

Paving the Way Forward:

Intelligent Road
Infrastructure

The Intel logo is displayed in a white square box. The background of the entire image is a night-time aerial view of a complex highway interchange with multiple levels of overpasses and ramps. A network of glowing blue lines and dots is overlaid on the scene, representing a data or communication network connecting various points on the road infrastructure. The cars on the roads are visible as small lights and shapes, and the overall color palette is dominated by the warm orange and yellow lights of the highway and the cool blue of the network overlay.

intel.

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Sameer Sharma, Global General Manager IoT, Intel Corporation

“Whether the goal is ensuring public safety, reducing congestion or creating long-term sustainability, cities around the world are meeting the challenges of urban growth with Intel-powered smart city technologies and solutions that solve problems today and build resiliency in the future.”

Sameer Sharma

GLOBAL GENERAL MANAGER, IOT,
INTEL® CORPORATION

“Safety has always been our top priority. In the new era of mobility, technology plays a critical role in making our transportation infrastructure safer and creating more mobility options for all citizens, no matter where they live.”

Shailen Bhatt

PRESIDENT/CEO, INTELLIGENT
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Overview

Throughout the ages, mobility of people and goods has provided us with access to opportunities in jobs and education as well as improved our quality of life through trade and healthcare.

Experts predict that the global human population will surpass nine billion in the next 20 years, and planning for this growth is of paramount importance.¹ We have reached an inflection point, where meeting the future demand for mobility cannot continue to create more congestion and pollution of the environment. Forward-thinking leaders envision that key technologies powered by the Internet of Things (IoT), artificial intelligence (AI), and everywhere connectivity can help build a safe, clean, and inclusive future for mobility.

The urban population is forecast to exceed 60% of the world's population by 2050.² Meanwhile, city and transportation leaders are under pressure to address environmental issues caused by traffic congestion and urban populations. Large cities consume more than two-thirds of the world's energy and account for more than 70 percent of global greenhouse gas emissions.³

On the horizon, changing global emissions standards and advancements in key edge technologies will necessitate investment in pervasive edge compute, 5G, and traffic management technology. Transportation authorities around the world are implementing e-tolling and exploring new monetization models. Cities, states, and provinces in North America and Europe are testing congestion pricing. In Asia, vehicle purchase taxes are more predominant.

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

Intel and its partners are accelerating innovation through Intelligent Transportation Systems (ITS) to develop and deliver efficient, cost-effective systems. By combining smart sensors, cameras, and embedded computers with lightning-fast, ubiquitous AI, city leaders and transportation officials can gain real-time insight into activities and events taking place on their roadways and prevent problems before they occur. Smart cities can now retime their intersections and improve traffic flow on the fly, clearing the way for ambulances, fire engines, and first responders. As a result of insights from traffic data, cities are becoming safer, greener, and more intelligent and ready for the future.

This eBook is intended to provide insight into how city and transportation leaders can transition from reactive to proactive measures to create smarter transportation systems with off-the-shelf hardware and open standards-based solutions that simplify integration and help lower long-term costs. Intel technologies can help city and transportation leaders solve the challenges they face today and become stronger and more resilient in the future, improving public safety and the quality of life for all citizens.



Challenges

The increasing number of vehicles on roadways along with decaying or insufficient infrastructure raises important challenges in terms of traffic congestion, infrastructure management, and road safety. Forward-thinking cities are preparing for continued growth of vehicles on roadways, the potential impacts on city services, and ultimately quality of life.



Safety



Road traffic crashes result in the deaths of approximately 1.35 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 6,721 pedestrians were killed on U.S. roads in 2020, up 4.8% from 6,412 fatalities in 2019.⁶ A number of factors may be influencing the rise in pedestrian

deaths, including the need for safer road crossings, unsafe driving behaviors, the increased presence of sport utility vehicles (SUVs), and the tremendous growth of smartphone use, which is a significant source of distracted driving.⁷ The related costs of accident-related healthcare take a substantial toll on the families and healthcare systems. Municipal leaders should consider new risks associated with human life and health as traffic congestion continues to increase. Injuries or urgent health issues requiring immediate attention cannot tolerate significant increases in transit times to doctors and hospitals. Future transportation networks and infrastructure must be able to prioritize urgent healthcare needs while also continuing to encourage and provide ready access for those seeking preventive health services.

Due to safety concerns related to the coronavirus, the public transit industry faces a \$39.3 billion shortfall.⁸ As city life normalizes after the pandemic, greener, more inclusive mobility solutions are a priority to regain public trust—and drive revenue for cities and transit authorities.

Congestion



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. Many major cities

date from ancient times, while other, newer cities still have roadmaps based on a horse-drawn carriage or automobile-only model that has not easily accommodated modern transportation. In addition to causing pollution, congestion also costs the average US citizen 99 hours and \$1377 every year.⁹ 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. As stated previously, traffic safety is also a growing crisis, along with the corresponding cost of accident-related healthcare and its toll on cities and citizens.

Environmental Impact



Today's cities account for between 71 and 76 percent of CO₂ emissions and between 67 and 76 percent of global energy use.¹⁰ Only half of the world's urban population has convenient access to public

transport.¹¹ Private cars are responsible for 60 percent of transport-related emissions, even though they account for only one-third of total urban travel.¹² Emissions targets are tightening for all countries and electric vehicles (EVs) are becoming increasingly attractive to consumers and enterprises. But governments must invest in

efficiency incentives and technologies, including EV charging standardization, grid modernization, and electrical metering. Europe's stringent constraints on air pollution have forced some cities, because of elevated CO₂/NO_x emissions, to close roads (at least temporarily), re-route traffic, and limit access to certain neighborhoods. Improving traffic flow and reducing congestions 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 would be emission-free.¹³

Legacy Infrastructure



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 the local, regional, or national level. 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 often must 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.

Economic Loss



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.¹⁴ 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

Cities, transportation authorities, fleet managers, and operators are seeking ways to alleviate the pressures of today's road transportation challenges. Modernized infrastructure delivers sustainable, efficient environments that enhance safety, traffic management, and environmental performance of roadways.

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 features such as 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 communication protocols will make those safety solutions more effective.

Ideally, sensor data from all infrastructure sensors is fused in an edge- or cloud-based system 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. A central safety module can, on the fly, monitor and issue warnings for drivers, cyclists, or motorcyclists. It is even possible to alleviate dangerous situations up front by, for example, 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.

Machine learning can predict traffic hot spots on 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 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.



Enhancing Traffic Management



Intelligent traffic management helps cities address road safety and congestion by using smart cameras in conjunction with AI techniques 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 and 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 ways 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 and future traffic management needs to integrate multi-modal travel including car sharing, electric scooter rental, robo-taxis, or automated buses. This approach also helps to address access to areas that cannot be reached easily by traditional public transport modes.

As computing power is pushed from the cloud to 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 experience at intersections. In addition, they can help protect vulnerable pedestrians and cyclists, and increase safety 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 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, while each vehicle needs to be equipped with an RFID card in accessible places, behind the windshield, for example. In a V2X (vehicle-to-everything) configuration, both 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/Congestion Pricing



Smart parking solutions that monitor parking availability and guide drivers to available parking spots help to reduce the 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, e.g., for parking, can be used more efficiently. Rules for where parking is allowed can be adapted in real time making more space available dynamically that is currently permanently blocked for parking.

EV Charging



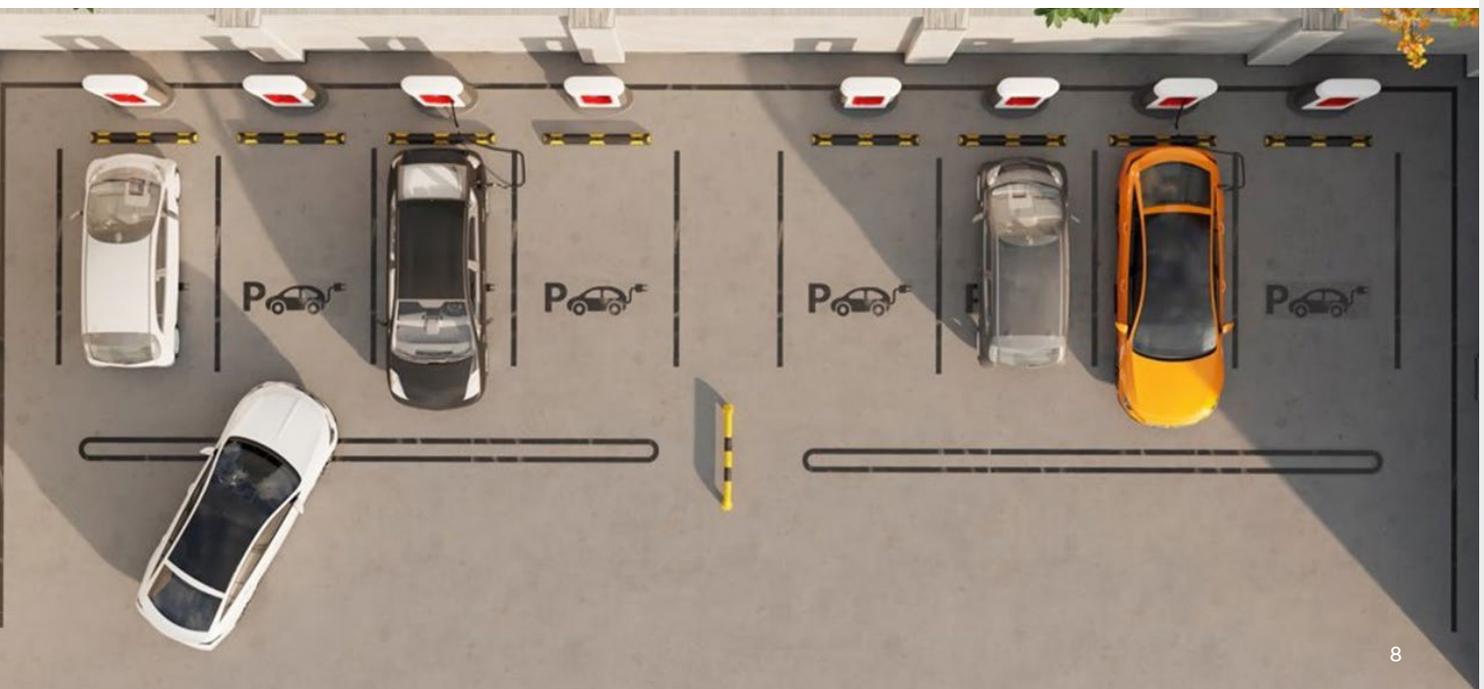
The proliferation of electric vehicles (EVs) has created a need for charging units at filling stations, parking lots, and on streets. A typical EV has a range of approximately 150 km (90 miles), which requires drivers to recharge often. Standard residential charging systems can take up to 8 hours for 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 the EV charging as 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. These chargers provide a frictionless customer charging experience, while generating revenue, promoting sustainability, and providing electric vehicle support. Volta charging stations present dynamic, interactive content, providing added value to stakeholders and enhancing customer experiences.

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.



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 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.

Edge Compute



Enhanced for IoT and embedded use cases, Intel processors come in a range of options for compute performance and power consumption, enabling the latest audio and visual quality for intelligent

cameras and sensors attached at roadside and within the vehicle. Intel offers a wide array of options for embedded and edge computing, from high-efficiency Intel® Movidius™ VPUs to low-power Enhanced for IoT Intel Atom® processors, high-performance Intel® Core™ processors, and Intel® Xeon® Scalable processors. Intel® Xeon® Scalable processors that are optimized specifically to run high-performance deep learning inference.

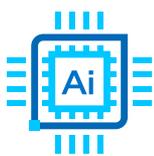
[Learn more about edge computing.](#)

Connectivity



Intel-powered solutions help transportation leaders simplify networking complexity and take advantage of edge-to-cloud computing. Intel-based edge computing nodes and MEC edge servers leverage the power of 5G with the help of [Converged Edge Reference Architecture \(CERA\)](#) to improve real-time traffic data at the edge while also advancing connectivity and transmission to and from wireless networks. The key wireless connectivity technologies are cellular and WiFi. In cellular, we have side link (C-V2X, NR V2X) and direct link (UU). Regardless of the technique, they must work together to provide low latency, high capacity, and high reliability connection to all road users.

AI Accelerators



Intel accelerators and appliances built on Intel® Movidius™ Vision Processing Units (VPUs) and Intel® FPGAs can add high-performance AI and vision technology from edge devices—smart cameras,

autonomous controls—to on-premises servers and AI appliances. The latest Intel® CPUs include integrated acceleration so you can run AI workloads on edge devices and servers. Processors with Intel® Iris® Xe integrated GPUs can put even more inference-processing power into low-powered edge devices.



Service Orchestration & Security

Keeping ITS software up-to-date is simplified with time-saving tools like remote device management and automated software deployment to devices at the edge. Intel processors feature multiple hardware-based security measures that help protect public and private data with hardware-based security technologies. Intel hardware includes chain of trust technologies for platform integrity: trusted execution environments that isolate applications. Dedicated cryptographic accelerators handle complex security calculations without taxing system resources.

“Cities around the world 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.”

Kathy Winter

VP, AUTONOMOUS TRANSPORTATION AND INFRASTRUCTURE, INTEL CORPORATION

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.

Developer Tools

Develop and deploy faster with Intel® development tools, Intel-engineered middleware, reference architectures, and ready-to-run applications that give you a solid foundation for building innovative smart city technologies.

- Get a head start on smart city, AI-powered applications. Build on our growing library of free reference implementations for traffic management, road infrastructure, and public health.
- Take the networking complexity out of container-based applications and orchestration. Smart Edge Open 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® 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/edge that makes it easy for developers to access reference designs, toolkits, and ready-to-launch containers that accelerate time to market and helps preserve interoperability through upgrades.

Policy Framework, Standards, and Technology Research

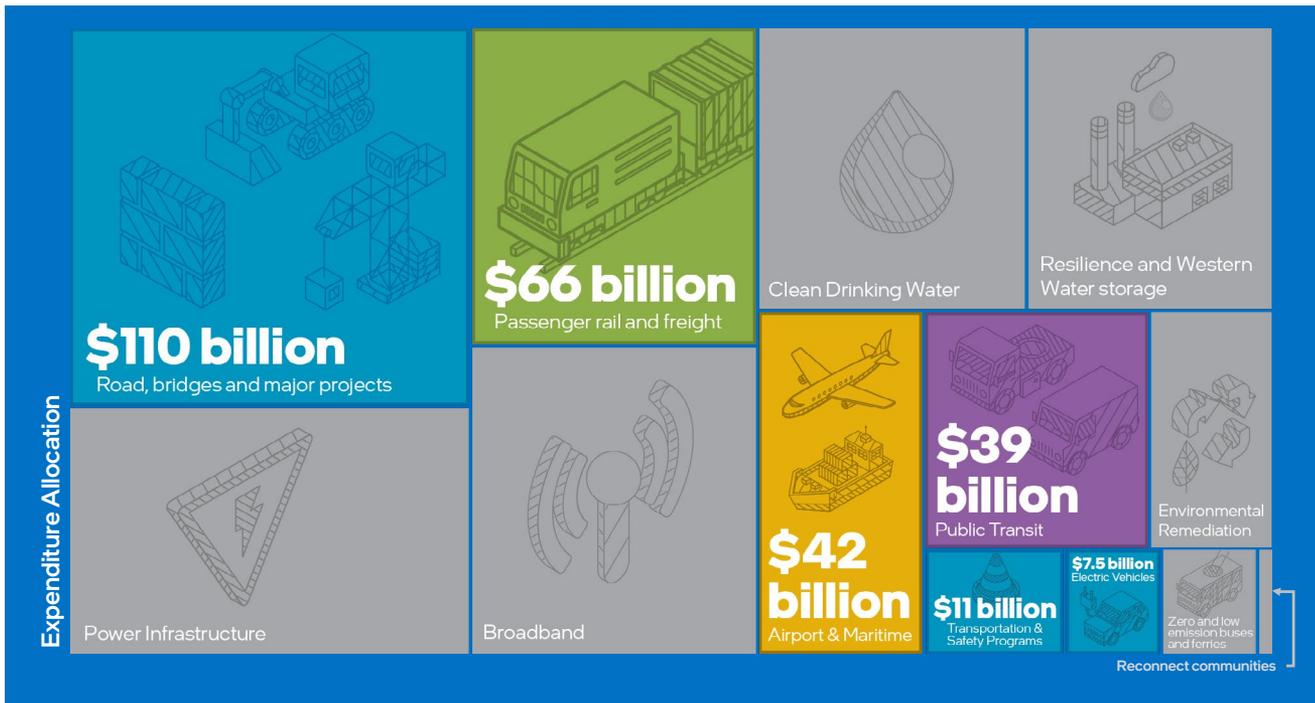
Policy, standards, and technology research are all critical building blocks for the technology industry. Intel participates in advocacy initiatives, standards bodies, and industry groups worldwide, and has led technology research to enable innovation across the ecosystem.

Policy Framework

A policy framework that harnesses the full potential of the transformational IoT 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 spectrum needs required to support IoT. 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 which Intel has contributed to from a policy standpoint designed to fund improvements and modernization of roads plus 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 which 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 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 recently 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 IoT, 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 which 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 worldwide and has played a significant role in bringing about globally adopted ubiquitous standards, including: Ethernet, USB, and Wi-Fi.

Technology Research and Contributions to 5GAA and ETSI V2X Standards

C-V2X is a cellular standards-based technology supported by 5G that 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 World Health Organization, about 1.3 million people die each year in road traffic crashes, out of which more than half of the victims are low-mobility, high-physical-impact-VRUs such as pedestrians, bicyclists, and motorcyclists. We at Intel envision that 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 the 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 and leading researchers around the world. That includes prominent university science and technology centers, The National Science Foundation, and the Semiconductor Research Corporation. Together we 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 at the roadside infrastructure. Furthermore, 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.⁹ 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. Towards this end, three service verticals supported at the RSUs can be envisioned: communication services, edge services, and digital twins.



Technology Spotlights

Providentia++ (Traffic Management/Edge Services)

Challenge: The Providentia++ (P++) project builds upon an extensive infrastructure of radar, lidar sensors, and cameras installed at a highway section and adjacent urban area in Munich. Providentia++ goal is to improve infrastructure-based sensor fusion for automated driving in terms of robustness and inclusiveness.



Solution: The project covers “over-all-fusion” with research of methods for dependable perception; that is the robust fusion of all sensor data from the vehicle and infrastructure using low latency wireless communications (LTE, 5G). The project also studies “vehicle-global control” through the generation of a global environment view, created with all available data, to reliably guide autonomous vehicles in a mixed traffic scenario where automated vehicles coexist with manual vehicles. Finally, P++ aims at providing high availability by enabling dependable and fault-free continuous operations under adverse environment conditions. This is achieved through self-organizing orchestration of compute loads between infrastructure and automated vehicles at the hardware and Operating System level.

Results: Intel Labs developed a dependable interlocked system of vehicles and infrastructure components that increased the robustness and intelligence of the infrastructure. In the process, Intel expects to facilitate access to a wide range of time-synchronized and annotated datasets from both vehicle and infrastructure and develop a clear understanding of requirements needed for large-scale deployments and value-added services in traffic management and roadside infrastructure.

Hangzhou Smart Highway (Edge Services)

Challenge: China transport authority and local governments are rolling out a plan to build a smart highway that connects one of largest ports, Ningbo, to one of the new ‘tier one’ cities in east China, Hangzhou. The project aims to solve challenges from increasing logistic needs and improved safety requirements in highways. This smart highway is targeted to improve container transport efficiency with higher speed limits, from 120km/h to 160km/h, while improving road safety by adding intelligence to both the highway infrastructure, as well as the vehicles on the road.



Solution: The initial plan foresees deployment of 1,200 roadside units with smart sensing and V2X communication capability along both sides of a 6-lane highway segment of 200km.

Results: Intel has partnered with Alibaba to enable edge computing and cloud computing infrastructure for the smart highway management system able to interact with the vehicles and monitor the highway traffic in real-time, supporting advanced semi-autonomous truck platooning. Intel Labs is contributing to this effort with V2X technology solutions.

Customer Case Studies

Arizona, USA

Traffic management
source: [Gridsmart](#)

Bell Road Highway's daily traffic exceeds 75,000 cars. Using the GRIDSMART single-camera system for intersection actuation reduced delays by 20% on weekdays and 43% on weekends. Travel times were reduced by 2% each day, and the overall speed of the corridor was increased by 1.8%.

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 cost while adhering to strict safety standards. Sitraffic® One is a complete intersection solution comprised of signal heads, controller 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 supports innovation and collaboration with partners in several ways. Intel's Go-to-Market support includes Engineering/Design-In collaboration and breakthrough technical advancements through the network of Intel Labs research. ISupport also includes Engineering/Design collaboration with the network of Intel Labs research. Intel's Go-to-Market support includes: sales enablement (collateral, demand generation); sales pipeline development for partner solutions; marketing and thought leadership; policy and standards contribution and influence; transportation grants support (the DIGIT Act, for example). For more information on partnerships, view the [Intel® IoT 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 facilitate traffic easier, 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 fog 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 which 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. Moreover, it grants agencies the extra benefit of reducing traffic congestion and accidents, both of which would help make our roads more efficient and safer.

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 from mitigating idling time and passenger commute time as well as increasing fuel efficiency through smart intersections.
- Lower total cost of ownership through incorporating existing infrastructure and eliminating redundant, proprietary systems with limited or no interconnectivity.

For more information:

[Solution](#)
[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 offers two packages. The Basic IQ Roads system has capabilities that are generally available from the main suppliers of such systems. The Advanced IQ Roads system provides additional capabilities that are quite unique based on patented technologies.



Key features and benefits:

- AI-based multi-sensory analytics
- Automated response system
- Insights from big data

For more information:

[Website](#)

SSE Intelligent Solutions AGENT

AGENT is a set of traffic signaling devices that processes traffic information in real time. With the ability to capture images with a system coupled to the chassis itself, it can read the traffic and through the algorithms distinguish the roads, vehicles, and pedestrians.

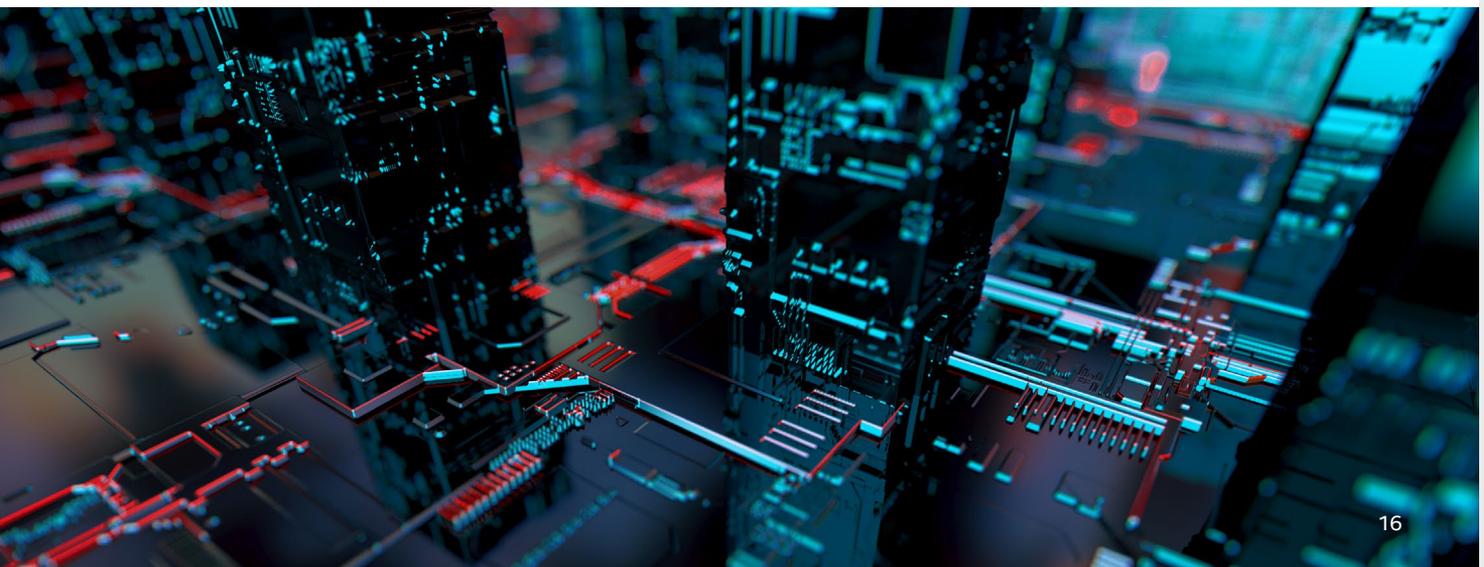


Key features and benefits:

- Road signaling: LED panel has high brightness and resolution so that, in addition to a traffic light, it can display signaling boards automatically and dynamically
- Road monitoring with real-time data: record, store, and transmit videos
- Detect transit infringements: generate snippets of videos with the detected event and identify license plate data
- Open API for 3rd party integration
- Traffic optimization: 30% improvement in flow of vehicles

For more information:

[Website](#)



Tolling (Electronic Toll Collection, Smart Parking)

NCS Smart Carparking

The NCS Smart Carparking module is an integrated smart parking solution with the IntelliSURF platform, magneto-sensitive sensors, and video cameras. The NCS Smart Carparking module delivers near real-time parking lot availability data powered by weather-proof, magneto-resistive ground sensors.



Key features and benefits:

- Weather-proof magneto-resistive ground sensors provide near real-time parking lot availability data, lending greater depth and accuracy to the collected information.
- Video cameras enable number plate recognition that can be used in anticipation of pre-selected VIPs, whitelisting/blacklisting, and capture of surveillance data for monitoring or forensic analysis.
- Parking management can use insights to make smarter, informed decisions when optimizing parking policy, resulting in a better experience for customers.
- Long battery life of the magneto-resistive sensors ensures durability and reliability.
- Low-cost installation with flexible, large-scale deployment.
- Reliable, near real-time wireless transmission of parking data ensures accurate and timely space availability awareness.
- Eliminates expensive and complex communication systems by eliminating need for repeaters or a mesh network.

For more information:

[Website](#)

ST Engineering Electronics S*Park Platform

S*Park Smart Car Park Solutions provide 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 parking experience with seamless payments, easy search for parking lot availability and rates, and secure parking space with advance 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.
- Support various use cases including stop & go, free-flow, bidirectional, multiple lanes.
- Supports various processing architectures including edge, server, and cloud.
- Open API for 3rd party integration.
- Plug and play setup.

For more information:

[Solution](#)

[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 implements Intel's Converged Edge Architecture (CERA), which 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 Intel Converged Edge Reference Architecture (CERA) and Capgemini Engineering ENSCONCE MEC Platform work in concert to maximize 5G network, cloud, and computing performance.
- By integrating technologies like Intel® Smart Edge Open 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:

[Solutions](#)

[Website](#)

The Cellnex Mobility Lab

The Cellnex Mobility Lab in Castellolí, near Barcelona (Spain), 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. Mobility Lab develops 5G-based sustainable, connected and autonomous mobility solutions for vehicles, traffic management, or road infrastructure. The racetrack has been equipped with several self-sustaining Green Edge sites to support the cellular Vehicle-to-Everything (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 Telecom to deploy an 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](#)

TietoEVERY

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. TietoEVERY 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, IoT and V2X communications enable alerting approaching cars. The system will help prevent accidents. In the future, the system can also serve autonomous vehicles.



For more information:

[Solutions](#)

[Website](#)

	Partner	Solution	Geo Availability
TRAFFIC MANAGEMENT	Advantech	Advantech 1551 + VEGA-330 Vision AI ready platform (APJ ODM)	Global
	Advantech	Advantech ARK-2250S (NEMA TS2 Certified) Traffic Controller	Global
	Advantech	Advantech ITA3650 Highway Traffic Management	Global
	Agent Video Intelligence Ltd.	Agent Video Intelligence innoVi AI at the Edge Kit	Europe
	AllGoVision	AI Powered AllGoVision Video Analytics	Asia/Pacific/Japan
	Arrow Electronics, Inc.	ARROW ELECTRONICS Balto by Seneca with IVAR	United States/ Canada
	Avnet	Avnet AI-Cube	United States/ Canada
	Awiros	Awiros Video Intelligence Application Suite	Asia/Pacific/Japan
	Axis Communications	Axis Communications>AXIS Camera Station - Video Management Software Solution	Global
	AxxonSoft	AxxonSoft Video Surveillance & Analytics Kit	Europe
	Cisco	Cisco Connected Roadways	United States/ Canada
	Cisco	Cisco Mass Transit	United States/ Canada
	ComBoxTechnology	ComBoxTechnology Passengers counter	Europe
	Dahua Technology Co., Ltd. Entity List	Dahua Technology Traffic Management Solution (ENTITY LIST)	People's Republic of China
	Digifort Cloud	Digifort IP Surveillance System Digifort Cloud	South America
	EdgeVision	EdgeVision Traffic	Europe
	EverFocus Electronics Corp.	EverFocus Electronics EverFocus Intelligent Edge Solution for Transportation	Asia/Pacific/Japan
	Getac Technology Corporation	Getac Technology Video Solutions	Asia/Pacific/Japan
	Gorilla Technology	Gorilla Technology Intelligent Video Analytics Recorder	Asia/Pacific/Japan
	GPC Systems Ltd	GPC Freight, Highways, & Woundcare Measure	Europe
	Graymatics India Private Limited	Graymatics India Private Limited AI driven Advanced Video Analytics	Asia/Pacific/Japan
	Green Ideas Technology	Green Ideas Technology Smart Outdoor Lighting	Asia/Pacific/Japan
	GRIDSMART Technologies	GRIDSMART Technologies System	United States/ Canada
	Hitachi Vantara	Hitachi Visualization Suite	Global
	Hitachi Vantara	Hitachi Edge Gateway and Smart Video Camera	Global
	IEI Integration Corp.	IEI Integration IVS-300-ULT3-QGW	Asia/Pacific/Japan
	IEI Integration Corp.	iEi Tank Ruggedized Surveillance Solution	Asia/Pacific/Japan
	Intelligent Security Systems (ISS)	Intelligent Security Systems (ISS) SecurOS UVSS	United States/ Canada
	Intelligent Security Systems (ISS)	Intelligent Security Systems (ISS) SecurOS Velox	United States/ Canada
	iOmniscient Pty Ltd	iOmniscient IQ Roads	Asia/Pacific/Japan
	IPG	IPG GearBox	United States/ Canada
	ISSD Electronics	ISSD Electronics Specto Incident Detection System	Middle East/Africa
	Klas Telecom	Klas Telecom TRX Connected Transport Platform	United States/ Canada
	Lecoo AI	Lecoo AI Smart Transportation and Access Solution	People's Republic of China
Macnica Inc.	MACNICA Intelligent Stereo Camera	Asia/Pacific/Japan	
NCTech Imaging	NCTech Imaging iSTAR Pulsar+	Europe	
Okaya Electronics Co., Ltd.	Okaya Electronics 3D LiDAR Evaluation Starter Kit	Asia/Pacific/Japan	
Omnivex	Omnivex Moxie Digital Signage	United States/ Canada	

	Partner	Solution	Geo Availability
TRAFFIC MANAGEMENT	Parifex	Parifex NANO CAM	Europe
	Seebot Soluções Inteligentes	Seebot Soluções Inteligentes Agent + Traffic Optimization	South America
	Shanghai Ruishi Machine Vision Technology Co., Ltd.	Shanghai Ruishi Machine Vision Technology Roseek Intelligent Transportation System Smart Camera Development Kit	People's Republic of China
	Siemens	Siemens Sitraffic Traffic Controller	APJ
	Siemens	Siemens TEV (Traffic Eye Video)	APJ
	SkyLab	SkyLab Transport Accelerator (STA)	Asia/Pacific/Japan
	Software Product Group	Software Product Group Navigation Kiosk with Pedestrian Traffic Monitoring	Europe/Russia
	SprinxTech	SprinxTech Automatic Incident Detection (A.I.D.)	Europe
	Vehant Technologies	Vehant Technologies TrafficMon (Traffic Monitoring vSolution)	Asia/Pacific/Japan
	Verizon	Verizon Smart City Suite Public Safety & Security	United States/Canada
	Videonetics	Videonetics Intelligent Video Management Software and Intelligent Traffic Management Solution	Asia/Pacific/Japan
	ZheJiang Uniview Technologies Co., Ltd.	ZheJiang Uniview Smart City Solutions	People's Republic of China
	Zotera LLC	Zotera Radius, Zotera Stratos, & Zotera Insight	United States/Canada
TOLLING	Acer ITS	Acer ITS Smart Parking & Transportation E-ticketing Solution	Asia/Pacific/Japan
	ADLink	ADLink MXC 6000 Electronic Highway Tollbooth & Surveillance	Global
	JHCTech	JHCTech ETC Solutions	PRC
	Moxa Inc	Moxa Smart & Connected Mobility	Asia/Pacific/Japan
	NCS Pte Ltd	NCS Smart Carpark Solution	Asia/Pacific/Japan
	Plate Smart Technologies	Plate Smart Technologies Plate Smart	United States/Canada
	Shenzhen JHC Technology Development Co., Ltd	Shenzhen JHC Technology Development Road Pricing Inspection System	People's Republic of China
	ST Engineering	ST Engineering S*Park	Asia/Pacific/Japan
	Uncanny Vision	Uncanny Gate ANPR	Asia/Pacific/Japan
EDGE SERVICES	22 Miles	22 Miles Interactive Wayfinding Kiosk Solution	United States/Canada
	Alphainfo Inc.	AlphaVRS	Asia/Pacific/Japan
	Chengdu Yuntu Wiselight Tech Co. Ltd.	Chengdu Yuntu Wiselight Smart Roadside Parking System	People's Republic of China
	Congatech	Congatech AG Realtime Workload Consolidation Starter Set	EMEA
	Intersection	Intersection IxNConnect	United States/Canada
	Kapsch Trafficom	Kapsch Trafficom RIS-9160 and RIS-9260 V2X Roadside ITS Stations	Global
	LG-MRI	LG-MRI BoldVu Kiosks	Global
	Merit LILIN Co., LTD	Merit LILIN High Speed Automatic Number Plate Recognition	Asia/Pacific/Japan
	SkyLab	SkyLab Multi-Edge Computing (MEC)	Asia/Pacific/Japan
	SmartAxiom Inc.	SmartAxiom Edge Blockchain IoT Security and Management	United States/Canada
SuperMicro	SuperMicro Outdoor Edge Systems	Global	

Next Steps

Strategic innovation and transformation are a continual 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 cities 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 require 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 roads 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 the US 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, 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 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. At Intel, we believe transportation and city leaders can successfully transform their cities by establishing clear priorities, encouraging active stakeholder participation, ensuring methodical technology infrastructure planning, while enabling the right policy and governance. With our edge to core to cloud technology 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

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® DevCloud for the Edge

The Intel® DevCloud for the 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 DevCloud contains a series of Jupyter* notebook tutorials and examples preloaded with everything needed to quickly get started. This includes trained models, sample data, and executable code from the Intel® Distribution of OpenVINO™ Toolkit as well as other tools for deep learning. These notebooks are designed to help developers quickly learn how to implement deep learning applications to enable compelling, high-performance solutions.

[Learn more about Intel® DevCloud for the Edge.](#)

Intel® Smart Edge/Smart Edge Open

Smart Edge Open drives the Intel vision of networks built on open, industry-standard edge computing. Built on OpenNESS, the Intel® Smart Edge offering is a multi-access edge (MEC) platform commercialized for market use cases for onpremises enterprise deployments that require low latency, private mobility, simplicity, and open architecture. Customers can stand up their own private network to enjoy security, service, and a broad set of network services. Networks can be configured in minutes and tailored to specific customer needs and applications.

[Learn more.](#)

Smart Edge is a cloud-native, scalable, and secure platform for multi-access edge computing (MEC). With Smart Edge, enterprises and communications service providers can enable cloud-like services closer to the user on the customer-premises or network edge. The Smart Edge platform is built to run on Intel technologies, such as high-performing Intel® Xeon® Scalable processors today and, going forward, Intel® Optane™ memory, Intel® FPGAs, and other accelerators. Smart Edge's software is also highly complementary with [Intel's Smart Edge Open](#) (Open Network Edge Services Software) project.

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, IoT, and V2X communications enable alerting approaching cars—preventing accidents.

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, IoT, advanced rendering, deep learning frameworks, and more—that are written in DPC++, C++, C, and Fortran languages.

[Learn more.](#)

Open Visual Cloud

To help strengthen the ecosystem and provide ready access to the building blocks and pipelines for cost effective visual cloud innovations, Intel is providing reference pipeline recipes for Visual Cloud services using existing open source functions from Intel in an open source project called the [Open Visual Cloud](#). 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 goal is to minimize barriers to innovation for quickly and easily creating and monetizing Visual Cloud services. Support for familiar industry standard frameworks leverage the larger open source community and include media (FFMPEG and GStreamer), AI (TensorFlow*, Caffe*, MXNet*, ONNX*, Kaldi*), and graphics (OpenGL, DirectX). *, ONNX*, Kaldi*), and graphics (OpenGL, DirectX).

[Learn more about Open Visual Cloud.](#)



Endnotes

- 1 UN [Growing at a slower pace, world population is expected to reach 9.7 billion in 2050 and could peak at nearly 11 billion around 2100](#), 2019
- 2 Nature [High-resolution global urban growth projection based on multiple applications of the SLEUTH urban growth model](#), 2019
- 3 C40 [100 days since the Paris Climate Agreement: 5 Reasons Why Cities Hold the Key to Delivering Success](#), 2016
- 4 WHO [Road traffic injuries \(who.int\)](#), 2020
- 5 GHSA [Pedestrian Traffic Fatalities by State: 2020 Preliminary Data](#), 2020
- 6 GHSA [Pedestrian Traffic Fatalities by State: 2020 Preliminary Data](#), 2020
- 7 GHSA [Pedestrian Traffic Fatalities by State: 2020 Preliminary Data](#), 2020
- 8 APTA [Public Transportation Industry Faces \\$39.3 Billion Shortfall](#), 2021
- 9 ITS Digest [Congestion Costs Each American Nearly 100 Hours and \\$1,400 Per Year](#), 2020
- 10 UN [Revision of World Urbanization Prospects](#), 2019
- 11 IISD [COVID-19 Led to First Rise in Extreme Poverty in a Generation](#), 2021
- 12 European Parliament [CO2 emissions from cars: facts and figures](#), 2019
- 13 C40 [Climate Action Planning Resource Centre](#), 2020
- 14 INRIX [Signals Scorecard Map](#), 2021
- 15 [The World Bank](#), 2021
- 16 [GHSA](#), 2021
- 17 [The World Bank](#), 2019
- 18 [INRIX Congestion Costs](#), 2020
- 19 [World Economic Forum](#), 2019



Performance varies depending on system configuration. No computer system can be absolutely secure. Check with your system manufacturer or retailer.

Test document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance. Consult other sources of information to evaluate performance as you consider your purchase. For more complete information about performance and benchmark results, visit intel.com/performance.

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Intel's compilers may or may not optimize to the same degree for non-Intel microprocessors for optimizations that are not unique to Intel microprocessors. These optimizations include SSE2, SSE3, and SSSE3 instruction sets and other optimizations. Intel does not guarantee the availability, functionality, or effectiveness of any optimization on microprocessors not manufactured by Intel. Microprocessor-dependent optimizations in this product are intended for use with Intel microprocessors. Certain optimizations not specific to Intel microarchitecture are reserved for Intel microprocessors. Please refer to the applicable product User and Reference Guides for more information regarding the specific instruction sets covered by this notice.

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November 2021



Think big

Assess all the ways technology can facilitate meaningful change

Start small

Get going with projects and opportunities

Move fast

Learn, adjust, iterate



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