Author: Dr Phil Marshall

Smart Cities Have Arrived

Smart cities have been on the horizon for more than a decade, and for much of that time experienced only glacial progress, stifled by politics, inaction and inadequate budgets. However, in the last five years smart cities have emerged with increasing velocity. Over 200 of the world's largest 300 cities, spanning both emerging and mature markets, are trialing and implementing smart-city solutions. These solutions are driven primarily by social and political motivations and are buoyed by growing digital service demand, and the availability of IoT devices, analytics, and cloud and edge computing.

This report studies the Edge Cloud (see definition on Page 8) requirements for smart cities. The study used Tolaga's Natural Language Processing (NLP) tools to analyze online content for 200 of the largest cities in the world and identify the salient characteristics of their smart city initiatives.

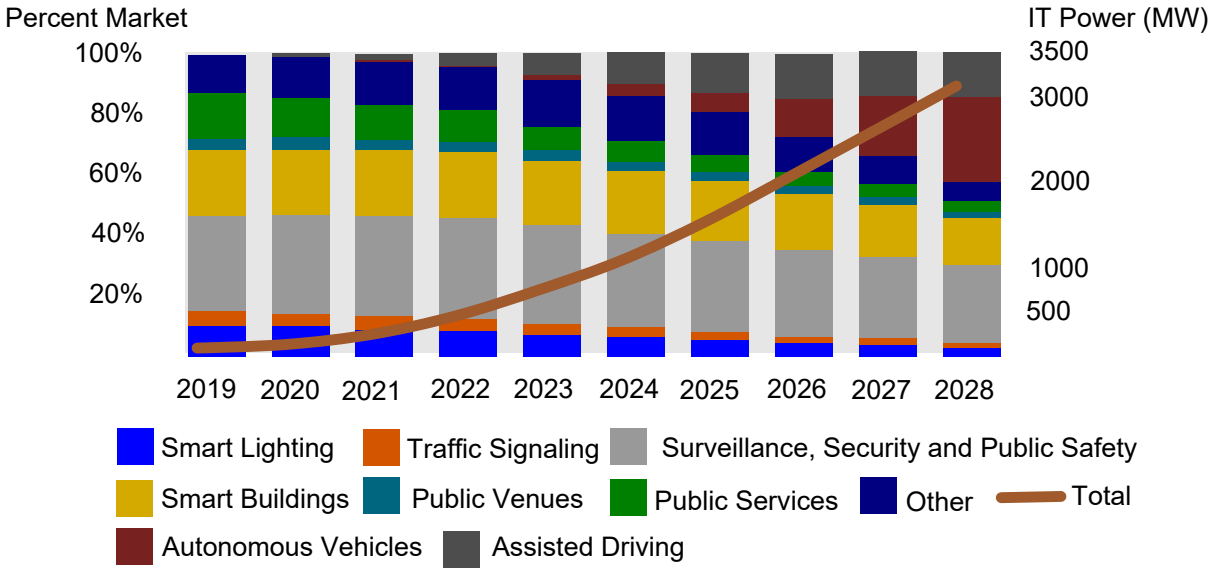
Edge Cloud and Smart Cities

The computing requirements for smart cities are increasing as services and applications proliferate. In many cases these requirements can be met using computing resources that are embedded in endpoint devices and other public cloud resources. However, in some cases Edge Cloud computing resources are also needed. In particular:

- It can be uneconomic or technically unfeasible to provision endpoint devices with the computing resources needed for some smart city applications. For example, real-time AI based video recognition for law enforcement and emergency services will likely become prohibitively expensive should all the video processing be executed in the camera devices.
- The public cloud cannot always meet the latency, security, bandwidth and massive connection requirements for smart city applications. For example, real-time applications often have latency demands that cannot be supported by the public cloud. Some mission critical services and applications must be geofenced to comply with data security and infrastructure reliability requirements. Large scale IoT implementations require hierarchal computing architectures (aka fog computing) to meet scalability and performance demands.
- Edge Clouds are sometimes needed to efficiently orchestrate services and applications across clusters of end-point devices, with real-time performance demands, such as for optimal traffic signaling for smart traffic applications.

Between 2019 and 2025 we forecast a six-fold increase in the number of IoT devices deployed for smart city instrumentation. This instrumentation will drive demand for sophisticated services and applications, with some requiring Edge Cloud capabilities. Recognizing these requirements, we forecast that the IT power footprint for the Edge Cloud to support smart-city services will increase from 29 to 1054MW, between 2019 and 2025, and on to 3052MW by 2028, see Exhibit 1. Between 2019 and 2027 the largest Edge Cloud demand will come from Surveillance. Meaningful demand for assisted and autonomous vehicles is forecast to emerge in the 2023-2024 timeframe. By 2028 it is forecasted that autonomous vehicles will contribute 28 percent to the overall Edge Cloud IT power footprint for smart cities.

Exhibit 1: The Edge Cloud IT power footprint for smart city services and applications
Source: Tolaga Research, 2019

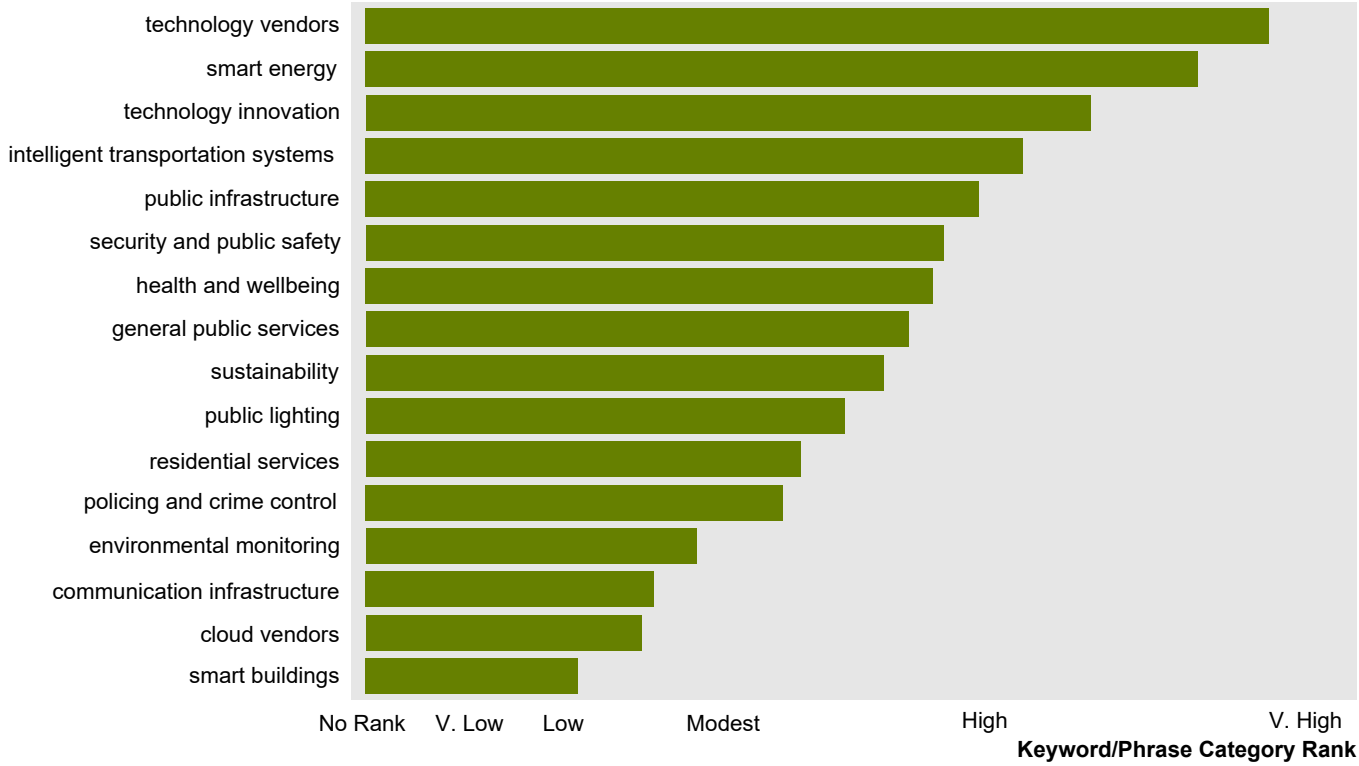


Smart city initiatives diverse, but trends are emerging

Already over 200 of the largest 300 cities in the world have established smart city initiatives, in addition to many of the nearly 23,000 other cities worldwide. In this report, Tolaga's natural language processing (NLP) platform was used to analyze the online content relating to smart cities. A dictionary containing nearly 400 keywords and phrases was derived from a sample of the online content. Each keyword or phrase was then ranked using several modeling techniques including graph-theory, and word frequency and placement grading techniques. The keywords and phrases were then associated with one of fifteen topic categories and the aggregate rank for each category was calculated. A summary of these category ranks is shown in Exhibit 2 and illustrates some salient characteristics of smart cities.

The ranks reflected in Exhibit 2, generally align well with Edge Cloud forecasts shown in Exhibit 1, except for smart buildings. Tolaga treats smart buildings as a smart city segment. However, in online content, smart buildings are generally treated as distinct from smart cities with their own ecosystems, supported by companies like Cisco, Google, IBM, Intel, Johnson Controls, Schneider Electric, and Siemens. Smart Buildings will be the topic of an upcoming Tolaga research report.

Exhibit 2: NLP online content analysis for 'Smart City'
Source: Tolaga Research, 2019



Technology vendors are the smart city cheer leaders

In aggregate, the keywords and phrases relating to **Technology Vendors** and **Technology Innovation** currently have dominant rankings in the online content relating to smart cities. This reflects the immaturity of many smart city use cases, where their technical and implementation underpinnings tend to be more newsworthy than the tangible benefits the use-cases deliver. There are exceptions for use-cases such as smart parking, video surveillance and environmental monitoring systems, where the solutions have matured with measurable and noteworthy value propositions.

The variety of vendors and technology innovations associated with smart cities are immense. Many use-cases, such as autonomous driving, depend on complicated ecosystems and extensive infrastructure upgrades before fully fledged solutions can be implemented. To overcome the ecosystem complexities, some cities are using targeted implementations to create beachheads for specific use cases. For example, several cities including Berlin, Columbus Ohio, Dubai and Singapore, are conducting localized autonomous bus service trials and deployments. These services capitalize on short and deterministic bus routes, which dramatically simplify implementation requirements and provide a platform to test and incubate autonomous vehicle technologies.

Rather than tactically deploying individual use-cases, cities are more commonly implementing smart-city infrastructure according to establishing long term strategic plans. For example, in some cases, cities are implementing sensor network technologies for future support of autonomous driving technologies once they become available.

We expect that technology vendors and their innovations will rank prominently over the next three to five years in online content relating to smart cities. This reflects the future technology advancements that we expect for smart cities and provides a useful bellwether for measuring the maturity of specific use-cases.

Energy and sustainability hit the right notes

Angst and debate over climate change have fueled tremendous interest in environmental sustainability initiatives, to reduce the global carbon footprint, pollution and to protect natural ecosystems and environments. For cities, efforts to reduce carbon footprints have seen smart lighting, intelligent transportation, smart waste, smart grid and renewable energy technology trials and deployments. Many cities are upgrading the streetlights with intelligent light emitting diode (LED) technology. LEDs enable a six-to-ten-fold decrease in power consumption, with bulbs that are touted to have two-to-four times the life expectancy of conventional solutions. In addition to the LED technology, cities, are trialing and implementing smart-lighting systems provided by companies like CIMCOM, Philips, Schneider Electric, Schreder and Telensa to optimize luminance and further reduce power consumption by up to 20 percent. Cities are also retrofitting their street poles with solar panels and smart city sensor technologies, such for air quality and population flow monitoring.

Key words and phrases relating to **Smart Energy** feature prominently in online content and smart city initiatives. These initiatives are popular amongst cities because they deliver cost savings and address heightened social and political interests relating to sustainability. Although **Sustainability** related keywords and phrases rank high in online content relating to smart cities, in aggregate they rank lower than those related to **Smart Energy**. We believe that this illustrates the significant progress of smart city initiatives towards implementing sustainability use-cases.

Population growth and traffic congestion fuels smart city initiatives

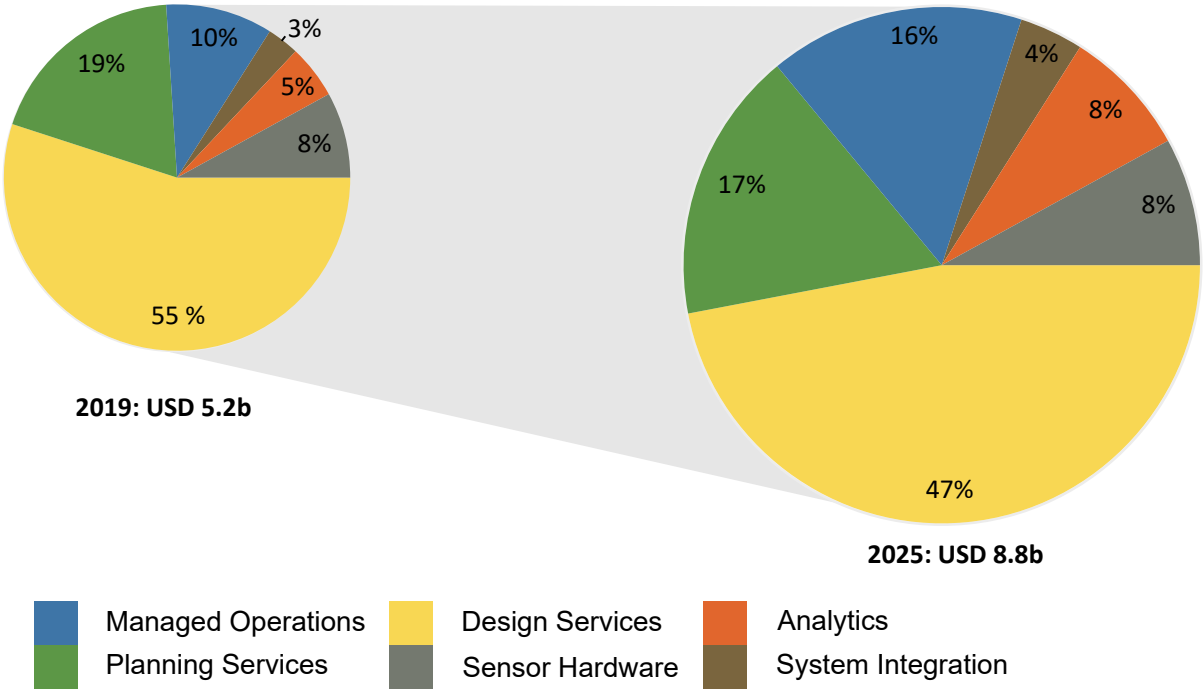
According to the World Health Organization (WHO), urban population is forecast to increase by 1.63 percent annually between 2020 and 2025. Urban citizens are also consuming more, particularly in burgeoning emerging markets. As urban population and consumption growth occurs, it places tremendous stress on city infrastructure, including roadways and transportation thoroughfares. This is juxtaposed with advancements in a variety of intelligent transportation system capabilities, including digital navigation, mapping and traffic management systems, artificial intelligence and machine learning, vehicle electrification and infotainment, and assisted and autonomous driving technologies.

Keywords and phrases relating to Intelligent Transportation Systems feature prominently in online content associated with smart cities, (see Exhibit 2). Most intelligent transportation systems are complicated and will take many years for

widespread adoption. However, some use cases, such as for smart parking, are already commonplace. Smart parking solutions deliver significant traffic management benefits, are easily retrofitted to existing city infrastructure and capitalize on advancements in geographical information systems (GIS) and smart device applications.

Globally we forecast that the intelligent transport systems will increase with a 9 percent CAGR from USD 5.22 to 8.05 billion between 2019 and 2025, with the support of companies like Iteris, Jenoptik, Kapsch, Siemens and Thales. The market consists of segments for design and planning services, hardware sensors and analytics, and professional and managed services. Amongst these market segments, 55 percent of the revenues are currently for planning and 19 percent for design services. Both planning and design services are forecasted to dominate revenues throughout the forecast period. The percentage revenues for managed operations are expected to increase from 10 to 16 percent between 2019 and 2025 and the percentage revenues for Systems Integration, Analytics and Sensor Hardware are forecast to remain relatively constant over the same period, see Exhibit 3.

Exhibit 3: Global expenditure forecasts for intelligent transport systems
Source: *Tolaga Research, 2019*



Security and public safety are high priority for citizens

In the last decade, global citizens have generally become increasingly concerned with public safety. This can be largely attributed to a rise in crime and terrorism, which ostensibly peaked in 2014. Although both terrorism and crime are decreasing, it is of little consolation to those who are affected, and citizens increasingly accept their privacy being compromised to improve their security and public safety.

In the last decade urban video surveillance has become commonplace, with over 700 million surveillance cameras now deployed globally. We expect that the number of deployed surveillance cameras will increase at a cumulative annual growth rate (CAGR) of 20.4 over the next five years to reach 1.8 billion cameras by 2025. The proliferation of surveillance cameras is driving advancements in digital security to protect the identity of citizens and advanced analytics with machine learning and artificial intelligence for techniques such as automatic number-plate and facial recognition. The market is supported by industry heavy weights like Cisco, Bosch, Huawei, Panasonic and Sony, and a host of specialist security and surveillance technology companies like Dahau, FLIR, Genetec, Hangzhou Hikvision, and March Networks. The market for surveillance solutions is highly fragmented and because of the bandwidth and analytics involved, surveillance is increasingly intertwined with connectivity technologies provided by companies like Ericsson, Nokia, Huawei and ZTE, and Edge Cloud platforms and semiconductor technologies provided by companies like Broadcom, Dell, HPE, Intel and Qualcomm.

A complex tapestry of opportunities

Cities are adopting smart solutions at a tremendous rate, with an emphasis towards opportunities that are easily attainable and deliver tangible social and political benefits. Commonly smart city use cases focus on energy efficiencies and sustainability, population control, traffic management, and public safety and security. We expect that these will remain target opportunities for the foreseeable future, with ever increasing technical advancements. We also expect that smart city solutions for health and wellbeing will also come to the fore over the next five years. Some cities are also seeking the limelight with trials that aim to demonstrate innovation and technology leadership, such as with autonomous solutions. Many cities are also equipping their infrastructure and street furniture with sensors and IoT technologies to support future applications such autonomous driving, thermal imaging and population control.

Smart city solutions are not being developed in isolation, and depend on digital technology innovations in other domains, such as the automotive and electrical utility industries. It is important that cities invest in digital solutions that anticipate the availability of innovations in other domains. In addition, incubation projects, such as the autonomous buses being trialed in some cities, are important in ensuring that cities have appropriate digital transformation and technology investment strategies. Cities must also anticipate the growing computing requirements for smart city solutions. While much of these computing requirements can be supported with embedded device and cloud computing, the Edge Cloud will also be important in delivering the performance, security, and reliability demands that a growing number of smart city solutions will require.

Smart city initiatives are unique in that they are just as relevant to emerging markets as they are to mature markets. There are already emerging market cities that are at the cutting edge of smart city technology innovation, with solutions that are particularly relevant to their respective market conditions. A digital divide between the smart and 'not so smart' cities is emerging, but this divide is not based on the relative economic prosperity of the cities involved. Instead it is determined by the technical conservatism of key decision makers in the cities, and the hurdles that innovators must overcome to drive smart city innovations.

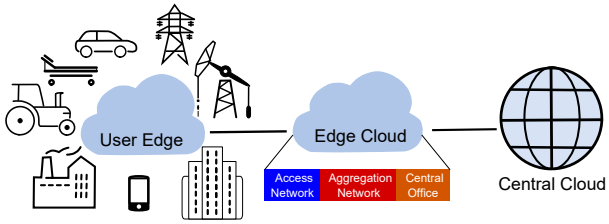
About Tolaga Research

Tolaga Research is a leading consulting and advisory firm with a focus towards communication networks and the Fourth Industrial Revolution. Tolaga was founded in 2009 and is the world's first firm to apply artificial intelligence with natural language processing and system dynamics modeling to industry research. By combining these sophisticated capabilities with its extensive primary research, Tolaga delivers unique and actionable insights that are fortified with robust data science and system modeling solutions.

For more information, contact us at: admin@tolaga.com

Tolaga Edge Computing Definition

Edge computing lacks a clear definition, which varies depending on perspective. For cloud service providers, edge is an extension of their cloud offering. For communication service providers, edge compliments their network and connectivity services, and for device and embedded solution providers it is an extension of their device applications. At Tolaga, we define edge computing in terms of two general categories, namely the User Edge and the Edge Cloud.

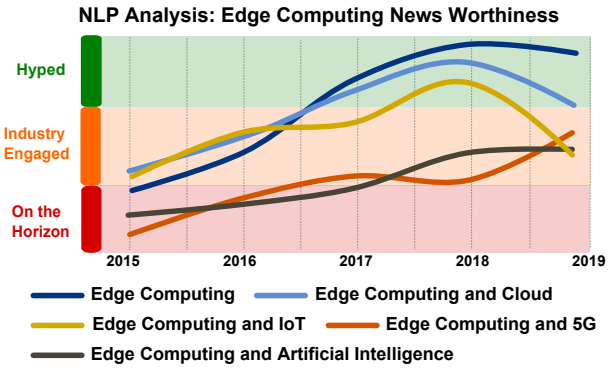


The **User Edge** consists of three general types, including end-point devices, gateways and on-premise computing equipment. End-point devices include IoT sensors, embedded systems, such and electronic control units in vehicles, and smartphone and tablet devices. Gateways include routers and aggregation platforms. On-premise equipment consists of specialist and general-purpose computing.

The **Cloud Edge** consists of managed edge computing equipment that is deployed outside of user premises. In contrast to the public cloud, the physical location of the Cloud Edge infrastructure relative to its end-users is important. For our definition of the Cloud Edge, we distinguish between infrastructure that is within a similar distance from end-users as access sites (e.g. radio base-stations), aggregation sites and central offices. As a rule of thumb, there are between ten and twenty access sites per aggregation site and between ten and twenty aggregation sites per central office.

Edge Cloud Priorities and Use Cases

Interest in Edge Computing has increased significantly in recent years, and according to our natural language processing (NLP) of online content, Edge Computing has been hyped in mid-2016, with an emphasis of its role in complementing cloud computing. Between 2017 and 2018, the role of edge computing in the context of IoT became hyped. Since then some attention has shifted to focus on specific edge use-cases and emerging capabilities such as artificial intelligence (AI) and 5G.



The Edge Cloud is a candidate for an increasing number of use-cases that feed the digital appetites of consumers and enterprises. Tolaga is continually expanding its use-case coverage for the Edge Cloud and edge computing. These use-cases currently focus on the following industry segments:

- **Communication Service Providers (CSP):** with use cases for Access, Aggregation and Central Office site deployments. CSPs are deploying edge computing to support the migration of their networks and to support specific use-cases for their customers.
- **Smart Grid:** including use-cases for generation, transmission, distribution, renewable, and operations and maintenance.

- **Mobile Consumers:** with digital use-cases for 4G and 5G subscribers, which include gaming, information, social, health and fitness, messaging and communications, media and entertainment and Internet.
- **Smart Home:** to include use-cases for security, smart applications, infotainment, assisted living and energy management.
- **Automotive:** including use-cases for autonomous vehicles, assisted driving, traffic management, infotainment and operations and maintenance.
- **Smart Cities:** with digital use-cases for smart lighting, traffic signaling, public safety, smart buildings and public venues and utilities/services.
- **Industry 4.0:** to include use-cases for asset tracking, remote operations, logistics and warehousing, operational automation, security management and enforcement, and diagnostics and maintenance.
- **Smart Retail:** with use cases for digital signage, instore surveillance and experience management, proximity marketing and supply chain optimization.
- **Smart Healthcare:** which focuses specifically on hospitals and clinics, with use cases for patient record management, continuous patient monitoring and intervention, remote patient care and intervention (including support for remote surgery) and physical therapy.
- **Commercial UAVs**: with use-cases for mapping and surveying, photogrammetry, 3D modeling and digital elevation modeling, and;
- **Enterprise IT:** which anticipates a proportion of IT workloads that migrate the cloud will reside at the Edge Cloud.