HD video and 2) Sidewalk Conditions from handheld LiDAR capture.
Delaware DOT	Three use cases are implemented or considered for AI traffic flow prediction. 1. Predictive traffic signal control (implemented for signal pattern selection, will apply to split and offset) 2. Congestion prediction (considered and partially implemented for freeway volume prediction vs. capacity) 3. Detour/routing selection based on predicted traffic flow/demand (in consideration) Additional AI use cases on machine vision and other sensors include the following. 1. Machine vision for traffic count, speed, turning movement, queue estimation (implemented) 2. Machine vision for vehicle reidentification (developed and tested) 3. Machine vision for vulnerable road users and conflict/near missing monitoring/prediction (being considered/planned/programmed) 4. Flood prediction using hydrology sensors for traffic management (planned/programmed).
Florida DOT	We are exploring both the Generative Language Models and use cases in transportation.
Georgia DOT	Investigating using generative AI for assistance with report writing and simple data visualization
Kentucky Transportation Cabinet	Incident detection for wrong way driving and TPIMs (based on site availability)
Massachusetts DOT	We are considering using it for our 511
MetroPlan Orlando	Safety, reliability, and system management.
New Jersey DOT	Planning, Reporting and Dashboard tools, Safety prediction, Plan request assistance, Structural analysis and Research.

Agency	What use cases have you implemented or thought about when using AI?
Pennsylvania Turnpike Commission	Crash analysis, Situation analysis, Emergency hazmat handbook and lane charts for lane closures
Rhode Island DOT	Survey responses are limited to the TSMO, and importantly, our TSMO implementation to date seems limited to at most some AI within vendor-proprietary algorithms for (a) Adaptive Traffic Signal Control (ATSC) and (b) traffic detection at traffic signals --- but these are largely 'black-box' so we aren't fully clear. RIDOT has been thinking about and learning about further AI use cases in/for these and other realms/systems wherever we believe it could help; recently, many vendors and private parties have made claims about how their use of AI can benefit our DOT, so we are trying to keep an open mind about such.
Tennessee DOT	Decision support system for integrated corridor management
Vermont AOT	Drafting communications to the public in response to specific requests, usually around mobility and signing laws. Superbot can discover, simplify, and communicate policies, procedures, and processes to the public. It is also used for wrong way driving detection.
Virginia DOT	We have used ML for reliability target setting and will be using AI for a decision support system.
West Virginia DOT	One major use case is extracting features/objects such as signs from pictures taken from roadway data collection projects; the second is estimating AADT data for paved local roads without traffic counters.

With these TETC use cases in mind, let's examine additional potential use cases from different aspects of the transportation agency business.

Use Cases of AI in Transportation

AI will continue to change many aspects of transportation agencies. The use cases for change fall into several categories:

- Business Enterprise
- Customer Service
- Safety and Mobility Services
- Planning
- Design
- Construction
- Maintenance
- Transportation Systems Management and Operations

Each of these was examined in greater detail. The results are shown in the following sections.

Business Enterprise

These changes could transform transportation agencies' business, affecting workforce needs, capacity, and efficiency.

- **Personalized Customer Experience**: AI-powered systems will enable highly personalized customer experiences. Through advanced analytics and machine learning algorithms, agencies can better understand customer preferences, behavior patterns, and needs, allowing them to tailor products, services, and public engagement strategies accordingly.
- **Automation of Routine Tasks**: AI and robotics will continue automating routine and repetitive tasks across various industries, increasing efficiency and productivity. Agencies can leverage AI-powered automation to streamline processes, reduce operational costs, and allocate human resources to more strategic and creative tasks.
- **Data-driven Decision Making**: AI enables businesses to analyze vast amounts of data quickly and accurately, providing valuable insights for decision-making. Predictive analytics, machine learning models, and data-driven optimization algorithms empower organizations to make informed strategic decisions, identify new service opportunities, and mitigate risks.
- **Enhanced Cybersecurity**: AI-powered cybersecurity solutions can help businesses detect and respond to security threats more effectively. Machine learning algorithms can analyze vast amounts of data to identify anomalous behavior, detect malware, and mitigate cyberattacks in real time, strengthening the resilience of business systems and data assets.
- **Personalized Outreach and Public Engagement**: AI enables organizations to deliver personalized marketing campaigns and strategies tailored to customer preferences and behaviors. Recommendation engines, predictive analytics, and natural language processing (NLP) algorithms can optimize marketing content, recommend relevant products, and enhance customer engagement across various channels.
- **Workforce Augmentation**: AI technologies such as augmented reality (AR), virtual reality (VR), and wearable devices can augment the capabilities of human workers, leading to enhanced productivity, safety, and collaboration in the workplace. Businesses can leverage AI-driven tools to empower employees with real-time information, training resources, and assistance in performing complex tasks.
- **Ethical AI Governance**: As businesses increasingly deploy AI technologies, there will be a growing emphasis on ethical AI governance and responsible AI use. Organizations must establish robust frameworks for ensuring transparency, fairness, accountability, and compliance with regulatory requirements in AI-driven decision-making processes.

Customer Service

AI is poised to revolutionize transportation customer service by enhancing efficiency, personalization, and responsiveness. Administrative requirements are being levied on the user at the state government level. The recipient must be informed that AI plays a part whenever AI is employed, especially in customer service. For transportation agencies, our customers are the users of our systems and resources, such as driver license renewals, public transportation reservations, trip planning, and others. Here are several ways AI could impact transportation customer service:

- **Chatbots and Virtual Assistants**: AI-powered chatbots and virtual assistants could provide 24/7 customer support, answer inquiries, assist with bookings, and resolve common real-time issues. These virtual agents can simultaneously handle many inquiries, reducing wait times and improving customer satisfaction.

- **Personalized Recommendations**: AI algorithms could analyze customer preferences, travel history, and behavior to provide personalized recommendations for transportation options, routes, and services, catering to individual needs and preferences.
- **Voice Recognition and Natural Language Processing (NLP)**: AI-driven voice recognition and NLP technologies could enable customers to interact with transportation service providers using natural language commands and inquiries, enhancing the user experience and streamlining the booking process.
- **Predictive Customer Service**: AI algorithms could analyze data on past customer interactions, feedback, and behavior to anticipate potential issues and proactively address them before they escalate, improving customer satisfaction and loyalty.
- **Real-Time Alerts and Updates**: AI-powered systems could monitor transportation networks in real-time, providing customers with timely alerts and updates on delays, disruptions, or changes to their travel plans. This would allow them to make informed decisions and adjust their itinerary accordingly.
- **Automated Assistance for Special Needs**: AI technologies could assist customers with special needs, such as disabilities or language barriers, by providing tailored assistance, guidance, and support throughout their journey, ensuring inclusivity and accessibility for all passengers.
- **Sentiment Analysis**: AI-driven sentiment analysis tools will monitor customer feedback and social media conversations to gauge customer satisfaction levels, identify emerging issues or trends, and inform service improvements and decision-making processes.
- **Efficient Complaint Resolution**: AI-powered systems could streamline handling customer complaints and grievances by automatically categorizing and prioritizing them, routing them to the appropriate channels, and providing prompt resolutions, thereby enhancing customer trust and loyalty.
- **Personalized Loyalty Programs**: AI algorithms could analyze customer data to identify patterns and trends, allowing transportation service providers, such as public transportation operators, to offer targeted promotions, rewards, and loyalty programs tailored to individual preferences and behaviors, fostering customer loyalty and retention.
- **Continuous Improvement through Data Analysis**: AI-driven analytics tools could analyze vast amounts of customer data to uncover insights into preferences, pain points, and trends, enabling transportation providers to improve their services continuously, anticipate future demand, and stay ahead of competitors.

AI will transform transportation customer service, enabling providers to deliver seamless, personalized experiences that meet passengers' evolving needs and expectations.

Safety and Mobility Services

AI could change the services offered by transportation agencies and the way that customers interact with transportation agencies, as shown in the list below.

- **Automated Vehicles**: AI-powered vehicles have the potential to transform transportation by reducing accidents, alleviating traffic congestion, and providing mobility options for those unable to drive.
- **Smart Traffic Management**: AI can optimize traffic flow, reduce congestion, and improve safety through real-time data analysis, leading to more efficient transportation networks.
- **Predictive Maintenance**: AI algorithms can predict equipment failures and schedule maintenance proactively, reducing downtime and disruptions in transportation infrastructure such as roads, bridges, and railways.
- **Ride-sharing and Mobility-as-a-Service (MaaS)/Mobility on Demand (MoD)**: AI-powered platforms optimize route planning, match passengers with vehicles, and

dynamically adjust pricing based on demand, transforming urban mobility, and reducing reliance on private car ownership. The interconnectivity of these systems and the harvested data could help plan new service offerings where gaps exist and help bring more equity to transportation by identifying and addressing "transportation deserts."

- **Smart Infrastructure**: AI-enabled sensors and cameras monitor road conditions, detect hazards, and provide real-time alerts to enhance road safety and prevent accidents.
- **Last-Mile Delivery Solutions**: AI-powered robots and drones enable fast and efficient last-mile delivery, particularly in urban areas, enhancing the speed and reliability of e-commerce and logistics services.
- **Public Transit Optimization**: AI algorithms optimize public transit routes, schedules, and capacity management, improving service reliability and accessibility for passengers.
- **Environmental Impact Reduction**: AI enables more sustainable transportation practices by optimizing fuel consumption, reducing emissions, and promoting the adoption of electric and alternative fuel vehicles.

Planning

AI can help planners revolutionize how cities and regions design, optimize, and manage transportation systems. Here are some ways AI is influencing transportation planning.

- **Data Analysis and Prediction**: AI algorithms can analyze vast amounts of transportation data, including traffic patterns, commuter behavior, and infrastructure usage, to identify trends, forecast demand, and predict future transportation needs. This data-driven approach allows planners to make informed decisions and allocate resources effectively.
- **Traffic Management and Optimization**: AI-powered traffic management systems can optimize signal timings, manage congestion, and dynamically adjust traffic flow in real-time based on current conditions. These systems help reduce travel times, minimize delays, and improve overall traffic efficiency.
- **Demand-Responsive Transit**: AI algorithms can optimize demand-responsive transit services, such as ridesharing and micro transit, by dynamically matching passenger requests with available vehicles and routes. This approach improves service coverage, reduces wait times, and enhances the overall efficiency of public transportation systems.
- **Accessibility and Equity**: AI-driven transportation planning can help improve accessibility and equity by identifying underserved communities, optimizing transit routes to better serve these areas, and designing inclusive transportation policies and infrastructure that address the needs of all residents, including those with disabilities and low-income individuals.
- **Integrated Mobility Solutions**: AI facilitates the integration of various transportation modes, such as public transit, ridesharing, biking, and walking, into seamless, multimodal transportation networks. By analyzing travel patterns and preferences, AI can optimize intermodal connections, improve transfer experiences, and encourage sustainable transportation choices.
- **Environmental Sustainability**: AI-enabled transportation planning can promote environmental sustainability by optimizing routes, reducing vehicle emissions, and encouraging the adoption of clean energy vehicles and alternative transportation modes. AI algorithms can also help identify opportunities for green infrastructure, such as bike lanes and pedestrian-friendly streets, to reduce reliance on cars and promote eco-friendly transportation options.
- **Scenario Analysis and Simulation**: AI-driven simulation and modeling tools enable planners to simulate different scenarios and assess the potential impacts of proposed transportation projects, policy changes, and emerging technologies. This allows planners

to evaluate alternatives, identify potential risks and opportunities, and make data-driven decisions that align with long-term transportation goals.

- **Resilience and Disaster Management**: AI technologies can enhance the resilience of transportation systems by predicting and mitigating the impacts of natural disasters, extreme weather events, and other disruptions. By analyzing historical data and real-time information, AI can help planners develop proactive strategies for disaster preparedness, response, and recovery, ensuring the continuity of transportation services in the face of unforeseen challenges.

Overall, AI is transforming transportation planning by providing planners with powerful tools and insights to design more efficient, sustainable, and resilient transportation systems that meet the evolving needs of cities and communities.

Infrastructure Design

Designing more effective infrastructure improvements focuses on identifying and cataloging in new data sets and historical data sets to inform the design process.

- **Safety Enhancement**: AI-powered sensors and cameras can monitor infrastructure conditions in real-time, detecting hazards such as potholes, debris, or structural defects and alerting authorities to take corrective actions promptly to enhance safety.
- **Smart Intersection Design**: AI can optimize intersection design by analyzing traffic data and pedestrian patterns, improving signal timing, lane configurations, and pedestrian crossings to enhance safety and efficiency.
- **Climate Resilience**: AI can help design transportation infrastructure that is more resilient to climate change-related hazards such as extreme weather events, flooding, and sea-level rise, mitigating risks and ensuring long-term sustainability.
- **Dynamic Signage and Markings**: AI algorithms can optimize signage and road markings based on real-time traffic conditions, weather forecasts, and events, providing drivers with timely information and guidance to improve navigation and safety.
- **Optimized Public Transit Systems**: AI can optimize the design of public transit systems, including route planning, station locations, and capacity management, to enhance accessibility, reliability, and efficiency for passengers.
- **Energy Efficiency**: AI can optimize the energy consumption of transportation infrastructure, such as lighting, heating, and ventilation systems, to reduce energy costs and environmental impacts.
- **Plan Development and Reviews**: AI can help design optimization by evaluating multiple variables and constraints to find the most efficient solutions. Techniques like genetic algorithms, neural networks, and machine learning can be used to analyze design parameters and optimize cost, material usage, and structural integrity. AI can also reduce the time and effort associated with manual drafting by using 3D model development. AI can be used in the engineering plan review process by identifying quality assurance concerns and errors through advanced pattern recognition and anomaly detection techniques.
- **Constructability Improvements**: By improving elements such as project management and scheduling by balancing predicted project timelines, resource allocation, and potential delays based on historical project data and by using knowledge management and decision support techniques based on vast amounts of data and previous experiences AI can make the transition from design to construction simple and more efficient.

Construction

With a focus on safety and productivity, advancements in how AI powered processes and equipment may provide valuable resources to expand and improve the built environment.

- **Predictive Analytics**: AI enables predictive analytics for construction projects by analyzing historical data, identifying potential risks and challenges, and providing insights to inform decision-making and risk management strategies.
- **Construction Site Monitoring**: AI-powered drones equipped with cameras and sensors can monitor construction sites in real-time, providing project managers with aerial imagery, progress tracking, and safety inspections to ensure compliance with design specifications and timelines.
- **Automated Construction Equipment: AI enables the development of automated** construction equipment, such as bulldozers, excavators, and cranes. This equipment can perform repetitive tasks more efficiently and accurately, reducing labor costs and improving productivity on construction sites.
- **Materials Optimization**: AI algorithms can optimize the selection and usage of construction materials based on cost, durability, and environmental impact, leading to more sustainable and resilient infrastructure.
- **Quality Control**: AI-powered computer vision systems can inspect construction materials and structural components for defects, deviations from design specifications, and compliance with safety standards, ensuring high-quality construction outcomes and reducing rework.
- **Safety Enhancement**: AI can improve construction site safety by analyzing data from sensors, wearables, and cameras to identify potential hazards, prevent accidents, and enforce safety protocols in real-time.
- **Resource Allocation**: AI algorithms can optimize resource allocation on construction sites, including labor, materials, and equipment, to maximize productivity, minimize waste, and meet project deadlines within budget constraints.
- **Collaborative Robotics**: AI enables collaborative robotics (cobots) that work alongside human workers to perform tasks such as bricklaying, welding, and assembly, enhancing efficiency, safety, and precision in construction processes.
- **Smart Construction Management**: AI-powered construction management platforms provide project managers with real-time insights, analytics, and decision support tools to optimize project planning, scheduling, and coordination, improving overall project performance and delivery outcomes.

Maintenance

Using AI to maintain systems relies on the next step in asset life cycle analysis and monitoring.

- **Predictive Maintenance**: AI algorithms analyze sensor data and historical maintenance records to predict equipment failures, prioritize maintenance tasks, and schedule interventions proactively, reducing downtime and extending the lifespan of infrastructure assets.
- **Condition Monitoring**: AI-enabled sensors and IoT devices continuously monitor the condition of infrastructure components such as bridges, roads, and tunnels, detecting signs of deterioration, corrosion, or structural defects in real-time and alerting maintenance teams to take corrective actions promptly.
- **Asset Management**: AI-based asset management systems track the performance, condition, and lifecycle costs of infrastructure assets, enabling agencies to optimize maintenance strategies, allocate resources effectively, and prioritize investments based on asset criticality and condition assessments.

- **Optimized Inspection and Assessment**: AI-powered drones with cameras and sensors can perform aerial inspections of infrastructure assets, capturing high-resolution imagery and data to assess their condition, identify defects, and prioritize maintenance needs more efficiently than traditional inspection methods.
- **Smart Repair and Rehabilitation**: AI algorithms analyze inspection data and structural assessments to recommend optimal repair and rehabilitation strategies for infrastructure assets, including prioritizing maintenance activities, selecting appropriate materials, and optimizing repair techniques to extend asset lifespan and minimize user disruption.
- **Remote Monitoring and Control**: AI enables remote monitoring and control of infrastructure assets, allowing maintenance teams to monitor performance, adjust settings, and implement interventions from centralized control centers, reducing the need for physical inspections and on-site visits.
- **Energy Efficiency**: AI algorithms optimize the energy consumption of infrastructure assets such as lighting, HVAC systems, and pumping stations, reducing energy costs, minimizing environmental impacts, and improving overall sustainability.
- **Workforce Augmentation**: AI-powered tools and wearable devices augment the capabilities of maintenance workers, providing real-time guidance, diagnostics, and safety alerts to enhance productivity, reduce errors, and ensure compliance with maintenance procedures.
- **Resilience Planning**: AI enables agencies to assess infrastructure vulnerabilities, model potential failure scenarios, and develop resilience plans to mitigate risks, enhance asset reliability, and ensure continuity of service in the face of natural disasters, climate change, and other external threats.

Transportation Systems Management and Operations

AI can transform transportation systems management and operations, revolutionizing how cities and transportation agencies optimize, monitor, and maintain their infrastructure and services. Here's how AI will influence various aspects of transportation systems management and operations:

- **Traffic Flow Optimization**: AI algorithms can analyze traffic patterns and optimize road network design to improve traffic flow, reduce congestion, and minimize travel times.
- **Traffic Management and Control**: AI-powered systems can analyze real-time traffic data from sensors, cameras, and other sources to optimize traffic signal timings, manage congestion, and dynamically adjust traffic flow. This helps reduce travel times, minimize delays, and improve overall traffic efficiency.
- **Fleet Management**: AI tools can optimize fleet operations by analyzing vehicle usage, maintenance needs, fuel efficiency, and driver behavior to improve scheduling, routing, and resource allocation. This increases operational efficiency, reduces fuel consumption, and enhances service reliability.
- **Demand-Responsive Services**: AI algorithms can optimize demand-responsive transportation services, such as ridesharing and micro transit, by dynamically matching passenger requests with available vehicles and routes. This improves service coverage, reduces wait times, and enhances the overall efficiency of public transit systems.
- **Dynamic Pricing and Incentives**: AI technologies can optimize pricing strategies and incentives to manage demand and encourage more sustainable transportation choices. By analyzing real-time data on traffic conditions, occupancy levels, and user preferences, AI can dynamically adjust fares, tolls, and incentives to optimize resource allocation and promote efficient use of transportation infrastructure.
- **Intelligent Transportation Systems (ITS)**: AI-powered ITS applications such as traffic surveillance, incident detection, electronic toll collection, and traveler information systems

enhance safety, efficiency, and user experience on roads and highways. These systems enable real-time monitoring, analysis, and response to traffic conditions and incidents.

- **Automated Vehicles (AVs)**: AI is the backbone of automated driving technology, enabling vehicles to perceive their environment, make decisions, and navigate without human intervention. AVs have the potential to enhance safety, efficiency, and accessibility in transportation systems by reducing accidents, optimizing traffic flow, and providing mobility options for individuals who cannot drive.
- **Energy Efficiency and Environmental Sustainability**: AI technologies can optimize transportation operations to reduce energy consumption, minimize emissions, and promote environmental sustainability. By optimizing routes, managing traffic flow, and promoting alternative transportation modes, AI helps mitigate the environmental impact of transportation systems.
- **Decision Support Systems**: AI-driven decision support systems provide transportation managers and operators with real-time insights, recommendations, and predictions to facilitate informed decision-making. These systems enable proactive management of transportation networks, improve service reliability, and enhance the overall quality of transportation operations.

Overall, AI is reshaping transportation systems management and operations by providing advanced tools and technologies to optimize efficiency, improve safety, and enhance the user experience in urban mobility.

Ideas to Consider

Reviewing current TETC efforts and potential future advancements identified overarching challenges for AI to reach its full potential. TETC members will continue to grapple with these challenges as they weigh the benefits of implementation. The TETC and its members clarify the way forward for each area.

Idea 1: Reduce the Noise

With all the AI discussions occurring within and adjacent to the transportation industry, identifying what is useful, appropriate, and trusted will continue to be at a premium. Conversely, identifying areas to avoid that may be dangerous or unhelpful is also crucial. The graphic below shows four key areas that may benefit from clarifying work.

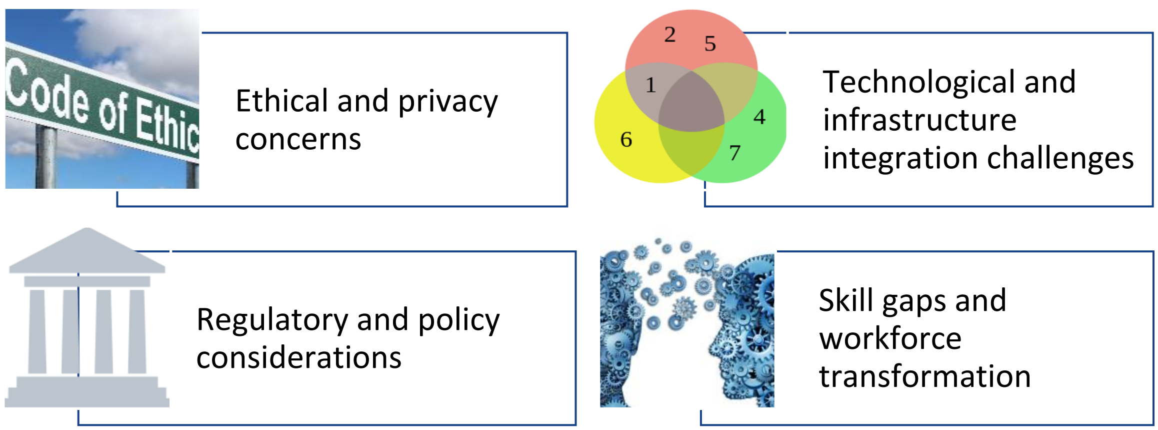

Figure 5: Four key areas to monitor and clarify.

Idea 2: Develop Evaluation Methods

An analytical method or maturity evaluation process could be developed or adopted to aid members in considering AI solutions.

Idea 3: Educate

While many sources of education and training are available, and more are on the way, TETC-vetted or created training could be helpful. TETC can focus on a specific path for developing AI capabilities in the long term. First, the training will likely need to focus on familiarity and fluency. Second, the training opportunities can progress toward policy setting. Third, the opportunities can focus on skills development for practitioners.

Idea 4: Develop Risk Management Tools and Approaches

Risk management is an overarching opportunity with current applicability. With the implementation of technology, the conversation is increasingly about risk versus reward. Common risk conventions are to avoid, accept, and manage risk. Today's practitioners can use the skills offered by an increased understanding of risk assessments.

Idea 5: Convene

Bringing members together to learn from one another is beneficial. A convened AI summit could help members 1) learn from early member implementation projects, 2) discuss the state of practice, including opportunities and gaps, and 3) continue to identify and refine member needs.

Before the summit, TETC should consider updating the survey distributed as part of the research for this whitepaper.

Idea 6: Prepare

Within 12 months, the hype around AI and ongoing work may begin to normalize, allowing gaps to be identified that can focus efforts. In addition, and on the heels of the summit described above, a 5-year AI implementation roadmap would be helpful. The roadmap could map out the clarity of how AI will develop in the time frame so that members can develop their own strategic plans to leverage the technology.

Conclusion

The future of AI is certain in one sense. Moving forward, it will impact transportation agencies dramatically. TETC is a trusted source for credible guidance for its members and beyond while being highly sought after for innovative partnerships. This position within the transportation industry is crucial for leveraging technology while properly managing risk. The implementation of AI requires a nimble approach to program development and delivery. This required approach stresses agencies that desire to respond to developing capabilities but worry about unintended consequences. The member survey revealed that members are widely distributed across the trial implementation phase and have many more questions than answers. However, the partnership model developed and implemented by the TETC is the perfect fit for turning this abstract topic into real-world solutions.

AI Glossary

AI model - a program or algorithm that uses trained data to spot patterns and automatically make predictions or decisions.

AI Spring - The AI boom, or AI spring, is the ongoing period of rapid progress in the field of artificial intelligence. Prominent examples include protein folding prediction and generative AI, led by laboratories such as Google DeepMind and OpenAI. The AI boom is expected to have a profound cultural, philosophical, religious, economic, and social impact, as questions such as AI alignment, qualia, and the development of artificial general intelligence became widely prominent topics of popular discussion.

Artificial general intelligence (AGI) - a theoretical field of AI research that aims to create software with human-like intelligence. AGI programs are hypothetical machines that can learn and think like humans and perform any intellectual task that a human can do.

Automated Machine Learning (AutoML) - operates by matching raw data and models together to reveal the most relevant information.

Conversational agents - A conversational agent, often referred to as a chatbot, is a type of artificial intelligence (AI) software that can simulate a conversation (or a chat) with a user in natural language through messaging applications, websites, mobile apps, or through the telephone.

Continuous Learning - about autonomous and incremental skill building and development.

Convolutional neural network (CNN) - a multilayered, with a convolutional layer, a pooling layer, and a fully connected layer. Each one performs a different task with the data. The output is classification. If a researcher has 10,000 images and needs to extract data—to recognize particular faces, for instance—the CNN would run until information could be inferred. In business, CNNs are used to identify anomalies in medical imaging, faulty products on a production line, blight on crops, and other irregularities.

Deep learning - Deep learning is a relatively new branch of machine learning. Programmers use special deep learning algorithms alongside an enormous corpus of data—typically many terabytes of text, images, videos, speech, and the like. Often, these systems are trained to learn on their own, and they can sort through a variety of unstructured data, whether it's making sense of typed text in documents or audio clips or video.

Diffusion model - a type of machine learning algorithm that generates high-quality data by adding noise to a dataset and then learning to reverse the process. Diffusion models are a type of generative AI model that can create new data using trained data. For example, if a model is trained on images of cats, it can generate realistic images of cats.

Generative adversarial networks (GANs) - As unsupervised deep learning systems, GANs are composed of two competing neural networks—a generator and a discriminator—that are trained on the same data, such as images of people. The networks compete against each other to perform a task, such as identifying the correct person, resulting in optimizing overall performance. GANs are useful when researchers don't have enough data to train an algorithmic model and are also used to create new, synthetic data. Deepfakes are generated using GANs.

Generative AI - a type of AI that can create new content, such as text, images, music, audio, and videos. Generative AI models learn the structure and patterns of the input training data and then create new data with similar characteristics.

General AI - Also known as strong AI, this type of AI has all the cognitive abilities of a human being.

General Reinforcement Learning Algorithms - Researchers are developing single algorithms to learn multiple tasks.

Imitation Learning - Neural networks are trained to perform tasks by watching humans do them. Imitation learning can be used to train AI to control robot arms, drive cars, or navigate web pages.

Large language model (LLM) - use deep learning techniques and large amounts of data to understand, generate, predict, and summarize new content. LLMs are trained using statistical models to analyze data and learn patterns and connections between words and phrases. LLMs can ingest large amounts of data, often from the internet, Wikipedia, and Common Crawl.

Machine learning (ML) - uses data to make predictions and recommendations on how to achieve stated goals.

Narrow AI - Also known as weak AI, this type of AI is designed to perform a specific task, such as facial recognition or speech recognition. Chatbots are an example of a narrow AI.

Natural language processing (NLP) - is a machine-learning technology that allows computers to interpret, manipulate, and comprehend human language.

Prompt Learning/Engineering - encompasses a collection of techniques that focus on customizing a foundational LLM for a particular use case, using a supervised learning technique.

Qualia - Many definitions of qualia have been proposed. One of the simpler, broader definitions is: "The 'what it is like' character of mental states. The way it feels to have mental states such as pain, seeing red, smelling a rose, etc."

Recurrent neural networks (RNNs) - These multilayered neural networks move and store information between input, hidden, and output layers. They are good at modeling sequence data for predictions. In business, they are used anytime the sequence of data matters, such as speech recognition and language translation. RNNs are used in digital assistants, to create captions for images and to generate narrative reports (sports, financial) using structured data.

Reinforcement learning - A system performs a task by repeatedly running calculations as it attempts to accomplish a stated goal. It's a trial-and-error process, where rewards or penalties are earned in response to the system's performance toward achieving the stated goal. RL is used when there isn't enough training data, when the researcher is trying to learn about an environment (such as a complex financial portfolio) or when the researcher needs to find greater optimization levels.

Reinforcement Learning with Human Feedback (RLHF) - a technique for aligning LLMs with human intentions. It is based on training a reward model to mimic human feedback and intentions.

Super AI - Also known as artificial superintelligence, this is one of the three main types of AI.

Supervised learning - A model that attempts to transform one type of data into another type using labeled examples. Supervised learning is used when teams know how to classify the input data and what they are trying to predict but can get accurate results much more quickly by relying on an algorithm rather than a human.

Unsupervised learning - Data is provided to a model without specific output parameters, and the model tries to learn the data set's structure without any designated labels. For example, if a researcher doesn't know what to do with a large data set, an unsupervised learning model could determine patterns, classify data, and make recommendations without a human supervisor.

Web crawling - the process of using a program or script to index data on web pages. Web crawlers are also known as spiders, spider bots, or crawlers.