PAVING THE WAY FORWARD
Intelligent Road Infrastructure
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

With increased urbanization and vehicles globally, the future of smart road systems/infrastructure must help reduce pedestrian, bicyclist, and road traffic fatalities and serious injuries. Through investments in technologies like AI and 5G, pushing open-standards and influencing policy, Intel is helping power a transformation in roads and highways, by enabling innovative solutions for safer, greener, and more efficient roads.

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OVERVIEW

Transportation is the lifeblood of the global economy as planes, ships, railways, commercial vehicles, buses, and cars help us physically connect with each other and navigate across town or around the world. Since the days of the Silk Road in Asia, pre-Colombian road networks in the Americas, and shipping networks in the Mediterranean, transportation has continually evolved to make the movement of people and goods more efficient. Now commonplace, transportation innovations such as the wheel, road networks, and sea-worthy ships supported trade, resulting in economic growth. Over millennia, transportation of goods and people has been a driving force in the advancement of human civilization.

Thanks to these advances, people now travel farther, explore more territory, and have expanded trade opportunities. Cities have historically been transportation hubs and are now experiencing increased demand for urban mobility – the ability for people to move around the city smoothly and effectively using road or rail transportation infrastructure. Urban mobility is expected to grow 2.6 times from current rates by 2050.1 Urban population growth is at the heart of this, with an expected 43 megacities around the world—cities with more than 10 million inhabitants—by 2030, up from 31 today.2

This explosive growth in urban populations will make rapid innovation in transportation, public services, conservation, and public safety a necessity. Increasing demand for movement within cities of occupants, workers and goods is putting pressure on transportation infrastructure that was designed in another era and often dependent on automotive transport.

Road infrastructure solutions can play an important part in helping cities become safer, greener, and smarter.3 Governments throughout the world have initiated plans to deploy technologies for Smart City, traffic management, Intelligent Transportation Systems, and road safety projects to mitigate the challenges faced due to rapid urbanization.3 Road safety represents measures that can be taken to reduce the risk of accidents and fatalities for road users (cyclists, motorists, pedestrians, vehicle passengers, and public transport passengers) in the road network of built-up urban streets, non-built-up rural roads, and major highways.3

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This e-book provides an overview for how City and Transportation Leaders can develop Smart City strategies for improving road infrastructure. These strategies bring together solutions that help cities and regional transportation authorities improve traffic management, electronic toll collection and Edge services (road asset and pavement conditions) to intelligently help manage multiple aspects of daily life, including traffic, transportation and infrastructure. With these advances, city and transportation leaders can achieve the ultimate goal of improving public safety plus quality of life for citizens.

**TOP 20 COUNTRIES WITH LARGEST ROAD NETWORKS**

1. **UNITED STATES** 6,586,610 km
2. **INDIA** 4,699,024 km
3. **CHINA** 4,106,387 km
4. **BRAZIL** 1,580,964 km
5. **RUSSIA** 1,283,387 km
6. **JAPAN** 1,218,772 km
7. **CANADA** 1,042,300 km
8. **FRANCE** 1,028,446 km
9. **AUSTRALIA** 823,217 km
10. **SOUTH AFRICA** 747,014 km
11. **SPAIN** 683,175 km
12. **GERMANY** 645,000 km
13. **SWEDEN** 579,564 km
14. **INDONESIA** 496,607 km
15. **ITALY** 487,700 km
16. **FINLAND** 454,000 km
17. **POLAND** 412,035 km
18. **UNITED KINGDOM** 394,428 km
19. **TURKEY** 385,754 km
20. **MEXICO** 377,660 km
Trends & Forces Impacting Road Infrastructure

The explosive growth in urban populations will demand rapid innovation in transportation, public services, conservation, and public safety. In addition to urban population growth and increasing numbers of cars, transportation authorities are experiencing several important trends:

- **Traffic Growth:** The expected doubling of global traffic volume to over 2 billion by 2040⁴ coupled with increased urbanization will continue to exacerbate the multibillion annual cost of congestion across large cities.

- **New Monetization Models:** 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. Australia and several countries in Europe and the Middle East are testing vehicle-miles-travelled taxes.⁵

- **Evolving Funding Models:** Cities and transportation authorities increasingly rely on public-private partnerships to increase project efficiency, share risk, and minimize road closure time. Private companies are important channel partners as they often own, operate, maintain, and finance roads.

- **Autonomous Driving:** New technology may be improved in a monitored, low-latency environment. This is driving increased transport authority and Automotive OEM investment in pervasive Edge compute, 5G, roadside units, and intersection technology.⁶

- **Connected Vehicle Technology:** As Automotive OEMs make strides in V2X technology, the global installed base will reach 6 million vehicles by 2022.⁷ Governments must keep up to improve safety. This will require Edge compute, workload consolidation, data management, and communications networks.

- **Environmental Considerations:** Emissions targets are tightening worldwide, and EVs are becoming increasingly attractive to consumers and enterprises. This is driving transport authorities to invest in efficiency incentives and technologies, including embedded solar panels, EV charging cables, and metering.

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⁴ World Economic Forum, Apr 2016.
⁵ Road Taxes in Different Countries, May 2017.
⁷ US Department of Transportation, Beyond Traffic.
CHALLENGES

Ever-increasing growth in the number of vehicles on roadways raises important challenges in terms of traffic congestion, infrastructure management, and road safety. Disruptive technologies such as autonomous vehicles and emerging business models like ride sharing introduce uncertainty in projecting the number of vehicles on roads beyond a few years out. Since these trends are no longer linear, forward thinking cities are preparing for continued growth of vehicles on roadways, and the potential impacts on city services and ultimately quality of life.

Transportation systems are struggling to keep pace with the demands of our global, connected economy. The increasing trend toward urbanization is creating unprecedented challenges for city leaders around transportation infrastructure. Rapidly growing cities are under pressure to address safety, congestion, and resulting environmental issues. These impacts to quality of life are intertwined and stemming from an outdated road infrastructure in locales around the world.

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. More than half of all road traffic deaths and injuries involve vulnerable road users (VRU), such as pedestrians, cyclists and motorcyclists and their passengers. The US saw a 5 percent increase in the number of pedestrian fatalities in 2019. 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. The corresponding costs of accident-related healthcare take a large 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 major 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.

Traffic Congestion

High volumes of vehicle ownership, coupled with 20th century urban planning modeled around the automobile, have created massive pressure on the roadway infrastructure. In fact, the number of vehicles on our roads are growing at a staggering rate. Total vehicles grew from 926 million units in 2006 to 1,282 million units in 2015, at a 38.5 percent increase; this includes an increase of 35.4 percent in commercial vehicles and 39.4 percent in passenger cars. Moving into the future, global traffic volume is expected to increase 2-4 percent annually; when coupled with increased urbanization, this will continue to exacerbate the multi-billion annual cost of congestion across large cities.

8 World Health Organization, Road Traffic Injuries, 2019.
10 United Nations, 2018 Revision of World Urbanization Prospects, 2019
11 Harbor Research, Road Infrastructure Update.
In the US alone, city traffic congestion costs $305 billion annually ($66 billion just in the freight industry). These numbers come from the lost productivity of workers sitting in traffic, the increased cost of transporting goods through congested areas, fuel wasted while cars idle in traffic. Even when motorists aren’t directly paying for the true costs of car transport, driving exacts other tolls, both internal (stress) and external (air pollution).

Traffic Congestion

According to the US Department of Transportation, 73 percent of the metropolitan workforce spend more than 90 minutes commuting to work, while an estimated 30 percent of traffic in urban areas is caused by cars looking for parking. Traffic congestion wastes 4.2 billion hours annually and 2.8 billion gallons of fuel are wasted in traffic jams each year. Outdated traffic signal timing cause more than 10 percent of all traffic delays on major routes in urban areas. City budgets do not support the upfront capital needed to deploy a city-wide solution. Funding is diminishing. For example, in the US, rising electric vehicle use has lowered gas tax revenues. In fact, the world is facing a $15 trillion gap between projected investment and the amount needed to provide adequate global infrastructure by 2040.

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. The slow movement of automobile and truck traffic increases the volume of microscopic particulate matter, affecting the health of drivers as well as those on the streets. Traffic and air pollution are serious issues facing cities today. Emissions targets are tightening for all countries and electric vehicles (EV) 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.

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.

The cost to implement Smart City deployments could reach $1.12 trillion by 2025. In contrast, adopting standardized solutions would equate to a cost of $781 billion – savings of $341 billion worldwide by 2025 – 30 percent of the non-standardized total. Cost savings would result from interoperability, freedom from vendor lock-in, and reduced systems integration costs that IoT standardization provides.

Non-Standardized IoT Deployments

Smart Cities could waste $341 Billion by 2025 on non-standardized IoT deployments.


13 World Economic Forum.
15 Harbor Research, Road Infrastructure Update.
OPPORTUNITY FOR INTELLIGENT ROAD INFRASTRUCTURE

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.

MODERNIZATION STARTS WITH TRANSPORTATION INFRASTRUCTURE

BY 2030, the world will have 41 MEGACITIES cities with more than 10 million inhabitants.

BY 2050, demand for urban mobility is expected to grow 2.6X.

THE WORLD IN 2050:
- 2.5M cities & towns
- 4,000 cities with 100K+ population

Advances in information and communication technology offer cities and transportation authorities the opportunity to enhance transportation and services to support a thriving economy. New transportation monetization models, expanding role of public-private partnerships, and key Edge technology advancements can help cities address today’s demands in innovative ways. To achieve the municipal benefits of autonomous buses, shuttles, and vehicles, cities must invest in pervasive edge compute, 5G, road-side units, and intersection technology.
Benefits to cities and citizens can be realized in 5 key areas: Public Safety, Traffic Management, Electronic Tolling, Smart Parking and Improved Road Conditions.

Improving Public Safety

Cities around the world 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, people, and devices 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 and road users.

Additionally, buses and vehicles equipped 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 warning ahead and in the blind spots of the vehicle, urban forward collision warning, lane departure warning, headway monitoring and warning, and speed limit recognition.
Enhancing Traffic Management

Traffic monitoring helps cities address road safety and congestion by using intelligent cameras in conjunction with Artificial Intelligence (AI) to optimize traffic flows and quickly detect incidents as they occur. 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 emergency vehicles such as ambulances, police cars, fire engines, and other responders to avoid traffic delays and help save lives and reduce loss of property.

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 an ever-changing environment and get more travelers where they need to go 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 the monitoring the path of vehicles as they drive through the tolling area/highway. And ETC systems that employ approach based on occupation time of location assess tolls depending on how long a vehicle occupies a parking location, mostly used in smart parking solutions.

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 could be classified from three different perspectives: the use cases, the tolling basis, and the technology used.
For tolling use cases, ETC solutions can be grouped into the following main categories:

- **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, ETC could be deployed based on three different 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 RFID card in accessible places, for example, behind the windshield. In a V2X 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.

**Reducing Congestion through Smart Parking and Congestion Pricing**

Smart parking solutions that monitor parking availability and guide drivers to available parking spots helps to reduce the traffic congestion caused by vehicles looking for parking and improve quality of life for citizens by reducing driving time. Intersection compute infrastructure can also be utilized to deploy 5G small cells to reduce latencies and for multi-access edge computing (MEC) to deploy value-added Edge applications such as advertising. All of these workloads could be consolidated to a single compute Edge server which in turn lowers the total cost of ownership (TCO) for the cities and reduces the complexity of managing individual use cases/solutions.

**Maintaining Road Asset and Pavement Conditions**

Road asset data collection powered by computer vision and AI is unparalleled to traditional and manual surveys. Vehicles traveling along their regular route and equipped with this non-intrusive data capture technology can survey thousands of miles of road at a very rapid rate and automatically compile a dynamic view of the city’s asset inventory and pavement conditions. 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.

**Pavement Conditions**

Road conditions are an important factor in road safety. For example, skidding crashes are often related to pavement rutting, polishing, bleeding, and dirt. Data and information on how pavement condition influences safety can inform a city’s paving decisions and the setting of priorities for maintenance. The empirical Bayes method was used to find that good pavements could reduce fatal and injury crashes by 26 percent compared with deficient pavements. Roads in need of repair cost American motorists $130 billion nationally, every year. If cracks are repaired at an early stage, they can be treated with a rout and seal technique for a relatively nominal cost of $62.50 per lane/km/year. If, however, the road is allowed to deteriorate to a point where full surface treatments are required, cost will be at least $1000 per lane/km/year.

17 Estimation of the Safety Effect of Pavement Condition on Rural, Two-Lane Highways, Jan 2014.
18 TRIPNET.org, Bumpy Road Ahead, Oct 2018.
19 Maine Department of Transportation, Pothole Prevention and Innovative Repair, Apr 2018.
Modernizing Legacy Architecture and Assets

Many road and transportation projects have been built by a single department to solve a single problem, creating islands of technology that may duplicate expenses while making it difficult to share systems or data. Successful Smart City initiatives often begin with a system-wide view and an integrated, cross-departmental approach, with alignment at the city, regional, and national level. This kind of holistic thinking and collaborative work are difficult, but successful initiatives that put in the effort upfront for integrated planning and management can achieve faster deployment and return on investment. Coordination across cities, regions, and nations can drive economies of scale and promote compatible solutions.

By adding incremental capabilities and making use of deployed technologies, cities and transportation authorities can gain the ability to evolve with changing needs. Many city and local governments would like to move to a more flexible and affordable computing platform but are concerned about the cost and risk of migration. However, by migrating from legacy architectures, cities and local governments can achieve significant benefits including better performance and reliability, lower capital and operating costs, and better flexibility and agility for future growth. Although careful assessment is always important to confirm viability, migration to modern architecture is most often a worthwhile process and tends to cost less than upgrading existing environments. Best practices have been refined over more than a decade, services and support are widely available, and most obstacles that are likely to arise can be overcome by a skilled team of Smart City experts and IT specialists working together.

Fortunately, modern IT architectures make it possible to connect city departments and solutions more easily today, helping cities to save time and enable new services that were not possible before. Along with this new approach, modern financial models are emerging that enable Smart City solutions to achieve rapid return on investment. By helping cities save money over the long run in many cases, technology can actually improve the city’s economic return.

By utilizing new computing technologies, cities and transportation authorities can move away from highly customized and difficult to maintain hardware and software systems. For example, workload convergence can allow functions including surveillance, traffic control, emergency event notification, and more to be decoupled from proprietary hardware systems. Instead, these functions can be implemented as “workloads” on general purpose, standards-based hardware platforms. This enables cities to optimize and simplify end-to-end processes to increase operational efficiencies, provide cost savings, and deliver faster, near real-time insights. With deeper, more precise insight, workload convergence helps address complexity, reduce total cost of ownership, and increase efficiency. Benefits for cities and transportation authorities include enabling near real-time quality control, reducing labor costs, performing preventive maintenance, improving processes such as traffic flow and emergency response.

### BENEFITS OF MODERNIZING ROAD INFRASTRUCTURE

#### BENEFITS

- Improve Traffic Flow
- Improve Safety
- Scale Confidently
- Realize Edge Value Quickly
- Expand Services
- Cost Savings for Logistic Operations

#### APPLICATIONS

- Environmental Monitoring
- Vehicle Tracking and Monitoring
- Real-Time Traffic Management
- Enforcement and Response
- Vehicle-to-Everything Communication
- GPS
- Tolling
- Parking
Considering the ever-increasing innovations in intelligent road infrastructure, imagine how the intersection of the future can be built, starting today. As computing power is pushed from cloud to Edge, new opportunities arise for Edge workloads that benefit from low latency, near real-time analysis, and connectivity such as network densification using 5G small cell deployment. Traffic monitoring, Adaptive Traffic Signal Management (ATSM), network technologies (5G, V2X), and AI technologies such as computer vision can be combined to improve intersections.

These technologies can assist with driver alerts and hyperlocal near real-time information, for example nearby restaurants can promote available reservations based on the previous dining habits of passengers. Drivers can also be notified of open parking spaces at nearby facilities and reserve a space with the push of a button. Onboard notifications like low fuel levels can lead to coordinated alerts that provide directions to nearby filling or charging stations.

**Adaptive Traffic Signal Management (ATSM)**

ATSM improves traffic flow through intersections by utilizing near real-time traffic information and AI to optimize streetlight scheduling. With capabilities including near real-time traffic information, forward connected/autonomous vehicle (CAV) design, AI and optimization, and adaptive signal coordination, ATSM reduces commute wait times, improves traffic flow, alleviates congestion and improves emergency response times through better driving conditions thereby increasing city accessibility.
**3GPP**

The 3rd Generation Partnership Project (3GPP) unites telecommunications standard development organizations (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC), known as “Organizational Partners” and provides their members with a stable environment to produce the Reports and Specifications that define 3GPP technologies. The project covers cellular telecommunications technologies, including radio access, core network and service capabilities, which provide a complete system description for mobile telecommunications. The 3GPP specifications also provide hooks for non-radio access to the core network, and for interworking with non-3GPP networks. 3GPP specifications and studies are contribution-driven, by member companies, in Working Groups and at the Technical Specification Group level. The three Technical Specification Groups (TSG) in 3GPP are: Radio Access Networks (RAN), Services and Systems Aspects (SA), and Core Network & Terminals (CT).

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**Roadside Sensors**

Intersections of the future must be able to detect and track complete information about dynamic objects in and around the intersection. Sensors act as the eyes of the smart intersection. Typically, a combination of multi-modal sensors such as cameras, high-precision RADARs, and LIDARs are used to gain diverse and complementary scans of the intersection amidst varying traffic and weather conditions. Dependability is a critical factor in safety critical use case such controlling an intersection. Therefore, robustness and reliability of the intersection perception is improved by converging workloads (camera, RADAR and LIDAR streams) to generate a global environmental view. Sensor fusion increases the dependability by means of multi-perspective coverage, inter-sensor anomaly detection, long-range vision, additional degree-of-freedom for dynamic system reconfiguration.

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20 [https://www.3gpp.org/about-3gpp](https://www.3gpp.org/about-3gpp)
Artificial Intelligence Technologies

Intersections of the future will also rely on computer vision powered by Artificial Intelligence (AI) to emulate human vision and perception to a certain extent. For example, with AI algorithms called Convolutional Neural Networks (CNNs) a computer application could detect, identify, and locate objects such as vehicles, bicycles, and pedestrians with accuracies and speeds closer to capabilities of humans. Computer vision algorithms process the data streams received by sensors (such as cameras, RADARs and LIDARs) to extract intelligence to understand the past and present behavior of objects within the intersection. With an accurate record of past and present behavior of moving entities in the intersection, advanced software applications could predict near-future behavior of each entity with some certainty.

In the next 5-10 years, forward looking cities will combine 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.
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 policies that promote innovation and open standards worldwide. We are active in advocacy initiatives around the globe, and our efforts have catalyzed the recent introduction of pro-IoT federal legislation and regulatory action for the US:

- To foster the Smart Cities space, the bipartisan Developing and Growing the Internet of Things (DIGIT) Act (S. 1611) creates a much-needed foundation for America’s policymakers and industry to develop and implement a world-leading IoT strategy. Demonstrating its IoT leadership, Intel has been working with the bipartisan U.S. Senate co-sponsors - Senators Deb Fischer (R-NE), Brian Schatz (D-HI), Cory Gardner (R-CO) and Cory Booker (D-NJ) - as well as a broad array of industry stakeholders to support this legislation which recently passed the Senate and has been referred to the House Committee of jurisdiction for its consideration.

- The Federal Communications Commission (FCC) recently issued a notice of proposed rulemaking which proposes to designate up to 30 MHz for C-V2X. Intel is a member of 5GAA which is working with policy makers, automakers, equipment manufacturers, and Infrastructure Owner Operators to enable C-V2X world-wide. 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.

Standards

Looking to the future of IoT, cybersecurity technology, autonomous systems, AI, connectivity, and cloud computing, standards are the common tools to bring new innovations to people around the world. Intel contributes to the development and adoption of many standards which support Intel business objectives. These include standards which address global environment issues and best practices for corporate governance and business operation 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 standards such as Ethernet, USB, and Wi-Fi.
Contributions to 5GAA and ETSI V2X Standards

Vehicle-to-Vehicle and Vehicle-to-Infrastructure (V2X) Standards are required to enable the future of Intelligent Transportation. Intel has been an active member of technical bodies, contributing to Intelligent Transportation System on the definition of standards for collaborative perception, maneuver coordination and misbehavior detection. In particular, we have developed mechanisms for the facilities layer of Collective Perception Service (CPS) to enable sharing of on-board/local sensing (local sensor raw data, perceived objects and free space, perceived layered cost map/occupancy grid) among the
proximity vehicles (and infrastructure/vulnerable-roadside users). Intel solutions provide fundamental technologies for connected autonomous vehicles to adopt collaborative/collective environment perception – extending the range and accuracy of perception beyond the vehicle’s local sensing capability.\(^{21}\)

Intel also developed a Maneuver Coordination Service (MCS) facilities layer in order to enable proximity vehicles to share, negotiate and coordinate maneuver intentions, and trajectory planning.\(^{22}\) This provides a way for vehicles to negotiate and interact with nearby vehicles and/or the infrastructure. MCS assists with traffic congestion avoidance and coordination, maintaining safe minimum distance between vehicles, improving traffic efficiency, managing intersections and emergency trajectory coordination. Maneuver coordination can also help in enhancing user experience by avoiding frequent hard breaks as front and other proximity vehicles indicate their intention in advance whenever possible.

In addition, we have developed Misbehavior detection techniques for connected autonomous vehicles. Since vehicles may intentionally or unintentionally share compromised or inaccurate data with neighboring road users, when safety critical information is shared among vehicles the trustworthiness of the data is crucial for the safety of vehicles and other road users. Intel is developing a misbehavior detection service (MDS) at the edge for verifying the data and take remedial actions. The Intel solution includes extended time series analysis, wireless and Radio Frequency properties-based techniques and multiple independent sensor observation-based techniques.\(^{23}\)

Finally, we are also contributing to the overall safety of Vulnerable Road Users (VRUs) in contributions to 5GAA and ETSI standards. The VRU basic service located in the facilities layer is linked with other application support facilities and responsible to transmit the VRU awareness message (VAM) to enable the assessment of the potential risk of collision of the VRU with the other users of the road. We have proposed solution directions such as the computation of safety metrics, along with their accompanying minimum values for safety considerations of the VRU profile transition awareness and VRU Clustering Concepts for reducing message exchange overhead.\(^{24}\)

**Technology Research**

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 we are doing research that’s transforming how machines think, learn, and adapt and how we compute, secure, and communicate the data that fuels 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 strong set of compatible solutions, platforms, products, technology innovations, and architectures to complement one of the world’s most dynamic set of ecosystem partners.

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21 ETSI TR 103 562 V2.1.1 (2019-12), Intelligent Transport System (ITS); Vehicular Communications; Basic Set of Applications; Analysis of the Collective Perception Service (CPS).
22 ETSI TR 103 578 V0.0.3, Intelligent Transport Systems (ITS); Vehicular Communications; Informative Report for the Maneuver Coordination Service.
23 ETSI TR 103 460 -2 (2020-01), Intelligent Transport Systems (ITS); Security; Pre-standardisation Study on Misbehavior Detection.
TECHNOLOGY SOLUTIONS FROM INTEL

Forward thinking 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 to insights. Intel technologies and the vast set of ecosystem partners and solutions create a more vibrant, extensible, and sustainable way for cities and transportation leaders to implement intelligent transportation strategies. Additionally, Intel helps protect connected systems from the inside out with a foundation of security technologies designed to harden and protect the entire device stack against a wide range of attacks.

Intel supports innovation and collaboration with partners in several ways. Intel’s Get to Market support includes Engineering/Design-In collaboration and breakthrough technical advancements through 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 influencing, transportation grants support (for example, the DIGIT act). For more information on partnerships, view the Intel® IoT Market Ready Solution.

Edge Computing

Today, most services are supported through the cloud to the device with the network as a simple transport mechanism. With the diverse needs of Smart Cities and, specifically, Intelligent Transportation System use cases that will be introduced with 5G, the network will be utilized in new ways. Some use cases will require both high-bandwidth and low latency, and some will require greater levels of privacy with a need to store the 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.

Because of this, the industry is looking at both increasing the capacity of the network and placing more computing and real-time analytics closer to the user at the Edge, where the data is collected and generated, to better manage network traffic and cost-efficiency. The goal is to deliver the right quality of experience for the specific use case.

THE EMERGING NEED FOR EDGE COMPUTE

45% of all data that IoT devices create will ultimately be stored, processed, analyzed, and acted upon at the Edge of a network.

Source: IDC

Latency expectation

Varies < 1ms < 5ms < 10–40ms ~ 60ms ~100ms
Intel® IoT Platform

Intel is helping IoT innovations get to market faster, reducing solution complexity, and defining how to derive actionable intelligence more quickly and securely. Intel® Compute technologies are hardened to support today’s IoT scenarios in Smart Cities. The Intel® IoT Platform breaks down barriers to IoT adoption by offering a defined, repeatable foundation for how devices will connect and deliver trusted data to the cloud. It allows original equipment manufacturers (OEMs), systems integrators (SIs), and vertical industries to develop and deploy solutions using building blocks on the Intel® IoT Platform.

Intel® Compute Technologies

Intel is deeply integrated and committed to the research and design of advanced computing for data centers running Intelligent Transportation System applications using new and emerging technologies, such as 5G, AI, autonomous vehicles, and advanced IoT sensors and data collection technologies. Intel® architecture helps intelligent city systems scale through a wide range of product offerings. Intel Atom®, Intel® Core™, and Intel® Xeon® processors each support a wide range of performance points with a common set of code. Industry-leading Intel® Xeon™ Scalable and Core™ processors support different operating systems (OS) and a wide range of workload requirements, providing ITS/Traffic Intersection operators a wide range of performance options. Intel® vPro™ technology is a comprehensive platform technology designed to reduce IT maintenance cost, improve security and save energy consumption. At this platform, Intel® Active Management Technology (AMT) is a hardware-based remote management technology that enables system administrators to remotely manage, repair, and protect various types of networked computer devices, including traffic controllers, through the network.

Intel® Artificial Intelligence and Computer Vision

Intel has the industry’s most comprehensive suite of hardware and software technologies that deliver broad capabilities and support diverse approaches for AI—including today’s AI applications and more complex AI tasks in the future. Intel’s AI portfolio helps customers enable AI model development and deployment at any scale from massive clouds to tiny Edge devices, and everything in between. Intel is leading the next wave of AI with new products designed to accelerate AI system development and deployment from cloud to Edge. The broadest in breadth and depth in the industry,

The next-generation Intel® Movidius™ Vision Processing Unit (VPU) is designed for Edge media, computer vision, and inference applications. The technology incorporates unique, highly efficient architectural advances that are expected to deliver leading performance — more than 10 times the inference performance as the previous generation — with up to six times the power efficiency of competitor processors.

Additional technologies supporting AI include:

- **Intel® Xeon® Scalable processors**: powerfully designed to handle the broadest range of AI workloads including deep learning.
- **Intel® FPGA**: Near real-time, programmable acceleration for deep learning inference workloads.
- **Intel® Vision Accelerator Design products**: Based on Intel® Movidius™ VPUs and Intel® Arria® 10 FPGAs, the Intel® Vision Accelerator Design products provide powerful, deep, neural network inference for fast, accurate video analytics to meet the demands of computer vision applications at the edge and to enable solution providers and their customers to take advantage of a wide spectrum of video analytics-based use cases.
Intel® Networking Technologies

Intel is a leader in driving network transformation and enabling edge compute that's needed to bring 5G to life. Intel is transforming purpose-built networks to become more agile, flexible, and scalable with Software Defined Networking (SDN) and Network Function Virtualization (NFV)—setting the stage for 5G.

For Intel's communications service provider customers, the work is already underway as they lay the foundation for 5G and transform their communications infrastructure to SDN. This enables more seamlessly connected, powerful, and intelligent 5G-ready networks in comparison to previous networks that were hardware-based. Leading service providers around the globe have made incredible progress in advancing SDN and NFV with solutions across the core network.

With the move to 5G, Intel is transforming the fundamental economics of service providers and enterprise. Intel powered networks are AI ready– with the compute power to handle networking, cloud, and AI workloads. Transformed networks with powerful computing resources at the edge enable operators and cloud providers to intelligently deliver highly personalized services for Smart Cities today and in the 5G future.

Networking is key to connecting devices to the cloud and making them smart or autonomous. A variety of network technologies are used in Smart Cities and Intelligent Transportation Systems, such as ethernet which connects sensors and Edge devices, Wi-Fi and wireless networks to provide connectivity without cables, and cellular connections for edge computing and cloud services. Intel provides solutions to support each of these needs.

Intel® Storage Technologies

The rapid and exponentially increasing rate of data growth is creating enormous needs in data storage technologies, particularly for Smart Cities and Intelligent Transportation Systems. Intel research and innovation is leading the way with advanced technologies for the Smart City data centers including:

- **Intel® Optane™ SSDs**: SSDs based on 3D XPoint and Apache Pass technologies is a simple, stackable, and transistor-less design that will create fast, nonvolatile storage memory with low latency to unleash a processor’s true potential and improve service capabilities.

- **Intel® ISA-L**: Libraries that can be used with Ceph to provide erasure coding to minimize disk space usage while reducing the latency/penalty imposed by calculations and data manipulation. This results in faster and more efficient deduplication and compression for storage when combined with Intel® Advanced Vector Extensions (Intel® AVX) with ISA-L.

- **Intel® 3D NAND SSDs with Non-Volatile Memory Express (NVMe)**: This technology outperforms SATA SSDs, running demanding workloads simultaneously, like transportation networks and critical city infrastructure services, while lowering costs and increasing system utilization for greater responsiveness.

- **Intel® Advanced Encryption Standard New Instructions (Intel® AES-NI)**: This technology allows for efficient encryption/ decryption operations on data traveling to/from storage with a minimum impact on performance.

Autonomous Vehicle Platforms

Autonomous driving is one of the fastest growing technology areas. Vehicles including cars, trucks, buses, trains, and ships are moving to the center of the software-defined autonomous world. Intel is delivering scalable, secure solutions from in-vehicle computing to interconnected devices in the cloud that accelerate the ramp of Advanced Driver/Operator Assisted Systems (ADAS) helping improve driving safety, and enable fully autonomous vehicles that will transform the transportation and delivery industries.

Intel and Mobileye (an Intel subsidiary company) are already recognized as technology leaders in ADAS and fully autonomous driving technologies. In fact, by 2018, 12 of the 16 cars that received a 5-star EuroNCAP safety rating utilized Mobileye’s EyeQ® technology for their ADAS solutions. Intel’s compute
and AI solutions are also already in use by many of the most recognized autonomous system developers demonstrating autonomous trial deployments in cities across the world. Through other collaborations, Intel and Mobileye are demonstrating that autonomous technologies can be utilized for shipping and other transportation segments as well.

**Road Mapping Technology**

Mobileye's Road Experience Management™ (REM) is an HD mapping solution that uses data collected by Mobileye-equipped vehicles to create near real-time, accurate maps of the road infrastructure, pavement conditions, furniture, and the surrounding environment. These crowd-sourced, cost-effective HD maps are the basis for advanced ADAS capabilities and are essential to enabling a fully autonomous future. In addition, the data collected by REM is useful for many industries beyond automotive, including utilities, municipalities, and more. Today, there are more than 50 million vehicles on the road equipped with Mobileye technology, including more than 25 major automakers including Volkswagen, and Nissan.

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**Intel® Mobileye Data Services**

Mobileye, an Intel company, supports local governments, transportation authorities, utilities and road maintenance companies with unique, fully automated road asset data collection technology, powered by computer vision and AI. Vehicles equipped with built-in and retrofit Mobileye ADAS technology survey millions of miles of road daily. The road asset and mobility information captured by the vehicles is then analyzed, processed, and turned into GIS data layers, updated at a high refresh rate.

**Road Asset Survey:** Fully automated survey of the road network and infrastructure assets delivered in the form of GIS layers along with change detection information.
Key benefits:
• Automate inventory surveys with rapid, ongoing asset data collection
• Save time and money when planning maintenance programs
• Prioritize inspection and renewal programs with asset change detection.

**Pavement Condition Assessment:** Fully automated survey of potholes and cracks, delivered in the form of GIS layers, along with updates on new potholes and cracks detected, given on a monthly or bi-monthly basis.

Key benefits:
• Monitor and improve pavement quality based on near real-time data on road conditions
• Identify the roads that require immediate attention
• Expedite pavement operations with accurate localization of surface distress.

**Dynamic Mobility Mapping & Live Traffic:** Aggregated and real-time mobility datasets including road risk score, near misses, pedestrian and bike mobility, traffic information and more.

Key benefits:
• Measure road safety and identify dangerous intersections and street segments
• Support grant applications and local infrastructure improvements with relevant, up-to-date mobility data
• Measure the efficacy of policies and infrastructure investments and monitor traffic in real-time.

**Developer Tools**

Intel provides tools and resources for developers and industry partners to build and deploy solutions easily.

**Intel® Distribution of OpenVINO™ Toolkit**

The Intel® Distribution of OpenVINO™ Toolkit is a comprehensive toolkit for quickly developing multiplatform applications and solutions that emulate human vision. Based on Convolutional Neural Networks (CNNs), the toolkit extends Computer Vision workloads across Intel® hardware, maximizing performance. Smart Cities can accelerate and deploy CNNs on Intel platforms with the Intel® Deep Learning Deployment Toolkit that’s 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. The OpenVINO™ toolkit:

• Enables CNN-based deep learning inference on the edge.
• Supports heterogeneous execution across computer vision accelerators—CPU, GPU, Intel® Movidius™ Neural Compute Stick, and FPGA—using a common API.
• Speeds time to market via a library of functions and preoptimized kernels.
• Enables development and optimization.

**Intel® OpenNESS**

Open Network Edge Services Software (OpenNESS) Toolkit offers cloud and IoT developers an easy-to-use toolkit to develop and deploy applications at the network edge or on-premises edge locations. By abstracting out complex networking technology, OpenNESS exposes standards-based APIs from 3GPP and ETSI Multi-access Edge Computing (MEC) industry group to application developers. Using this software toolkit, applications can steer data traffic intended for the edge at 5G latencies.
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.

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. 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).

Regional Spotlights on Road Infrastructure Projects
Arizona, USA
The 31-miles of Bell Road Highway serves an average daily traffic of 75,000 cars, placing it over capacity by 30 percent on its busiest days. The highway also sees an influx of almost 2 million fans for the Cactus League MLB Spring Training Events. With the GRIDSMART single-camera system for intersection actuation, delays were reduced by 20 percent on weekdays and 43 percent on weekends. Travel times were reduced by 2 percent each day, and the overall speed of the corridor was increased by 1.8 percent.

San Diego, USA
In partnership with GE and AT&T, the City of San Diego deployed Intel based GE CityIQ Smart City platform with 4,200 intelligent sensors on streetlight poles, thereby enabling optimized traffic and parking, enhanced public safety, and estimated 2.8 million USD in annual savings.

Pittsburgh, USA
Paralleling its trailblazing autonomous driving pilots with Uber and Carnegie Mellon University, Pittsburgh is preparing its roads for vehicles of the future. The city has implemented “smart intersections” using RapidFlow Technologies for optimized traffic flow.

Moreno Valley, USA
The City of Moreno Valley partnered with Intel and Hitachi to build a comprehensive visualization solution. Two years after their implementation, mostly at intersections and parks, the department has improved traffic management and investigated more than 800 crimes through this city-wide system.

Hanoi, Vietnam
Siemens Mobility developed a traffic management solution utilizing standard CCTV traffic cameras, AI, and cloud-based traffic management. Deployed at one intersection in Hanoi, Vietnam, the solution resulted in an average traffic throughput increase of 15 percent. Traffic density towards the city center, particularly during peak hours, could be significantly eased. Furthermore, the on-site Silux 2 traffic lights were equipped with Siemens Mobility’s 1-Watt technology, which reduced the energy consumption by 30-50 percent.

Jinan, China
In preparation for autonomous vehicles, China has created a 1 kilometer stretch of smart highway embedded with solar panels, EV charging, and sensors used for monitoring environment and traffic conditions.
Hyderabad, India
Hyderabad has about 5.4 million registered vehicles on its roads, with almost 1,200 new vehicles added every day, making it difficult for the city to manage traffic and ensure people safety on roads. With Vehant Technologies TrafficMon powered by Intel, different types of violations are now being captured by the system, helping to make enhance enforcement of traffic violations and reduce the traffic-related offences.

Kaohsiung, Taiwan
The Transportation Bureau is responsible for all traffic affairs in Kaohsiung, Taiwan, including transportation policies for road, air, and sea, as well as supervising traffic services. As of June 2019, the bureau managed 900,000 cars and 2 million motorcycles on the city’s roads. By using smart cameras at intersections to detect motorcycles making illegal turns, including the time, location, and license plate data, the bureau can assist law enforcement by providing full digital evidence of infractions. Combining Intel® OpenVINO architecture with Gorilla Technology Edge AI, smart analytics identify more diverse traffic violations and help police eliminate potential accidents.

Nagpur, India
Videonetics supported Nagpur in achieving the Smart City status, under the Smart City Mission of Government of India, by securing its roads with an AI-powered Intelligent Traffic Management Solution. The solution has helped the city to solve its traffic enforcement problems such as red light jumping, zebra crossing/stop line violations, over-speeding violations, tracking of suspect/stolen vehicles, and generating e-challan/e-ticket for violators as per the Motor Vehicles Act. It includes applications like Automatic Number Plate Recognition (ANPR), Red Light Violation Detection (RLVD), and Integrated e-Challan Management Software. With the successful implementation of the solution, Nagpur has witnessed greater traffic discipline and substantial decrease in traffic violations. More efficient traffic management has helped the city achieve its Smart City objectives.

Raipur, India
One of the most challenging areas for traffic police in Raipur to manage is enforcement around two-wheelers and triple riders (on two-wheelers). The city has tried a variety of methods to decrease violations, including free distribution of helmets. However, Vehant Technologies TrafficMon powered by Intel, different types of violations are now being captured by the system. This helps traffic enforcement efficiency, while reducing the traffic-related offences.

Seoul, Korea
To enable its plans for driverless and electric public transportation, Seoul has installed Online EV (OLEV) charging and sensor-studded “smart highways” for traffic management and communication.
**Bangkok, Thailand**

The Kingdom of Thailand’s Ministry of Transport (MOT) deployed GRIDSMART to track vehicles, bicycles, and pedestrians from horizon-to-horizon and through the center of an intersection. This enables identification of the critical zone where most accidents occur, in order to adaptively optimize signal timing. The proprietary adaptive software control system was built by New Trend Development using the Intel® SSD DC S3510 Series and Intel® Core™ i5-4422E processor. The control system is integrated with GRIDSMART’s Application Program Interface (API)—the industry’s only open API. Deployed in three intersections, the solution has helped reduce traffic delays between 8.5 and 24.5 percent and decrease red light running by 68 percent, while cutting average queue length by as much as 30.5 percent. The solution has saved 51,964 vehicle commuter hours over the course of one year and an estimated cost savings of more than 855,000 USD per year.

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**China**

Intel and Shenzhen JHC Technology Development Co., Ltd. (JHCTECH) launched a solution for ETC systems which can collect, process, and analyze traffic data. ETC data at the roadside Edge and in the cloud helps China transportation authorities accelerate the deployment of the ETC systems and lay the solid foundation for Intelligent Transportation System solutions. After eliminating the province-border physical toll stations and using the solution, the average time for passenger vehicles to pass the provincial border was reduced from 15 to 2 seconds, and the time of cargo vehicles to pass the provincial border was reduced from 29 to 3 seconds. The traffic efficiency of expressways is significantly improved.

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**Singapore**

Singapore’s Intelligent Transportation System is a leader in the region. It incorporates electronic road/congestion pricing systems, near real-time traffic information, integrated public transport, expressway monitoring and advisory, and routes for upcoming autonomous buses.
Sacramento, USA
The city of Sacramento, California became one of the first cities in the world to go live with the 5G wireless network in partnership with Verizon. By making available a high-speed, high-capacity telecommunications network, Sacramento expects to enable Smart City applications that will improve public safety and mobility. To make 5G use possible, the city entered a public/private partnership with Verizon in which the company installed intelligent traffic technology at problem-area intersections and set up Wi-Fi in parks. According to the 2017 contract between the company and city, Sacramento is deferring up to 2 million USD in lease payments on Verizon's 101 small-cell towers on city-owned assets over 10 years, while Verizon gets streamlined permit approvals for wireless and wired network deployments.

China
One of the largest projects is China’s One Belt, One Road program, which may be the most significant global economic initiative in the world today. One Belt, One Road is a 21st century Silk Road made up of a belt of overland corridors and a maritime road of shipping lanes. From Southeast Asia to Eastern Europe and Africa, Belt and Road includes 71 countries that account for half the world’s population and a quarter of global GDP.

UK
In May 2019, Mobileye, an Intel company, and Ordnance Survey, Great Britain's national mapping agency, began a joint project in response to an articulated need by highways and street asset owners to have current, consistent reliable mapping of all features of the road infrastructure. In order to create an infrastructure asset data service for Great Britain, utility fleets are equipped with Mobileye 8 Connect, collision avoidance system and data collection enabler.
TRAFFIC MANAGEMENT

Germany: Digital Motorway TestField A9

Challenge: To achieve full agility of automated vehicles, enhance safety, and improve overall traffic flow, roads of the future must be able to transmit near real-time and complete information about dynamic objects on the road to approaching vehicles, to augment information that vehicles generate using their own on-board sensor systems. This means current traffic situations need to be transmitted to subsequent vehicles, so that the virtual field of vision of on-coming vehicles can be considerably expanded.

Solution: To address this challenge, Siemens AG, Infineon, Hochschule Augsburg, Intel, and the Technical University of Munich are collaborating in a joint research project called the Cooperative Radar Sensors for Digital Test Field A9 (KoRA9). Siemens Mobility Solutions installed an intelligent infrastructure on a section of the A9 motorway between Munich and Nuremberg that will transmit traffic situation information to on-coming vehicles in order to expand their perception range. To do this, special RADAR sensors were newly developed and installed in guideposts to create a gapless image of traffic. The project includes algorithms for tracking and classifying radar targets. In addition, the project will investigate the benefits of radar fields that improve overall perception by applying overlapping fields of view and multi-sensor fusion algorithms. The Digital Motorway Test Bed A9 Project is powered by Intel® Xeon® D Processors inside edge processing units that also deploy the Open Source StarlingX stack as dependable and multi-tenant virtualization stack.

Result: With the help of the sensor data, a complete near real-time picture of the German Autobahn traffic for a two-kilometer section of the highway can be generated. Data sets of radar raw observations are collected which are normally not accessible through commercial sensors. Track-to-track fusion algorithms improved by Intel make use of overlapping sensor fields and improve the precision of the results considerably. Dangerous situations can be detected early on and traffic flow can be optimized more quickly. The road infrastructure will help identify potential risks, even if they are not in oncoming vehicles’ immediate surroundings. Vehicles gain expanded environment recognition to help determine when it is safe to change lanes, when to reduce speed early on, and when to avoid critical situations. The radar sensors in the field level will work reliably during changing weather and light conditions compared to other sensor technologies and are less prone to privacy concerns. During the project it also became clear that current V2X standards are not ready to deal with all communication requirements needed for level 4 or 5 automated driving and cannot fully benefit from added intelligence at the edge. Therefore, an advanced communication scheme called V2X Membership Protocol was developed to automatically setup contracts between vehicles and infrastructure, allowing for different infrastructure support levels that can serve individualized data to the vehicles.

Learn more: Website
**EDGE SERVICES**

**Providentia++**

**Challenge:** The Providentia++ (P++) project builds upon an infrastructure of radar sensors and cameras installed at a highway section 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 video and radar 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 guide reliably autonomous vehicles in a mixed traffic scenario where automated 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 is focusing to explore and develop a dependable interlocked system of vehicle and infrastructure components where automated driving benefits from an increased robustness and intelligence of the infrastructure. In the process, Intel anticipates facilitating 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**

**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.
**EDGE SERVICES**

**Institute of Automated Mobility—Arizona**

**Challenge:** Intel has been working with the State of Arizona to establish The Institute for Automated Mobility (IAM), established by the governor in late 2018, which brings together the state's department of transportation, policy organizations, universities, and interested commercial companies to advance the broad use of Automated Driving Systems (ADS)-equipped vehicles and to ultimately establish the state as one of the nation's earliest adopter of proven, safe automated driving technology.

**Solution:** Intel was a driver behind the establishment of the IAM and is directly involved in its sponsored research and in the institute's management.

**Results:** The institute's current efforts are focused on the definition of metrics and the design of systems for the measurement and analysis of the impacts of the introduction of Society of Automotive Engineers levels 3 to 5 ADS-equipped vehicles on roadway safety.

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**Remote Driving Assistance**

**Challenge:** Innovations in remote driving assistance and teleoperation of vehicles are often targeted to increase operational reliability of partial or full vehicle automation, but their practical application often requires next-generation technology performance in bandwidth, data rates, latency, and robustness.

**Solution:** Intel Labs is developing technology solutions that extend commercially available LTE systems to facilitate new use cases such as remote driving assistance or teleoperation.

**Results:** Intel Labs has enabled demonstration of these use cases with existing LTE systems by reducing communication latencies from network and video encoding via Forward Error Correction, rate control, scheduling and tightly coupling sensors with compression mechanisms to achieve 46ms network roundtrip and 96ms End-to-End average latencies.
Intel® Market Ready Solutions

The Intel® IoT Market Ready Solutions (MRS) program is designed to help members of our broad ecosystem of partners strengthen their delivery of solutions through unique support and scaling opportunities. These solutions give transportation leaders scalable, repeatable, end-to-end solutions. That means less time, cost, and risk. These solutions are made up of sensors, edge hardware, software, cloud, and analytics from across the IoT ecosystem. By choosing Intel® IoT Market Ready Solutions, transportation leaders get scalable, repeatable solutions designed to solve key challenges in vision technology, mobility, traffic management, and more. Intel has already vetted these solutions, so transportation leaders can move forward with the assurance of intelligent connectivity, exceptional performance, and easy manageability.

Intel® IoT RFP Ready Kits

Intel® IoT RFP Ready Kits (RRK) are focused technology offerings that solve a class of market problems, have been deployed and tested in the field, and provide bundled hardware, software, and support. The technology is scalable and designed to grow with customer requirements, enabling accelerated development and time to market.

Intel® AI in Production

As one of the world’s most trusted ecosystems, Intel® AI In Production (AIIP) provides a wide range of offerings and capabilities to reduce the challenges of developing AI-centric solutions. Whether industry partners or developers are looking for Intel® technologies, software tools, development kits, code samples or partner end-to-end solutions - Intel® AI: In Production offers a single developer platform with access to building blocks for faster, more agile development and improved business outcomes, all in one place.
Intel® IoT Solutions Alliance

Transportation leaders can also find optimized solutions through the Intel® IoT Solutions Alliance (ISA), one of the world’s most trusted ecosystems for hardware, software, systems, and services. The Intel® IoT Solutions Alliance helps providers deliver first-in-market IoT solutions. A global ecosystem of more than 800 industry leaders, the Alliance offers its members unique access to Intel® technology, expertise, and go-to-market support. By accelerating the design and deployment of intelligent devices and analytics, technology providers can win greater market share. With more than 6,000 solutions, from hardware and software to systems and services, Intel® helps fulfill nearly every requirement in a range of markets. Early access to Intel® road maps and design support enables Alliance members to stay ahead of the competition, as well as reduce risk and development costs.

Table 1: Intel® Partner Solutions for Road Infrastructure

<table>
<thead>
<tr>
<th>#</th>
<th>Solution</th>
<th>Geo Availability</th>
<th>Intel® Technology</th>
<th>AI</th>
<th>Scale Program</th>
</tr>
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<td>Advantech ARK-2250S (NEMA TS2 Certified) Traffic Controller</td>
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<td>Intel® Distribution of</td>
<td>MRS/AIP</td>
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<td>15</td>
<td>FETCI Digital Vehicle Digital Service Platform (DVSP)</td>
<td>Asia Pacific, Europe, Middle East, Africa</td>
<td>Intel® Xeon®, Intel® SSD</td>
<td>AI Available</td>
<td>MRS</td>
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<td>16</td>
<td>Merit LILIN Co., LTD LILIN High Speed Number Plate Recognition with Object &amp; Car Make Detection Solution for Smart City</td>
<td>Asia Pacific, Europe, Middle East, North America (USA)</td>
<td>Intel® Xeon®, Intel® Vision Accelerator Design with Intel® Movidius™</td>
<td>Intel® Distribution of OpenVINO Toolkit</td>
<td>MRS</td>
</tr>
<tr>
<td>17</td>
<td>Videometrics Technology Intelligent Video Management Software (IVMS), Intelligent Traffic Management Solution</td>
<td>Asia Pacific, Europe, North America (USA)</td>
<td>Intel® Xeon®, Intel® Core™</td>
<td>Intel® Distribution of OpenVINO Toolkit</td>
<td>MRS</td>
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<tr>
<td>18</td>
<td>Siemens Sitrtraffic Traffic Controller</td>
<td>Asia Pacific, Japan</td>
<td>Intel Atom®</td>
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<td>ISA</td>
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<td>19</td>
<td>Siemens Traffic Eye Video (TEV)</td>
<td>Asia Pacific, Japan</td>
<td>Intel® Xeon®, Intel® Core™</td>
<td>AI Available</td>
<td>ISA</td>
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<tr>
<td>21</td>
<td>Videometrics Technology Intelligent Traffic Management Solution</td>
<td>Asia Pacific, Japan</td>
<td>Intel® Xeon®, Intel® Core™</td>
<td>Intel® Distribution of OpenVINO Toolkit</td>
<td>MRS</td>
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<tr>
<td>22</td>
<td>Gorilla Technology Intelligent Video Analytics Recorder (IVAR)</td>
<td>Asia Pacific, PRC, North America (USA)</td>
<td>Intel® Core™, Intel® Xeon®, Intel® Media SDK</td>
<td>Intel® Distribution of OpenVINO Toolkit</td>
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<td>23</td>
<td>Awiros Intelligent Traffic Management System (ITMS)</td>
<td>Asia Pacific (India)</td>
<td>Intel® Core™</td>
<td>Intel® Distribution of OpenVINO Toolkit</td>
<td>MRS</td>
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<td>24</td>
<td>SprinxTech Automatic Incident Detection (AID)</td>
<td>Europe</td>
<td>Intel® Core™</td>
<td>Intel® Distribution of OpenVINO Toolkit</td>
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<td>25</td>
<td>Seebot Soluções Inteligentes Agent + Traffic Optimization</td>
<td>Latin America</td>
<td>Intel® Core™</td>
<td>Intel® Distribution of OpenVINO Toolkit</td>
<td>MRS/AIIP</td>
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<td>PlateSmart</td>
<td>North America, Latin America</td>
<td>Intel® Core™, Intel® Atom®</td>
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<td>AIIP</td>
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<td>27</td>
<td>GE CityIQ</td>
<td>North America</td>
<td>Intel Atom® + Wind River in endpoint, Intel Inside GE Predix on backend</td>
<td>Intel® Distribution of OpenVINO Toolkit</td>
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<td>28</td>
<td>Verizon Smart City Suite - Public Safety &amp; Security</td>
<td>North America (USA)</td>
<td>Intel® Core™, Intel Atom®, Intel® Cyclone® FPGA</td>
<td>AI Available</td>
<td>MRS</td>
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<td>#</td>
<td>Solution</td>
<td>Geo</td>
<td>Intel® Technology</td>
<td>AI</td>
<td>Scale Program</td>
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<td>29</td>
<td>Acer ITS Smart Parking</td>
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<td>Intel® Xeon®, Intel® Core®, Intel® Quark®</td>
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<td>MRS</td>
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<td>30</td>
<td>Adlink MXC 6000 Electronic Highway Tollbooth &amp; Surveillance</td>
<td>Global</td>
<td>Intel® Core®</td>
<td>AI Available</td>
<td>ISA</td>
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<td>31</td>
<td>NCS Smart Carpark Solutions with LPR</td>
<td>Asia Pacific, Japan, PRC</td>
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<td>MRS/IIIP</td>
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<td>Uncanny Vision Solutions Pvt Ltd: Uncanny Gate ANPR</td>
<td>Asia Pacific, North America (USA)</td>
<td>Intel® Celeron®</td>
<td>Intel® Distribution of OpenVINO Toolkit</td>
<td>MRS</td>
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<td>33</td>
<td>PT. Alfabeta Solusi Nusantara Automated Yard Management System</td>
<td>Asia Pacific (Indonesia)</td>
<td>Intel® Xeon®, Intel® Core®, Intel® NUC</td>
<td>Intel® Distribution of OpenVINO Toolkit</td>
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<td>34</td>
<td>ST Engineering S*Park Smart Parking Platform</td>
<td>Asia Pacific</td>
<td>Intel® Core®, Intel® Movidius®</td>
<td>Intel® Distribution of OpenVINO Toolkit</td>
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<tr>
<td>35</td>
<td>JHCTech ETC Solutions</td>
<td>PRC</td>
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<td>AI Available</td>
<td>-</td>
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<td>36</td>
<td>Zhe.Jiang Unview Technologies Co., Ltd.: Uniview Smart Community Solutions</td>
<td>PRC</td>
<td>Intel® Xeon®, Intel® Core®, Intel® Atom®, Intel® Movidius®</td>
<td>Intel® Distribution of OpenVINO Toolkit</td>
<td>MRS</td>
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**Table 1: Intel® Partner Solutions for Road Infrastructure (cont.)**
TRAFFIC MANAGEMENT SOLUTION

Hitachi Edge Gateway and Hitachi Smart Camera
Hitachi Edge Gateway for Video brings intelligence to legacy cameras and enables intelligent systems to scale from single cameras to thousands of simultaneous streams. Hitachi Edge Gateway for Video is a small form factor, fanless compute platform used to integrate third-party video systems. This intelligent Edge device can be configured for local recording with direct camera connections, placed in a car or light truck, or used for Hitachi Visualization Suite (HVS) software video ingestion. The gateway supports up to four power over Ethernet (PoE) camera connections and up to eight indirect cameras for HVS connectivity. Redundant onboard recording and 4G connectivity enable quick and easy deployment in most environments.

Hitachi Smart Camera Models 600 and 800 help meet your outdoor video intelligence and management objectives. These are all-in-one Edge video intelligence solutions, providing real-time video data ingest, analytics, and storage at the Edge. Designed for outdoor environments, these smart cameras are easily deployable and provide complete remote monitoring, climate control, and data management capabilities. They support multiple camera and video management system (VMS) vendors.

For more information: Website

TRAFFIC MANAGEMENT SOLUTION

Siemens Traffic Eye
Siemens Traffic Eye solutions are overhead sensors for your traffic management tasks. Their compact design helps minimize street clutter. Siemens overhead detectors score with high detection rates and made-to-measure functionality for any requirement.

Key capabilities:

- Needs no cabling, neither for data exchange nor for power supply: it uses GPRS via the mobile radio network as a cost-effective data transmission solution and receives its power from a small solar panel, keeping operation costs low.
- Installation location can be selected based on purely traffic-related reasons and systems can be placed wherever they best serve the respective detection needs.
- Uses infrared overhead sensors for detection, and mobile radio for transmitting the results to the Sitraffic Concert traffic center.
- The high accuracy of the data allows fast and reliable calculation of the prevailing traffic situation.
- A single unit can monitor traffic on up to ten lanes in one or two directions.

For more information: Website
TRAFFIC MANAGEMENT SOLUTION

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 a number of additional capabilities that are quite unique based on patented technologies.

Key capabilities:

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

For more information: Website

TRAFFIC MANAGEMENT SOLUTION

GRIDSMART System

Powered by Intel, GRIDSMART is the world’s only single camera solution for intersection actuation, traffic data collection, and situational awareness. The GRIDSMART System uses computer-vision tracking algorithms to track moving objects at intersections, providing near real-time data to manage the timing of traffic lights and improve intersection efficiency and safety. Smart Cities can leverage the GRIDSMART System to help existing infrastructure and roadways handle additional traffic with less delay.

Key capabilities:

- The bell camera delivers the industry’s only horizon-to-horizon visibility, including center-of-intersection views.
- The GS2 Processor runs the GRIDSMART Engine—a suite of vision-tracking algorithms able to create a 3-dimensional model on objects approaching the intersection.
- GRIDSMART Client software with virtual pan-tilt-zoom functionality lets traffic managers set up detection and counting zones, view intersections and highways in near real time, and automatically configure reports and alerts.

Key benefits:

- The industry’s only horizon-to-horizon visibility, including center-of-intersection views where cars, bikes, and pedestrian cross paths.
- An easy-to-install and low cost-of-ownership traffic monitoring system with durability, reliability, and ease of access requiring minimal maintenance.
- Internal cybersecurity team availability for all customers

For more information: Solution • Website • Video
TRAFFIC MANAGEMENT SOLUTION

Advantech ARK-2250 NEMA TS2 Controller

As urban populations and vehicle numbers increase, car accidents and traffic crime rates increase. As a result, road surveillance and traffic control are regarded as paramount segments of municipal infrastructure. Advantech is a leading brand in IoT intelligent systems, Industry 4.0, machine automation, embedding computing, embedded systems, and transportation. The Advantech ARK-2250 is a flexible, rugged device designed for traffic control.

Key capabilities:

- Powered by Intel® Core™ i7-6822EQ QC/ Intel® Core™ i5-6442EQ QC Soc.
- NEMA TS2-certified, -34 ~ 74 °C.
- Support for TPM2.0.
- Extreme graphic performance, support up to 1080p 120fps video encode and decode.
- Stackable extension design, option extension kit for applications.
- Isolated 12 ~ 24VDC wide-range power input.
- Diversity communication extensible, ex. WLAN, WWAN.
- Anti-vibration & shock proof, certified by MIL-STD-810G.
- Certified for general standard, CE, FCC, CB, UL, CCC and BSMI.
- Built-in Advantech remote management software WISE-PaaS/RMM.

For more information: Datasheet

Siemens Sitraffic sX Traffic Controller

Setting parameters for traffic signal systems using a smartphone or tablet computer? With Sitraffic sX, this is no longer a futuristic scenario. The Sitraffic sX Traffic Controller can be easily operated via the Web while meeting the highest security standards and availability requirements. For all its simplicity, Sitraffic sX covers a wide range of applications: it can be used as a standalone solution without connection to sensors and a higher-level traffic control system, or works smoothly as an integral part of the extensive traffic management system of a large city. Sitraffic sX Traffic Controller offers an extended range of features and functions that allow the implementation of solutions for challenging traffic control applications as well as the integration of different standards.

Key capabilities:

- Increase accessibility with secure communication between control center and Web interface.
- Use Sitraffic sX for sophisticated advanced control, connection of up to four partial nodes, and parameterizable signal monitoring functions.
- Enhance usability from direct Web access to error memory.
- Plug and play link-up to the control center with automatic data synchronization.
- Increase interoperability with the openness of an API interface for local applications.

For more information: Datasheet
TRAFFIC MANAGEMENT SOLUTION

SEEBOT Intelligent Solutions - AGENT

SEEBOT’s smart solutions provide software to enable AI-at-the-edge devices that resolve urban traffic mobility problems. The SEEBOT AGENT traffic optimization solution identifies and mitigates common urban traffic issues such as traffic congestion. Traffic signaling devices process traffic information in near real time. With the ability to capture images with a system coupled to the chassis itself, SEEBOT AGENT uses AI to read the traffic and distinguish the roads, vehicles, and pedestrians.

Key capabilities:

- **Road Signaling LED Panels**: High brightness and resolution LED panels can display signs automatically and dynamically.

- **Interoperability**: SEEBOT AGENT is open for integration with other manufacturers and suppliers, even allowing integration with obsolete green wave systems.

- **Road Monitoring**: Record, store, and transmit videos of monitored roads.

- **Reconstruction of Accidents**: Reconstruct accidents detected on the road, in 3D.

- **Supervision**: Detect transit infringements and generate automatic video snippets with the detected event, with identification of license plates based on information from law enforcement.

- **Emergency System**: The system integrates with emergency vehicle applications, which allow traffic lights to be automatically opened for fire brigade vehicles, ambulances.

- **Sensing**: Generate near real-time data about the number of vehicles on each monitored road.

- **Optimization**: Traffic optimization reports show a 30 percent improvement in vehicle flow.

- **Environment**: SEEBOT AGENT helps cities to reduce pollutants through traffic optimization.

For more information: [Website]
TOLLING SOLUTION

Acer Smart Parking Solution

Acer ITS combines e-ticketing, license plate recognition, image recognition, cloud service, and a mobile parking app to form an intelligent parking cloud service. The cutting-edge parking system, the Smart Parking Meter, can automate the entire parking management process for a city. Equipped with an array of sensors, the Smart Parking Meter detects when a car enters a parking spot, identifies the vehicle’s license plate number, and sends the data to the cloud system connected to the database of the parking app to update the parking vacancy information. Parking tickets issued manually and collected through various service channels are costly and run the risk of human error. This system improves parking space efficiency and rate management results for roadside parking operators.

For off-street parking, drivers can use the app service to locate available parking spaces, which are sorted by categories such as pricing, distance, and remaining spaces. The navigation service can guide the driver to the right spot. In a parking lot with a license plate recognition system, a driver can simply park in the parking lot and leave without getting a token or paying a fee. As the driver leaves the parking lot, s/he will receive a payment notification from the parking app. The entire parking experience is streamlined and automatic. Car parking becomes an easy thing to do in the city using Smart Parking Meter.

Key capabilities:

- Smart Identification and mobility with entry gate via LPR/ANPR/e-Tag
- Multi-Payment/Mobile Payment with Easy Card/TWSC Card/i-Pass/Mobile Phone app
- Parking space detection
- Big Data Parking Service

Key benefits:

- ITS provides cities a more efficient way of parking, particularly the management of roadside parking.
- Availability of parking vacancy information makes it easier to look for parking lots and parking spaces.
- Increased efficiency improves parking operator revenue and operation performance

For more information:  Solution  •  Website
**TOLLING SOLUTION**

**JHCTech ETC Solutions**

Electronic Toll Collection (ETC) systems are an important part of the intelligent highway, playing a key role in the toll collection for the roads, bridges and parking lots, while improving traffic efficiency and mining the value of the traffic data. Powered by Intel, the JHCTECH ETC IPC series system can automatically detect and identify vehicles, so that the toll transactions can be completed without stopping the vehicles. This allows vehicles to quickly pass through the toll stations, alleviates their bottleneck effect of delaying the traffic, and improves the overall traffic efficiency.

In addition to toll collection for roads, bridges, and parking lots, JHCTECH ETC systems can be used for tolling based on vehicle identification and financial payment capabilities, as well as the gantry systems and networks. These capabilities can support traffic control, flow investigation, path labeling, congestion charges and management, and traffic law enforcement.

For more information: [Datasheet](#)

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**TOLLING SOLUTION**

**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 capabilities:**

- 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.

**Key benefits:**

- 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 capabilities:**

- 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](#)
Cisco/Davra Connected Mass Transit

The Cisco/Davra Mass Transit Solution is a dynamic estimated time of arrival (ETA) system that responds to changing variables to keep riders informed of schedule changes and arrival times. Information is shared on digital signage at all bus and train stations and on the transit vehicles themselves. In addition to the ETAs, the configuration supports a passenger announcement (PA) system to bus or train depots and stations throughout the city. Cisco, Davra Networks, and Intel have formed a strong partnership to bring together different pieces of the value chain to enable business outcomes for mass transit. Davra brings the software element, the analytics algorithms; Intel brings the compute engine that is running the Cisco ruggedized gateway routers. Because the data-driven IoT system requires interoperability, integration, and connectivity between disparate hardware and software components, as well as the transit system assets (from trains and buses to legacy infrastructure), the multiplayer ecosystem collaboration is critical to developing and piloting the Smart City solution.

The rich data and two-way communication system can also inform related MTS initiatives such as predictive maintenance, increased monitoring of environments for security and safety, and near real-time display of alerts and notifications. Near real-time diagnostics gives the maintenance staff a window on train or bus operations and thresholds, and replacements can be installed proactively to prevent major service failures. Security cameras at stations allow data sharing with police and contribute to a more secure environment for travelers.

Key benefits:

- Improve customer service by keeping riders informed of schedule changes and arrival times.
- Share information on digital signage on transit vehicles and at bus and train stations.
- Improve transit operations by gathering data for proactive diagnostics and maintenance.
- Enhance cross-system monitoring to increase security, safety, and efficiency.

For more information: Datasheet • Solution • Website
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 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.
- Curtained 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 • Video • Website
INFRASTRUCTURE EDGE SERVICE

Kapsch Trafficom RIS-9160 and RIS-9260 V2X Roadside ITS Stations

The V2X Roadside Unit supports up to two 5.9GHz radio channels and is based on a ruggedized high performance Linux driven dual-core 64 Bit single board computer platform utilizing extensive interface capabilities while keeping the advantages of Power Over Ethernet (PoE) feed-in and passive cooling.

The product comes with standard compliant V2X communication stack as needed for deployment in IEEE WAVE™ and ETSI ITS G5 based cooperative systems. A software development kit (SDK) is available for integrators and infrastructure operators allowing them to create own software applications running on the device.

Due to its modular design the product can be delivered in different hardware configurations. The modularity helps sustainable infrastructure investments with respect to evolutions within the C-ITS environment, especially in technical, legislative and standardization aspects. The IP67/NEMA 4X conform housing is made of die cast aluminum designed for long life roadside deployments in rural and urban environments.

Extended temperature range, shock and vibration durability combined with high MTBF are the key factors for sustainable, reliable and maintenance-efficient large-scale field deployments. RIS-9260 represents the latest generation of Roadside ITS Stations (R-ITS-S) providing V2X applications a powerful computer platform for “Day 1” V2X use cases and beyond. The product targets the worldwide 5.9 GHz ITS market.

INFRASTRUCTURE EDGE SERVICE

Skylab Multi-Access Edge Compute (MEC)

SkyLab’s Multi-access Edge Computing, or MECs, are designed to be deployed at the Edge along with your other devices and systems, either as a physical or virtual appliance. With additional computing, storage, and processing power, and latest in containerization technology, SkyLab’s MECs ensure operability for whichever application you choose to run and however you choose to develop it. Running your applications at the Edge means you can offload processing, network usage and time from the cloud, complimenting your existing infrastructure.

Key capabilities:

- Immediate on-site data processing through deployed applications, allowing for ultra-fast responses to critical information.
- Back-haul large amounts of data to offload your network.
- Built-in load balancing and self-healing capability.

For more information: Datasheet
GETTING STARTED

Leading transportation networks through strategic innovation and transformation is a continual journey. Many transportation leaders plan their Intelligent Transportation System 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 System to support safety, civic, and economic goals.
3. Combine systems and use cases at the Edge for greater efficiency and value.

Initially, leaders should examine which services offer the greatest potential for the most valuable outcomes and benefits. Stakeholder participation and clear priorities are essential foundation points for building your plan. Leveraging experience working with many governments and cities worldwide, Intel is bringing together the right organizations and companies to deliver the necessary building blocks that transportation leaders can use to create an informed plan and start implementing.

To help enable a transformation journey, Smart Cities Council has developed a roadmap comprised of elements that all transportation leaders, regardless of community size, can apply to their technology transformation efforts. The following is adapted from the Smart Cities Readiness Guide published by Smart Cities Council and represents a helpful way to begin an intelligent road infrastructure journey.

**Assessment**
Create a clear snapshot of where your road infrastructure is now, measured in terms of the key performance indicators you will use to quantify success. What works? What needs work?

**Vision**
Establish a clear picture of the ultimate outcomes, expressed in terms of benefits to road users such as cyclists, motorists, pedestrians, vehicle passengers, and public transport passengers. The vision should not be expressed solely as technical achievements but also as the lifestyle and workstyle improvements the technology makes possible. It is essential to build that vision with citizen involvement to achieve better and more diverse suggestions, consensus, and commitment.

**Project plans**
Develop “blueprints” for the most important components of your Intelligent Road Infrastructure. Possibilities include master plans for:
- Land use
- Digital infrastructure (communications and computing resources)
- Integration with self-driving cars and sensors
- Structural maintenance monitoring systems
- Safety feature implementation
- Gathering of key data points for both drivers and transportation administrators
Milestones

Identify waypoints at which you measure progress, share lessons learned, and discuss course corrections and strengthen commitment.

Metrics

Publish key performance indicators that quantify success and align to the vision. Examples include carbon footprint, average commute time, safety improvements, energy efficiency achievements, etc. In some cases, it is possible to choose metrics that also let you calculate your return on investment.

Supportive Policies

Policymakers should establish supportive policies to enable Smart Cities and connected vehicles.

Exploring 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.)

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 an Intelligent Road Infrastructure 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 and Intelligent Transportation vision to life.

LET’S EXPLORE THE POSSIBILITIES TOGETHER

Learn more about Intelligent Road Infrastructure at www.intel.com/IoT

Resources


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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THINK BIG
...not just smarter, but better cities

START SMALL
Get going with projects and opportunities

MOVE FAST
Learn, adjust, iterate