AI in Transportation

Iteris' Unique and Comprehensive Approach to AI is Enabling the Connected Transportation Network of the Future

AI WHITE PAPER

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iteris®

AI is Poised for Sweeping Impacts on Transportation

A Digitally-Enabled, Data-Driven Future

The transportation or mobility sector is undergoing an exciting transformation due to the adoption of cloud infrastructure, cellular vehicle-to-everything (C-V2X) communication, and connected and automated vehicles (CAVs). With its unique ability to process, analyze, and interpret massive data sets both in the cloud and "at the edge," artificial intelligence (AI) will be a key enabler of the connected transportation network of the future. Indeed, a compelling future approaches—one that is digitally-enabled and data-driven to enable safer, more predictable, and more sustainable transportation.

By analyzing very large data sets, AI can augment traditional systems to improve transportation efficiency, flow, safety, sustainability, and demand management. Because AI continuously learns and adapts, AI will also enable proactive transportation management and CAVs that are safer than today's vehicles.

Predictive Management Improves Public Safety

Due to its broad observations of everything from traffic speed and density to risky driver behavior and unsafe road conditions, AI will help transportation systems transition to proactive management from the usual reactive management—where organizations must wait for substantial data to accumulate only to then make decisions based on past events. Using a proactive approach, AI flips the script by predicting and preventing crashes, improving infrastructure utilization through real-time updates to drivers, and supplying data that streamlines the delivery of public services, road maintenance, travel time, and much more.

Contextual Awareness Makes CAVs Safer

The highest levels of self driving are SAE Level 4 (High) and SAE Level 5 (Full).[1] These levels will require automated vehicles to see what's around them—including objects that may be invisible to their in-vehicle sensors.

AI can provide this valuable extrasensory perception in combination with infrastructure-to-vehicle communication, where AI-enabled fixed sensors deployed in the connected transportation network can share their contextual awareness with vehicles in their proximity. Thus, AI-enabled communication will make automated vehicles safer than non-automated vehicles.

1. Shuttleworth, Jennifer, 2019. *SAE Standards News: J3016 Automated-driving Graphic Update* https://www.sae.org/news/2019/01/sae-updates-j3016-automated-driving-graphic

Transportation Technology Today

Siloed, Outdated, and Rigid

Although many of the next generation technologies essential to a connected transportation ecosystem already exist, the path to migrate from the legacy technologies that underpin today's mobility infrastructure is complex. Most of the current technology architectures, which infrastructure owner operators (i.e., state and local transportation agencies) use today, are siloed, outdated, and rigid. Additionally, a lack of cloud connectivity, data standardization, and technical interoperability create further obstacles to technology migration.

Lack of Integration Between Infrastructure and Vehicles

Due to Geographic Information System mapping software, many cities are nearly fully mapped, providing more information than ever on where people and goods are moving. However, mapping on its own won't eliminate accidents, as insights don't do any good if they can't drive action. This shift requires integration between the software used to manage roadway infrastructure and the software in vehicles, which is not the case today.

AI, in concert with sensing technologies and mapping software, will enable a cognitive model where observations lead to countermeasures, which lead to changes, which lead to actions. Already, AI has the potential to provide observations and recommendations to better manage traffic flow, erratic driving, physical obstacles, and more. These observations, when put into practice, will increase safety and efficiency for all road users, including drivers, cyclists, pedestrians, and others.

> We believe that AI can be a critical contributor to significant public benefit within the transportation sector, helping transportation stakeholders successfully achieve ambitious improvements to the way that transportation planning, operation and user experience are managed within the U.S.
>
> *— ITS America and Cambridge Consultants - The Impact of AI on Transportation and Mobility, December 2023*

Limited Insights Limit Action

Many of the vision sensors in use today can detect the number of vehicles on the road, but not the type. While they can distinguish among cars, pedestrians, and bicycles, they can't distinguish among buses, heavy trucks, and emergency vehicles. This lack of fidelity limits the potential benefits of certain vision-based sensors.

Additionally, legacy sensors observe traffic only within pre-defined boundaries, requiring users to draw zones around the areas they want to detect, but these boundaries limit the scope of decision-making, and preclude holistic, predictive observations. Similarly, anonymized geolocation information that is collected from smart devices (i.e., probe data) is only observational and often outdated within seconds.

These limitations force traffic engineers to rely on traffic theories instead of actionable, real-world data when it comes to planning and design. This leads to reactive choices rather than predictive or preventive decision-making, which is the ideal approach to reducing speeding and increasing safety.

Messy Data Sets Add to the Confusion

Mobility data sets (e.g., sensor, vehicle, probe, and other geospatial data sets) often lack standard data definitions, attributes, formats, and metadata. Additionally, it is common to find significant variations in data quality, time series, and collection techniques. Even within a single organization, the methodologies for mobility data collection, processing, and storage may vary among different departments.

It is essential to apply supervised training of AI tools against relevant, comprehensive mobility data sets to construct an AI model with useful performance and accuracy. Likewise, it is essential to apply the resulting AI models against validated mobility data sets to generate meaningful insights and recommendations. Therefore, a holistic data strategy is critical to the successful use of AI for mobility infrastructure management.

Iteris takes a Unique, Comprehensive Approach to AI

Iteris offers a comprehensive, integrated approach to AI that leverages the Iteris ClearMobility® Platform—a smart mobility infrastructure management ecosystem based on a distributed open architecture that operates in conjunction with a broad range of data sources and devices. Unlike various point solutions that dot the mobility infrastructure market, the ClearMobility Platform incorporates smart sensors, services, and applications—all of which are supported by cloud infrastructure, microservices, open application programming interfaces (APIs), and a proprietary mobility data processing engine. Every day, the ClearMobility Platform ingests, enriches, aggregates, and validates terabytes of mobility data from smart devices, connected vehicles, public agency systems, third-party sensors, and Iteris' own smart sensors.

The ClearMobility Platform Offers a Multi-layered Approach to AI

Iteris applies AI tools including machine learning (ML), an application of AI that frequently utilizes neural networks, across multiple levels of its ecosystem as presented in Figure 1 on the following page.

For example, Iteris utilizes AI within individual vision sensors (i.e., at the edge) to perform critical localized tasks and enrich the data collected by these sensors. This data is used to run analyses that enhance the effectiveness of tasks such as signal timing and predictive action by providing real-time information.

With third-party Internet of Things (IoT) devices and Iteris sensors connected to the ClearMobility Platform, all data is published to the cloud, where Iteris uses other forms of AI to better identify and classify objects. Then, with this further enriched data, Iteris applies AI to continuously monitor, visualize, and optimize mobility infrastructure.

Using this approach, data sets that come back from IoT devices and other sources can be overlaid on top of historical data sets, where Iteris can run AI against this combination of data in the cloud. Thus, a combination of Convolutional Neural Networks (CNNs) based on real-time visual data and Recurrent Neural Networks (RNNs) based on historical data analysis can enable the ClearMobility Platform to perform predictive analysis.

These advanced techniques are bolstered by Iteris' deep domain knowledge and pervasive infrastructure data sets, as larger data sets allow AI to provide more in-depth insights.

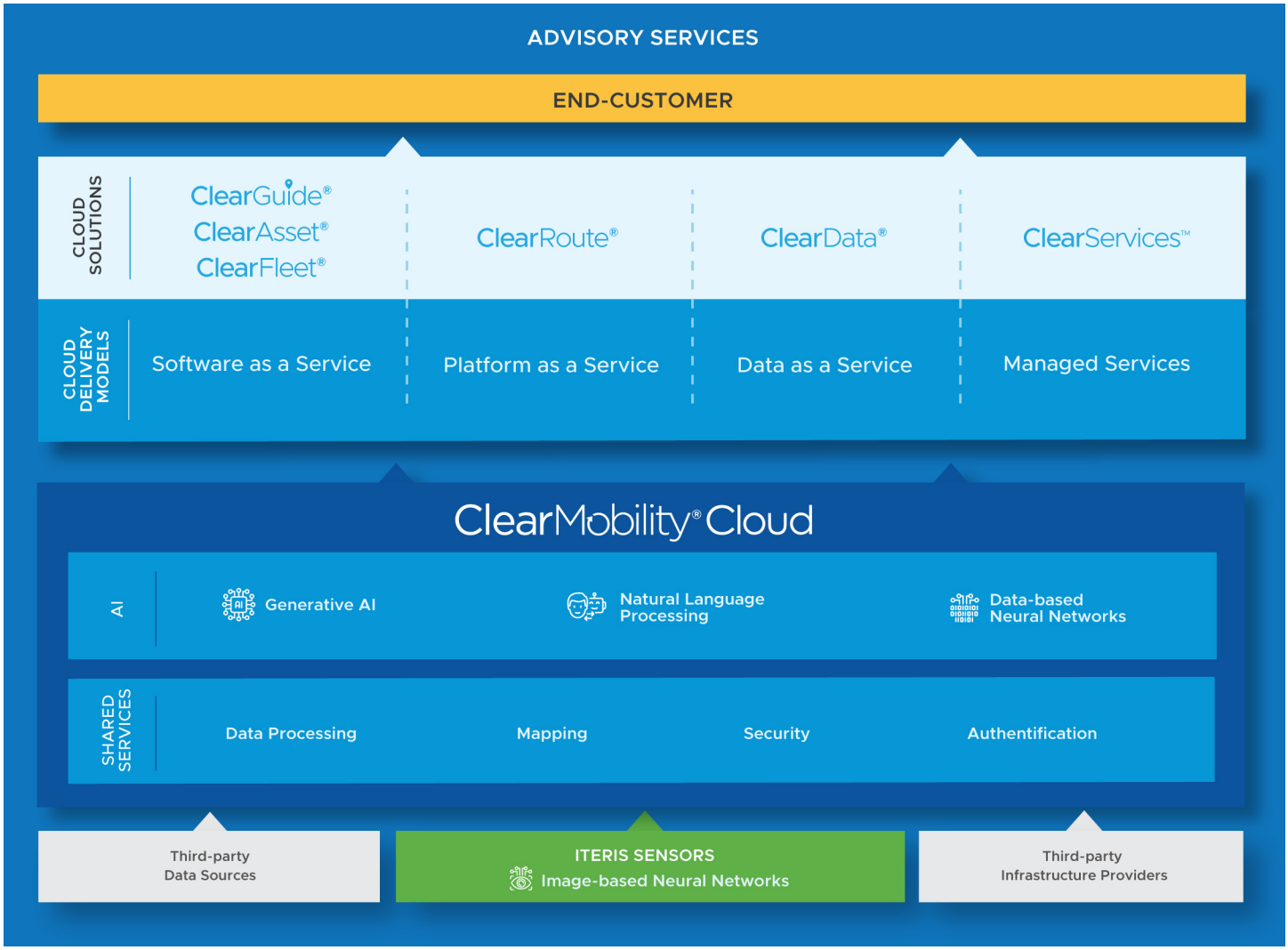
Iteris focuses on three important forms of vision-based and data-based neural networks

Convolutional Neural Networks (CNNs) are specialized neural networks suited for analyzing visual data. CNNs are commonly used for tasks like image and video recognition, which are crucial in traffic management (e.g., identifying the types of vehicles on the road).

Recurrent Neural Networks (RNNs) are designed for handling sequences of data, making them ideal for tasks that involve time series data like traffic patterns over time. RNNs can be used to predict traffic jams or to optimize traffic signal timings based on historical data.

Transformer Architecture is a deep learning framework that utilizes advanced mechanisms to focus on different parts of the input data simultaneously and to understand the relationships among the data. As a result, it offers certain performance advantages to RNNs, when analyzing massive time series data sets.

Figure 1: Iteris ClearMobility Platform



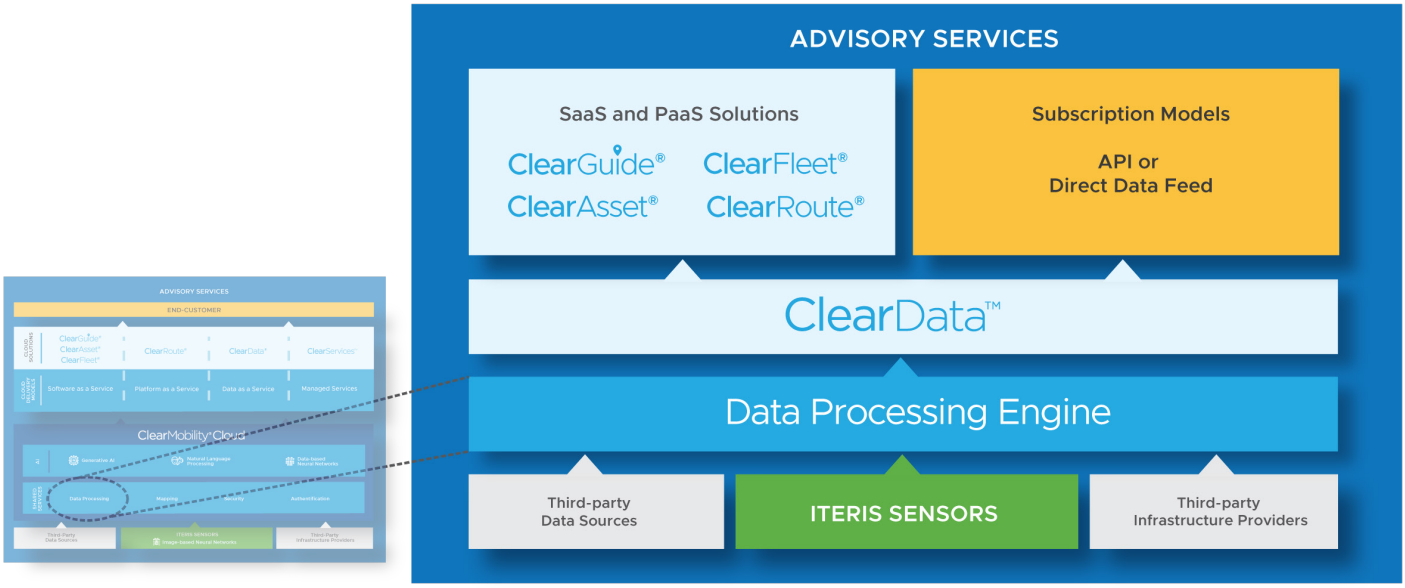
Sophisticated AI Techniques Differentiate ClearData

ClearData® is the enhanced mobility data output of the ClearMobility Platform's data processing engine, which aggregates and validates proprietary and third-party mobility data. This uniquely curated mobility data is sourced from public agencies, media partners, verified crowd-sourced data, mobile applications, GPS devices, and Bluetooth and roadside sensors.

As presented in Figure 2 on the following page, the data processing engine can use ML and natural language processing to standardize ClearData according to international norms. The data processing engine can also use data-based neural networks to translate GPS probe points into actual traffic volume, and accurate, real-time travel time estimates—a benefit for transportation companies and the traveling public alike.

Iteris bundles ClearData with its software-as-a-service, platform-as-a-service, and managed services offers. Alternatively, public and private-sector customers can consume ClearData on a data-as-a-service basis via data feeds or APIs for use with various internal systems. With either approach, customers can subscribe to ClearData by distinct geographic regions (e.g., states or portions of large states), or by type of roadway, such as highways, large arterial roads, or local roads.

Figure 2: Iteris' Proprietary Data Processing Engine is a Critical Element of the ClearMobility Platform



Vantage Apex Sets the New Standard for Use of AI at the Edge

Iteris' Vantage Apex® is the industry's first full 1080p high-definition (HD) video and 4D/HD radar hybrid sensor with integrated AI algorithms. Vantage Apex's AI algorithms use neural networks and extensive, proprietary image libraries to provide precise and detailed traffic detection, tracking, and classification. Due to this unique AI-enabled capability, Vantage Apex offers special advantages, such as distinguishing vehicle types and providing insights into the entire intersection, as opposed to just a limited, selected view. Using proactive real-time information, the system is able to infer more activities and potential incidents at intersections than traditional detection sensors.

Additionally, Vantage Apex will be able to render a digital twin representing the trajectory of objects at the intersection, making it possible to share geolocation and other related information at scale, in near-real time. Furthermore, Vantage Apex will be able to distinguish vehicles for vehicle prioritization.

Vantage Apex is truly predictive

Using AI and ML, the Vantage Apex sensor is capable of adjusting traffic signal phases in real time. Industry experts, who study AI and traffic signal optimization, have concluded this is the most effective form of detection.[2]

Additionally, Iteris' Vantage Apex uses AI to detect when a vehicle, within a trip line at an intersection, will not stop for the red light. The sensor then alerts the traffic signal controller to extend the opposing red light until the speeding vehicle is safely through the intersection. The offending vehicle's signal also remains red, allowing for drivers to be ticketed while T-bone collision risk is virtually eliminated.

In operation with a roadside unit, Vantage Apex can then send an alert to a connected vehicle's onboard unit that a red-light runner is approaching the vehicle. Thus, the automated real-time signal adjustments and vehicle communications enabled by Vantage Apex can drastically reduce crashes caused by red-light running.

A 2019 AAA survey reported that 31% of drivers admitted to running a red light within the last 30 days.[3] This is one reason red-light running deaths recently hit a 10-year high.

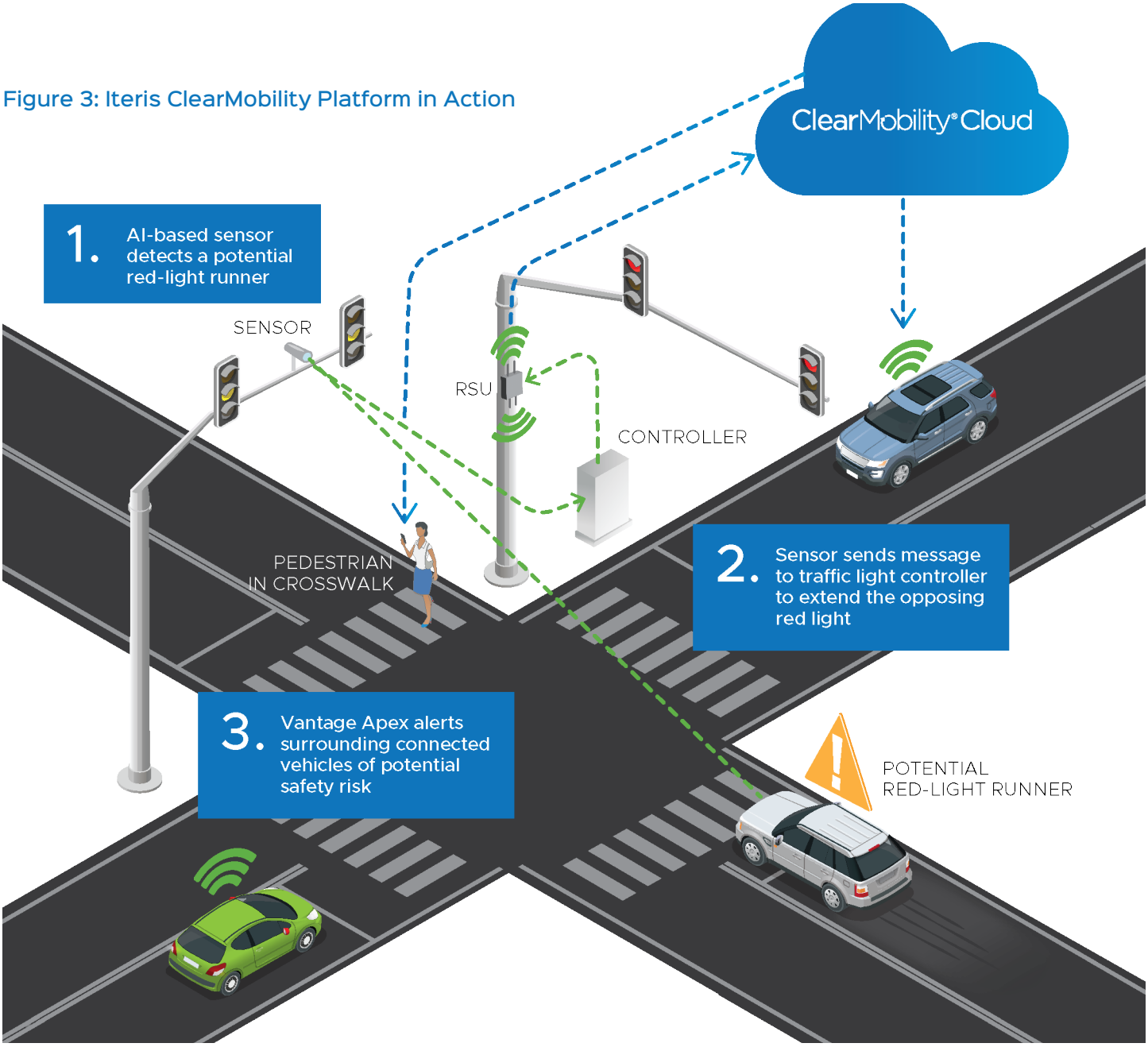
2. Ault, James, 2021. *Reinforcement Learning Benchmarks for Traffic Signal Control* https://people.engr.tamu.edu/guni/pistar/Papers/NeurIPS-signals.pdf
3. Gross, Andrew, 2019. *Red Light Running Deaths Hit 10 Year High* https://newsroom.aaa.com/2019/08/red-light-running-deaths-hit-10-year-high/

The ClearMobility Platform's Comprehensive Approach to AI Enables Contextual Awareness

To respond to other vehicles that may not obey traffic rules or may be responding to emergencies, automated (or self-driving) vehicles need to be aware of their surroundings—including objects up to 600 feet away. However, current in-vehicle sensors struggle with far-field and angled vision, and existing self-driving algorithms are not sufficiently developed to provide the vehicle with comprehensive situational awareness. Additionally, it is impractical to equip every vehicle with enough sensors to fully capture the realm of external factors that could impact its path.

As presented in Figure 3, the ClearMobility Platform shares infrastructure-level insights to augment the awareness of CAVs. With a four-sensor system at intersections, for example, vision-based intersection detection systems can publish information to CAVs about objects up to 600 feet away and at 90-degree angles. Thus, these AI-equipped fixed sensors can warn automated vehicles of potential risks, like an oncoming car that can't stop, or a cross-traffic vehicle invisible to the driver due to occlusion from another object, such as a truck in a closer lane blocking the driver's vision.

Figure 3: Iteris ClearMobility Platform in Action



ClearGuide is the Industry's Leading Mobility Intelligence Software

While Iteris roadway sensors such as Vantage Apex utilize integrated AI algorithms for precise detection and classification at the edge, Iteris' ClearGuide® software leverages AI performed in the cloud to analyze large amounts of complex transportation data that help agencies and commercial entities make smart, data-driven decisions. Table 1 below presents common use cases for ClearGuide.

As the industry's leading mobility intelligence software, ClearGuide can use AI and ML to identify patterns and trends, resulting in detailed insights related to traffic flow, congestion, and safety. The majority of ClearGuide's predictive features are available without any dependence on field hardware; however, ClearGuide can also interface with signal controllers for advanced intersection-level analysis.

Table 1: Example ClearGuide Use Cases

Use Case	Description
Traffic Prediction and Management	• **Advanced Machine Learning Algorithms** can leverage historical data, real-time observations, and even external factors like weather conditions to make accurate predictions about traffic patterns, congestion, and intersection safety. • **Predictive Work Zones** allow the system to forecast the impact of a work zone on traffic flow and safety, helping both governmental agencies and construction companies to pre-emptively manage resources and reduce risks. • **Traffic Bottleneck Prediction** identifies areas where traffic congestion and queues are likely to occur, providing valuable insights for both routine traffic management and specific use cases like work zones.
Resource Allocation and Planning	• **Time and Space Granularity** provides both short-term and long-term forecasts and can target specific areas, whether it's an entire region or a single traffic route. This granular level of detail is invaluable for more precise resource allocation and operational planning. • **Volume Estimation** is able to use machine learning models to estimate traffic volume in places where direct detection isn't feasible. It uses a combination of other information sources—data points collected directly from vehicles, toll booths, count stations, or weigh stations—as training data to extrapolate real-world traffic conditions across the network, effectively providing a form of virtual detection.
Safety Enhancement	• **Predictive Safety Features** focus on predictive analytics related to speeding behavior in work zones and at intersections, enabling agencies to proactively take countermeasures like signal adjustments or even deploying extra safety equipment based on predictions of emerging crash trends before incidents occur, all while using existing infrastructure. • **Pedestrian Conflict Detection** complements predictive analytics by allowing agencies to implement countermeasures based on real-time and predictive data. For example, where the ClearGuide signal performance measures module identifies that right-turning vehicles frequently conflict with pedestrians, agencies can set up Leading Pedestrian Intervals from within the software, a feature giving pedestrians 3 to 7 seconds of walk sign before the turning vehicle receives the green signal.

AI-Powered Solution, ClearAsset, Manages IoT for Mobility Infrastructure

With large and growing numbers of IoT and other electronic devices deployed throughout the nation's transportation infrastructure, maintenance of these devices is increasingly critical. Therefore, ClearAsset® is designed to help transportation agencies track and maintain both IoT and other electronic equipment in the warehouse or field, conduct device lifecycle analysis, and monitor equipment performance over time. By improving preventive maintenance, the solution improves device uptime for better overall operations.

ClearAsset utilizes AI to assist with asset management. For example, ClearAsset applies AI to predict device lifespan and reliability, identify visual and other obstructions, and initiate device self-maintenance.

The potential for self-maintenance, which will leverage both AI and robotics, is particularly important given the increasing ubiquity of roadside sensors. An example of self-maintenance which is technically feasible today includes the use of drone-based cleaning mechanisms triggered by AI to clean video sensor devices.

Leveraging AI for Smarter Mobility Infrastructure Management

Iteris is at the forefront of using AI for Smart Mobility Infrastucture Management. The ClearMobility Platform, with its broad ecosystem integration, is the most comprehensive approach to enabling the AI-powered connected transportation network of the future.

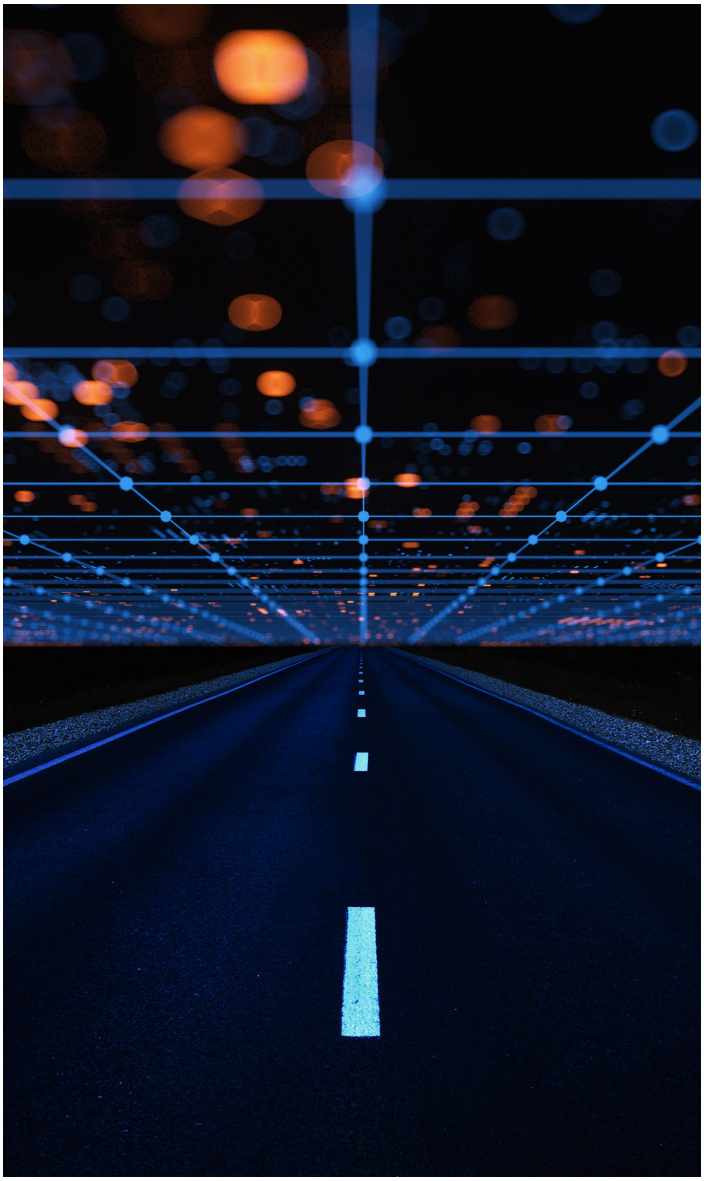
The ClearMobility Platform is designed for public-agency and commercial customers to seamlessly integrate applications and actionable mobility data, as well as automate much of the workflow incorporating, analyzing, and visualizing that data. Thus, Iteris' AI and ML research and development continuously improves not only transportation safety, efficiency, and sustainability, but unlocks transportation funding and streamlines transportation operations.

Simple to manage and easy to use, the AI-powered ClearMobility Platform provides access to a borderless universe of historical and real-time data that is validated, standardized, and actionable. This uniquely curated data set is aggregated from a diverse set of essential sources, including signal controllers, Iteris sensors, CAVs, GPS, Bluetooth, agency systems, and third-party providers.

Leveraging a unique combination of deep domain and data science expertise, Iteris applies the most appropriate forms of AI at both the edge and in the cloud to generate superior insights and recommendations. Iteris continues to expand this holistic, multi-layered, end-to-end use of AI across all aspects of its smart mobility infrastructure management ecosystem. As a result, Iteris is the leading provider of comprehensive and relevant solutions that make mobility safer, more efficient, and sustainable for everyone.

About Iteris

Iteris is the world's trusted technology ecosystem for smart mobility infrastructure management. Delivered through Iteris' ClearMobility® Platform, our AI-powered end-to-end solutions monitor, visualize, and optimize mobility infrastructure around the world, and help bridge legacy technology silos to unlock the future of transportation. That's why more than 10,000 public agencies and private-sector enterprises focused on mobility rely on Iteris every day. Visit www.iteris.com for more information.



Legal Mentions

Statements in this White Paper that refer to future plans or expectations are forward-looking statements. These statements are based on current expectations and involve many risks and uncertainties that could cause actual results to differ materially from those expressed or implied in such statements. Further information on Iteris, Inc., including additional risk factors that may affect our forward-looking statements, as contained in our Annual Report on Form 10-K, our Quarterly Reports on Form 10-Q, our Current Reports on Form 8-K, and our other SEC filings are available through the SEC's website (www.sec.gov).

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