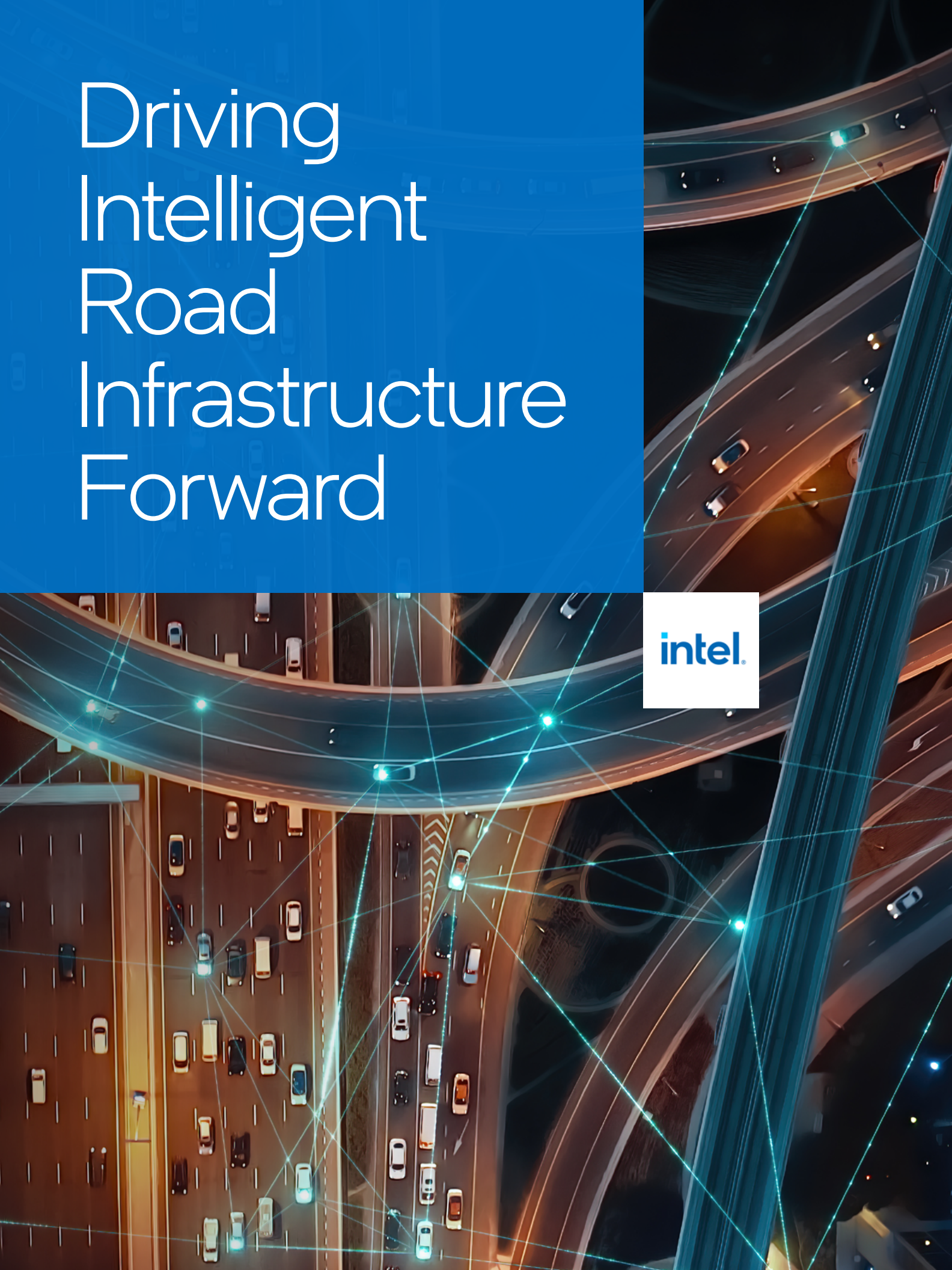
Driving Intelligent Road Infrastructure Forward



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"Investment in cities, transportation, and related national infrastructure has become a competitive imperative for cities across the globe. Intel has been bringing not only smart city technologies and solutions to market but also working closely with our ecosystem as a trusted advisor to cities. We have been implementing disruptive Edge AI and video-based offerings to solve challenges in safety & security, livability, pervasive connectivity, digitization of infrastructure, sustainability, and mobility."

Renu Navale

VICE PRESIDENT, NETWORK & EDGE GROUP, GENERAL MANAGER, VIDEO & AI CITIES TRANSPORTATION, INTEL® CORPORATION

"The last 50 years have been about focusing on investments in physical infrastructure: resurfacing roads, widening roads, upgrading bridges. While it's absolutely critical to invest in physical infrastructure, we also need to invest significantly in the digital layer: in sensors, in software code, in computing, in data sharing networks, because if we don't have this solid layer of digital infrastructure, we cannot adapt our transport systems for the future. We are quickly maxing out road space, when we can't create more lanes, we must use space more efficiently. The digital layer does that."

Laura Demeo Chace

PRESIDENT & CEO, INTELLIGENT TRANSPORTATION SOCIETY OF AMERICA

Overview

Infrastructure is undergoing a period of transformation: government investment in infrastructure has increased by an order of magnitude, artificial intelligence has taken over headlines and electric vehicles have continued to take market share from internal combustion engine (ICE) vehicles. What hasn't changed is the need for digital infrastructure to support economic, safety and sustainability objectives for transportation systems. More people die in transportation-related accidents today than a decade ago, time and money are wasted on needless traffic congestion, and pollution from transportation activities now accounts for more than 20% of global greenhouse gas emissions. All of these challenges present an opportunity for digital solutions that combine sensors, networks, software, and artificial intelligence to create the New Infrastructure of the future. This guide expands on the challenges and opportunities key stakeholders face and offers technologies and solutions that can enable truly intelligent, safe and optimized transportation systems.

In the coming decades, global population growth will surpass nine billion.[1] Addressing this growth is crucial. However, traditional mobility solutions lead to congestion and environmental pollution.

Forward-thinking leaders recognize that artificial intelligence (AI) at the edge and connectivity is crucial for a cleaner, safer, and more inclusive future for mobility. As physical and digital environments come together, AI and edge solutions can propel enterprises to make better-informed decisions quickly. AI at the edge is unlocking greater business value by handling routine tasks so enterprises can focus on critical thinking activities.

By 2050, over 60% of the world's population will live in urban areas, pressuring city and transportation leaders to combat environmental issues.[2] Major cities consume most of the world's energy and emit the majority of greenhouse gases.[3] Evolving emissions standards and edge technologies will demand investment in edge computing, 5G, and traffic management. Globally, transportation authorities are adopting e-tolling and exploring new monetization models.

Intel and its partners drive innovation through Intelligent Transportation Systems, leveraging high-performance edge-to-cloud computing, cameras, and AI for real-time insights and traffic flow improvements. This data contributes to safer, greener, and more intelligent cities.

This eBook guides city and transportation leaders in using AI at the edge to transition from reactive to proactive measures, addressing road infrastructure issues before they become major problems and safety hazards. With hardware, software, and AI together at the edge, Intel helps modernize road infrastructure. Intel technologies can address current challenges and help build a more resilient and safer future, enhancing the quality of life for all citizens.

Challenges

The rising number of vehicles on roads, coupled with deteriorating or inadequate infrastructure, presents significant challenges in terms of traffic congestion, infrastructure management, and road safety. Cities with a forward-thinking approach are proactively addressing the ongoing surge in vehicular traffic, anticipating potential impacts on city services, and ultimately aiming to safeguard and enhance the quality of life for residents.

Urban areas collect massive volumes of data on transportation patterns and infrastructure daily. In a smart city, IoT sensors can be installed in roadbeds to connect to smart streetlights, optimizing energy efficiency while delivering real-time data to edge servers that can be used to reduce traffic congestion or improve safety. Deploying integrated hardware and software solutions across diverse urban environments enables cities to resolve challenges and improve services.

The U.S. has 17 million center-line miles of roads. From 2000 through 2016, the U.S. built an average of 30,427 lane miles of roadway per year.[19] At this pace, it will take 180 years to increase the U.S. land mass covered by roads to even 1 percent.

Urbanization Presents Challenges to Safe Mobility

Safety

Road traffic crashes result in the deaths of approximately 1.19 million people around the world each year and leave between 20 and 50 million people with non-fatal injuries.[4] More than half of all road traffic deaths and injuries involve vulnerable road users (VRU), such as pedestrians, cyclists, and motorcyclists and their passengers.[5] An analysis of data reported by

State Highway Safety Offices (SHSOs) projects that 7,508 pedestrians were killed on U.S. roads in 2022, a 77% increase since 2010.[6] A number of factors may be influencing the rise in pedestrian deaths, including speed, alcohol involvement, light condition, smartphone use while driving, an increasing number of large SUVs, and roadway factors.[7]

Environmental Impact

The high volume of vehicle ownership, coupled with outdated urban planning from the 20th century or earlier, has created massive pressure on the roadway infrastructure. Newer cities often have roadmaps based on horse-drawn carriage or automobile-only models that have not easily accommodated modern public transportation or pedestrians, leading to higher rates of traffic congestion, fatalities, and injuries.[8] Internet-enabled transit business models like food and parcel delivery and ridesharing are clogging many city streets as cars orbit previously quiet neighborhoods, taking up parking spaces and causing pollution by idling. Slow-moving traffic also increases the volume of microscopic particulate matter, affecting the health of drivers and pedestrians on the streets.

Traffic congestion wastes billions of hours and billions of gallons of fuel annually. Researchers found that nearly 7% of any car ride was spent waiting at traffic crossings and intersections.[9] City budgets do not support the upfront capital needed to deploy a city-wide solution. Fortunately, federal governments are recognizing this gap and trying to fill it.

Today's cities account for between 71 and 76 percent of carbon dioxide emissions and between 67 and 76 percent of global energy use.[10] Private cars are responsible for 60 percent of transport-related emissions, even though they account for only one-third of total urban travel.[11] Despite the environmental toll of private cars, only half of the world's urban population has convenient access to public transport.[12]

Emissions targets are tightening for all countries and electric vehicles (EVs) are becoming increasingly attractive to consumers and enterprises. For wide adoption of EVs, governments must invest in efficient incentives and technologies like EV charging standardization, grid modernization, and electrical metering. Europe's stringent constraints on air pollution have forced some cities to close roads (at least temporarily), re-route traffic, and limit access to certain neighborhoods because of elevated carbon dioxide and nitrogen oxide emissions.

Improving traffic flow and reducing congestion are known to alleviate this problem. Mayors of "C40" cities have already pledged to use only emission-free buses starting in 2025 and that by 2030, a significant area of their cities will be emission-free.[13]

Economic Loss

Many transportation providers today rely on independent point solutions and equipment intended to last several decades. However, technologies have historically been deployed in a "siloed" approach, in which individual departments built individual applications, without broader cross-department coordination for sharing costs, infrastructure, and data across local, regional, or national levels. The result can be expensive redundancies and unnecessary difficulties in coordinating between those isolated applications. This approach is the result of short-term financial constraints, as cities tackle challenges in a piecemeal fashion. Cities may face additional technology complexity related to interoperability lock-ins, open data sources, network coverage/capacity, and cybersecurity. Standards and governance, lack of interagency collaboration, and talent shortages also challenge implementation plans.

In addition to the costs of maintenance and upgrades, traffic congestion wastes billions of hours and billions of gallons of fuel annually. City budgets do not support the upfront capital needed to deploy a city-wide solution. Fortunately, federal governments are recognizing this gap and trying to fill it.

Opportunities

The global population has grown from three billion in 1960 to 8.1 billion today. Much of the world's existing infrastructure was not built for this population density and needs upgrades, expansion, and modernization to alleviate the pressures of today's road transportation challenges. Modern infrastructure, or the New Infrastructure, combines physical infrastructure with digital technologies to deliver sustainable, efficient environments that enhance the safety, efficiency, and environmental performance of transportation systems.

Leveraging AI also becomes very important for different use cases like integrated traffic management to enable traffic signal syncing, open parking space detection, faster accident response times, more accurate mass transit scheduling, and better urban planning.

Government Investment is Spurring Innovation Globally

There will be more than $6 trillion in infrastructure spending globally in the next 10 years, including:

- **US:** $1.2 trillion from the Infrastructure Investment & Jobs Act for upgrading transportation and critical infrastructure
- **EU:** $1 trillion from the Green Deal Investment Plan
- **China:** $1.1 trillion for transportation and critical infrastructure
- **India:** $1.2 trillion from Gati Shakti for transportation, connectivity and technology
- **Saudia Arabia:** $1 trillion from 2030 Vision for Infrastructure

Safety

Improving Traffic Safety

Cities worldwide are planning for Vision Zero, a multi-national road traffic safety project that aims to achieve a highway system without fatalities or serious injuries involving road traffic. When data from vehicles, pedestrians, and roadside infrastructure converges, the factors that cause roadway accidents can be reduced or even eliminated. As an ethics-based approach, Vision Zero emphasizes that responsibility for safety is shared by the transportation system designers, operators, and road users alike.

Buses and vehicles with collision avoidance systems can assist drivers in preventing or mitigating collisions by warning them of potential dangers before the collision occurs. These systems include AI-enabled features that provide pedestrian and cyclist collision warnings ahead and in the blind spots of the vehicle, forward collision warning, lane departure warning, headway monitoring and warning, and speed limit recognition. Usually, these are limited by the field of view of the in-vehicle sensors. Making a more comprehensive field of view available through sensors in the infrastructure that share their data via V2X (vehicle-to-everything) communication protocols will make collision avoidance safety solutions more effective.

Ideally, data collected at the edge from physical infrastructure is fused in a unified edge-to-cloud AI fabric to create a comprehensive digital twin of the roads and traffic, which is then made available to all road users. As a result, the likelihood of accidents due to occlusions or limited field-of-view will be significantly reduced. For example, a central safety

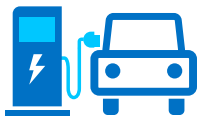
module enabled by AI can monitor and issue real-time warnings for drivers, cyclists, or motorcyclists. It is even possible to alleviate dangerous situations up front by giving a green light to a bicycle lane while providing a red light to all intersecting vehicle lanes. This could also lead to safer passage for pedestrians possibly without the use of traffic lights because all traffic participants receive the necessary information from the digital twin.

The implementation of V2X technologies, including Roadside Units (RSUs), provides tangible results in safety and efficiency. In the U.S. alone, the expected impact of RSU-enabled and V2X safety applications, such as Vulnerable Road User (VRU) Detection, Intersection Movement Assist (IMA), and Left Turn Assist (LTA), could prevent up to 615,000 crashes, saving more than 1,300 lives and over $70 billion in associated costs.

Machine learning and AI can predict traffic hot spots at a given time of the day and optimize traffic management systems through traffic light phasing and driver re-routing to avoid traffic congestion along a corridor. AI-enabled traffic signals at the edge can help reduce air pollution by keeping traffic moving. By capturing and consolidating data, cities can expand their traffic monitoring and incident prevention capabilities, improving public safety by reducing the number of accidents/incidents and increasing response times.

Environmental Impact

EV Charging



The proliferation of electric vehicles (EVs) has created a need for charging units at filling stations, parking lots, and on streets. A typical EV has a range of approximately 150 km (90 miles), which requires drivers to recharge often. Standard residential charging systems can take up to eight hours for a full charge, while new fast-charging systems can recharge a vehicle in 15 to 20 minutes. Networks of fast-charging stations are already being deployed countrywide in Belgium and Estonia. The MEC and 4G/5G cellular network would help to provide EV charging as a mobility as a service (MaaS) feature with reservation and billing capabilities. Intel processing, workload consolidation, and AI platforms enable next-gen Level 3+ EV Charging/ Type 3 DC Fast Chargers.

In urban landscapes where EV charging spots are limited, efficient usage is paramount. Unauthorized vehicles occupying these spots pose a significant challenge. Advanced machine vision and AI algorithms are crucial to accurately identify violations, ensuring EV-exclusive usage. By maximizing spot efficiency, these technologies enhance accessibility and streamline existing infrastructures.

These chargers also provide a seamless customer charging experience with an AI-driven approach. Volta charging stations present dynamic, interactive content, interactive kiosks, and shopping experiences while waiting for vehicles to be charged. This not only provides vehicle support and promotes sustainability but also helps to generate new revenue streams.

Maintaining Road Asset and Pavement Conditions

Roadside data crowdsourcing powered by computer vision and AI is a significant improvement over traditional and manual surveys. Visual sensors, equipped with edge computing and AI, can survey thousands of miles of road and compile a dynamic view of the city's asset inventory and pavement conditions. This non-intrusive data capture technology can also be used to create a digital twin of physical infrastructure. Cities can receive Geographic Information System (GIS) data and change detection information on a monthly basis instead of once every couple of years. This technology can allow city or transportation leaders to improve frequency and amount of maintenance based on changing conditions. The crowdsourcing could be customized for providing targeted advertisements, additional services, law enforcement, etc.

Economic Impact

Enhancng Traffic Management

Intelligent traffic management helps cities address road safety and congestion by using smart cameras in conjunction with AI-enabled data at the edge to optimize traffic flows and quickly detect dangerous situations or incidents as they happen. With capabilities including near real-time traffic information and AI and optimization, traffic monitoring captures important traffic data, such as vehicle count and speeds, cyclists, pedestrians, and objects potentially blocking the roadway. Data from intelligent cameras and AI can help alleviate congestion by identifying incidents in near real-time and notifying responders quickly to better manage the situation. Authorities can also prioritize ambulances, police cars, fire engines, and other responders to avoid traffic delays, help save lives, and reduce loss of property.

Traffic management increasingly targets new transportation modes or ways to optimally share public space. On one side, a stronger focus is put on environmentally friendly modes of transportation by dedicating more space to bicycles or electric shuttles. Some cities are already planning bicycle expressways or car-free zones in the central districts. On the other side, new modes of people transport are constantly on the rise. Future traffic management needs to integrate multi-modal travel including car sharing, electric scooter rental, robo-taxis, and automated buses. This approach also helps to address access to areas that cannot be reached easily by traditional public transport modes.

In today's hypercompetitive environment, the ability to operate with speed is just as crucial as innovation, and companies must put AI at the edge to keep pace. By eliminating the delays and bandwidth costs of cloud-based processing, Edge AI automates decision-making, creating "self-healing" systems that help circumvent talent shortages, brittle supply chains, and strict regulatory laws. It also opens up net-new revenue streams, enabling organizations to act on highly-regulated data by keeping it secure at the edge. Gartner expects that by 2026, at least 50% of edge computing deployments will involve machine learning.

As computing power is pushed from the cloud to the edge, new opportunities arise for edge workloads that benefit from low latency, near real-time analysis, and connectivity. Traffic monitoring, roadside sensors (camera, Lidar, Radar, etc.), Intelligent Traffic Signal Management (ITSM), connectivity (4G/5G, V2X), computer vision, and AI technologies can be combined to improve safety and optimize traffic efficiency and citizen experiences at intersections.

In addition, they can help protect vulnerable pedestrians and cyclists by detecting objects and abnormalities and warning them well ahead of the danger.

Forward-looking cities are already combining AI, open data platforms, and high-performance networking to enable smart mobility through pervasive and predictive monitoring to optimize traffic flows, reduce incident response times, and facilitate multi-modal transit. For example, Bangkok uses the Cubic GRIDSMART System for Traffic Management, which provides real-time data to manage the timing of traffic lights and improve intersection efficiency and safety.

Streamlining Electronic Toll Collection

Electronic Toll Collections (ETC) systems collect tolls electronically and help manage road usage and congestion, enabling cities to keep up with changing traffic conditions, natural disaster evacuation facilitation, and extreme weather while generating revenue for much-needed infrastructure improvements. Control point ETC systems base the toll on passing control points like toll gates or toll booths. Continuous location tracking ETC systems toll based on monitoring the path of vehicles as they drive through the tolling area/highway. Electronic tolling leverages edge computing, networking (4G/5G), cloud connectivity, and AI technologies. With many ETC solutions, drivers can continue at highway speeds through the toll gate without having to stop or slow down. ETC solutions can be categorized by tolling method or technology used.

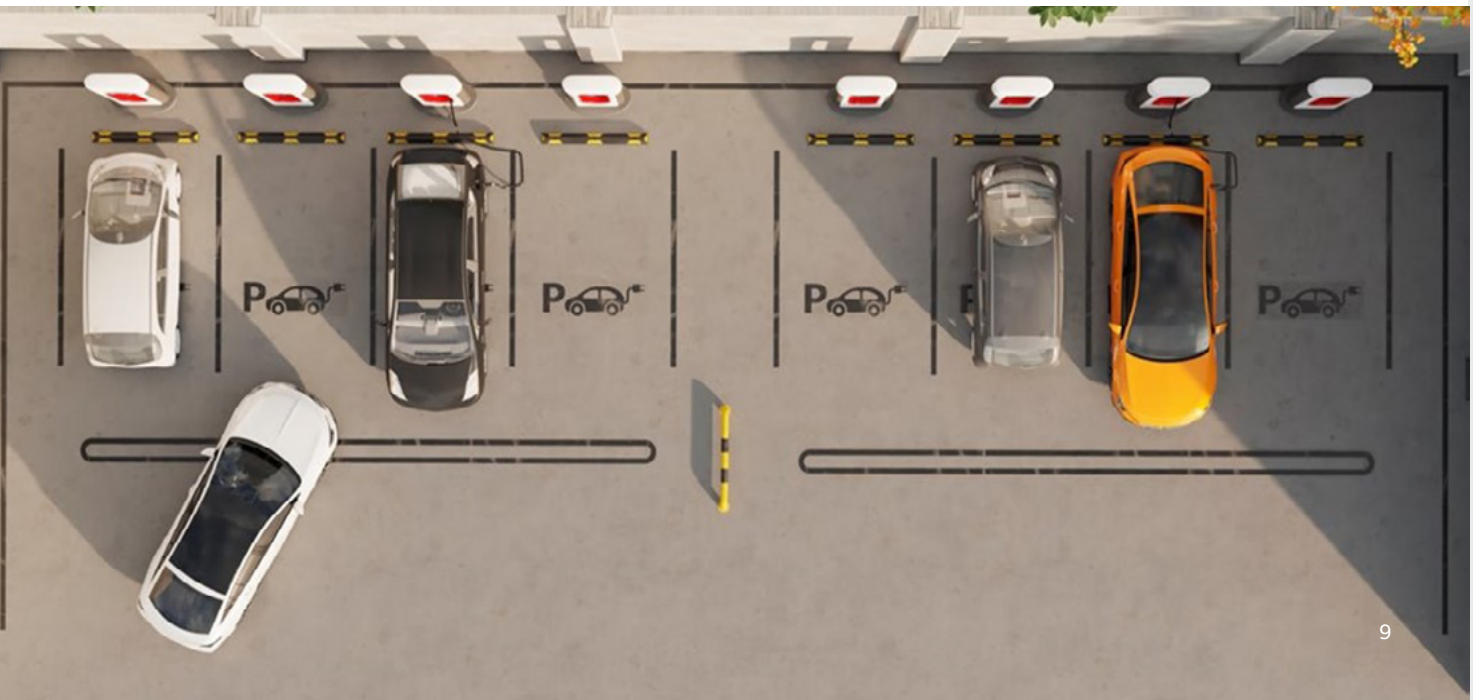
There are three main categories of tolling use cases:

- **Highway Tolling:** This includes both traditional tolling at plazas/toll gates and unrestricted, multi-lane, free-flow solutions.
- **Urban Tolling:** This is typically related to congestion or clean air zones aimed at restricting traffic in the most congested or high-pollution areas.
- **Area Tolling:** General per kilometer charge or tax independent of type of road or location. This type of ETC can only be implemented via continuous tracking technologies based on global navigation satellite system (GNSS) and wide-area connectivity such as cellular and satellite.

From a technology solution point of view, there are several possibilities for ETC deployment configurations. In a Radio Frequency ID (RFID) configuration, RFID readers can be installed at the toll gate or booth, and each vehicle needs to be equipped with an RFID card in an accessible place, such as behind the windshield. In a V2X configuration, both the roadside and vehicle side have V2X communication modules installed and can communicate to process the tolling transaction. In a video recognition configuration, only the infrastructure side needs to install video capture devices and video recognition software to identify and track vehicles based on license plate information.

Reducing Congestion through Smart Parking and Congestion Pricing

Smart parking solutions that monitor parking availability and guide drivers to available parking spots help to reduce traffic congestion, too. Intersection computing infrastructure can also be utilized to deploy 4G/5G small cells with direct ad side links and multi-access edge computing (MEC) to deploy value-added edge applications such as targeted advertising and parking. All of these workloads can be consolidated to a single edge server which in turn lowers the total cost of ownership (TCO) for the transportation authority and reduces the complexity of managing individual use cases/solutions. Furthermore, the free space in the city can be used more efficiently for parking. Rules for where parking is allowed can be adapted in real time making more space that is currently permanently blocked for parking available dynamically.



Technology Summary

Visionary transportation leaders can simplify the path to safer, more efficient, and connected road infrastructure with an end-to-end transportation solution based on Intel technology. Intel powers every segment of the smart, connected world, from the device to the network to the cloud. Intel technologies and the vast ecosystem of partners and solutions create a more vibrant, extensible, and sustainable way for transportation and city leaders to implement intelligent transportation strategies. Additionally, Intel helps to protect connected systems from the inside out with a foundation of security technologies designed to protect the entire device stack against a wide range of attacks.

Intelligent Transportation Systems require high-capacity, high-reliability, and low-latency, with some applications requiring greater levels of privacy when storing data locally. In addition, various services will require more compute and intelligence closer to the endpoint devices that are both generating and consuming data at the edge. Hence industry leaders are looking at both increasing the network's capacity and placing more compute and real-time analytics closer to the edge, where the data is collected and consumed. Moreover, there is a strong demand for efficient hardware accelerators to support AI solutions in an energy-efficient and real-time manner.

Intel's Comprehensive Edge Portfolio

From distributed compute and embedded systems to advanced connectivity, networking & cloud-enabled services, Intel's Smart Road Infrastructure portfolio provides a diverse range of high-performance solutions, rooted in efficiency and secure workload resource management. Intel's range of Edge Compute solutions supports efficient workloads for embedded edge applications and power high-performance edge servers for massive, real-time data analytics and AI applications. Intel's Networking solutions enable communications for critical components of transportation systems with software-defined wireless and network function virtualization. Enabling the network edge and facilitating efficient services delivery is reinforced by a combination of AI Engines and Accelerators and Software Development Toolkits.

The combination of edge-configured software solutions and developer tools creates a powerful arsenal for innovators and stakeholders to solve many transportation system safety, efficiency and sustainability challenges.

As transportation authorities and other stakeholders move through their digital transformation journey, the exposure to bad actors and the scope of cyberthreats necessitates end-to-end security assurances. Intel's robust range of security products provides the critical layer of confidence that is required to participate in the future of smart roadways and intelligent transportation. Inherent in the architecture of Intel's portfolio is a suite of security solutions and digital safeguards ensuring trusted system orchestration, optimized performance management and uptime, and predictive detection and risk mitigation. Intel's Security portfolio appends its hardware and software solutions with system-level protection, offensive detection and response, and comprehensive assurance.

Intel's portfolio enables value across the solution and partner value chain, rooting design & functionality in the needs of stakeholders and end users. As such, Intel positions its portfolio of solutions & partner capabilities as a mechanism of value creation from edge to cloud.

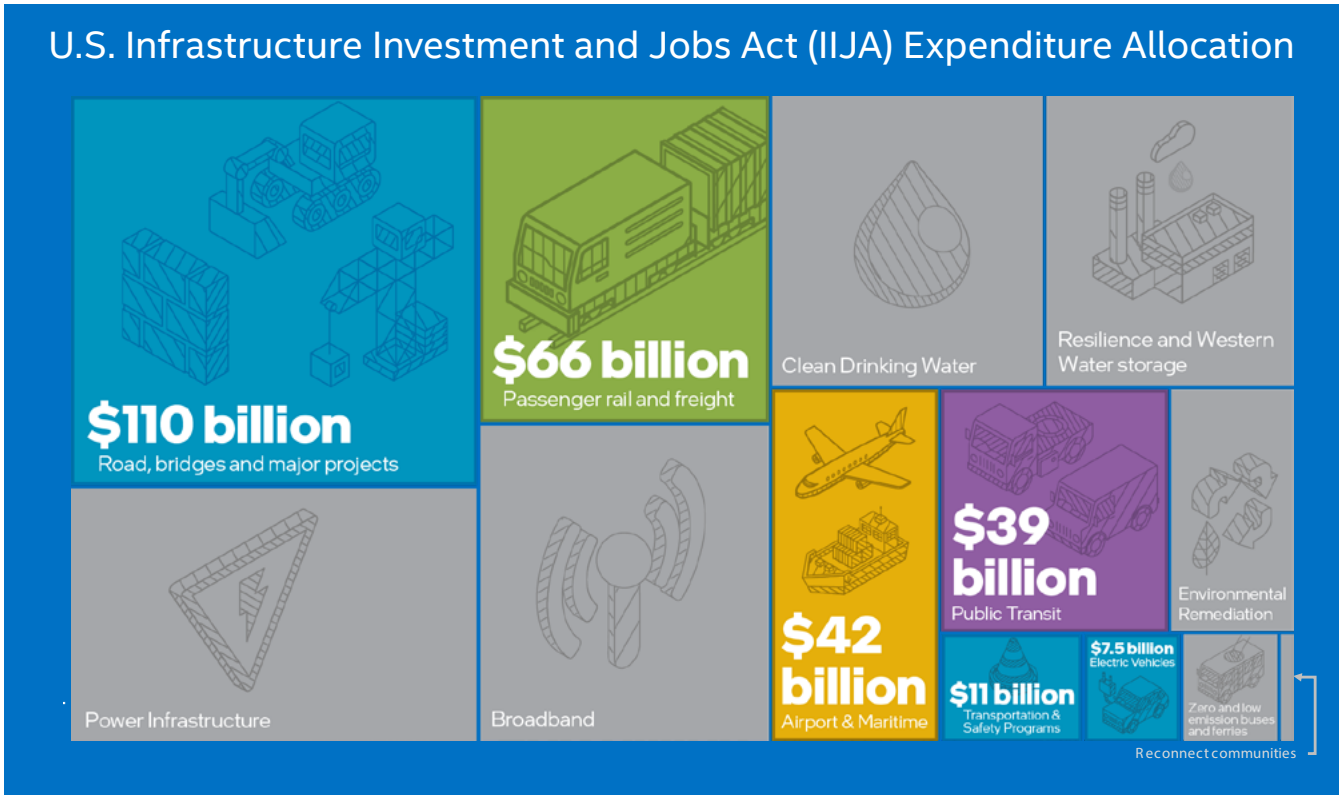
- Evolutionary compute for the edge: new architectures enhanced for manageability and security, with built-in networking and AI acceleration, allow us to rapidly build SKUs tailored to evolving edge workloads and the wide range of light, medium, and heavy edge AI. We utilize CPUs for latency sensitive use cases, integrated AI accelerators for optimal performance per watt, and discrete GPUs for peak AI performance.

- A unified edge-to-cloud AI fabric with new Ethernet offerings that supply critical edge features such as time-sensitive networking and scalable reliable transport to reduce data movement barriers for the entire edge-to-cloud AI fabric. Based on industry standard protocols that offer competitive or better speeds than today's proprietary solutions, Ethernet is quickly becoming the preferred fabric for cost-effective, flexible AI fabric solutions.
- Cloud-to-edge infrastructure management software with zero-touch lifecycle management that makes it easier for builders and operators to deploy, manage, orchestrate and secure edge infrastructure and the applications that run on top. Defense-in-depth is enabled by zero-trust device onboarding, workload, model and data protection across heterogeneous nodes, trusted execution environments without sacrificing performance and uptime, and tooling to solve for compliance while balancing budget and time. Tight platform-level security with silicon and software constantly reinforcing one another.
- AI platform software and tools for cloud-to-edge AI, including OpenVINO, a hardware-agnostic AI runtime optimized for client and edge environments that allows developers to quickly build or bring in a model, optimize it, and deploy it across a wide variety of inference targets, assigning model layers to whichever compute architecture is most effective and efficient. By expanding OpenVINO as a common runtime across our wide PC and edge installed base, we are driving hybrid AI for seamless inference across any model, any hardware, anywhere, without rewriting the application, all with a cloud-like experience.
- Commercial-ready, vertical-specific solutions offered through our partners or directly from Intel, built from years of repeatable success driving clear proof of business outcomes, to get you to market fast.

"Cities around the world are meeting the challenges of urban growth with Intel-based smart city technologies and solutions that improve public safety, help reduce congestion, build resiliency, and support long-term sustainability initiatives."

Joe Mayberry

GENERAL MANAGER, GLOBAL EDGE AI INFRASTRUCTURE AND COMPUTER VISION, INTEL CORPORATION



Policy Framework, Standards, and Technology Research

Policy, standards, and technology research are all critical building blocks for the technology industry. Intel participates in advocacy initiatives, standards bodies, and industry groups worldwide, and has led technology research to enable innovation across the ecosystem.

Policy Framework

A policy framework that harnesses the full potential of the transformational edge opportunities in the automotive and transportation sector is critical to a country or region's economic leadership and productivity in the 21st century. Intel works with governments, organizations, and industries around the world to advocate for policies that promote innovation and open standards.

Our advocacy initiatives have been deployed across the globe, and continue to catalyze pro-IoT legislation:

- In the United States, the US Senate passed a bipartisan IoT-focused bill, Developing Innovation and Growing the Internet of Things Act (DIGIT). Intel contributed to this legislation to convene a working group of federal entities and experts from the private and academic sectors tasked with providing recommendations to Congress on how to facilitate the growth of connected IoT technologies. Additionally, the DIGIT Act directs the Federal Communications Commission (FCC) to complete a report assessing the spectrum needs required to support edge. The DIGIT Act was enacted into law in January 2021 as part of the 2021 National Defense Authorization Act. Shortly after, in August 2021, the US Congress approved the Infrastructure Bill, another key initiative that Intel has contributed to from a policy standpoint designed to fund improvements and modernization of roads, as well as other key infrastructure.
- From a standards perspective, Intel has been active with the 5GAA US task force to enable C-V2X operation in the 5.9 GHz band. As a result, the Federal Communications Commission (FCC) recently issued a report and order that updated the rules to allow C-V2X technology to operate in the top 30 MHz of the 5.9 GHz band. Intel and 5GAA continue to work with the FCC to enable reliable C-V2X operation.
- In China, the Ministry of Industry and Information Technology issued in 2018 the Administrative Regulations on the Use of 5905-5925MHz Spectrum for Direct Connected Communication on the Internet of Vehicles, which allocated the dedicated spectrum for LTE-V2X direct communication. In 2020, eleven ministries, including the Ministry of Industry and Information and Technology (MIIT) and the National Development and Reform Commission

(NDRC) jointly issued the Intelligent Vehicles Innovation Development Strategy, which progressed the deployment of intelligent transport systems, as well as smart city-related facilities.

- In the European Union, spectrum for safety-related ITS applications in the 5.9 GHz band has been extended from 30 to 40 MHz (as part of a total 80 MHz spectrum allocation for ITS applications). Intel has worked with European regulators and other ITS stakeholders to ensure that sufficient spectrum is made available on a technology-neutral basis.

Standards

Looking to the future of edge, cybersecurity technology, autonomous systems, AI, connectivity, and cloud computing, standards are the common tool to bring innovations to markets around the world. Intel contributes to standards that address global environmental issues and best practices for corporate governance and business operations as well as product safety. Intel participates in hundreds of standards bodies and industry groups globally and has played a significant role in bringing about globally adopted ubiquitous standards, including Ethernet, USB, and Wi-Fi.

Technology Research and Contributions to ETSI V2X Standards and 5GAA

C-V2X is a cellular standards-based technology supported by 4G/5G. Its evolution will enable advanced connectivity between vehicles, infrastructure, and other road users to promote safe mobility. Vehicle-to-Vehicle and Vehicle-to-Infrastructure (V2X) standards will enable the future of Intelligent Transportation Systems (ITS). Intel has been an active member of technical bodies, contributing to the definition of ITS use cases and specifications.

Collective Perception Service (CPS)

Intel developed facilities layer mechanisms for the CPS, extending the range and accuracy of perception beyond their embedded sensors, with roadside infrastructure playing a significant role.

Vulnerable Road User (VRU) Awareness Basic Service

According to the World Health Organization, more than half of the 1.35 million annual traffic fatality victims are low-mobility, high-physical-impact-VRUs such as pedestrians, bicyclists, and motorcyclists. Intel-powered smart roadside infrastructure, such as roadside units (RSUs) deployed within the smart intersections, can play a crucial role in improving VRU safety.

Decentralized Congestion Control and Multi-Channel Operations (DCC and MCO)

Intelligent Transportation Systems utilize 'day 1' environment awareness and traffic management applications and services delivered by LTE C-V2X and DSRC over the 5.9 GHz ITS band. More advanced applications and services ('day 2 and 3' services—collective perception, maneuver coordination, sensor sharing, and infrastructure as a service) are being introduced with increased bandwidth requirements. Multi-service orchestration, scheduling, and prioritization-

based mechanisms for resource sharing (communications and compute) to support heterogeneous service classes will help address the overall challenges in DCC and MCO.

Technology Research Outreach

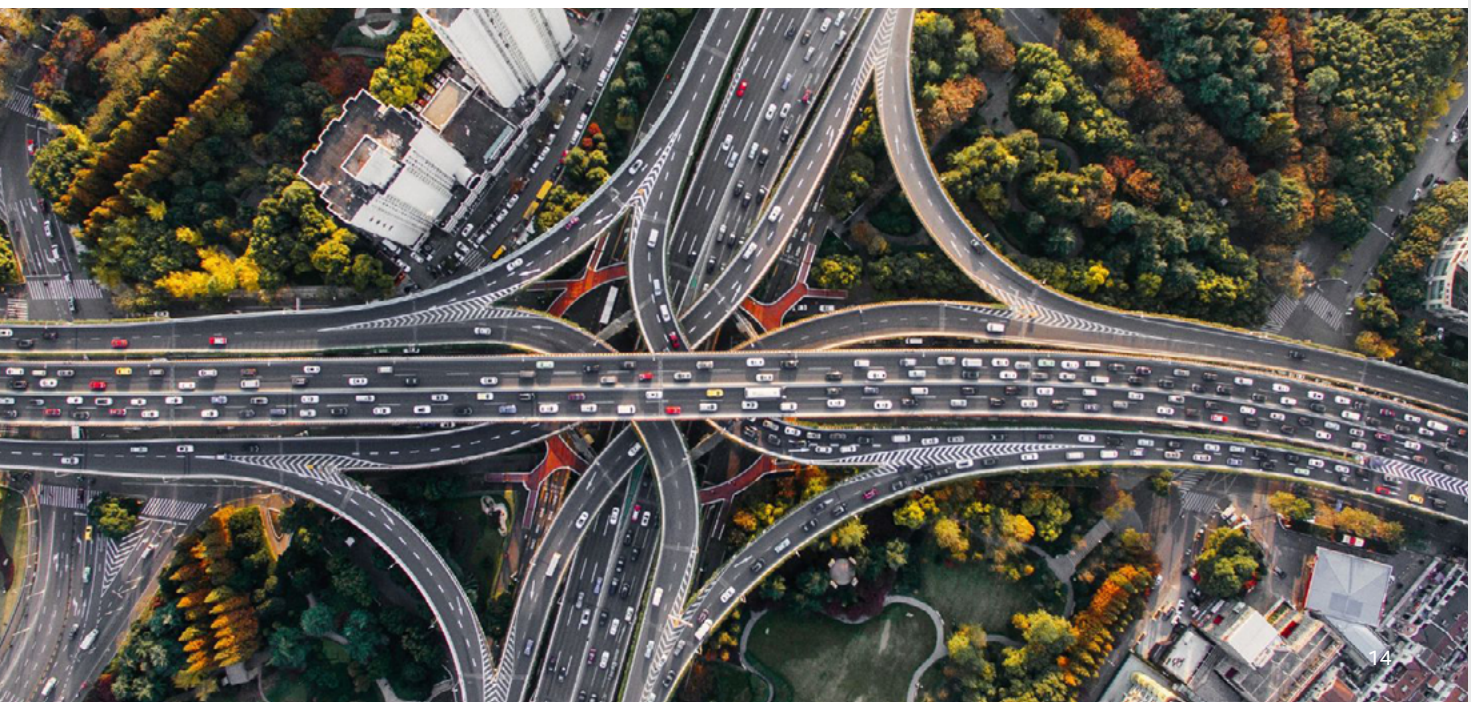
Intel Labs works with and sponsors leading researchers around the world. That includes prominent university science and technology centers, The National Science Foundation, and the Semiconductor Research Corporation. Together they are doing research that is transforming how machines think, learn, and adapt, and how we compute, secure, and communicate the data that will help fuel our digital economy.

For decades, Intel has been at the forefront of technology research, innovation, and development for compute, storage, and networking that power many of the world's data centers, communications infrastructure, and personal computing. Intel is continuing that legacy with the intent to continue to lead technologies and platforms for assisted driving, 5G communications infrastructure, and AI. At every step, Intel takes a deeply integrated approach with technology to provide a robust set of compatible solutions, platforms, products, technology innovations, and architectures to complement one of the world's most dynamic set of technology ecosystem partners.

Digital Twin Virtual Environment Orchestration and On-Demand Services

Recent breakthroughs in multimodal sensing and real-time environmental perception technologies have led to accurate semantic and kinematic parameter estimation of objects in the sensors' field of view, which can be leveraged in roadside infrastructure. By utilizing edge computing capabilities, the roadside infrastructure may create a digital twin model of its surrounding environment where each actor in the virtual environment is assigned a temporary unique tracking identifier, and their kinematic parameters are continuously tracked.[20]

Such a virtual environment at the edge can enable the roadside infrastructure to provide safety and on-demand commercial services to vehicles in need of additional sensor data/analytics or augmentation, or other road users (such as pedestrians, bicyclists, etc.). For example, the environmental perception in the digital twin can be used to detect the availability of parking spaces in real-time, and such live information can be used to disseminate parking information and reservation services to road users.



Technology Spotlights

Ferrovial AIVIA Smart & Connected Roads (Traffic Management)

Challenge: Develop infrastructure and technology to ensure the safe and efficient co-existence of conventional and autonomous vehicles.

Solution: AIVIA Smart Roads provides a modular, extendable, and scalable technical solution that enables real-time AI-powered detection, monitoring, and risk determination of complex events from multiple data sources at points along a road, as well as management and automated facilitation of associated response plans.

Results: AIVIA's advanced capabilities can detect and notify road users and operators of wrong-way driving, hazard detection of stopped/slow vehicles, accidents, and pedestrian or other obstacles on the road in real-time. The initiative aims to create fully-refined corridors that deliver orchestrated traffic management for all vehicles across urban and inter-urban domains. This maximizes capacity, fluidity, and flexibility without the need for additional construction by leveraging AI at the edge.

Learn More: https://www.ferrovial.com/en-us/innovation/aivia-orchestrated-connected-corridors/

3D Lidar Imaging Traffic Safety

Challenge: Cities seek solutions to improve traffic safety and efficiency through Cellular Vehicle-to-Everything (C-V2X) connectivity and applications.

Solution: Camera and Lidar sensors collect data on vehicles, pedestrians, and road conditions which is fused and analyzed by Roadside Edge Computing Equipment. These analytics generate various Infrastructure-to-Vehicle (I2V) messages which are sent by the Roadside Unit (RSU) to road traffic participants (including networked vehicles and vulnerable road users) through the wireless links to improve traffic safety and efficiency. The JHCTech® Roadside MEC Equipment is based on the 11th-Generation Intel® Core™ Processors and Intel® Distribution of OpenVINO™ Toolkit, which is used to support the 3D point cloud processing based on deep learning and the Sensor Fusion for Leishen® All-in-One Roadside Sensing Equipment (Lidar and Camera).

Results: The Roadside Edge Computing Equipment based on Intel® Architecture has shown superior performance in processing the 3D point cloud generated by lidar (whether it is deep learning or traditional computer vision). Intel Labs is contributing to this effort with V2X technology solutions.

Learn More: Leishen, JHC Tech, and Intel Collaborate on Lidar 3D Point Cloud Processing and Sensor Fusion

Customer Case Studies

USA

Traffic management
source: Derq Solution Brief

Derq has developed its Real-Time AI Perception Platform that aggregates data from video cameras and different sources such as traffic sensors, signal controllers, and connected infrastructure. It uses AI-powered processes to extract intelligence from the data to enable traffic control applications, connected and autonomous vehicles (CAV) alerts, and actionable traffic insights to improve safety for drivers, pedestrians, and cyclists.

China

Tolling & parking
source: JHCTech ETC Solution Brief

Intel and partners launched an ETC system that automatically detects and identifies vehicles, so that toll transactions can be completed without stopping. This allows vehicles to quickly pass through the toll stations, alleviates bottlenecks, and improves overall traffic efficiency.

Asia Pacific

Edge services: 5G MEC
source: SkyLab MEC Platform Solution Brief

SkyLab helps cities develop and deploy the right traffic management solutions to reduce congestion and emissions and integrate the latest technology into legacy environments. Administrators can easily manage the system, push updates, or deploy more software apps from the SkyLab marketplace.

EMEA (Europe, Middle East, Africa)

Traffic management
source: Siemens Sitraffic One

Sitraffic One is a complete suite of 1-watt devices that help city leaders save energy and reduce costs while adhering to strict safety standards. Sitraffic® One is a complete intersection solution comprised of signal heads, controllers, and peripherals based on innovative 1-watt technology.

"Houston has been one of the fastest-growing cities in the U.S. for over a decade. In order to accommodate this growth, we are augmenting our traditional traffic systems with best-in-class technology working alongside leaders in IoT, AI, 5G, and Cloud."

Sylvester Turner
MAYOR OF HOUSTON, TEXAS

Solutions

Intel® offers a broad portfolio of tested and proven Intel® Edge Market Ready Solutions and Intel® RFP Ready Kits that deliver business results today while laying the foundation for an even more connected tomorrow. Each of these scalable solutions is vetted for completeness, repeatability, and scalability, and designed to tame the complexity of solution development and implementation.

For more information, view the Intel® Edge Market Ready Solution and Intel® RFP Ready Kits.

Traffic Management

Cisco Smart Connected Roadways

Cisco® Connected Roadways helps secure and connect Intelligent Transportation Systems, allowing vehicles, roadways, travelers, and traffic management centers to all communicate with each other in near real-time. Smart intersections can more easily facilitate traffic, reducing congestion and improving fuel/energy consumption. Emergency vehicles can respond to traffic accidents sooner, saving lives. Digital signage above roads can update in near real-time, warning drivers of impending accidents or dangerous conditions ahead. Even secondary effects are noteworthy—reducing congestion would alleviate secondary accidents and vehicle carbon emissions could be drastically reduced thanks to improved traffic signal efficiency, smart parking, and the sharing of third-party applications that can help in dynamic re-routing, such as TomTom.

Cisco Connected Roadways allows cities and transportation agencies to gain insightful advantages to simplify operations and maintenance without necessarily replacing existing legacy infrastructure. The solution is based on a proven architecture and provides a secure, converged, standards-based infrastructure that can simultaneously replace redundant, proprietary, and single-application solutions with limited (or no) interconnectivity. Consequently, operators can optimize both capital and operating expenditures for their network infrastructure.

Key features and benefits:

- Enhanced safety through fewer accidents and collision-related deaths, faster incident response, and automated near real-time weather and traffic alerts.
- Improved mobility through traffic incident management and intelligent traffic signals that can optimize vehicles' fuel/energy efficiency by prioritizing directional right-of-way.
- Increased efficiency with automated software actions.
- Curtailed carbon emissions by mitigating idling time and passenger commute time as well as increasing fuel efficiency through smart intersections.
- Lower TCO by incorporating existing infrastructure and eliminating redundant, proprietary systems with limited or no interconnectivity.

For more information:
Solution
Website

Outsight.ai Shift LiDAR Software

In the evolving landscape of Intelligent Transport Systems (ITS), Outsight's Shift LiDAR Software is a comprehensive suite designed for a wide array of ITS and Vehicle Flow Monitoring applications and sets a new standard in the field of Smart Road Infrastructure. At its core, the software uses advanced 3D LiDAR data processing techniques, driven by Intel's robust CPUs, to provide real-time, accurate tracking of vehicles and pedestrians, while being privacy-compliant. As cities and transport authorities strive towards smarter, safer, and more efficient roads, Outsight's solution offers a glimpse into the future of urban mobility and ITS.

Key features and benefits:

- Shift Perception: This module is the heart of the system, processing data from LiDAR sensors for continuous and precise object tracking.
- Edge Processing: Leveraging Intel CPUs for efficient point cloud fusion and classification.
- Fusion: This feature integrates point clouds from all connected LiDARs from different manufacturers, creating a seamless and comprehensive view of the monitored area.

Sample use cases:

- Automatic Incident Detection (AID): Quick identification of road incidents, enhancing response times.
- Traffic Flow Measuring, Tolling & Analytics: Efficient management of traffic flow and toll collection.
- Vulnerable Road User (VRU) Safety: Enhanced safety measures for pedestrians and cyclists.

Key Benefits of Outsight's Shift LiDAR Software:

- High Accuracy and Real-Time Tracking: The use of 3D LiDAR data ensures unparalleled accuracy in tracking and monitoring, crucial for real-time decision-making.
- Scalable and LiDAR Agnostic Architecture: The software's ability to work with various LiDAR manufacturers and models and its scalable nature makes it suitable for different environments and applications.
- Customizable and Integrative Approach: The availability of different software licenses and the Perception API allow for tailored solutions that can integrate seamlessly with existing systems.

For more information:
Website

LTTS Fusion Transforms Traffic Management

With over 11 million citizens, Hyderabad maintains an Integrated Command and Control Center (ICCC) to oversee the day-to-day operations and incident response of its vast infrastructure. In partnership with Intel, Hyderabad adopted the LTTS Fusion platform, an Intelligent Traffic Management System (ITMS), powered by ultra-light OpenVINO models on Intel Xeon 2nd generation servers, to address challenges around effective traffic management and rule violations detection, and to ensure public safety as the city expands.

The platform enables efficient and accurate processing of video analytics, enabling real-time detection and analysis of different on-road scenarios, including automatic number plate recognition (ANPR), and violation detection for offenses like no helmets or illegal overtaking. The integration of Intel's servers and OpenVINO-optimized models within the Fusion platform ensured optimal utilization of resources while maximizing the efficiency of video analysis. As a result, Hyderabad's traffic flow was improved significantly as Fusion identified congestion hotspots and dynamically adjusted signal timings, helping optimize travel times and traffic flow city-wide.

Key features and benefits:

- Hyderabad's traffic flow was improved significantly as Fusion identified congestion hotspots and dynamically adjusted signal timings, helping optimize travel times and improve overall city-wide mobility.
- The platform's traffic violation detection capabilities provided law enforcement authorities with real-time alerts, enabling swift action against traffic offenses to ensure safer roads.
- Fusion's video analytics capabilities ensured a faster detection of potential trouble from fire, smoke, abandoned objects, and other hazardous scenarios.

For more information:
Website

iOmniscient iQ Roads

Good management of a nation's roads can result in less congestion, fewer accidents, less pollution, and a more satisfying road experience for both drivers and pedestrians. Intelligent Traffic Systems provide capabilities that can improve the overall traffic experience in many dimensions. iOmniscient is a technology leader and pioneer in video analytics with expertise in AI-based multi-sensory analytics. Their solutions address hundreds of use cases with their AI technology excelling in complex, extremely crowded and realistic environments.

iOmniscient offers two packages: The Starter Pack provides basic capabilities for traffic monitoring, incident detection, and event data management. The Standard Pack provides unique, additional capabilities based on patented technologies.

Key features:

- Decrease data processing with iOmniscient's Nuisance Alarm Minimization System (NAMS) module that removes noise from video streams.
- Detect traffic infringements with various features, like speed detection, intrusion of bike/bus lane alerts, red light violations, jaywalking, and optional license plate recognition capabilities.
- Reduce response time of emergency responders and traffic officers with iOmniscient's Automated Response System.

Key benefits:

- Increase road safety with traffic monitoring and incident detection features, as well as advanced automated response systems.
- Streamline monitoring processes by viewing events remotely/in a centralized location, and accessing archived reporting and historic event data.
- Increase insight into road conditions with advanced camera diagnostics and data that can be analyzed in both spatial and temporal dimensions.

For more information:
Website

Toll Management

ST Engineering Electronics S*Park Platform

S*Park Smart Car Park Solutions provides cloud-based car park management that centralizes all car park operations and maintenance on a single platform. It offers operators an overview of their portfolio's revenue collection and occupancy records and manages multiple operators' car park systems and apps.

S*Park leverages ANPR and mobile payment apps to provide non-intrusive, efficient, and seamless parking services to motorists while offering optimized cost savings and enhanced operating efficiency for car park operators and building owners.

Key features and benefits:

- Reduce operational and maintenance costs by using cashless payments to replace ticketing and parking meters.
- Increase revenue with dynamic or premium pricing and data analytics for effective and targeted enforcement.
- Optimize car park lot allocation based on drivers' parking behavior (seasonal, handicap accessible, limited time, and Electric Vehicle parking)
- Leverage occupancy trends and profiling to enhance city planning, advertisement, and tenant mix.
- Enhance the parking experience with seamless payments, easy search for parking lot availability and rates, and secure parking space with an advanced booking function.

For more information:
Website

Uncanny ANPR

Uncanny ANPR is an end-to-end AI-based number plate recognition system that can identify vehicles in very challenging conditions.

Key features and benefits:

- High accuracy and deep learning model.
- Supports various license plate types.
- Supports various use cases including stop & go, free-flow, bi-directional, multiple lanes.
- Supports various processing architectures including edge, server, and cloud.
- Open API for 3rd party integration.
- Plug and play setup.

For more information:
Website

Edge Services

Capgemini 5G RSU

Designed in conjunction with application developers, enterprises, operators, and device makers, the Smart RSU solution enables intelligent transportation applications like traffic management, EV charging, smart lighting, and connected vehicle services. By placing computing at the network edge, the Smart RSU solution reduces network latency and processing times. The Smart RSU solution incorporates Capgemini Engineering's ENSCONCE multi-access edge computing (MEC) platform. ENSCONCE brings intelligence to the network edge while hosting 5G network capabilities and microservices. CERA allows solutions designers to build disaggregated nodes while converging network, compute, and AI acceleration.

Key features and benefits:

- Platform elements, including multiple Intel technologies for AI and Machine Learning, work in concert to maximize 5G network, cloud, and computing performance.
- By integrating technologies like Intel's Smart and Intel® Distribution of OpenVINO™ toolkit into the ENSCONCE platform, Capgemini Engineering has enhanced the capabilities of its edge computing solution with converged edge use cases.

For more information:
Solution
Website

Tietoevry

As road traffic increases, so does the risk of traffic accidents, especially at intersections. The risk of injury and death is especially high for pedestrians. Tietoevry has piloted a solution to improve pedestrian traffic safety. The solution can automatically detect when a pedestrian is planning to cross the street at an intersection. Advanced AI, edge and V2X communications enable alerting approaching cars, helping to prevent accidents. In the future, the system can also serve autonomous vehicles.

For more information:
Solution
Website

The Cellnex Mobility Lab

Based in Castellolí near Barcelona (Spain), Cellnex is focused on the development of vehicular use cases. The lab is the result of the digital transformation of Circuit Parcmotor Castellolí, which has been converted into an innovative technological center that supports experimental living labs for smart mobility and connected/ autonomous vehicles. Cellnex develops 5G-based sustainable, connected, and autonomous mobility solutions for vehicles, traffic management, and road infrastructure.

The racetrack has been equipped with several self-sustaining Green Edge sites to support the cellular V2X (c-V2X) wireless network that provides coverage to the whole circuit, allowing connectivity between vehicles, high-definition cameras for monitoring vehicles on the track, and on-board units for transmitting telemetry, voice, and video data. One of the use cases under implementation is the automatic detection of car incidents (spinning, collisions, breakdown), where captured images are analyzed locally at the edge nodes and shared anonymously at the local node level.

Key features and benefits:

- Demonstrates the feasibility of implementing a converged edge architecture, enabling Cellnex to deploy efficient and open management of the physical infrastructure, the VNFs, and Edge applications in a completely sustainable c-V2X environment.
- Each Green Edge site is enabled with a rugged and compact Lenovo ThinkSystem SE350 server, running Intel® Xeon® D processors. The server continuously monitors its power consumption, the status of the battery, and the level of energy generation.
- The integrated solution, enabled by technologies from Lenovo, NearbyComputing, and Intel, provides new business models for Cellnex Telecom to implement c-V2X services with high levels of service continuity and open modularity to host third-party applications and VNFs.

For more information:
Website

DFI

DFI leverages virtual machine (VM) virtualization technology to introduce a robust Workload Consolidation platform that can run multiple operating systems simultaneously with just one Intel CPU for applications such as EV charging. These solutions enhance user experiences and promote sustainability in the AIOT era. The platform maximizes functionality and energy efficiency while simplifying operations and lowering costs. Workload consolidation utilizes Over-The-Air updates for maintenance and features DFI's M.2 A Key OOB Module, making it a reliable approach to post-deployment maintenance.

DFI's EV charger runs Mistral 7B LLM, utilizes Intel Arc GPU's XMX AI Engine for fast AI inference and consolidates multiple workloads like EV charge controller, digital signage, payment transaction, and interactive kiosk, through virtual machines on the 13th Gen Intel Core Processor.

For more information:
Website

Edge & Traffic Management

Smart RSU Solution

The Intel Smart RSU is a versatile platform that places computing at the network edge. Its collaborative design process with application developers, enterprises, operators, and device makers ensures seamless integration with diverse industry partners to enable a wide range of intelligent transportation applications such as:

- Traffic Management: Operators can optimize signal timings and implement dynamic traffic control strategies to enhance overall traffic efficiency with accurate data on traffic flow, congestion, and incidents.
- EV Charging: Smart RSUs can facilitate intelligent EV charging management by monitoring charging station availability, power demand, and billing information to ensure optimal usage of resources and a productive charging experience.
- Connected Vehicle Services: Through continuous data exchange between vehicles and infrastructure, the Smart RSU enhances communication for cooperative driving, traffic safety warnings, and improved situational awareness for drivers.

By leveraging the power of edge computing, the Smart RSU solution delivers real-time processing, reduced network latency, and enhanced data security. As a result, transportation authorities can harness its capabilities to optimize traffic management, EV charging infrastructure, smart lighting systems, and facilitate seamless connected vehicle services. This solution is designed to foster smarter and safer transportation networks, benefitting both road users and the community at large.

Key benefits of Edge Computing:

- Reduced Network Latency: Processing critical data closer to the source significantly reduces data transfer times to ensure faster response times for safety-critical applications, enhancing real-time decision-making capabilities.
- Enhanced Processing Efficiency: On-device processing minimizes the need to transfer large volumes of raw data to central data centers, thus optimizing overall system performance.
- Bandwidth Savings: Performing data processing and analytics at the edge significantly reduces the amount of data that needs to be transmitted over the network and results in substantial bandwidth savings.
- Improved Data Privacy and Security: Edge computing minimizes the exposure of sensitive data by processing it locally rather than transmitting it across networks. This approach enhances data privacy and strengthens the overall security posture of the transportation ecosystem.

For more information:
Solution

Partner Solutions

Intel has a growing network of trusted partners, and members of the Intel Partner Alliance with a sampling of the latest market-ready solution offerings to meet global business needs.

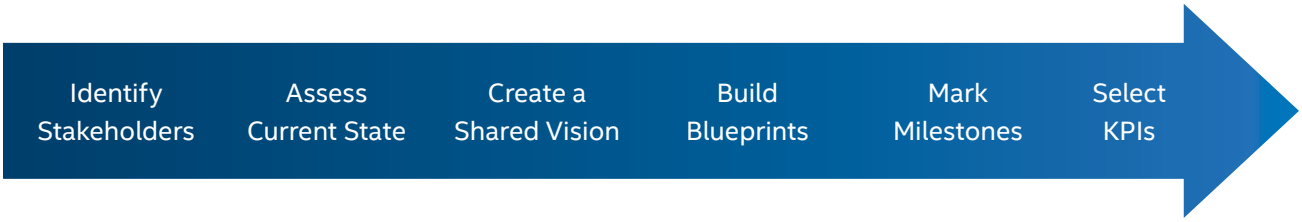
Intel has a growing network of trusted partners, and members of the Intel Partner Alliance with the latest market-ready solution offerings to meet global business needs. For more information on our partners and offerings please visit the Intel® Partner Showcase.

Next Steps

Strategic innovation and transformation are a continuous journey. Many city and transportation leaders plan their intelligent road infrastructure initiatives across three action areas to:

1. Transform data into new insights in road infrastructure with intelligence from edge to cloud.
2. Leverage proven solutions for Intelligent Transportation Systems to support safety, civic, and economic goals.
3. Consolidate systems and use cases at the edge for greater efficiency and value.

Initially, leaders should examine which services may have the most impactful outcomes. Stakeholder identification, participation, and clear priorities are essential foundation points for building a plan. Leveraging experience working with many governments and infrastructure authorities worldwide, Intel is bringing together the right stakeholder organizations and companies to deliver building blocks that transportation and smart city leaders can use to create and implement an appropriate plan.



Here are the major steps to enable the intelligent road infrastructure transformation journey:

Identify Stakeholders

Within the complex structure of your transportation organization, identify who the major stakeholders in any digital transformation project would be. Depending on the project, this can include government representatives, members of the transportation team, employee representatives, concessionaires, urban mobility IT team, transportation security team, and passenger advocates.

Assess Current State

Determine where your road infrastructure system is now, measured in terms of the same key performance indicators you will use to quantify success. What works? What needs work? How can you improve satisfaction, security, safety, and success for all stakeholders?

Create a Shared Vision

Establish your ultimate outcomes, expressed in terms of stakeholder benefits. The vision should not be expressed solely as technical achievements but also as experiential improvements that technology can make possible. It is essential to build that vision with stakeholder involvement to achieve better and more diverse suggestions, consensus, and commitment.

Build Blueprints

Develop blueprints for the most important components of your transportation needs. Possibilities include master plans for:

- Digital infrastructure (communications and computing resources)
- Data collection
- Transportation infrastructure and use cases
- Business and commerce
- City services

Mark Milestones

Identify waypoints at which you measure progress, share lessons learned, discuss course corrections, and strengthen stakeholder commitment to your shared vision.

Select KPIs

Decide on key performance indicators that quantify success and align with your vision.

Explore Financing and Partnerships

Implementing a comprehensive smart city vision and ITS upgrades requires committed funding. It is a critical component that should be thoughtfully planned. Innovative funding and financing alternatives can accelerate smart city projects.

Many regions rely on tax revenue to support road infrastructure projects. Although Vehicle Purchase Taxes (VPT) and fuel taxes are common worldwide, Vehicle Miles Travelled (VMT) taxes are replacing some fuel taxes to stabilize revenue as fuel prices experience volatility and decline. VMT taxes can also improve data acquisition, congestion, emissions, and value-added services (for example: safety alerts, real-time traffic management, routing assistance, and pay-as-you-drive insurance).

London, Stockholm, Gothenburg, and other cities have implemented congestion-based tolling, which allows for dynamic pricing based on real-time traffic patterns. For example, during rush hour, toll prices will be raised. During low-demand hours, prices are lowered. This is being adopted in U.S. cities including New York and Chicago to spread out road demand, relieve congestion, and improve commutes.

Exploring multiple funding sources such as regional economic development; state and federal agency funding for transportation, public safety, and environment; and private developer and industry partnerships are a few examples of broadening sources. Developing partnerships to embrace industry knowledge, best practices, key solutions, and technologies can yield insights from planning to implementation. New business and monetization models are being explored by leaders throughout the world to support the implementation of ITS systems.

Defining and executing a smart city and ITS strategy is neither straightforward nor without risks—but the benefits can be significant. Intel believes a successful city transformation requires certain key components: the right level of stakeholder participation, clear priorities, and methodical planning of technology infrastructure.

This is only a starting point for a transformative city journey. Intel believes transportation and city leaders can successfully transform their cities by establishing clear priorities, encouraging active stakeholder participation, and ensuring methodical technology infrastructure planning while enabling the right policy and governance. With Intel's Edge AI solutions and strong partner ecosystem, Intel can help bring your smart city vision to life.

For follow-up questions, please contact:

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Appendix

Developer Tools

Intel® development tools, Intel-engineered middleware, reference architectures, and ready-to-run applications give developers a solid foundation for building innovative smart city technologies, allowing them to develop and deploy faster.

- Get a head start on smart city, AI-powered applications. Build on our growing library of free reference implementations for traffic management and road infrastructure.
- Take the networking complexity out of container-based applications and orchestration. Intel's Edge Platform abstracts network infrastructure so it is easier to build, deploy, and orchestrate microservices applications at the edge over 4G/5G and next-generation networks.
- Develop AI applications that can run on a mix of Intel® hardware. The Intel® Distribution of OpenVINO™ toolkit optimizes deep learning models for Intel® hardware and gives you a single development environment for deep learning inference applications, video analytics, audio analytics, speech recognition, and natural language processing.

The Intel® Geti™ platform is a collaborative, intuitive platform that makes training AI for computer vision accessible and agile. Intel® Geti™ can help cities develop AI for traffic-management systems to route traffic automatically, build solutions that recognize and respond to emergencies, and use camera data to improve road safety in near-real time. It works with most AI frameworks and exports trained computer vision AI that can run on the devices you already have— laptops, industrial PCs, servers, and data centers in the cloud.

Intel® SceneScape is a software foundation that transforms data from audio, vision, Intel® RealSense™ depth cameras, lidar, and radio frequency sensors to build and update dynamic digital twins of your physical space in near-real time. Designed specifically for re-creating environments in 3D scene graphs, Intel® SceneScape gives organizations deep visibility into assets, systems, and environments and provides the means to simulate changes or predict behaviors in a virtual realm. These insights lead to fast process improvement or adaptation on a vast scale.

The Intel® Developer Catalog is a consolidated resource for key Intel® software offerings, supporting open ecosystems and an end-to-end portfolio of technology across multiple use cases, including AI, client, cloud, 5G, and edge. The catalog makes it easy for developers to access reference designs, toolkits, and ready-to-launch containers that accelerate time to market and helps to preserve interoperability through upgrades.

Intel® Distribution of OpenVINO™ Toolkit

The Intel® Distribution of OpenVINO™ toolkit optimizes deep learning models for Intel hardware and gives you a single development environment analytics, audio analytics, speech recognition, and natural language processing. Based on Convolutional Neural Networks (CNNs), the toolkit extends Computer Vision workloads across Intel hardware, maximizing performance. Road Infrastructure ecosystem can accelerate and deploy CNNs on Intel® platforms with the Intel® Deep Learning Deployment Toolkit available in the OpenVINO™ toolkit and as a stand-alone download. Together with the new Intel® DevCloud for the Edge, OpenVINO™ addresses a key pain point for developers—allowing them to try, prototype, and test AI solutions on a broad range of Intel processors before they buy hardware.

Learn more about Intel® Distribution of the OpenVINO™ Toolkit.

Intel® AI Suite for Visual Analytics

Vision-based solutions have seen significant growth in deep learning adoption over the past decade. Global forecasts indicate that 45% of global Smart City solutions will be deep learning-based by 202621 and as high as 97% of U.S.-based systems22 will have deep learning or rules-based analytics capabilities over the same horizon. As deep learning-based solutions continue to grow, Intel will continue to work closely to design our silicon roadmap to platform offerings from our partners, helping our customers select the ideal silicon SKU based on the video, software, and analytics requirements of the end solution.

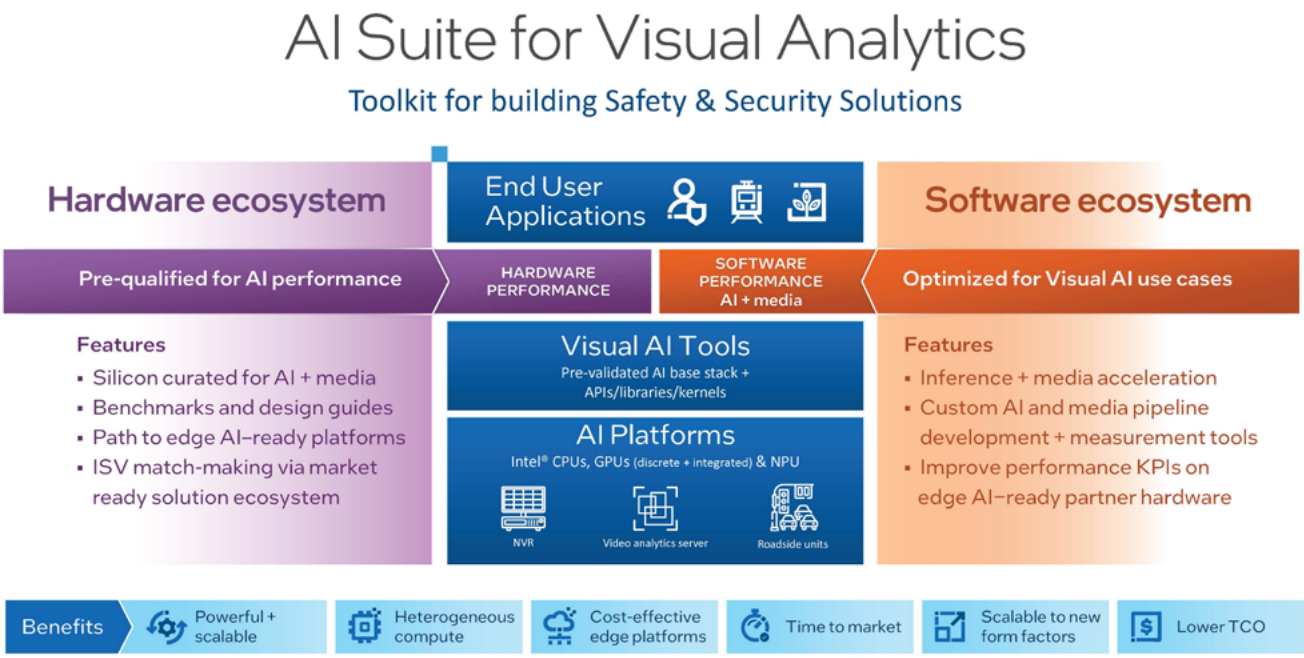
Edge AI Suite for Smart Cities: AI suite for Visual Analytics are solutions for smart cities and transportation infrastructure with hardware and software stacks for inference at the edge We deploy software from OneAPI, OpenVINO, DL Streamer, Network and Edge Platform, and dGPUs (Arc™ and Flex), to provide the best in class AI-enabled technologies to support our market use-cases. These technologies accelerate time to market and optimize development costs for our solution builders and customers. We are already seeing significant traction in our ecosystem, with 40 different Edge AI Box platforms from 15 key OXMs available in China and across Asia.

Technologies that used to be separate are converging into unified systems providing more insight to drive efficiency. Intel hardware and software have the performance and flexibility city leaders need to manage these ever-growing demands and workloads.

Learn more:

Intel® Geti™: a user-friendly, low-code/no-code interface that enables non-data scientists to help train AI computer vision models

Intel® Tiber™ Edge Platform: a new software offering that allows you to securely develop, deploy, run, manage and scale edge solutions.



Intel® Tiber™ Developer Cloud for Edge

The Intel® Tiber™ Developer Cloud for Edge allows developers to actively prototype and experiment with AI workloads for computer vision on Intel hardware. Developers have full access to hardware platforms hosted in the Intel® cloud environment, designed specifically for deep learning. Developers can test the performance of their models using the Intel® Distribution of OpenVINO™ Toolkit and combinations of CPUs, GPUs, VPUs such as the Intel® Neural Compute Stick 2 (NCS2) and FPGAs, such as the Intel® Arria® 10. The Developer Cloud runs Generative AI, Large Language Models, and Edge solutions on Intel® Distribution of OpenVINO™ Notebooks. These notebooks are designed to help developers quickly learn how to implement deep learning applications to enable compelling, high-performance solutions. Developers can try the code on Intel's latest hardware through a web-based JupyterLab environment or explore a library of over 70 tutorials and sample applications.
Learn more about Intel® Tiber™ Developer Cloud for Edge.

Intel® Smart Edge Open

Intel® Smart Edge Open is a software toolkit for building edge platforms to speed up development of edge solutions that host network functions alongside AI, media processing, and security workloads with reference solutions optimized for common use cases powered by a Certified Kubernetes* cloud native stack.

Intel® Smart Edge Open is a cloud-native, scalable, and secure platform for multi-access edge computing (MEC). With this software stack, enterprises and communications service providers can enable cloud-like services closer to the user on the customer-premises or network edge. Intel® Smart Edge Open is built to run on Intel technologies, such as high-performing Intel® Xeon® Scalable processors today.

For enterprises and service providers, Smart Edge enables new opportunities and revenue streams while reducing the total cost of ownership for intelligent edge solutions. For example, the city of Tampere, Finland and Tietoevry implemented a pilot solution to improve pedestrian safety by automatically detecting when a pedestrian is planning to cross the street. Advanced AI, Edge applications, and V2X communications enable alerting approaching cars—preventing accidents.
Learn more about Intel® Smart Edge Open.

Intel® oneAPI

Intel oneAPI products deliver the freedom to develop with a unified toolset and to deploy applications and solutions across CPU, GPU, and FPGA architectures. Data science and AI toolkits support machine learning and deep learning developers who primarily use Python* and AI frameworks.

These toolkits are for performance-driven applications—HPC, Edge, advanced rendering, deep learning frameworks, and more—that are written in DPC++, C++, C, and Fortran languages.
Learn more about Intel® oneAPI.

Open Visual Cloud

The Open Visual Cloud is a set of open-source software stacks (with full end-to-end sample pipelines) for media, analytics, graphics, and immersive media, optimized for cloud-native deployment on commercial-off-the-shelf x86 CPU architecture. The Open Visual Cloud provides availability of high performance, high quality, open source, validated building blocks—across encode, decode, inference, and rendering—as well as reference pipelines that support visual cloud workloads such as traffic management. The open-source software stacks presented for the Open Visual Cloud are provided under the FFmpeg and GStreamer frameworks as ready-to-use Docker* images and Dockerfiles, which can help to implement cutting-edge Visual Cloud services for advanced video distribution and processing. The goal of the Open Visual Cloud is to unleash innovation, simplify development, and accelerate time to market for visual cloud services by providing open-source, interoperable, high-performance building blocks, and containerized reference pipelines.
Learn more about Open Visual Cloud.

Endnotes

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Think big

Assess all the ways technology can facilitate meaningful change

Start small

Get going with projects and opportunities

Move fast

Learn, adjust, iterate

intel