SMART CITIES

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2017-2022

Deep Dive Strategy & Competition

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Foreword

Juniper Research Limited

Juniper Research is a European based provider of business intelligence. We specialise in providing high quality data and fully-researched analysis to manufacturers, financiers, developers and service/content providers across the communications sector.

Consultancy Services: Juniper is fully independent and able to provide unbiased and reliable assessments of markets, technologies and industry players. Our team is drawn from experienced senior managers with proven track records in each of their specialist fields.

Regional Definitions

North America:	Canada, US
Latin America:	Argentina, Aruba, Bahamas, Barbados, Belize, Bolivia, Brazil, Cayman Islands, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Mexico, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Surinam, Trinidad and Tobago, Turks and Caicos Islands, Uruguay, Venezuela, Virgin Islands.
Western Europe:	Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Liechtenstein, Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland UK.
Central & Eastern Europe:	Albania, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Macedonia, Moldova, Poland, Romania, Russia, Serbia/Montenegro, Slovakia, Slovenia, Turkey, Ukraine.
Far East & China:	China, Hong Kong, Japan, Macao, South Korea, Taiwan.
Indian Subcontinent (ISC):	Bangladesh, India, Nepal, Pakistan, Sri Lanka.
Rest of Asia Pacific:	Australia, Brunei, Fiji, New Caledonia, New Zealand, Cambodia, Indonesia, Laos, Malaysia, Maldives, Mongolia, Myanmar, Philippines, Singapore, Thailand, Vietnam.
Africa & Middle East:	Afghanistan, Algeria, Angola, Armenia, Azerbaijan, Bahrain, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Cote d'Ivoire, Democratic Republic of Congo, Djibouti, Egypt, Equatorial Guinea, Ethiopia, Gabon, Gambia, Georgia, Ghana, Guinea, Guinea-Bissau, Iran, Iraq, Israel, Jordan, Kazakhstan, Kenya, Kuwait, Kyrgyzstan, Lebanon, Lesotho, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Oman, Palestine, Qatar, Reunion, Rwanda, Saudi Arabia, Senegal, Seychelles, Sierra Leone, South Sudan, Sudan, Swaziland, Syria, Tajikistan, Tunisia, Turkmenistan, Uganda, United Arab Emirates, Uzbekistan, Yemen, Zambia, Zimbabwe

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1. Leading Smart Cities of the World

1.1 Introduction

As technology has developed and concepts such as Ubiquitous Computing have emerged, early visions of so-called 'smart cities' involved the notion of cities becoming fully-connected environments, where almost every conceivable element in the city limits is integrated into some sort of automated computing system. In turn, this vision gives rise to a divide in opinion. On the one hand, the city is a utopian paradise of efficiency with systems, running with metronomic precision; on the other, the city is a dystopian centre of restricted possibilities, shackled by the measurement of every event occurring inside it.

At present, the Ubiquitous City as described in the paragraph above is limited to a small number of projects across the globe. Indeed, these cities are purpose-built settlements developed on greenfield sites. This is in contrast to the vast majority of cities elsewhere, now resting on brownfield sites, where planning the full transition from city to Ubiquitous City would entail enormous complexity and expense.

Consequently, today's vision of a smart city, certainly for the near-term at least, is quite different from the notions driven by the concept of Ubiquitous Computing.

1.2 Smart City Definition

Before proceeding further with the research, Juniper feels it appropriate to define a smart city; this will help provide focus not only for the strategic elements detailed in this research, but also for the accompanying market forecasts.

Juniper Research defines a Smart City as an urban ecosystem that places emphasis on the use of digital technology to drive efficiencies in existing social, economic and environmental processes, while simultaneously opening avenues for new, data-driven processes.

It should be made clear at this point, however, that technology should not be applied for technology's sake; there must be a clear goal of what is intended to be achieved, particularly as most cities' budgets are limited. Cities around the world are quite distinct in their various smart city initiatives, with goals ranging between revenue generation, cost saving, energy reduction and Meeting regulatory targets.

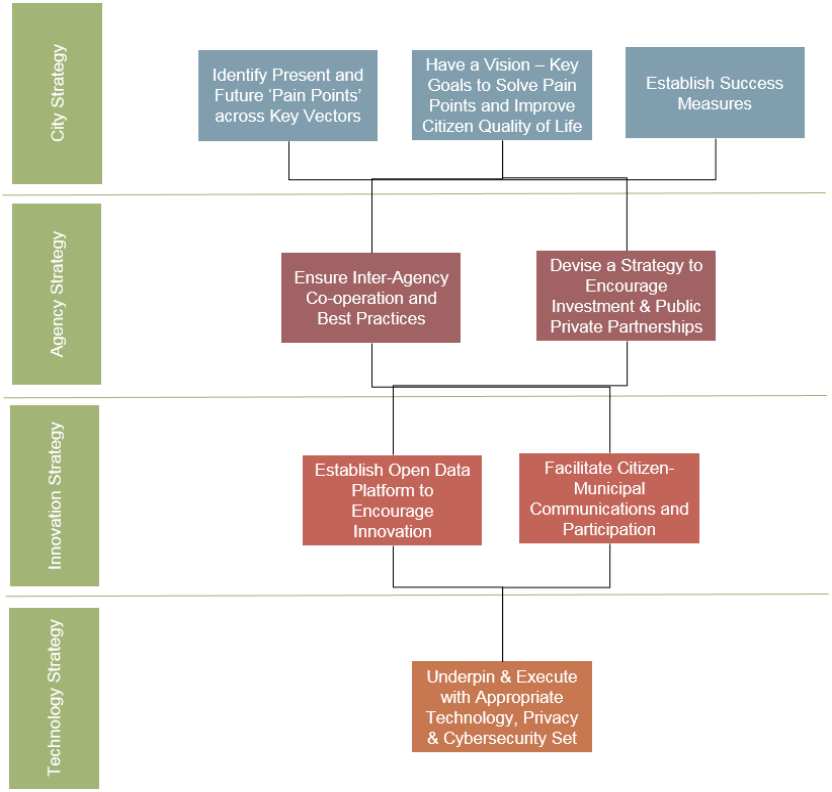
Munish Khetrapal from Cisco concurred: 'It's really about competitive differentiation in Asia-Pacific. Trying to create next-generation cities through new infrastructure and digitisation of the entire city. Key aims are job and value creation, to increase competitiveness. In Europe there is legacy infrastructure so the situation is different, with the principal aim geared towards sustainability and quality of life for citizens. In America, there is a lot of economic value and increase ROI or decreased total cost of ownership of services.'[1]

[1] Juniper Research interviewed Munish Khetrapal, Managing Director - Global Head of Solutions, Smart Cities at Cisco Systems, October 2017

1.3 A Blueprint for Smart Cities

The following figure shows Juniper's visualisation of a 'blueprint' for smart cities, including strategies for the city-wide, agency and technical level

Figure 1.1: Smart City Blueprint



Source: Juniper Research

1.3.1 The Journey to Becoming a Smart City: Key Strategic Considerations for Cities

Essentially there are 4 key challenges the city must address before embarking on any such initiative with the aim of achieving success.

- The city must be aware of what its key constraints are and prioritise addressing these appropriately. Poor urban mobility will likely result in lower business competitiveness and increase the chance of brain-drain; nevertheless, a high crime rate may make the city a less attractive place to live and work in overall.
- Financing smart city projects is a challenge for any city. Cities should press authorities for national policies that encourage investment, facilitate talent acquisition and create favourable environments for disruptive companies and solutions.
- Technology is used to underpin the smart city vision. Thus it is imperative to avoid solutions that will likely reach obsolescence quickly, or solutions that result in vendor lock-in. Marc Jadoul from Nokia observed: 'Smaller cities in particular have no real experience with technology procurement. And very often, they get locked into a single vendor, which may impact the scalability and future application scope.

For that reason an open platform approach is essential, so that the whole ecosystem can compete.'[2]

- The importance of cybersecurity cannot be understated, given the fact that citizens' data, as well as critical infrastructure, are attractive targets for cybercriminals. Haider Iqbal from Gemalto added: 'Some cities tend to overlook some of the security building blocks that need to be there, in favour of harnessing Big Data and analytics. The Mirai botnet was a bit of an eye-opener for many, however…'[3]

1.4 Evaluating the Top 10 Smart Cities in the World

Juniper examined a wide range of cities around the globe and scored them using quantitative measurements where possible and qualitative data where information is lacking. The results of the top 10 cities from Juniper's study are presented in-depth here.

1.4.1 Background

The aim of this ranking is to determine, and highlight, where cities around the globe are developing in terms of their smart city vision and execution.

For this year's ranking, the key focus areas analysed have been expanded in contrast to 2016's ranking to cover a larger number of city service areas. Readers should therefore be aware that 2016's ranking and 2017's ranking are not like-for-like comparisons, despite the fact that several cities retain their high ranking positions this year.

Indeed, a key issue for this year's ranking was to focus on the cities' emphasis on vision and deliverables. Each service area in turn is examined, not only in terms of deployments in place but also the overall strategy for that particular service area. The depth that the city outlines here is important as, for example, how it sees itself as succeeding in that area

The following table is a summary of the service areas that were analysed for Juniper's 2016 global smart city ranking.

Table 1.2: Summary of 2016 Ranking Areas

2016	Comments
Technology	Broadband and mobile communications, technology uptake
Transport	Private vehicle ownership, public transport performance, smart traffic management implementation
Energy	Smart meter rollout, smart street lighting rollout
Open Data	Open data availability & depth in realms of crime, transport & air quality
Economic Development	Productivity as measured by GDP (Gross Domestic Product) per capita

Source: Juniper Research

[2] Juniper Research interviewed Marc Jadoul, Market Development Director, Internet of Things, Marketing and Corporate Affairs, Nokia, October 2017

[3] Juniper Research interviewed Haider Iqbal, Director Public Services and Transport Enterprise IoT Ecosystems, Gemalto, September 2017

1.4.2 Ranking Data Inputs

The key services areas determined by Juniper include the following.

i. Transport

Congestion and inner city transport are key concerns for modern cities, with problems exacerbated as population densities increase. Congestion not only wastes time, leading to an economic impact (INRIX and the Centre for Economics and Business Research estimated the cost of congestion in the US during 2014 to be $124 billion[i]), but there are other side effects.

For instance, congestion increases the amount of harmful particulates in the air. This type of pollution was, according to WHO (World Health Organization), estimated to be the cause of death for 3 million individuals in 2012.[ii]

Table 1.3: 2017 Smart City Index – Transport Indicators

Datapoint	Source	Purpose – What does this indicate?
Average Vehicle Speed	City publications, press releases, third party sources	Peak time congestion
Private Vehicles per Capita	City publications, press releases, third party sources	Congestion driver
Cycle Scheme Rollout	Vendor existence & city announcements	Congestion reduction & health improvement driver
MaaS (Mobility-as-a-Service)	Vendor existence & city strategic vision publications	Congestion reduction driver
Congestion Charge	City publications	Air quality improvement & congestion reduction driver
Road Accident Injuries per capita	Transport statistics releases	Public health reduction driver
Air Quality	WHO	Public health reduction driver
EV (Electric Vehicle) Charging Stations	Cross-network charging station maps	Next-gen transport preparedness
Public Transport Journeys per capita	Transport statistics releases	Network performance, availability & uptake
e/mPayment Infrastructure	Transport service provider websites	Transport payment convenience, time-benefit indicator
Autonomous Vehicle Testing	Press releases/city strategic vision	Next-gen transport preparedness
Smart Transport Initiatives, of which:	City strategic vision, vendor case studies, press	
- *Smart traffic light phasing*		Congestion reduction driver
- *Smart parking*		Congestion reduction driver
- *Open data for transport*		Congestion reduction driver
- *Strategy to reduce motor vehicle use*		Congestion reduction driver
- *Strategy to increase public transport use*		Congestion reduction driver
- *Citizen information dissemination solutions*		Congestion reduction driver
- *Inter-agency collaboration strategy*		Congestion reduction driver & time-benefit indicator
- *Road safety strategy*		Healthcare improvement indicator

Source: Juniper Research

ii. Healthcare

Strained resources and escalating costs for cities and citizens are driving new, efficient solutions. Meanwhile, cities are rolling out strategies in an attempt to promote a healthier population.

Table 1.4: 2017 Smart City Index – Healthcare Indicators

Datapoint	Source	Purpose – What does this indicate?
Hospital Beds per capita	City, regional or national healthcare statistics	Bed availability
Hospital Bed Occupancy Rate	City, regional or national healthcare statistics	Bed availability
Congestion Charge	City publications	Air quality improvement & congestion reduction driver
Cycle Scheme Rollout	Vendor existence & city announcements	Congestion reduction & health improvement driver
Public Transport Journeys per capita	Transport statistics releases	Network performance, availability & uptake
Road Accident Injuries per capita	Transport statistics releases	Public health reduction driver
Violent Crime Rate	Law enforcement statistics	Public health & safety reduction driver
Police Force Size	Law enforcement statistics	Public health & safety improvement driver
Higher Education	Third party indices & statistical releases	Public health & safety improvement driver
City Terrorist Attacks since 2013, Domestic & Foreign Initiated	Global Terrorism Database	Public health & safety reduction driver
Public Safety Index	Numbeo	General safety & health indicator
Air Quality	WHO	Public health reduction driver
EV (Electric Vehicle) Charging Stations	Cross-network charging maps	Public health improvement driver
Autonomous Vehicle Testing	Press releases/city strategic vision	Public health improvement driver
Smart Healthcare Initiatives, of which:	City strategic vision, vendor case studies, press	
- *Telehealth/Remote healthcare services*		Healthcare service improvement
- *Digital health portals*		Healthcare service improvement
- *Chatbot services*		Healthcare service improvement
- *Digital healthcare for elderly strategy*		Healthcare service improvement
- *Transparent healthcare Key Performance Indicators*		Healthcare improvement indicator
- *Active lifestyle strategy*		Healthcare improvement indicator
- *Road safety strategy*		Healthcare improvement indicator

Source: Juniper Research

iii. Public Safety

Cities are often viewed as dangerous places to live, on account of high crime rates and concerns over issues such as road traffic safety. Smart policies and technology are now being deployed in an effort to create safer environments.

Table 1.5: 2017 Smart City Index – Public Safety Indicators

Datapoint	Source	Purpose – What does this indicate?
Smart Street Lighting	Utilities, municipal energy departments	Public safety improvement indicator
Intelligent Video Surveillance	Press releases, law enforcement case studies	Public safety improvement
Congestion Charge	City publications	Public safety/road traffic safety improvement indicator
Cycle Scheme Rollout	Vendor existence & city announcements	Public safety reduction indicator
Emergency Services Response Co-ordination	City publications	Public safety improvement
Violent Crime Rate	Law enforcement statistics	Public health & safety reduction driver
Police Force Size	Law enforcement statistics	Public health & safety improvement driver
Predictive Crime Software	Press releases, law enforcement case studies	Public safety improvement
Fire/Flood Prediction Software	Press releases, vendor case studies	Public safety improvement
Higher Education	Third party indices & statistical releases	Public health & safety improvement driver
City Terrorist Attacks since 2013, Domestic & Foreign Initiated	Global Terrorism Database	Public health & safety reduction driver
Public Safety Index	Numbeo	General safety & health indicator
Smart Public Safety Initiatives, of which:	City strategic vision, vendor case studies, press	
- *Emergency services integration*		Public safety improvement
- *Road safety strategy*		Public safety improvement
- *Disaster plan*		Public safety improvement
- *Crime reduction strategy*		Public safety improvement indicator
- *Cybersecurity strategy*		Public safety improvement indicator

Source: Juniper Research

iv. Productivity

Juniper believes that smart cities will aim to democratise access to technology, simplify municipal service delivery and encourage innovation from both domestic and foreign origins.

Table 1.6: 2017 Smart City Index – Productivity Indicators

Datapoint	Source	Purpose – What does this indicate?
Project Funding Sources	City publications, press releases	Service expansion & productivity improvement indicator
Public-Private Partnership Incentives	City/national publications	Service expansion & productivity improvement indicator
Talent Acquisition Incentives	City/national publications	Service expansion & productivity improvement indicator
Ease of Doing Business	World Bank	Time-benefit potential
Digital Education Policies	City/national publications	Productivity improvement indicator
City Governance	Municipal websites	Regulatory complexity, time-benefit indicator
City Chief Technology Office/Equivalent	Municipal websites	Service expansion & productivity improvement indicator
Smart City Conference Hosting	Press/event releases	Engagement & productivity improvement indicator
Smart City Hackathons	Press/event releases	Engagement & productivity improvement indicator
Smart Productivity Initiatives, of which:	City strategic vision, vendor case studies, press	
- *Digital services access*		Productivity improvement & time-benefit indicator
- *Smart education projects*		Productivity improvement indicator
- *Cybersecurity & privacy strategy*		Service uptake & productivity improvement indicator
- *Equality strategy*		Productivity improvement indicator
- *Retail & city services cashless payments*		Productivity improvement & time-benefit indicator

Source: Juniper Research

v. Energy

High municipal bills related to energy consumption, as well as ageing grid infrastructure and the prospect of mass-deployed EV and AV (electric and autonomous vehicles) mean that cities must develop new strategies for energy consumption and delivery.

Table 1.7: 2017 Smart City Index – Energy Indicators

Datapoint	Source	Purpose – What does this indicate?
LED Street Light Deployments	Utilities, municipal energy departments	Energy use improvement indicator
Smart Street Light Deployments	Utilities, municipal energy departments	Energy use improvement indicator
EV (Electric Vehicle) Charging Stations	Cross-network charging station maps	Smart grid demand indicator
Smart Energy Initiatives, of which:	City strategic vision, vendor case studies, press	
- Energy use reduction strategy		Energy use improvement indicator
- Smart grid pilots, proof of concepts		Next-gen energy strategy indicator

Source: Juniper Research

1.5 Methodology

Following the collection of the raw datapoints, these were translated into uniform scores of 1-20, with 20 being the maximum score according to the range of raw scores recorded. These scores were then assigned weights according to their importance in the index, which were then used to arrive at a score for the index.

- Where city-specific data was missing, regional or national data was sourced and translated into a city figure, using either per capita extrapolation or other assumptions.
- The overall indices have not been assigned weights in this year's index. In last year's index, key service areas; transport and energy; were assigned equal weighting, with lower weighting for open data and economic performance. As these latter categories are now incorporated into the various indices as broad city indicators, it was decided to apply equal weights across the indices.

1.6 Global Smart Cities: 2017 Ranking Results

The top 5 cities are highlighted and summarised below. Note that all cities in the top 10 ranking are investigated in-depth in section 1.6.1

- Singapore's 'One Nation' Initiative and its position as a city-state makes it unique in its ability to execute its Smart City vision. Its transformation to the world's leading smart city in a remarkably short time following its split from Malaysia, provides an example from which other cities can learn.
- London is one of the world's tech hubs, so is in a good position to develop and rollout digital services. Its smart city vision is consistent and well thought out across each index, although public safety and high levels of violent crime remains a key issue for the city and its citizens.
- New York City has demonstrated a dramatic transformation in terms of public safety through smart policy and technology. Its violent crime level is now well below many other US cities.
- San Francisco has one of the most ambitious visions for reinventing its urban transport landscape; it also has a progressive energy policy in place.
- Chicago is one of the few cities to explicitly address the issue of data privacy and security. Meanwhile it actively promotes and encourages innovative smart city talent and private investment to boost citizen services.

The following table presents Juniper's findings, with cities ranked accordingly:

Table 1.8: Top 10 Global Smart Cities, Overall Ranking, 2017

	City	Region
1	Singapore	Rest of Asia Pacific
2	London	West Europe
3	New York	North America
4	San Francisco	North America
5	Chicago	North America
6	Seoul	Rest of Asia Pacific
7	Berlin	West Europe
8	Barcelona	West Europe
9	Tokyo	Far East & China
10	Melbourne	Rest of Asia Pacific

Source: Juniper Research

Performance rankings across transport, healthcare, public safety, energy and productivity are shown below. As the previous table displayed overall rankings, this means that some cities appear here, but do not perform sufficiently well overall to be in the overall top 10. The results are as follows:

Table 1.9: Top 10 Global Smart Cities by Index, 2017

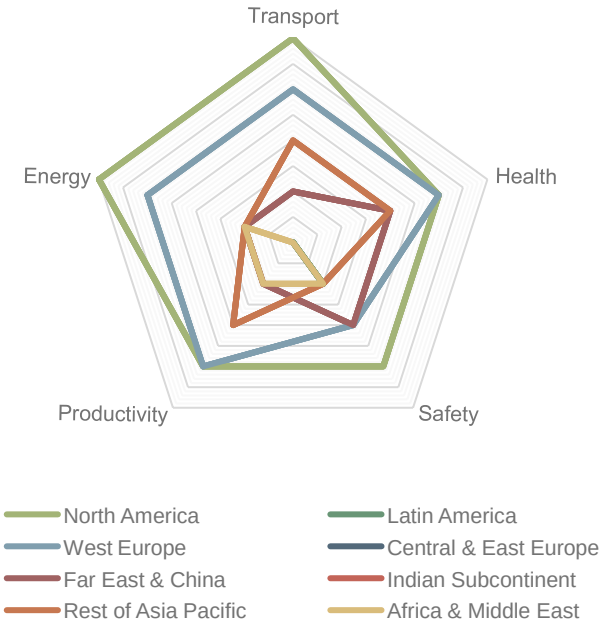
	Transport	Healthcare	Public Safety	Productivity	Energy
1	Singapore	Singapore	Singapore	Singapore	Seoul
2	San Francisco	Seoul	New York	London	San Francisco
3	London	London	Chicago	Chicago	New York
4	New York	Tokyo	Seoul	San Francisco	Portland, OR
5	Barcelona	Berlin	Dubai	Berlin	Barcelona
6	Berlin	New York	Tokyo	New York	Chicago
7	Chicago	San Francisco	London	Barcelona	Dubai
8	Portland, OR	Melbourne	San Francisco	Melbourne	Berlin
9	Tokyo	Barcelona	Rio de Janeiro	Seoul	London
10	Melbourne	Chicago	Nice	Dubai	Melbourne

Source: Juniper Research

1.6.1 Relative Performance Across Regions

The following figure highlights the relative regional performance of cities in the mix.

Figure 1.10: Juniper Competitive Web: Regional Analysis of Smart City Performance Across Indices, 2017



Source: Juniper Research

Case Study: Singapore

i. Key Strengths

The city-state of Singapore finds itself at the top of the rankings for the second year in a row. Last year's ranking highlighted Singapore's strength in addressing the challenges of urban mobility, using a range of technology to limit traffic volume and smooth overall traffic flow. This year's study has reinforced this leading position by delving deeper into the city's overall transport strategy.

Singapore has implemented aggressive policies to limit the number of private vehicles. Its COE (Certificate of Entitlement), duties and registration costs are so high as to make owning a new private vehicle very difficult for much of the population. Undoubtedly unpopular with some of the city's younger, lower-earning demographic, urban transport is balanced out by an affordable, highly-available public transport system. Indeed, when the total number of annual public transport trips per capita are calculated, only Tokyo and Mexico City exceed Singapore.

The relative lack of city congestion helps lower air pollution, in turn leading to a healthier population. Indeed, healthcare is a key priority for the city, with strategies in place to address an ageing population, including remote monitors to alert caregivers of patient distress or other abnormalities. Meanwhile, healthcare services have largely been migrated to digital health delivery, with appointment-making and healthcare information, such as test results, available through the city's health portal.

Crucially, Singapore has fostered a highly competitive environment so that only 2.5 days are required to start a business compared, for example, to Rio de Janeiro where those starting a business must wait on average 45 days. The removal of unnecessary 'red tape' helps drive new, innovative services, in conjunction with a relatively business-friendly tax environment and a focus on 'test beds' for the development of services without, for example, strict regulation of a full market deployment scenario.

Singapore has also taken note of the future development of the labour market, and made adjustments as appropriate in an attempt to ensure that its citizens are well-positioned to compete in a digital-first economy. In that sense, schools begin teaching children how to code at the primary school level.

ii. Opportunities

In terms of smart energy, Singapore is effectively hampered by its own environment. On the one hand, limited space on the landmass means that large solar PV (photovoltaic) fields cannot be used to generate power. Meanwhile, placid seas around the city and low average wind speeds mean that neither tidal nor wind energy can be used to any great extent. Singapore is therefore highly dependent on imported energy resources, over which it has limited control.

Nevertheless, deployment of smart meters and smart lighting rollouts have ensured that the city does have policies in place to reduce overall consumption.

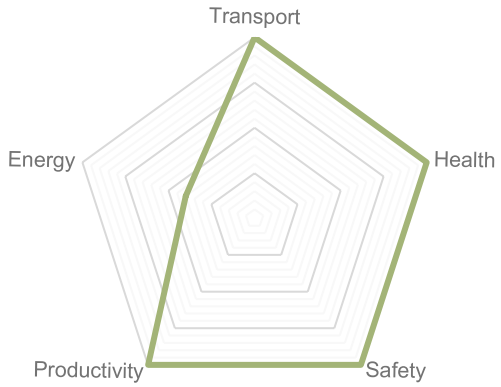
Despite Singapore actively promoting the development of AVs (Autonomous Vehicles), it is

Case Study: Singapore

apparent that infrastructure development is not being considered in tandem with the likely impacts of the arrival of such vehicles in mind. For example, EV (electronic vehicle) charging stations are few and far between; given that the future of AVs and EVs is likely intertwined, this will have to be addressed somehow.

Meanwhile, development of smart grid technologies remains at an early phase, with issues such as vehicle-to-grid delivery yet to be fully considered.

Figure 1.11: Juniper Competitive Web: Singapore



Source: Juniper Research

Case Study: London

i. Key Strengths

London's high-ranking position of is not entirely surprising when one considers the city's position as a global tech-hub. London's 'silicon roundabout' is home to a large number of start-up companies and has been boosted by the 'Tech City UK' initiative, This has received funding from the government to attract investment, as well as the ability to sponsor candidates for a special, 'exceptional talent' visa scheme.

The city has performed very well in both transport and healthcare segment analysis, beaten only (aside from Singapore) by San Francisco and Seoul respectively. For London, urban mobility is, and will continue to be, a tremendous concern, with London drivers subjected to an average of 100 hours of delays per annum. Nevertheless, the analysis found that plans for a MaaS (Mobility-as-a-Service) platform, as well as the aim to foster the deployment of AVs on city streets, are likely key in providing a future solution to the city's congestion problem.

Meanwhile, London's 2012 overall strategy had several digital healthcare schemes. Indeed, long-term health issues affecting over 1.5 million Londoners and a high prevalence of low physical activity across the population creates strain on local NHS trusts. The city, working in conjunction with the DigitalHealth.London accelerator programme, has developed apps such as DrDoctor, allowing patients to organise appointments digitally at their convenience. As well as saving time, this helps reduce 'no shows' at appointments, thus freeing up resources.

Meanwhile, funding for telehealth has been successfully deployed across 8 city boroughs, in a pilot scheme where healthcare wearables and connected scales were both used to manage Type 2 diabetes. Patients on the scheme have successfully managed to reduce their weight by an average of 5.3kg; weight loss is cited as a key factor in reversing the condition.

Further measures aimed at improving citizens' health include goals to improve road safety, particularly for pedestrians and cyclists, which should lead to reductions in motor vehicle use, thus improving air quality. Additionally, some 1,500 EV charging stations are planned to be installed by 2018, helping promote emission-free vehicles.

London's air quality has frequently been cited as one of the leading causes of premature death for citizens (9,500 annually according to a 2015 study[iii]); these measures should help reduce that number.

ii. Opportunities

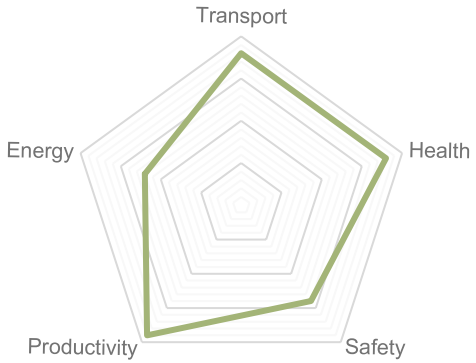
London's key challenge remains its handling of energy policy, although this is as much of a national issue as it is a city one. For example, the UK's bungled rollout of smart meters has led to confusion over standards and functionality while offering vague promises of energy cost savings for consumers without any supporting data.

Case Study: London

Meanwhile, uncertainty surrounds the effects of Britain's exit from the EU on the country's green energy policies. In the context of London, the city may choose to take a different approach to the one outlined by the incumbent government, in similar fashion to several US cities.

Additionally, the analysis found that despite intelligent surveillance video trials and predictive crime software, the city suffers from a high level of violent crime relative to the police force presence. Numbeo's crowdsourced data rating citizens' safety has left London in the bottom quartile of cities analysed. These data, combined with high levels of preventable travel delays across the city, undoubtedly lead to increased levels of stress for citizens, which in turn can have a negative impact on their wellbeing.

Figure 1.12: Juniper Competitive Web: London



Source: Juniper Research

Case Study: New York

i. Key Strengths

Some readers will perhaps be surprise to find New York City ranked second in terms of public safety. Indeed, New York is not renowned for safe streets, particularly in light of its violent history during the 1990s.

Nonetheless, it was this violent streak that led the city to pioneer data-driven law enforcement approaches, with the CompStat concept forming a part of modern policing in numerous cities across the globe.

In addition to the statistical approaches, New York has deployed ShotSpotter, a gunshot detection system able to triangulate the origin of shots and alert law enforcement. The city has noted the system's effectiveness, particularly in instances where the general public have failed to call in such incidents.

Juniper also found that New York made substantial efforts to increase the productivity of its citizens. The city has developed an online portal, nyc.gov, with the aim of delivering a more efficient service for citizens. For example, the portal can be used by aspiring new business owners to rapidly (within 10 minutes) generate a list of City, State, and Federal licences that will be required, according to the location and nature of their business. In a similar vein, the city has developed a tool to help business owners establish which permits and regulations apply to their business.

The city has also expanded its 311 service by creating a smartphone app, which helps citizens rapidly access information and communicate with the city across a range of services, enabling them to pay bills and find real-time traffic and public transport information.

The LinkNYC project aims to replace 7,500 payphones with gigabit-speed Wi-Fi access points, available for citizens to use at no charge. The operation of the hotspots is funded through advertising partnerships, with 55" displays used for this purpose. As a result of further sponsorships and partnerships, the city expects to generate $500 million in revenue during the project's first 12 years.

These efforts are part of the city's aim to both democratise services and reduce poverty levels. The target is to reduce the number of citizens living below the bread line by 800,000; success in this regard is already evident by the fact that New York was the only major US city to reduce poverty levels between 2000 and 2013.

Finally, New York has the most comprehensive open data platform of any of the cities analysed, with more than 1,800 datasets available. This highlights the city's effort to be transparent and promote innovation from published data.

ii. Opportunities

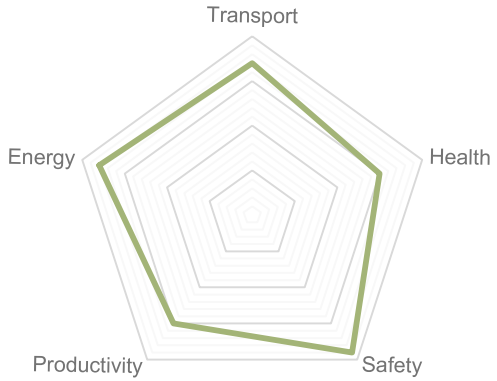
Juniper believes that New York could elevate its position by addressing some healthcare concerns. There is no current strategy to introduce telehealth services, for example, which have been shown to offer substantial benefits in terms of both access to healthcare and also in positive outcomes.

Case Study: New York

Despite the fact that the US healthcare system is very much driven by the private sector, there are a few city-driven initiatives, such as funding to encourage the development of services that challenge the *status quo*.

Additionally, the analysis found that the city would benefit from a traffic congestion charge, based on a strategy of reducing harmful air pollution. This would not only benefit citizens' health directly as a result of reduced traffic, but would also encourage citizens to use other transport modes, such as bicycles or walking.

Figure 1.13: Juniper Competitive Web: New York City



Source: Juniper Research

Case Study: San Francisco

i. Key Strengths

San Francisco has taken a forward-looking approach to traffic management in the city and has developed a comprehensive strategy around the shift away from private transport.

The city believes that the key to underpin this vision is in the direction of shared transport modes, with connected vehicles playing a fundamental role in enabling the development of MaaS offerings. When MaaS is fully rolled out, the city envisions that cross-city journeys should take no longer than 20 minutes, while the on-demand nature of MaaS will ensure that the chosen transport mode will be available to the consumer within 2 minutes of booking.

San Francisco has thus set out a vision for a technology platform supporting an integrated service, allowing citizens to choose from a range of modal options. The primary elements of this vision are:

- Transportation as a Platform: establishment of a city framework for an integrated service across multiple providers;
- Transport as a Service: development of a consumer solution to handle pricing, routing, booking and payment through a single platform.

The city continues to perform well in terms of its energy policy. Smart meters are currently being rolled out, while several smart grid pilot projects have been conducted. In line with this, the city has deployed a substantial network of EV charging stations; 3 solar powered charging stations were unveiled in April 2015 to enable citizens to charge their vehicles at no cost. Meanwhile LED smart street lights ensure that the city's energy bill is minimised along with its associated carbon footprint.

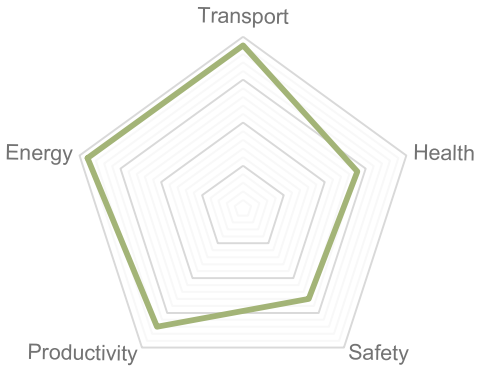
ii. Opportunities

Like many US cities, San Francisco suffers from a high violent crime rate (8 per 1,000 capita). This figure alone is relatively high; when the incumbent police force size per capita is considered alongside that metric, it is clear that the city has some issues to address, which it has made an attempt to do. Gunshot detection hardware and software is active across the city, although the presence of this solution does not help crime prevention, merely detection.

Solutions that do help deter crime (by virtue of police presence in the area), such as predictive crime software, have not yet been deployed in the city.

According to Numbeo, crowdsourced data suggests that citizens feel that San Francisco has some of the least safe streets of the cities under analysis here, bettering only Rio de Janeiro, Mexico City and Chicago.

Figure 1.14: Juniper Competitive Web: San Francisco



Source: Juniper Research

Case Study: Chicago

Case Study: Chicago

i. Key Strengths

Chicago, famous for its AoT (Array of Things) initiative has taken steps to ensure that the technology is of clear benefit to citizens, despite fears of a dystopian implementation of the project as dramatised in video games such as *Watch Dogs*. For instance, the city is one of the few analysed that explicitly aims to address cybersecurity and privacy challenges.

An AoT charter has been drawn up, which also incorporates measures to limit cybercriminal damage. The AoT project includes sensors positioned across the city to measure environmental variables such as air quality and microclimate as well as footfall levels. Before data from connected nodes is released to the public, its accuracy, reliability and compliance with the city's privacy policy is checked by the program operators and oversight committee.

The AoT, along with initiatives to increase engagement, such as hosting of conferences and hackathons, all serve to promote interest in the smart city concept and increase innovation.

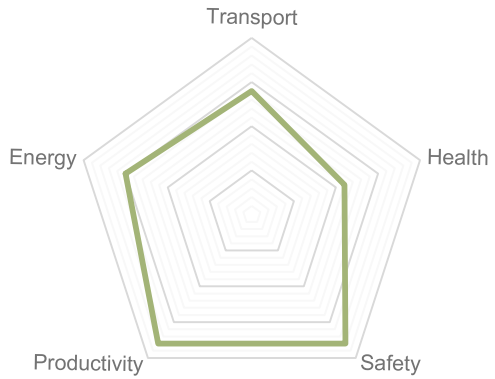
ii. Opportunities

Chicago continues to suffer from issues with the urban transport sector. Private vehicle ownership is among the highest of all the cities analysed, while road safety is poor: only Portland OR and Mexico City have a higher recorded number of road traffic injuries per capita. That said, the city has shown a desire to improve road safety and encourage public transport use in place of private means.

Additionally, the city anticipates competing as a test-bed for AVs, which should lead to improvements in urban transport in the long-term. Crucially, however, the statistics show that the vision has not yet been effectively executed. The city must therefore take additional steps to ensure that its goals are achieved.

One of the recurring themes throughout the analysis was the relatively poor performance of US cities where healthcare is concerned. As noted earlier, this can be partly attributed to the market structure in place, although the city has done little to encourage the fruition of innovative services. At present, city healthcare is inefficient: hospital bed space is underused for example, which only serves to increase patient costs.

Figure 1.15: Juniper Competitive Web: Chicago



Source: Juniper Research

Case Study: Seoul

i. Key Strengths

Seoul, in company with other cities such as Tokyo, is beginning to face the very real problem of how to care for an ageing population.

The fact that the city scored the highest of all those analysed in terms of smartphone and fixed line broadband penetration, means that Seoul is well-positioned to rollout digital health services to care for the elderly. Indeed, this is one of the cornerstones of the city's vision. In this context, the city's 'U-Health Care' initiative incorporates the provision of telehealth equipment for elderly and disabled residents, while the city also envisions rolling out the technology to those suffering from long-term conditions.

Meanwhile, motion sensors alert caregivers when an elderly patient is in distress. The availability of healthcare services, at least in terms of hospital care, is bested only by Tokyo.

Meanwhile, a combination of strategies including a city congestion charge, investment in the public transport system, as well as the build-out of its EV charging infrastructure has not only reduced congestion levels in the city, but also improved citizens' wellbeing. Road accident injuries per capita are low, while air quality levels are above average.

This performance carries over to public safety. For example, smart street lighting has been deployed, with the city able to respond quickly to failed lighting fixtures. In turn, illuminated streets help deter crime.

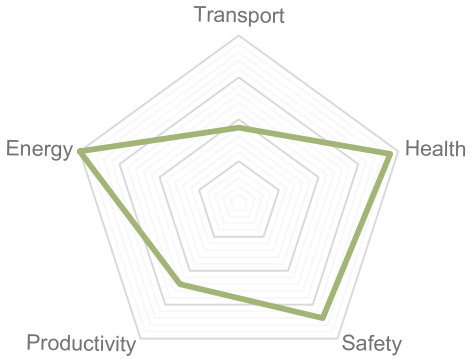
ii. Opportunities

Despite the implementation of a congestion charge in an attempt to reduce traffic volumes, the city is still in the grip of frequent, chronic congestion. Indeed, the city's average vehicle speed is a crawling 19kmh (11.9mph). Part of the problem is the city's inability to deter residents from owning a vehicle: Seoul's 496 vehicles per 1,000 residents is beaten only by the US cities analysed, as well as Dubai and Melbourne. The city also has no clear strategy on how to address this, save for continuing to promote public transport as a modal option.

Nevertheless, strategies such as MaaS and AV development are under consideration, with trials underway in the latter instance. These types of projects must be actively pursued if Seoul is to achieve further improvements to its transport network.

However, the use of road sensors and real-time traffic information to help the public transport network has led to a highly available, punctual system, with little clear room for improvement.

Figure 1.16: Juniper Competitive Web: Seoul



Source: Juniper Research

Case Study: Berlin

i. Key Strengths

Berlin's healthcare strategy is perhaps a reaction to the relatively poor statistics on the wellbeing of its citizens. Some 30% of the adult population are smokers (versus the sample average of 20%), while just under 70% of the population reportedly lead sedentary lives. The city is therefore faced with ongoing pressures on its healthcare system.

To that end, Berlin has announced plans to develop telehealth services, initially using the technology to help elderly, disabled or chronically ill citizens. According to the city's strategic framework, these initiatives will be supported by strategic grants and subsidies.

Berlin is also notable for its focus on increasing the productivity of its citizens: eGovernment forms a core part of the city's strategy, with business interactions with administrative bodies intended to be undertaken entirely online.

On a similar note, citizen interaction with the municipal authorities can be handled electronically using the mein.berlin.de platform launched in 2015.

Tying into the theme of productivity, the city has rapidly developed its open data portal, with the volume of Berlin's available datasets second only to New York. Indeed, the city has managed to increase the number of datasets by nearly 60% over the course of 2 years.

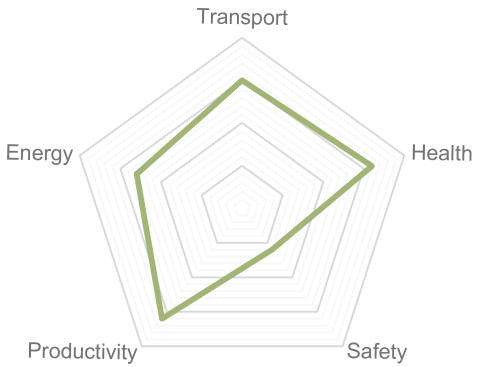
ii. Opportunities

Berlin performed relatively poorly in Juniper's analysis of public safety. Although violent crime rates are low and remain flat, the terrorist attack on the city's Christmas market in 2016 prompted a rethink on the attitude to CCTV, which has historically been viewed as a device to potentially threaten individual privacy rights. Meanwhile, the city has suffered some 13 other domestic incidents classified as terrorism over the past 3 years.

Although the city has deployed a predictive crime software platform, that solution could be bolstered by the deployment of an intelligent video surveillance system to detect anomalous events, such as suspicious items left behind by individuals or a panicked crowd. This would allow a more rapid response to any incident by the emergency services.

Naturally, any such system would have to take into account the strict protection of privacy rights, with minimal recording of data. Any service provider would likely be limited in terms of how available video data would be for algorithm training purposes.

Figure 1.17: Juniper Competitive Web: Berlin



Source: Juniper Research

Case Study: Barcelona

Case Study: Barcelona

i. Key Strengths

Barcelona's smart city strategy is one of the more comprehensive among the cities analysed, and placing emphasis on the concept of shared learning and information to drive innovation. Indeed, in that vein, the city's sensor monitoring platform, Sentilo was open sourced following development, with the code available for other cities to use via GitHub.

The city has a vision for a low overall carbon footprint, which is reflected in its strong-performing transport network. The city's bus network has been upgraded to show time-of-arrival information for waiting passengers, while Barcelona is home to one of the larger EV charging networks among the cities analysed. Meanwhile, a sponsorship deal between Barcelona city council and the nearby Circuit de Barcelona-Catalunya racetrack has created a suitable venue for AV testing. Overall, the city has employed a strategy that aims to reduce private vehicle use in favour of modal shifts to public transport.

Barcelona performed strongly in its overall energy strategy, which in turn fits with the city's low-carbon agenda. Smart meter rollouts, as well as several smart grid projects, such as the GrowSmarter initiative, are being deployed to deliver low- to zero-emissions zones in the city.

ii. Opportunities

When the city's violent crime rate is measured against the police force presence per capita, only London has a worse statistic. Meanwhile, crowdsourced data indicates a perceived increase in crime by the public and a lowered perception of Barcelona as a 'safe city'.

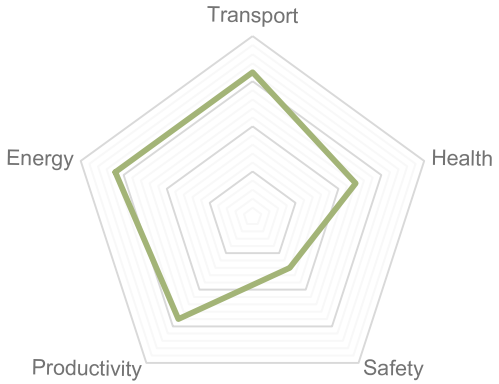
Predictive crime detection is something that has reportedly been rolled out across the city; it is likely that the addition of smart CCTV in key areas would serve to provide rapid response options for emergency services. This would not only help detect panicked crowds, but also in the reduction of pickpocketing, a common criminal activity on the popular *Las Ramblas* street.

Meanwhile, an expansion of the city police force to respond appropriately to crime data would likely reduce the violent crime rate.

Meanwhile, it is likely that Barcelona would benefit from the implementation of a congestion charge. Indeed, studies such as those conducted by the Lancaster University,[iv] have indicated that London's congestion charge has resulted in a dramatic reduction in the number of road traffic accidents, largely because more people are choosing public transport over private vehicles.

Barcelona, where approximately 7.3 per 1,000 capita suffer from road traffic accident injuries, only rated over Chicago, Mexico City and Portland OR in that regard. Road safety is thus a key issue to address.

Figure 1.18: Juniper Competitive Web: Barcelona



Source: Juniper Research

Case Study: Tokyo

i. Key Strengths

Alongside Seoul, Tokyo can be viewed as one of the cities in prime position to deploy smart city services that benefit the majority of the population. Its citizens are highly connected to fixed line and mobile broadband services, for example. This means that where smart city services are used to distribute information, or make decisions based on real-time citizen movement, a highly-connected population is likely to yield better results.

Tokyo performed well on citizen healthcare. Hospital bed availability is high, while occupancy rates are below 85%, while figures above this show an increase in hospital-contracted infections.

Meanwhile, high investment in public transport services ensure that public transport use lowers the number of road traffic-related injuries. Room for further improvement exists in the form of telehealth services, which would go some way to addressing the issue of healthcare for the city's ageing population.

The analysis found that, unlike most cities, Tokyo has not yet rolled out a cycle-sharing scheme, so citizens have been unable to benefit from the associated health improvements. Nevertheless, it was also found that significant societal shifts would be required to popularise road cycling.

ii. Opportunities

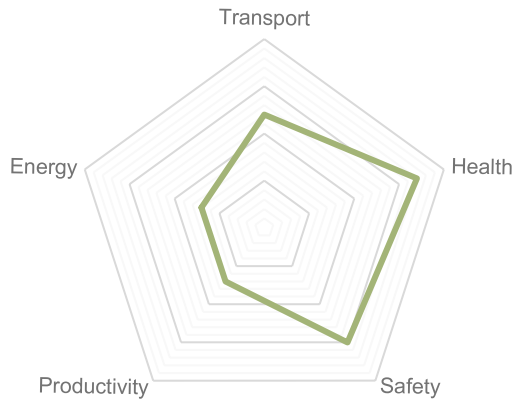
Juniper has found that in many instances (such as traffic management, for example), the benefits of open data and shared information concepts exceed the benefits enabled solely by the deployment of smart technology solutions.

For example, services built on open data were found by Juniper, in the long term, to have a potential 15% reduction impact on the time taken to travel across the city, while intelligent traffic management solutions are likely to only have a 10% benefit. Thus, the rollout of open data services for most cities will be critical in realising higher citizen engagement and smart city project success.

With that in mind, Tokyo has an opportunity to expand the number of datasets it makes available to developers and the public. This is particularly pertinent in the context of urban mobility where, despite one of the most efficient public transport systems in the world, citizens are subjected to chronic service overcrowding during rush hour.

Open data, alongside an approach that aims at the integration of services into API-accessible platforms, would undoubtedly spur innovation in the city's transport sector. Nevertheless, achievements would also need to be made at societal level, where flexible working hours and greater openness to teleworking would deliver benefits necessary to reduce pressure on the city's road infrastructure and 'make room' for alternate, on-demand transport services.

Figure 1.19: Juniper Competitive Web: Tokyo



Source: Juniper Research

Case Study: Melbourne

i. Key Strengths

Melbourne was found to excel in using its smart city vision and policy to improve citizen productivity. The city has, for example, focused on improving digital services accessibility, while an action plan for the support of the start-up and entrepreneur community was recently developed, with the aim of improving the city's competitiveness in emerging technology sectors.

Meanwhile, Melbourne has a strong position in terms of international competitiveness, in part thanks to state activity and investment in improving international trade links. A focus on digital key skills education at primary school level, conference hosting and hackathons all ensure that innovation is encouraged and that citizens are, in so far as is possible, prepared for the demands of a digital-centric economy.

Additionally, the city performed relatively well in terms of its energy strategy. The city has conducted innovative trials, such as Ausnet's 'mini grid' project, to demonstrate the viability of small-scale power networks that are not reliant on centralised, expensive infrastructure.

In tandem with efforts such as these, the city has begun to install smart street lighting in an effort to reduce city energy consumption, while smart meter rollouts are underway.

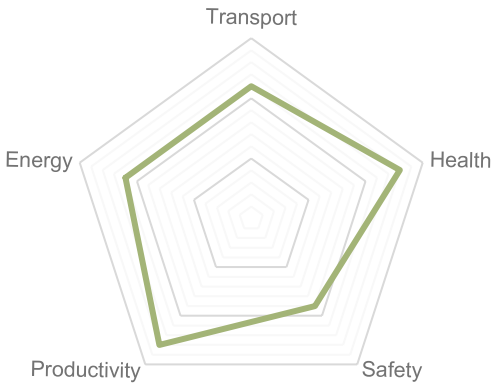
ii. Opportunities

Melbourne's smart development opportunities are principally in the domain of energy. It may seem odd that energy features both in the city's strengths and opportunities, but the incumbent government has recently signed a proposal to scrap renewable energy subsidies. Therefore, potential future energy performance is likely to be impacted by national policy as much as city policy.

For this reason, Melbourne must, as far as possible, encourage initiatives that aim to reduce the city's carbon footprint. This could be achieved, for example, by increasing the number of projects that aim to engage citizen participation in energy use reduction, where schemes similar to Amsterdam's 'Tree Wifi' project would be comparable.

Meanwhile, utilities could be encouraged to develop 'value-add' services on top of smart meters and smart grid innovations, with future revenues assured based on delivery of renewable energy to the city.

Figure 1.20: Juniper Competitive Web: Melbourne



Source: Juniper Research

1.7 US & UK Smart Cities: The Leaders 2017

Coverage of this year's smart city rankings has been extended to cities specifically in the US and UK to provide readers with a broader picture of the overall landscape. The same methodology was used as that for global city rankings, but it should be noted that city scores are relative, not absolute. Therefore, a city may perform better (or worse) in an index in the global ranking versus the country-specific ranking.

1.7.1 UK Rankings: Top 10 Smart Cities

Juniper Research found that the cities shown in table 1.21 lead the UK's smart city rankings.

- It should come as no surprise that London tops the UK rankings, although notably it is outperformed by several cities in the transport and healthcare service areas. In large part, this is due to the sheer population density and resultant demand placed on services and infrastructure that reduce the efficacy of smart city initiatives relative to others.
- Indeed, analysis presented at the country-level highlights 2 key challenges in the smart city market today:
  a) It is difficult to scale a project across a large city;
  b) The overall benefits of smart city initiatives are constrained by the size of the city and the demands of the population.

Table 1.21: Top 10 UK Smart Cities, Overall Rankings 2017

	City
1	London
2	Edinburgh
3	Glasgow
4	Bristol
5	Manchester
6	Brighton & Hove
7	Liverpool
8	Oxford
9	Birmingham
10	Milton Keynes

Source: Juniper Research

Table 1.22: Top 10 UK Smart Cities According to Index, 2017

	Transport	Healthcare	Public Safety	Productivity	Energy
1	Glasgow	Bristol	London	London	Milton Keynes
2	Manchester	Oxford	Edinburgh	Bristol	Glasgow
3	Edinburgh	Edinburgh	Leeds	Birmingham	London
4	London	Liverpool	Glasgow	Edinburgh	Manchester
5	Bristol	Glasgow	Bristol	Glasgow	Brighton & Hove
6	Brighton & Hove	Manchester	Brighton & Hove	Manchester	Bristol
7	Liverpool	London	Birmingham	Milton Keynes	Edinburgh
8	Oxford	Brighton & Hove	Manchester	Oxford	Liverpool
9	Birmingham	Nottingham	Liverpool	Liverpool	Birmingham
10	Milton Keynes	Birmingham	Oxford	Leeds	Leeds

Source: Juniper Research

i. London

London undoubtedly has the most in-depth smart city strategy of all UK cities. That said, in Juniper's opinion, this is necessary; the poverty rate is 27%: nearly 1 in 3 Londoners live in poverty, while it simultaneously produces the highest GVA (Gross Value Added) per capita. Combined, these statistics show enormous inequality levels which must be addressed by using smart city projects to increase opportunities and citizen well-being. A recent consultation to address healthcare inequality goes some way towards this, although encouraging local educational institutions to make use of data and target learning plans at the individual, rather than the classroom. Despite not ranking well on the global stage where public safety is concerned, London performs rather better at a national level. This is due to projects such as smart street lighting deployments, intelligent video surveillance analytics, predictive crime and fire risk software that, despite the Grenfell Towers incident, have elevated the city's score.

Despite the aforementioned issues with inner-city inequality, London tops the productivity index for UK cities. Conference hosting, hackathons and the Tech City UK initiative have helped drive engagement with the smart city concept, while the latter's sponsorship of 'exceptional talent' visas is useful to some extent in encouraging foreign talent to contribute.

ii. Edinburgh

Edinburgh's smart city vision is actually something that began to be realised in 2001, as the city signed a 15 year deal with BT, one of the UK's major telecoms service providers. The result of this partnership allowed the city to learn from mistakes (such as disparate maintenance of systems and control of systems by separate council units) and apply its 'One Council' principle to better deliver citizen services.

The city performed well in terms of urban transport, with a plan for MaaS in place; meanwhile, the city streets are among the safest of those analysed in terms of the number of road traffic injuries per capita. Nevertheless, potential vulnerabilities in the city's transport strategy are quite apparent and, if left unattended, could serve to damage its performance in future rankings. For example, public transport systems are underused and thus strategies should be examined for ways to improve service viability. Private vehicle ownership is high meaning that, without further mechanisms to discourage use, city congestion is only likely to get worse.

iii. Glasgow

Glasgow's strengths were noted in its urban transport and energy performance. In the first instance, the city has built out its EV charging infrastructure, resulting in a higher per capita charging station availability than any other city save for Milton Keynes. Meanwhile, Glasgow's 'operations centre' provides a centralised point for real-time traffic monitoring and signal adjustments, allowing the city to not only manage typical urban traffic flow, but also to make adjustments based on emergency response requirements, effectively reducing the time taken for services to reach an incident. In turn, this has the potential impact of saving lives.

Meanwhile, in addition to its EV charging infrastructure, the city is one of the more proactive among those analysed where energy policy is concerned. LED street lighting projects were relatively common, on account of the substantial cost-saving benefits achievable using this technology over HPS (High Pressure Sodium). Nevertheless, few cities have implemented connected street lighting in addition to LED (Glasgow has), which offers further energy savings, while helping reduce the city maintenance bills when lights fall into disrepair.

iv. Bristol

Bristol's smart city effort is enabled by the city's 'Bristol is Open' initiative, a joint venture between the council and the University of Bristol. The initiative is unmatched in terms of its technological capabilities: a 30Gpbs (Gigabit per second) connection, excessive in today's landscape, but intended to be future-proof, is aimed at supporting sensor projects and other smart city services around the city, with data opened in measurement of traffic flows, energy use, crime and health trends. Analysis of, and innovation built on, this data is intended to be used to raise citizen quality of life, in turn raising productivity.

Meanwhile, Bristol is notable in its efforts to improve the wellbeing of its citizens. A diesel vehicle congestion charge has been proposed to create 'clean air zones' in the city, while city hackathons have been held with the aim of encouraging development of healthy intra-city transport solutions. Meanwhile, the VIVALDI (Visionary and Vibrant Actions Through Local Transport Demonstration Initiatives) project, which Bristol city council co-ordinates, aims to deliver solutions for clean transport as well as promoting modal shifts away from private vehicle use in favour of cycling and walking.

v. Manchester

The foundations for Manchester's smart city effort are in its overarching digital strategy developed in 2012, which emphasises on digital equality; by connecting citizens and businesses to high quality broadband, productivity will be raised. Meanwhile, the same strategy aimed to address the national shortfall in coding skills. The EON Enterpeneur School was established in 2013 and offers to teach coding skills in the realms of VR (Virtual Reality) and AR (Augmented Reality) for industry and education. These courses are offered to 100 individuals annually free-of-charge and uses real-word projects as the basis for its training programme.

The analysis found that Manchester is one of the leading cities for urban transport initiatives. Smart traffic management solutions plan to monitor vehicle movements according to type. In turn, this will allow the city to plan its infrastructure more effectively to minimise the impact on congestion. Meanwhile, drivers are alerted as to nearby available parking spaces based upon their normal driving route, with notifications directing drivers

close to nearby public transport routes. In this manner, the city hopes to entice drivers away from their vehicles. Overall, the data found that Manchester has the safest roads of all the cities in the analysis. The city currently has a project underway to investigate the potential of IoT (Internet of Things) technology for the purposes of improving road safety for the elderly and the young.

vi. Brighton & Hove

Brighton (Brighton & Hove) has increased its focus on becoming a smart city in recent years. Its tech sector is the fastest-growing part of the city's economy and was boosted by the opening of a 'Digital Catapult Centre' in 2015. The Centre is principally focused on the development of innovation around what it calls the 'Internet of Place', whereby real-time and location data are harnessed to deliver new services and drive local business productivity.

That said, Brighton has significant challenges it has been attempting to address. City congestion is steadily increasing; on the one hand, while public transport use is high, although worsening traffic conditions mean that bus service become less attractive over time. In 2015, the city announced an ITS scheme to manage traffic light phasing, while aiming to reduce the misuse of designated bus lanes through intelligent camera systems. Meanwhile, the city's cycle sharing scheme was launched in September 2017; as a relatively compact city, the scheme should have a positive impact on urban mobility within the city limits.

vii. Liverpool

Liverpool's 'Connected Liverpool' initiative is the city's smart vision. It is underpinned by the city region innovation plan published in 2014, which aims to develop employee skills, new technologies and services while attracting foreign and domestic investment. Part of this effort is aimed at addressing the health and well-being of citizens; in that context, the University of Liverpool is involved in the development of personalised medical treatments (where treatments and drugs for ailments are administered based on historical analysis of patient success factors and other data) aimed at improving positive healthcare outcomes and reducing adverse drug reactions.

Meanwhile, the city is actively seeking to improve its position in terms of energy and sustainability; it is in talks to test hydrogen-powered trains in the area, while development of smart grid technologies are in the city's 'innovation pipeline'.

viii. Oxford

Oxford has begun work on developing its smart city vision, having launched the 'Oxford Smart City Programme' in January 2015. The programme itself was initiated by the OSP (Oxford Strategic Partnership), a collaboration of stakeholders across the enterprise, public, education and community sectors. A number of pilot projects have been kickstarted as a result of the OSP's efforts, many of which aim to deliver superfast broadband services to residents and businesses. The current Smart City Programme aims to increase sustainability, increase equality, stimulate local job growth and investment from external sources and improve city efficiency and safety.

Transport is a significant concern in the city, with rising levels of congestion leading to crawling vehicle speeds during peak times; the analysis found that only London vehicles were slower. The city has a well-used public transport system, while the development of MaaS has been mooted as a possible solution to ongoing transport concerns.

Meanwhile, the city's Mobox project has already been established, with the aim of collecting a dataset which will allow stakeholders to analyse urban mobility to determine where, and which, solutions will be most appropriate to improve mobility.

ix. Birmingham

Birmingham's Smart City Vision, published in 2012, outlines the key principles of the city's strategy for the future. One of the indices on which the city has decided to focus is productivity. In that context, the aims of the smart city vision include digital inclusion and boosting economic output. Success has undoubtedly been achieved in this respect; the city reported that 18.5% of adults in Birmingham were still offline in 2012; by 2014, the ONS reported that this figure had dropped to 15.4%.[v]

Meanwhile, the council has been working to improve its digital strategy and published a strategy document last year, outlining its goals. Key elements of the strategy include an integrated approach, allowing separate departments under the council to work more closely together, share information and gain insights from the data. Meanwhile, emphasis has been placed on designing systems around citizen needs rather than council ones, with the overall aim of increasing citizen engagement. This latter point is further emphasised by the city's organisation of smart city hackathons.

x. Milton Keynes

Milton Keynes is perhaps one of the more famous smart cities in the UK due to its high emphasis on technology to achieve its smart city vision, the core of which has been developed and delivered via the MK Smart project. In the smart city context, the 'nerve centre' of Milton Keynes is the MK Data Hub: a central repository for the large number of sensors deployed around the city, with over 3,000 datasets available to smart city application developers. To facilitate innovation, the Hub includes analytics tools to help developers extract value from the data.

Meanwhile, the city has recently announced a £3 million (S4.04 million) project in partnership with Vivacity Labs to deploy an AI-controlled smart traffic light system. Software will manage control of connected lights individually according to real-time traffic demand, making a rather unique system in the UK. Further elements of the city's high-tech traffic aspirations include AVs, with testing taking place in the city. It is envisioned that its new traffic light system will in future be capable of communicating with AVs.

Milton Keynes has placed high emphasis on addressing its energy and resource footprint, with initiatives to rollout home energy storage solutions, solar panels and infrastructure for EV charging; trials have shown promise in managing demand during peak times and reducing overall consumption.

1.7.2 US Rankings: Top 10 Smart Cities

Juniper Research found that the following cities lead the US's smart city rankings.

Table 1.23: Top 10 US Smart Cities, Overall Rankings 2017

	City	State
1	New York	New York
2	San Francisco	California
3	Chicago	Illinois
4	Washington DC	n/a
5	Seattle, WA	Washington
6	Boston, MA	Massachusetts
7	San Diego, CA	California
8	Portland, OR	Oregon
9	Pittsburgh, PA	Pennsylvania
10	Kansas City, MO	Missouri

Source: Juniper Research

Table 1.24: Top 10 US Smart Cities According to Index, 2017

	Transport	Healthcare	Public Safety	Productivity	Energy
1	San Francisco	New York	Chicago	Pittsburgh	Kansas City
2	New York	San Francisco	New York	New York	San Francisco
3	Seattle	Boston	Pittsburgh	Washington DC	New York
4	Boston	Washington DC	Seattle	Baltimore	Washington DC
5	Portland	Portland	Washington DC	San Diego	Portland
6	Washington DC	Chicago	San Francisco	Boston	Chicago
7	Austin	San Diego	Kansas City	San Francisco	San Diego
8	San Diego	Pittsburgh	San Diego	Kansas City	Austin
9	Chicago	Austin	Boston	Austin	Seattle
10	Baltimore	Seattle	Austin	Portland	Baltimore

Source: Juniper Research

i. New York, NY

New York City's average ranking of second place across each of the indices analysed highlights the consistency of the city's smart city vision and execution. Indeed, no other city achieved a better average rank across Juniper's global, US and UK rankings. That is not to say that the city is without issues; 1 in 5 residents live in poverty, for example. Meanwhile. Kansas City citizens are roughly 5 times safer from traffic accidents resulting in injury than New York.

Nevertheless, the city performed strongly in trying to improve the safety of its citizens, having made great strides in reducing the violent crime rate in the city over the past 2 decades. Machine learning is now being used to enhance data-driven processes across both law enforcement and emergency services, helping to manage efficiently resources and alert citizens of danger ahead of time.

ii. San Francisco, CA

With a population at less than 1 million, San Francisco is under less pressure than New York in terms of overcrowding and resource constraints. Its position close to Silicon Valley means that the average citizen income is substantially higher than most other cities in the analysis.

However, the city's relatively compact size gives rise to challenges in terms of urban mobility, which San Francisco hopes to address via a combination of on-demand, shared transport solutions offered under the MaaS umbrella. The city views its carbon footprint as a key responsibility not only in terms of the environment, but also in terms of liveability. The build out of its EV infrastructure is underway, while the city is encouraging the development of smart grid technology which, in turn, will support zero-emissions vehicles. It will also protect the city, to a large degree, from the consequences of large-scale earthquakes cutting the city off from a centralised power source.

iii. Chicago, IL

Chicago is perhaps one of the key cities to highlight the benefits of smart city technologies in conjunction with smart policies from local authorities. There is no doubt that Chicago is one of the more violent cities found in the analysis, with close to 9 violent crimes per 1,000 capita recorded. Nevertheless, the city has announced plans to expand its police force by some 1,000 members, while predictive crime software and gunshot detection sensors have been deployed around the city. All these factors should help reduce violent crimes in the medium-term.

The city is one of the better performers where smart grid deployments are concerned, with smart meter rollouts anticipated due to be completed by the end of 2017, while the city's 'Retrofit' scheme aims to help residents and businesses reduce energy consumption. Nonetheless, Chicago remains behind in committing to zero-emissions vehicles, with charging infrastructure insufficient relative to the city's population.

iv. Washington DC

Washington DC's smart city project is defined in the 'Smarter DC' initiative and encompasses goals for improvements in urban transport, healthcare, safety, urban planning, economy, energy, environment and infrastructure. Given the city's position and role in the government of the US, it places high emphasis on public safety improvements; an automated gunshot detection solution has been deployed across the city, while a project is underway to modernise the city's CCTV surveillance network, with the aim of leveraging high-bandwidth communications to deliver improved services.

Meanwhile, the city has numerous projects in the planning or implementation phase that aim to deliver improvements to municipal services. For example, smart cameras are envisioned as part of a project to provide detection of, or early warnings, for flooding events, while the smart streetlight network is aimed at delivering energy reductions, citizen movement data as well as helping emergency response teams.

v. Seattle, WA

Seattle's population has grown by an astonishing 70,000 individuals over the last 5 years, roughly 10% of the present total population. The city has recognised the need to develop data-driven services and has focused on tools that aim to support the concept of shared information and cross-departmental integration.

Meanwhile, Seattle partnered with the University of Washington in response to the Obama administration's creation of the White House Smart City initiative. As part of this partnership, the 'Seattle MetroLab' is participating in the AoT project pioneered by Chicago, as well as developing open data services and energy services.

vi. Boston, MA

One of Boston's key strengths is its approach to the challenge of urban mobility, where high private vehicle ownership is a key factor in elevating city congestion; meanwhile, Boston was found to have the worst performance of all US cities analysed when examining road accident injuries per capita. To address these issues, Boston has begun using video and sensor data to analyse citizen movements, road hazards and other information to improve future urban planning. It is hoped that in this way, road traffic safety can be improved.

Additionally, the city has focused on improving the delivery of municipal services, developing and distributing mobile apps for services such as parking, complaint registration and so on. City hackathons have also been held to encourage third party innovation in the smart city space.

vii. San Diego, CA

San Diego has a relatively comprehensive plan to develop as a smart city, with related projects in plan, or underway, in the realm of transport, energy, sustainability and resilience against the impact of climate change.

Encompassed in the city's plans are what it notes will be the largest city sensing project to date, with some 3,200 sensors used as part of an effort to direct drivers to available parking spaces, as well as monitor environmental conditions and urban movement. Meanwhile, the city has set out aims to deliver low-carbon initiatives, with trials testing solar-powered EV charging stations. Nevertheless, while the city envisions a shift to EVs, it has not made significant inroads in developing a robust charging network.

viii. Portland, OR

The city of Portland was one of 7 finalists in the US's 'Smart City Challenge', in which the city outlined a comprehensive plan to develop and deliver a 'ubiquitous mobility' solution for citizens. Via this MaaS platform, citizens will be able to buy and sell transport options via a single integrated platform. The resultant shift away from high levels of low-occupancy vehicle use is thought to be a significant contributor to the city's 2035 target of reducing its carbon emissions by 50% from 1990 levels.

The city's 'Portland Plan' includes a number of objectives for the years to 2035, including job creation and a reduction in inequality. The city still has some work to do, with poverty levels among minority groups on the increase.

ix. Pittsburgh, PA

Pittsburgh, which also featured as a finalist of the 'Smart City Challenge', has laid out its smart city vision in the 'Pittsburgh Roadmap for Inclusive Innovation'. Indeed, with a 23% poverty rate among its citizens, Pittsburgh has recognised the need to increase the productivity. As part of this effort, it has laid out plans to increase digital literacy, while also promoting STEAM (science, technology, engineering, arts and maths) education and offering opportunities for all segments of the population to participate in coding. In this way, the city aims to ensure the future workforce is well-positioned for a digital-first economy.

Additionally, Pittsburgh aims to improve and streamline its procurement processes, which should help minimise excess costs related to obsolete or single-vendor technology solutions. This plan also incorporates a demand for a horizontal approach to digital products and services procurement, ensuring that systems are able to integrate with one another, maximising the possible benefit.

x. Kansas City, MO

Kansas City has focused heavily on development aimed at cementing the city's position as a tech hub. This vision was initially spurred on by Google's deployment of its gigabit 'Fiber' service in 2011, with the city viewing digital inclusion as a key objective. Meanwhile, it has announced projects with the likes of Cisco and Sprint to develop connected street lighting, with additional service provision for citizens via a Wi-Fi network, using street posts as access points.

Further focus has been placed on the delivery of municipal services via digital channels, with a 'paperless' City Hall processes and creation of city apps and online resources.

1.8 Regional Smart Cities Analysis

Regional smart cities are not created equal. Indeed, the immediate or medium-term success of any smart city is dependent not only on the attitude and approaches of municipal agencies, but also on the extant national framework to support innovation. For instance, it is safe to say that smart cities require; in nearly all instances; technical and implementation expertise, funding and best practice learning from multiple sources, including international ones.

The key to smart cities' long-term success is dependent on creating an ecosystem that addresses the wider market from a number of perspectives. Cities unable to achieve this will likely see investment and development move to more competitive environments, causing them to fall back. Juniper believes the key perspectives are as follows.

1.8.1 Funding/Financing

Unsurprisingly, a key pain point for cities wishing to develop smart city services is the issue of obtaining sufficient funds, whereby it is understood that:

- Funding implies that monies are directed to a project without any expectation of receiving that money back;
- Financing is a cash injection where the supplier expects to receive those funds back at a later time.

Additionally, this pain point applies to SMEs (Small to Medium Enterprises) who may well have developed, or wish to develop, smart city services. In many instances, SMEs lack the capital to develop and market their solution to the stage where any rollout might be achieved. It is therefore critical that national frameworks are developed in the interests of driving innovation through funding or financial sources.

'Smart city finance and VC investments in this space are starting to increase, funding from other sources is beginning to be fed in, there is a clear linkage of financial

returns for many of the smart city service.'

Munish Khetrapal, Cisco[4]

1.8.2 Talent Acquisition

Smart cities are principally composed of services, rather than products, with hardware components forming only a relatively minor proportion of the overall solution, considering the fact that benefits are ultimately delivered by the software in place.

As cities become more data-heavy and aim to become more pro-active, issues begin to arise where Big Data and AI (Artificial Intelligence) are concerned. While industry-at-large continues to struggle with the extraction of value from Big Data, the pattern analysis and predictive capabilities that form the basis behind current AI solutions require considerable expertise where data scrubbing and algorithm training are concerned.

Additionally, data-heavy cities will undoubtedly gather citizen data in some form or another. As this data becomes richer, the need to ensure that data security and privacy breaches are minimised will require further expertise.

1.8.3 Governance

City governance is often a significant challenge for smart cities. In the absence of national frameworks defining both the need for, and the overall direction of, smart cities, the nature of democracy means that shifting political sands will often undermine projects begun under a previous administration. Additionally, municipal agencies will ultimately determine the manner by which projects are initiated and rolled out. Top-down approaches may be perceived as ignoring the needs of citizens in favour of business investment, technology for technology's sake, while bottom-up approaches encounter their own issues in terms of scaling, investment and meeting the needs of the whole population, as opposed to a subset.

Roei Ganzarski of BoldIQ highlighted the need for balance: 'In the context of solving congestion for example, the city has to decide that it wants to do that. Some kind of taskforce or committee with the authority and budget must be established with the aim of delivering a long-term vision of the city. This means collaborating with public and private transportation companies as well as securing consumer buy-in. Cities cannot expect consumers or companies to drive this for the benefit of the city as a whole, so they must lead this effort themselves.'[5]

1.8.4 Innovation

Tying in loosely with governance is the concern about innovation. Government-developed digitals services, such as access portals relating to information services or similar, typically have a poor reputation in terms of user benefit and overall functionality. Meanwhile, it is accepted that opening ecosystems to a wide pool of developers leads to more innovative services; mobile app stores are a case in point here. Smart cities should encourage innovation and interest from a wide range of stakeholders, partners and developers through hosting events such as conferences and hackathons.

[4] Juniper Research interviewed Munish Khetrapal, Managing Director - Global Head of Solutions, Smart Cities at Cisco Systems, October 2017

[5] Juniper Research interviewed Roei Ganzarski, CEO BoldIQ, September 2017

1.8.5 Regional Readiness

The following table highlights regional readiness in terms of smart city development. It is intended as a guide to where activity will most likely take place in the near-to-medium term.

Table 1.25: Regional Smart City Readiness Analysis

	Funding/ Financing	Talent Acquisition	Governance	Innovation
North America				
Latin America				
West Europe				
Central & East Europe				
Far East & China				
Indian Subcontinent				
Rest of Asia Pacific				
Africa & Middle East				

HIGH LOW

Source: Juniper Research

West Europe (on account of the EU Commission and EIB, in conjunction with the ability to secure private funding) and Far East & China (through governmental input) show strong performance where funding is concerned. In these regions, there is scope for SME innovation, although the Chinese market aims to promote national services over imports.

North America, to some extent, is more reliant on PPPs (Public–Private Partnerships) which limits input to corporate scale vendors.

According to Roei Ganzarski from BoldIQ: 'In the US and China, both governments have money that can be used to fund smart cities and relevant players. Banking systems, private equity and lending structures are in place in both countries to support this as well. The difference is that in China the government can decide, and has decided, that funding should go to the development of smart cities and they simply do it. In the US, it's left to the community and private companies to develop the market and thus it will lag behind.' [6]

That said, North America performs well where talent acquisition is concerned owing to a strong tech sector. This performance is matched by Rest of Asia Pacific owing to active campaigns to secure foreign talent in many countries in this region.

Rest of Asia Pacific, North America and Far East & China have, in many instances, what amounts to a national framework for smart city development, although this is less apparent in North America.

Ganzarski added: 'China and India have established government-driven policy with regard to smart city development; something which doesn't exist in Europe and the US today. It's likely that smart cities will develop faster in China, Indonesia, India and the Middle East as a result. Regulations and policies are being developed and enforced today, with a long-term view'. [7]

[6] Juniper Research interviewed Roei Ganzarski, CEO BoldIQ, September 2017

[7] Ibid

2. Smart City Service Markets

2.1 State of the Smart City Market

Under the umbrella of the IoT, the smart city market is undoubtedly one of the segments that has a high level of engagements. This is primarily due to the fact that the business case for project deployment is strong, while evidence of ROI (Return on Investment) is increasing.

'This market is really starting to take off. Right now we see clear spend and upward momentum. It's gone beyond defining the smart city with stakeholders asking questions over where to start, to a situation now involving budgets being allocated and real city wide rollouts.'
Munish Khetrapal, Cisco[8]

2.2 The Smart Grid

Global electricity consumption in cities, according to Juniper Research, is expected to reach over 8,115TWh (Terawatt hours) in 2017, a global average of 3.7MWh (Megawatt hours) per capita. For energy suppliers, this resource volume presents significant challenges that must be addressed, as explained below.

2.2.1 Challenges Presented by 'Dumb' Grids

In general, the growth and establishment of nations' electricity grids has been organic, with the construction of distribution grids and substations being established where necessary in proximity to urban environments. Naturally, this has led to most grid systems being extremely large and complex in nature. Indeed, most of these were originally established as isolated systems to serve settlements, with grid interconnects being established at a later point in similar fashion to the Internet. As well as the present regional level grid interconnects, many grid interconnections reach across several countries. For example, the West European interconnection reaches from the UK across Scandinavia, Italy and Greece, as well as several East European countries.

While such interconnections have enabled the establishment of regional and international trade and capacity sharing, the size of these networks demands extremely high reliability be, not only to serve customers according to demand, but also to allow the economic machines behind the scenes to operate as desired.

i. Thermal Limitations

By their nature, electricity transmission components are capacity-constrained by their ability to cope with high temperatures. As the current transmitted across a power line is increased, so does the line's temperature. Therefore, any electrical line's capacity is limited by the amount of temperature increase it can handle before events such as:

- Line sagging;

[8] Juniper Research interviewed Munish Khetrapal, Managing Director - Global Head of Solutions, Smart Cities at Cisco Systems, October 2017

- Line loss of tensile strength.

Either state could result in the power line malfunctioning due to contact with a foreign body, in turn disrupting the power supply.

From that standpoint, it is therefore highly desirable to monitor the state of important transmission lines to ensure that line capacity is not exceeded. In particular where electricity trade is active. Even the day's weather (from a heat perspective) can alter a line's capacity which, in turn, creates a need to monitor not only the lines themselves, but also the local temperature at various points along the grid.

ii. Constrained Interconnections

Problems arise when grids of varying quality attempt to form interconnects, in particular where a poorly-maintained grid is involved. On the one hand, trade can be established and provide capacity to the weaker grid should issues arise, thus alleviating the effects of outages on the weaker grid side. On the other hand, high demand from the weaker side could put the overall network under pressure, impacting other areas of the grid remotely from the end-customer.

iii. Renewable Energy Sources

Renewable energy sources, such as wind and solar power, are in increasing demand due to a combination of regulation alongside a near universal push to more sustainable energy sourcing. By nature, these do not provide a consistent source of energy and can thus cause voltage fluctuations along distribution lines, leading to 'brownouts' or even blackouts in worst-case scenarios. Therefore, monitoring the grid at every stage of delivery becomes important as the proportion of energy supplied by renewable sources increases.

'There's a huge transition happening right now in terms of transport electrification, smart buildings and the switch to renewables. To reliably run renewables on the current grid is not possible today; utilities and stakeholders are seeing the need for smart grids, and that's something that's now being reflected in city leaders' view.'
Martin Powell, Siemens[9]

iv. Non-Technical Losses

Where extreme temperatures and voltage fluctuations can cause grids problems on the technical side, a lack of monitoring electricity flow from end-to-end in real-time makes the grid vulnerable to non-technical losses. In most cases, these losses can be attributed to:

- Accounting errors;
- Customer non-payment;
- Electricity theft.

The last 2 bullets are of principal concern here, in that losses can be mitigated by more precise knowledge of the flow and use of power in the

[9] Juniper Research interviewed Martin Powell, Head of Urban Development at Siemens, October 2017

grid. A reduction in non-technical losses realises not only direct benefits in terms of revenue assurance, but also cost-savings through the ability to close the gap between total power produced and total power bought.

v. Juniper's View

It is clear, then, that a recurring concern for the 'dumb' grid is loss:

- Loss of potential trade;
- Revenue loss through technical or non-technical causes.

The ability to reduce these losses has led to the development of the smart grid concept: the establishment of network-wide monitoring and communications infrastructure to create a real-time managed energy grid. Current electricity grids, where they have not been upgraded to smart grids, are characterised by the notion of the grid being a 'one-way' system, whereby a recipient of energy is neither able to relay any information back to the supplier in real-time, nor able to return surplus energy to the system for use elsewhere.

A one-way communications system means that problems along the supply chain are therefore difficult to identify at an early stage, leading to increased, widely effected blackouts.

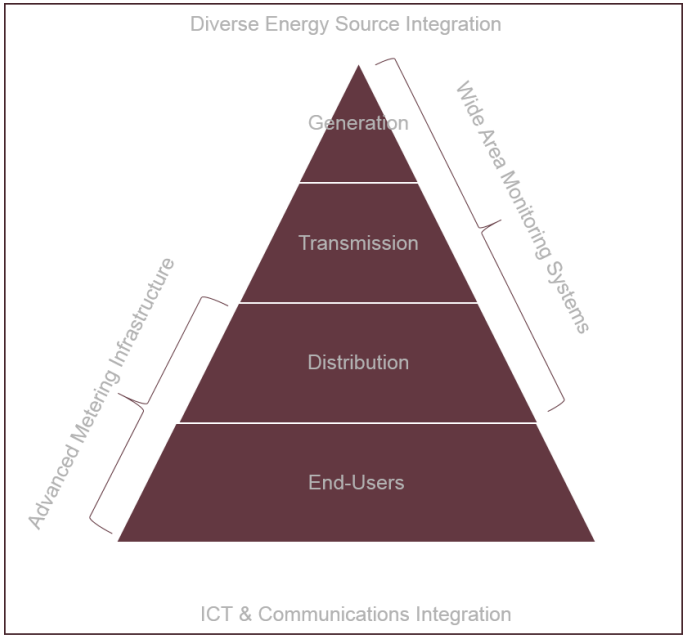
Indeed, the US Department of Energy estimates the annual cost of electricity blackouts to be 'at least $150 billion.'[vi] Despite this value being a little less than 1% of the US GDP, the economic cost of blackouts is attributable to the fact that grid supply is 99.7% reliable.[vii] In the near-term, it is highly likely that greater demands will be placed on the grid, leading to a tighter margin of available energy versus demand.

In the UK, for example, the National Grid has warned that spare electricity capacity during the winter of 2014 was close to 4%.[viii] During the winter of 2015, this capacity was down to 1.2%[ix] without balancing measures, forcing the National Grid to offer financial incentives to businesses to reduce power consumption.[x]

2.2.2 Global Electricity Markets

Before analysing the nature of electricity markets around the globe, it is first important to understand the value chain behind the industry. In the following figure, elements in the pyramid represent the components of the overall energy market. Elements surrounding those components represent possible smart grid services.

Figure 2.1: Electricity Value Chain & Smart Grid Services



Source: Juniper Research

Essentially, the grid has 3 components:

- Generation, where fuel is converted into electricity;
- Transmission, where high-voltage power is carried over long distances from the generation point to a distribution network;
- Distribution, where voltage is converted to lower levels for commercial and private use and distributed along a localised network.

In the case of smart grids, the system is underpinned by the integration of ICT to establish network-wide data flow and analysis. Furthermore, the increased flexibility this affords means that the sources of energy across the grid can be highly diversified and allow micro-generation or capacity sharing at an individual level to become energy sources.

Finally, the ecosystem depends on the establishment of 2 critical services:

- WAMS (Wide Area Monitoring Systems) to monitor and respond to grid health and capacity in real-time.
- AMI (Advanced Metering Infrastructure): here, smart meters are installed in residential and commercial establishments. Using two-way communications, energy distributors are able to monitor consumption in real-time while the meters themselves can interact with non-critical devices, such as white goods, and allow them to operate only when capacity demand is low. Meanwhile, up-to-the-minute electricity pricing can be provided to the recipient, so commercial users are then able to reduce consumption costs from their operations insofar as is possible.

2.2.3 Types of Electricity Market

Historically, the production and supply of energy to end-users has been via vertically integrated monopolies. Indeed, the sheer infrastructure cost and other variables has meant that competition not resulting from regulatory action has been near-impossible.

i. Regulated Markets

In regulated energy markets, supply is restricted to a single supplier who typically controls generation, as well as transmission and distribution. The

supplier may be either a private company or state-owned. Energy prices are set by the industry regulator.

ii. Deregulated Markets

In this case, privatisation of the energy market has occurred, with measures having been taken to induce competition, whereby:

- The end-user is free to choose between available suppliers;
- Energy costs are no longer determined by a regulator, but the market itself;
- Value chain components are unbundled from one another, removing vertically integrated monopolies.

iii. Impact of Market Status on the Smart Grid

In theory, deregulated energy markets encourage competition between suppliers. Therefore, the principal targets for competing companies will include:

- Offering an improved or differentiated service over competitors
- Employing, or looking for, cost-saving measures to improve margins.

These targets make deregulated energy markets more likely to be areas of high smart grid investment as smart grid technologies offer cost-saving opportunities, while the chance to offer end-users differentiated services and potential cost-savings through AMI increases the incentive to develop and deploy smart grid technologies in such markets. Meanwhile deregulation opens up the market to foreign investment.

Nevertheless, governmental policies and targets continue to have significant impact, while other variables have caused the development of the smart grid in some deregulated markets to be slower than in well-funded regulated markets.

That said, a lack of vertically integrated suppliers in deregulated markets means that the smart grid business case is not immediately clear: after all, their deployment is likely to result in lower, not higher, levels of energy consumption. Naturally, this is not compatible with the current business model of many utilities competing at the distribution level.

Martin Powell of Siemens was of the opinion that: ‘A utility needs to think about who and what they invest in moving forward. It’s not so much about selling more energy, but it’s providing a certainty and reliability and charging a premium for that. Even as they sell less energy, there are opportunities with regard to different premiums and services that they will be able to charge for.’[10]

It is for these reasons that we shall examine the smart grid opportunity on a regional level; not only in terms of how regulated these markets are, but also the policies and drivers shaping smart grid progression.

[10] Juniper Research interviewed Martin Powell, Head of Urban Development at Siemens, October 2017

2.2.4 Driving Investment: 2017 Market Developments & Emerging Opportunities in Smart Grids

i. Paris Agreement

The smart grid is, in large part, driven either by the need or the desire to on-board unreliable sources of energy; that is to say, renewable energy sources that do not provide a consistent supply. The Paris Agreement of 2015, which 200 countries signed in agreement to limit the production of GHGs (greenhouse gases) will, according to the IEA, require some $13.5 trillion in clean energy investment over the next 13 years.[xi]

- The Paris Agreement plays a key role in invigorating investment in the smart grid; indeed, even oil- and gas-rich nations such as the UAE and Russia are now accelerating their investment in smart grid development.
- The US, despite having announced that it intends to withdraw from the Agreement, will not legally be eligible to do so until 2020. It is unlikely that the prospect of withdrawal will have an impact on short-term investment plans in this market. In any case, the US remains subject to the Clean Air Act, which mandates reductions in GHGs. Martin Powell of Siemens noted: 'Trump's withdrawal from the Paris Agreement has actually had the inverse effect in terms of how cities are looking at the market: the majority are in favour of delivering the Agreement goals'[11]

ii. Cost of Renewables

It can certainly be said that the cost of renewable sources is declining; at this time the LCOE (Levilised Cost of Electricity)[12] of some renewable energy sources is approaching that of economic fossil fuel resources, such as gas. It should be noted that coal is rapidly becoming an uneconomical source of energy, when CCS (carbon capture and storage) technologies are taken into consideration.

Table 2.2: Projected LCOE for plants Entering Service, 2022 ($ per MWh)

	Average LCOE	Average LCOE, Including tax Credit
Advanced Coal with CCS	$139.5	$139.5
Natural Gas-Fired, of which:		
- Conventional Combined Cycle	$58.1	$58.1
- Advanced Combined Cycle	$57.2	$57.2
- Advanced Combined Cycle with CCS	$84.8	$84.8
- Conventional Combustion Turbine	$110.8	$110.8
- Advanced Combustion Turbine	$94.7	$94.7
Advanced Nuclear	$102.8	$102.8
Geothermal	$45.0	$41.9
Biomass	$96.1	$96.1
Wind	$64.5	$56.9
Wind, Offshore	$158.1	$146.7
Solar PV	$84.7	$66.3
Solar Thermal	$235.9	$179.9
Hydroelectric	$67.8	$67.8

Source: IEA

Indeed, the table above highlights the IEA's projection of the market in

[11] Juniper Research interviewed Martin Powell, Head of Urban Development at Siemens, October 2017

[12] LCOE: An assessment of the average total cost to build and operate a power-generating asset over its lifetime divided by the total energy output of the asset over that lifetime.

2022, including LCOE adjusted by tax credits (which encourage renewable energy investment).

Naturally, this table highlights US energy prices. Nevertheless, it should be noted that the US is home to substantial coal and gas resources. even without the impact of tax credits, wind and solar PV run close to the average LCOE of gas technologies, where CCS technology is applied. With tax credits, the direction of investment will inevitably turn to wind and solar power, which in turn will drive the need for smart grid technologies.

iii. Blockchain

Blockchain is emerging as a future technology through which the business model of the smart grid will be enabled. It has been noted in the past and indeed, by the author of this research report, that many countries' utilities rely on the sale of more, not less, energy to increase profits. Therefore the energy use reduction potential of the smart grid would, if other overriding factors were not in play, stifle smart grid development.

Blockchain can be used to solve this issue, by virtue of its ability to streamline energy trading. For instance, payments to large-scale energy generators commonly have more than 2 months lag-time, making it difficult for new, innovative suppliers to enter the market. Were this hurdle removed, the vision of utilities' potential as energy and service providers (eg for smart homes) could be galvanised, increasing competition while offering utilities the opportunity to diversify their revenue sources.

Meanwhile the current structure of the market means that energy trades rely on a complex certification system that is susceptible to accounting errors and increased costs, in much the same manner that traditional contracts are expensive and susceptible to mistakes and paper loss. Distributed ledger technology could be used to simplify the trading process, dramatically reducing costs for players. Reduced revenues as a result of a lower volume of energy sold could thus be offset by cost reductions during trading. Additionally, payments could be made immediately, creating room for new players in the market.

Case Study: Gemalto

Juniper Research interviewed Haider Iqbal, Director Public Services and Transport Enterprise IoT Ecosystems, Gemalto, September 2017

Sponsored by the European Commission, the SUNSEED project was engaged as a PoC (Proof of Concept) for blockchain use across the smart grid.

The project engaged Gemalto to ensure the integrity and accuracy of supply and demand data from smart meters, enabling automated certification. Upon certification, data was then written to the Ethereum blockchain.

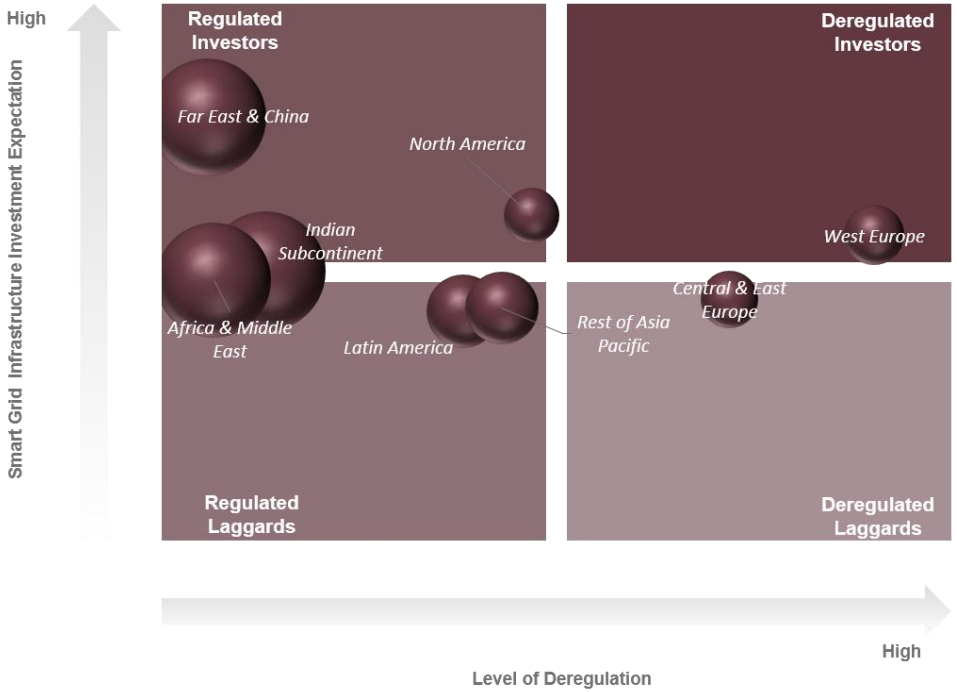
One of the key aims of the project was to showcase the potential for distributed energy generation and how potential energy trades might be transformed in the future.

Haider Iqbal noted that the PoC can be used across a larger ecosystem, and works for energy consumption as well as generation.

2.2.5 Regional Smart Grid Status

The quadrant below shows the expected regional status with regard to level of market deregulation and expected smart grid investment plans; the bubble size reflects regions' population

Figure 2.3: Juniper Strategy Quadrant: Regional Smart Grid Prospects Evaluation



Source: Juniper Research

i. North America

The North American market is mixed, with 16 states in the US and 2 territories in Canada having deregulated the market somewhat. Plans for nationwide deregulation were underway in the US at the turn of the millennium, although these were halted after the Enron scandal and California crisis that took place during the early 2000s. Both Canada and the US suffer from the fact that much of the power infrastructure is ageing and is likely to lead to greater reliability concerns. Indeed, reliability is one of the main drivers behind smart grid investments.

As both Canada and the US intend to follow NIST (National Institute for Standards and Technology) guidelines for smart grid standards and interoperability, issues in that respect should be of less concern than in other regions.

Investment in this region was the highest in the world between 2009 to 2013, in principal due to ARRA (American Recovery and Reinvestment Act) funding in the US that was used to install several million smart meters and PMUs (Phase Measurement Units). With this funding now at an end, private investment will be required to continue growth.

Juniper's View: Juniper expects this to be a key region for smart grid development, despite overall investment not taking first place. Policies dictate the modernisation of the grid alongside relatively strong carbon reduction goals.

Meanwhile, grid support for an anticipated 0.8 million EVs, and a large proportion of over 3.3 million hybrid vehicles, will be required by 2020.

ii. Latin America

Latin America is highly dependent on the supply of power from hydroelectric sources. It is therefore unsurprising that the area has been badly affected in times of drought, causing average prices on the wholesale spot market to rise dramatically. This, coupled with the fact that electricity theft is high in this region contributing to large non-technical revenue losses, means that incentives to deploy smart grid technologies are high.

Brazil is the largest electricity market in the region, although most of the country's grid is state-controlled or owned, limiting the private investment opportunity. Colombia, on the other hand, is the most deregulated Latin American market, with US smart grid company Innovari having partnered with the EMCALI utility to deploy a software solution for peak demand energy management in 2015.

Juniper's View: The business case for smart grid investment is very strong due to the need to reduce dependency on limited energy resources, as well as a reduction in non-technical losses. However, this region does not have a robust policy in place for the development of smart grid services, while Brazil in particular does not have a favourable environment for foreign investment.

iii. West Europe

West Europe is characterised by its strong policies on carbon reduction and the smart grid is seen as playing a key role in achieving these goals. This market is highly deregulated, beginning with the UK in the 1980s and followed by the vast majority of West European countries. The Nordics and Italy are market leaders where deployments of smart meters are concerned, while the region invests heavily in the development and deployment of renewable energy generation.

Nevertheless, a challenging environment remains despite a high level of deregulation, as many countries' retail energy prices continue to be set by a regulator, which in turn prevents companies being able to pass on smart grid investment costs to the end-user. Given the fragmented nature of West Europe's distribution grid, characterised by many smaller, locally-focused vendors, attracting investment to this portion of the grid is difficult.

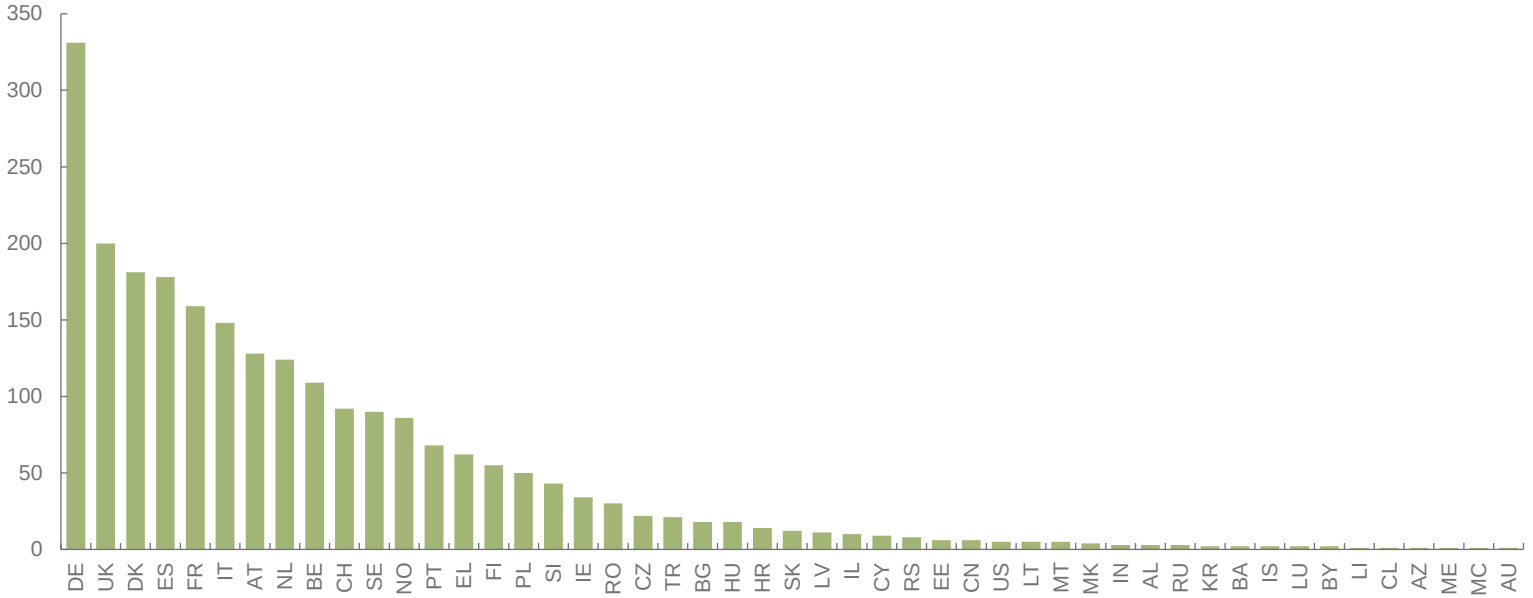
'Projects are happening, but they're not happening at an accelerated pace. However, the demand on the grid that electric vehicles will create is becoming a fundamental concern.' Martin Powell, Siemens[13]

Juniper's View: Juniper believes that this region is likely to continue to be an innovator in terms of policies and smart grid pilot projects. However, large-scale deployments are likely to be hampered, partly due to unfavourable conditions on the wholesale market, coupled with increasing deployments of relatively expensive renewable energy sources lowering industry profits. The key opportunity at present therefore, will be the optimisation of capacity via AMI and the implementation of

[13] uniper Research interviewed Martin Powell, Head of Urban Development at Siemens, October 2017

demand-response programmes. As renewable generation increases further, smart grid technologies must be deployed to ensure that the intermittent nature of renewable energy sources does not cause widespread reliability issues.

Figure 2.4: Total Number of Smart Grid Projects by European Country 1994-2016



Source: Adapted from European Commission Joint Research Centre, Smart Grid Projects Outlook 2017

iv. Central & East Europe

Central & East European markets are deregulated to a large extent in countries such as Turkey and Poland, while Russia is, by and large, a market with little competition across the generation and distribution portion of the network. Investment in smart gird technologies has lagged behind West Europe, with the average budget for smart grid pilot projects reaching less than €1 million ($1.14 million).[xii] Smart meter deployment is advancing, with a view to adding the necessary infrastructure for other smart grid technologies over the next 10-15 years. Indeed, countries retaining Soviet-era infrastructure are likely to prioritise the replacement of these assets over other deployments.

Juniper's View: As a whole, this region is not expected to be a key area for the development of the smart grid. On the one hand, in Russia in particular, development in renewable energy sources is likely to be low owing to substantial gas reserves for generation in the country. Furthermore, energy policies are not as developed as in West Europe owing to lack of control from a body such as the EU.

v. Far East & China

Far East & China is a region with one of the most regulated energy structures in the world. Nearly all assets are controlled by the Chinese state for example, save for a small proportion of generating capacity. Meanwhile Japan and South Korea are both served by vertically integrated monopolies.

While this structure might seem to create adverse conditions for smart grid investment, in fact the opposite is true. The Chinese government has invested heavily in smart grid development since 2009, while the desire to reduce reliance on Russian power is high and is likely to be achieved once the country is better able to distribute its hydroelectric energy through improved infrastructure and digital technologies. South Korea, in the meantime, has set ambitious carbon reduction goals for 2020, helped by the establishment of a national smart grid project. KEPCO, the national utility, has already launched a scheme to buy back energy from EV batteries, while $122 billion in funding for smart grid development was announced by the government in 2013.[xiii]

Finally, Japan has been a leader in smart grid development for many years, with much of the grid already consisting of advanced technologies, with close to 100% of substations already converted to digital technologies. 2011's earthquake and subsequent nuclear accident dramatically changed the power generation landscape for Japan, with the country shifting to expensive energy imports to make up the nuclear shortfall. Consequently, the establishment of a nationwide smart grid is a top priority. With market deregulation underway, development of the smart grid should begin to accelerate.

Juniper's View: Owing to massive investment on the part of China, it is likely that this region will continue to lead smart grid development for the foreseeable future. However, low competition and a tendency to favour domestic contracts over foreign ones, means that the region is a difficult investment prospect for the time being, although this is beginning to change on the generation side in China, while the opening of the retail market in Japan should present an opportunity.

vi. Indian Subcontinent

This region is characterised as one with poorly developed infrastructure in relation to more affluent regions, while a high level of electricity theft accounts for nearly 20% of total losses in India.[xiv] Power shortages are therefore not uncommon.

Nevertheless, Pakistan is committed to the rollout of smart meters, while the Indian government has not only announced the development of 100 smart cities to 2022, but also 14 smart grid pilot projects around the country. One of the targets for these smart cities is to ensure a 24x7 supply of energy, which will only be achievable through an upgrade of the current power infrastructure.

Juniper's View: Although market deregulation has begun in this region, it is far from complete, reducing the opportunity for smart grid players. Nonetheless, the size of the population here demands large-scale

investment in AMI and smart grid technologies, so market development in India should be closely monitored in the near-term.

vii. Rest of Asia Pacific

This region is growing rapidly in terms of urbanisation and consequent economic growth through industrialisation and commercial development. Nevertheless, energy resources are relatively scarce while achieving 100% electrification remains a target. The principal focus of the smart grid therefore will be achieving efficiency gains to reduce additional power generation resources or energy imports and ensure continued economic growth.

Unsurprisingly, Australia has been a leading market in the development of smart grids following the implementation of the 'Smart Grid, Smart City' project that ran from 2010-2014. The project identified a possible AU$28 billion in annual savings through advanced grid fault detection and mitigation.[xv]

Meanwhile Singapore, Malaysia and the Philippines have smart grid policies in place and are either in the pilot phase of technology development and deployment, or in the phases, of smart meter rollouts.

Juniper's View: Excluding Australia and New Zealand, some 20% of this region remains without electricity,[xvi] while the area's overall focus is not on low-carbon energy generation. Nevertheless, targets for energy efficiency include policies for industry and buildings, while Singapore and the Philippines have energy efficiency and renewable energy policies in place respectively. The smart grid opportunity is therefore likely to be limited in scope in the near-term, as the initial focus will concentrate on delivering additional capacity, with smart grid technologies likely to play a greater role once more renewable capacity is brought online.

viii. Africa & Middle East

This region is another where competition in all facets of the electricity market is limited. Existing infrastructure in Africa is often of poor quality or non-existent, leading to a situation where diesel-fuelled generators often supply local power. Where the grid has been established, its lack of reliability has led to consumer mistrust. Meanwhile in the Middle East, smart meter deployment is well underway, with Qatar starting the first phase of its rollout in 2016. As a region with an abundance of potential energy from the sun, the focus on alternative sources of energy from traditional sources is firmly on solar, which will require the installation of power storage mechanisms for use during night-time hours.

Juniper's View: Although not as well positioned financially as other more developed regions, there is certainly an opportunity for smart grid players to capitalise on the region's growing need for smart grid technologies. This is owing to the infrastructure improvement potential through the integration of diverse energy sources in Africa, while the whole region stands to benefit from solar energy investment.

2.3 Smart Traffic Management

Traffic volume is a growing concern, particularly in city environments. A high volume of traffic not only causes drivers annoyance, but congestion also contributes to:

- Economic losses through delays;

- Increased CO_2e (CO_2 equivalent) levels;
- Increased use of fuel;
- Greater concentration of vehicle exhaust emissions, contributing to the development of photochemical smog. The chemical compounds in this type of smog are known to have severe health risks, particularly for citizens who are suffering from, or are susceptible to, lung problems.

There are several factors that contribute to impaired traffic flow across a city, of which the number of vehicles on the road is undeniably the greatest factor. Elements such as poor road planning, poor traffic flow control and lack of information for drivers can also contribute to the development of congestion.

TomTom's annual city congestion report highlights the issue of heavy traffic, revealing that Mexico City drivers must, on average, spend 66% (up from 59% in 2016) more time getting to their destination than if there had been no traffic on the roads; more detailed results are shown in the figure overleaf.

Putting this figure into perspective, the average vehicle speed in inner London dropped from 12.2 mph (19.6 km/h) in 1968 to 10.1 mph (16.3 km/h) in 1998;[xvii] a 17% drop over the course of 30 years. It appears then, that little has changed since the era of horse-drawn vehicles; a New York traffic survey conducted in 1907 found that these travelled at an average speed of 11.5 mph (18.5 km/h).[xviii]

Figure 2.5: TomTom Global Top 20 Most Congested Cities

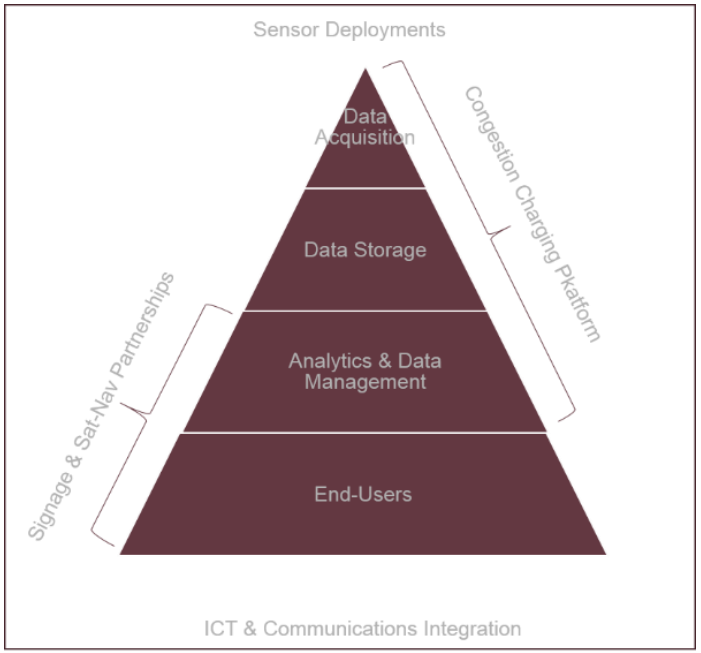
RANK BY FILTER	WORLD RANK	CITY	COUNTRY	CONGESTION LEVEL	MORNING PEAK	EVENING PEAK	TOMTOM CITY
1	1	Mexico City	Mexico	66% ↑7%	96%	101%	
2	2	Bangkok	Thailand	61% ↑4%	91%	118%	
3	3	Jakarta NEW	Indonesia	58%	63%	95%	
4	4	Chongqing	China	52% ↑14%	90%	94%	
5	5	Bucharest	Romania	50% ↑7%	90%	98%	
6	6	Istanbul	Turkey	49% ↓1%	63%	91%	
7	7	Chengdu	China	47% ↑6%	74%	79%	
8	8	Rio de Janeiro	Brazil	47% –0%	63%	81%	
9	9	Tainan NEW	Taiwan	46% ↑10%	51%	71%	
10	10	Beijing	China	46% ↑8%	72%	84%	
11	11	Changsha	China	45% ↑8%	70%	82%	
12	12	Los Angeles	United States	45% ↑4%	62%	84%	
13	13	Moscow	Russia	44% –0%	71%	94%	
14	14	Guangzhou	China	44% ↑7%	58%	85%	
15	15	Shenzhen	China	44% ↑7%	62%	84%	
16	16	Hangzhou	China	43% ↑5%	61%	64%	
17	17	Santiago de Chile NEW	Chile	43%	73%	88%	
18	18	Shijiazhuang	China	42% ↑6%	70%	84%	
19	19	Buenos Aires NEW	Argentina	42%	64%	68%	
20	20	Kaohsiung NEW	Taiwan	41% ↑5%	47%	70%	

Source: TomTom

2.3.1 Traffic Management Strategies

Cities are employing numerous approaches in an attempt to alleviate some of the traffic issues encountered by drivers. We will therefore look at the value chain in the first instance to understand how the industry can be broken down in terms of its parts and opportunities.

Figure 2.6: Smart Traffic Management Value Chain



Source: Juniper Research

Table 2.7: Road Traffic Sensor Solution Evaluation

	Location	Measures	Cost	Vendor
AMR	Embedded	Count	Medium	Honeywell, Memsic
Piezoelectric	Embedded	Count, Class, Mass	Medium	TDC Systems, IRD
Pneumatic Tube	Road Surface	Count	Low	Clearview Traffic
Video	Overhead	Count, Class, Model	High – installation & maintenance	Trafficvision, FLIR
Infra-red	Overhead	Count, Speed, Length	Medium – high maintenance	ASIM, OptiCom
Microwave	Overhead	Count, Speed, Length	Medium	ASIM, IRD

Source: Juniper Research

- For all smart traffic management systems, sensor deployments are crucial to gather data regarding real-time traffic volumes. Traditionally, this has involved the deployment of induction-loop sensors, which need to be embedded into the road itself, further disrupting traffic. Other solutions also include overhead cameras, overhead infra-red or microwave sensors, among others.
- Naturally, since the volume of traffic in one area of a city is heavily influenced by traffic flows in connected areas of the road network, it is necessary to establish ICT and communications infrastructure to

visualise data in real-time, while issuing commands to various nodes to positively influence traffic flow.

- Data storage solutions are also desirable, as an analysis of historical trends can prove invaluable in positively influencing future road planning.
- Clearly, for data to have an impact, it must be integrated into a management system where analytics can be performed. Combining the above elements can provide cities with the opportunity to address traffic congestion through a tolling system, such as has been successfully implemented in London and Singapore.
- Finally, it is also beneficial to establish communications between the analytics system and the end-users, ie the drivers. Traditionally this has been achieved through VMS (Variable Messaging Signage) or radio reports. Opportunities have now arisen to allow municipal agencies to partner with sat-nav system suppliers and app developers to alert drivers to traffic problems through their vehicle's sat-nav or a smartphone app.

i. No 'One Size Fits All' Approach

It is now relatively well-known that merely adding to the road infrastructure does not alleviate congestion in the long-run. Therefore, other strategies must be applied that attempt to address the problem, either by reducing the volume of vehicles on the road at any given time, or by attempting to improve traffic flow in potential bottleneck areas.

Undoubtedly, it must be understood that the only sure-fire method to reduce congestion in a city is to reduce the number of cars travelling on the streets. This is a policy, rather than a technology, issue and is something that cities are loathe to address.

Nevertheless, Roei Ganzarski of BoldIQ contends that this approach is something that will define the smart city of the future: 'When your city is so congested that it needs traffic or parking help, introducing a new app to help a driver find a parking spot does not make it a smart city. Quite the contrary. Using technologies to eliminate the congestion and parking issue, that is what will make the city smart. One of the key challenges for cities moving forward is the adoption of new and relevant policies that take advantage of technology rather than technology alone.'[14]

Munish Khetrapal of Cisco was broadly in agreement: 'If you want to solve a transportation problem in a city that is going to get 70% more congested over the next 30 years, the only way to solve this is to change the demand side of the equation. That means, for example, changing the way you work, removing unnecessary travel and so on through remote solutions. A lot of cities are looking at budgets for that type of solution right now.'[15]

ii. The Congestion Charge

Famously adopted by cities such as Singapore, London, Oslo and Stockholm, the goal of the congestion charge is to reduce private vehicle use inside cities. Commercial vehicles are less likely to be discouraged by congestion charging; in many cases they have no choice about whether they enter an enforced area or not, as their business demands it.

[14] Juniper Research interviewed Roei Ganzarski, CEO BoldIQ, September 2017

[15] Juniper Research interviewed Munish Khetrapal, Managing Director - Global Head of Solutions, Smart Cities at Cisco Systems, October 2017

Results from congestion charging have been shown to be effective; within a year of the establishment of a congestion charging zone in London (2004), Transport for London reported:[xix]

- Reduction of congestion in the charging zone by a factor of 30%;
- Traffic entering the charging zone had fallen by 18%.

Nevertheless, congestion has been shown to be steadily on the rise since 2008, despite the charging zone.[xx]

Case Study: Stockholm

Case Study: Stockholm

Introduced permanently during 2007, the project is the result of a collaboration between the Vägverket (Swedish Road Administration), IBM and Q-Free.

During the trial, vehicles were identified using short-range transponders communicating with toll gates; this mechanism was then abolished in favour of ANPR.

Unlike in London, Juniper believes that the use of time-variable pricing has been a crucial factor in the project's ongoing success, with charges rising from 0 SEK ($0) during the night-time to 35 SEK ($4.30) during rush hours. Initially, there was a reduction of 25% of vehicles inside the charging zone, while traffic volumes have been stable since 2007.[xxi]

iii. Opportunities

Aside from the obvious benefit of reducing traffic levels inside the charging zone, implementation of a congestion charge also provides a city with an invaluable source of revenue, which can then be reinvested in the transport infrastructure or used for the improvement of services in other city agencies. Nevertheless, it is important that the city ensures that it controls revenue gained, rather than such revenue being claimed by the national authority.

Furthermore, while congestion charging aims to reduce vehicle traffic, it does not directly address the fact that drivers are still likely to need to make the same journey they would normally have made in their vehicle. Indeed, the scheme pushes drivers to alternative means of transport. In most instances, this will result in an increase in public transport use, resulting in further economic benefits. Here, not only are public transport networks being utilised by more customers, but the fact that these services are more efficient transport vessels (ie more people can be transported in a smaller amount of space) means that the city's economic potential is expanded as well.

A 2013 study by the University of California concluded that the expansion of public transport systems by 10% per capita would be worth between $1.5 million and $1.8 billion annually in the US, depending on the size of the city.[xxii]

a) Caveats

Implementing a vehicle charging zone is no small undertaking. Cites must consider whether such as project is economically viable, both from a municipal authority standpoint as well as from the perspective of the city's drivers. Undoubtedly, there will be a public backlash against the scheme, which must be managed. Meanwhile, maintenance and operational costs must be balanced against the new revenue stream, which cannot be calculated without an understanding of existing traffic volume inside the charging zone.

Without a doubt, even before considering the cost of deployment from a capex (capital expenditure) and opex (operating expenditure) perspective, cities should consider whether it is suitably equipped to handle the same number of individual trips per day into and out of the charging zone using alternative forms of transport, be it via public transport, bicycle or on foot.

This presents a complex situation where cities in developed regions often have a high-quality public transport system available that is likely to already be in heavy use (owing to, for example, extant heavy road traffic). Public transport systems in less developed regions are certainly likely to exist, but are less likely to be supported by ICT infrastructure to ascertain capacity levels and possible optimisation levels.

Needless to say, investment outside the congestion charging project will be required, either to improve existing public transport services directly, or to implement capabilities that offer greater insight into the performance of the services themselves.

Case Study: Rio de Janeiro

Owing to difficult topography, Rio has long been one of the most congested cities in the world. It is therefore unsurprising that concerns were raised over the city's ability to cope with an influx of visitors for the 2014 FIFA World Cup and the 2016 Olympic Games.

Historically, bus services have been relatively cheap, although of poor quality. Consequently price rises in 2013 sparked widespread protests about perceived poor service management and quality not warranting such an increase. The protests eventually forced a reversal of the decision.

The city has recognised the need to improve its public transport services for some time through plans to extend subway lines, while a BRT (Bus Rapid Transit) service has been established. The BRT uses dedicated lanes to cut travel times, while the service is controlled centrally. Tickets are issued before boarding as opposed to on the bus.

Further improvements are being made in partnership with Viktoria Swedish ICT through a project named TIME-RIO (Transport Information Innovation in Megacity Rio de Janeiro). This is based on the premise that opening public transport data to the public, as has been done in many cities worldwide, will encourage third party app developers to deliver a useful service to citizens. In doing so, some of the investment required for overall service improvement is displaced, while developers of well-performing apps also stand to benefit.

2.4 Smart Parking

A major challenge for drivers in cities is finding an available parking space. Consequently, the time spent looking for a space also leads to increased levels of congestion.

A popular figure cited by smart parking stakeholders[xxiii] is that 30% of traffic is caused by drivers searching for parking spaces. This figure is derived from a paper by Donald Shoup of the University of California. In it he cites 16 studies conducted between 1927 and 2001 that concluded, on average, 30% of drivers in congested traffic were looking for a parking space.[xxiv]

Taking this into account, it is clear that the drivers looking for parking were already in traffic during their search; they were not necessarily the direct cause of 30% of traffic. Nonetheless, as the drivers were found to be in traffic when searching for parking, the fact that they contribute to congestion is undeniable.

Typically, the protracted hunt for a parking space and delay in lightening the traffic load can be attributed to the following causes:

- Pre-existing congestion through lack of traffic management, slowing overall traffic flow;

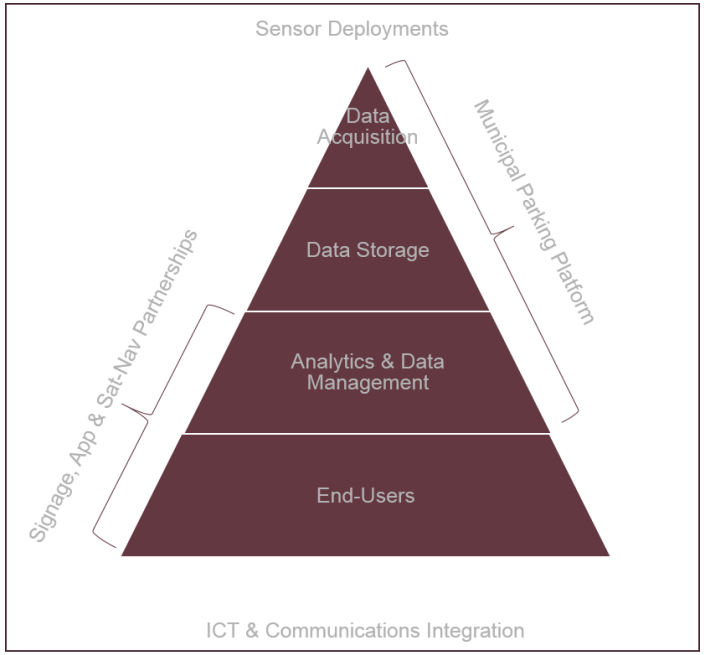
- Poor placement of parking spaces where accessing or exiting the parking area is difficult;
- Narrow road infrastructure preventing other drivers from passing a car attempting to park;
- Lack of information given to drivers about where free spaces are available;
- Poor pricing structure leading to drivers not being directed away from a potential congestion area, on account of price parity or overly aggressive pricing in some areas.

2.4.1 Smart Parking Strategies

As with smart traffic management, the possible approaches available to tackling a city's parking problem are numerous. We will therefore look at the value chain in the first instance, to understand how the industry can be broken down in terms of its parts and opportunities.

Unsurprisingly, this value chain is remarkably similar to that for smart traffic management:

Figure 2.8: Smart Parking Value Chain



Source: Juniper Research

i. Data Acquisition

For any designated parking area, proper management can only be achieved by monitoring parking space availability and occupancy. Without such insight, future planning for efficient parking expansion becomes very difficult. Therefore, it is desirable to deploy some form of sensors that are able to establish real- or near-real-time space occupancy levels.

Table 2.9: Smart Parking Occupancy Sensor Evaluation

	Location	Weakness	Accuracy	Cost	Vendor
Magnetic	Embedded	EM interference, double parked vehicles	~95%	High	Fastprk, Libelium
Camera	Overhead	Vision can be obstructed by objects eg trees	~97%	Medium-Low	Mindteck
Infra-Red	Surface	Performance degraded by dirt & adverse lighting	Variable, based on weather conditions	High	Smart Parking
Hybrid	Surface	Can revert to mono-tech performance	>98%	High	Bosch
RADAR	Overhead or Surface	High SNR (signal-to-noise) required	>95%	High	Siemens

Source: Juniper Research

For the vast majority of cities, cost is a dominant factor in deciding how viable deployment of smart parking around the city is. Naturally, that cost rises or falls indirectly as a result of drivers' time lost through searching for parking, as production is lowered, while revenue from unoccupied, undetected spaces is not collected. Cities should therefore assess, in the first instance, how much revenue is being lost through lack of smart parking services.

Nevertheless, smart parking sensors have historically meant high capex for customers, with individual magnetic sensors typically costing around $200. For city-wide deployment, capex can be substantial.

Owing to recent improvements in CV (computer vision) algorithms, it is now possible to use overhead CCTV cameras in combination with a communications stack to detect parking space occupancy. Where high-resolution CCTV can be expensive, CV software can typically identify objects using low resolution images. Meanwhile, cameras can cover a wide area owing to their field of view and position. Combined, these factors mean that deployment costs can be lowered, although areas where cameras are likely to be obstructed will demand other, more expensive, solutions.

Costs can be lowered further when cities consider the possibility of minimising hardware deployments, relying instead on existing external data sources:

- Smartphone ownership is relatively high in cities globally, while ownership in developed regions' cities has reached proportions close to 80%.
- Wi-Fi and Bluetooth technologies can be used to detect nearby smartphones (and therefore drivers). Combined with a lower number of 'traditional' occupancy sensors than would normally be required alongside a filtering algorithm to eliminate pedestrians and other non-drivers, this data fusion can offer smart parking at a substantially reduced cost.

ii. Data Storage

As is the case with smart traffic management, the ability to capture historical parking data with regard to occupancy level, time of day and pricing can be invaluable for future city parking planning. This is true in particular as occupancy levels and pricing have been shown to be linked; indeed, higher pricing is likely to deter drivers and encourage them to look for cheaper parking elsewhere.

iii. Analytics & Data Management

Combining sensors, data storage and analytics and data management software will enable municipalities to establish a smart parking platform. Such solutions are offered by third parties, such as Siemens and Streetline, as cohesive solutions, although decisions must still be taken with regard to the underlying communications infrastructure.

Case Study: Streetline

STREETLINE
Connecting the Real World

Streetline offers several solutions as part of its overall smart parking platform.

While parking sensors are a key element of the solution, the company now has 6 other sources of parking occupancy including smartphones, cameras, LPR (Licence Plate Recognition) equipment, parking payment data and existing parking counting equipment. The combined data from these other sources means deployed sensors are reduced to 1 every 10 spots, thereby cutting hardware outlay by 90%. This makes Streetline efforts to capture parking occupancy more flexible and less expensive.

- API (Application Programming Interface): offering an API to third parties enables developers of any city app to make use of Streetline's parking data. As generating citizen and visitor awareness of smart parking services can be difficult, the API widens the possible reach and helps guide drivers to available spaces.
- Consumers: via the Parker app, drivers are offered parking policy data (price, hours, etc), as well as real-time occupancy data for both on-street and off-street parking.
- Merchant partnerships: Streetline partners with merchants so they can offer customers real-time nearby parking information. According to Kurt Buecheler, this type of service, where deployed, has driven merchant revenue up by as much as 11%
- City: the parking department can optimise price, policy and inventory. Enforcement can increase compliance and productivity. Transportation gets a new and useful data source to help optimise trip planning and traffic management.

iv. Partnerships & Opportunities

As noted in the Case Study above, partnerships with nearby merchants not only generate revenues for the merchants themselves, but also maintain a high level of parking occupancy in key retail areas, directly generating revenue for the city.

In Juniper's view, the most important part of a smart parking solution is addressing the issue of end-user awareness of the service, as well as that of proper guidance to suitable spots. Historically, VMS has been used to indicate space availability, although this has tended to be restricted to larger car parks. With the prevalence of vehicle sat-nav use today, it is also important that stakeholders partner with relevant vendors to ensure that parking data can be integrated into the sat-nav solution. While most software is aware of the location of various parking areas within city limits, it still lacks the ability to identify if spaces are available in that particular area.

Meanwhile, it is important that cities consider a dynamic pricing strategy for parking spaces, although this may not be suitable in all areas of the city. In areas of low occupancy, for example, it may be the case that rates are simply too high, while nearby services and businesses are insufficient to create high demand for spaces. Dynamic pricing is more likely to be effective in areas of high occupancy, where drivers can be directed to cheaper car parks within proximity of the more expensive one.

2.5 Driving Investment: 2017 Market Developments & Emerging Opportunities in Smart Traffic & Parking

2.5.1 Video

One of the key technologies to emerge in the smart city space is that of video, principally for 2 reasons:

- Video can be repurposed for several use cases;
- Platforms and analytics services are emerging that offer real-time automation in response to video data. This is exemplified by cities such as Nice, where authorities are automatically notified when video surveillance detects suspicious activity.

Where horizontal platform approaches are taken by cities, the high costs of video installation, data storage and analytics can be offset by the ability to use and share the data across several municipal agencies. This can help not only improve the overall efficiency of city services, but reduce costs.

Case Study: Moscow

Juniper Research interviewed Sergey Tingaev, Head Analyst, Smart City Lab Moscow in October 2017

Moscow's smart traffic management initiative combines several technologies, including CCTV and road sensors, to monitor congestion levels and parking availability in real-time. Indeed, Moscow is home to the largest smart parking deployment in the world.

However, the city's smart traffic effort is particularly notable for the fact that the information supplied by various sensors positioned in the city can be leveraged by other city agencies.

For instance, this plays a key role in improving emergency response efficiency. Data from the traffic management platform, alongside information regarding the nature of the incident in question, is distributed to response crews equipped with tablet devices.

In this way, the optimum route can be determined; this has enabled emergency response services to improve their arrival times be 20%.

Such an improvement in response time may often prove vital in life-saving efforts, particularly when one considers that in critical situations every minute without CPR or defibrillation, reduces survival chances by 10%; saved time is therefore vital.

2.5.2 Reducing Costs

It has been noted that smart traffic management solutions can often be expensive to implement, limiting their overall rollout. However, this situation can be overcome if a city is prepare to implement policy changes that offer it a view of the traffic situation without costly projects that involve disrupting the road infrastructure.

Seoul, for example, tried to understand real-time traffic conditions by spending money on road sensors, but found that the data was too unreliable to be used effectively. As an alternative, the city's 25,000 taxis introduced a touchcard payment system using GPS technology, effectively giving the city real-time traffic information. In this way, Seoul was able to rollout a management solution at greatly reduced costs.

Case Study: Ruckus Wireless

Juniper Research interviewed Mark Davis, Senior Director of Global Product and Scott Heinlein, Marketing Director, Ruckus Wireless, October 2017

One of the market leaders in enterprise Wi-Fi, Ruckus has developed solutions for smart cities that, by virtue of wireless technology and a ubiquitous communications standard, promise to reduce costs for cities aiming to develop connected solutions.

'Public Wi-Fi is often the first use-case, but the city can take that further and use Wi-Fi for services such as traffic management', notes Scott Heinlein.

In the case of traffic management, Ruckus' Wi-Fi technology offers to deliver communications capability in areas of the city that do not have backhaul infrastructure in place. Indeed, the company's Wi-Fi mesh technology allows network coverage over an entire city, substantially reducing costs over a complete fibre build-out project.

Scott Heinlein notes that the potential of Wi-Fi overlaps with many projects currently undergoing evaluation in smart cities today: 'A lot of street light vendors are developing lamps that have telecoms equipment installed, using 5G or similar. As cities start to deploy these smart street lights, that's a prime time to install things like Wi-Fi too, which can offer cities an additional revenue stream.'

2.5.3 Open Data & MaaS

First pioneered by cities such as London, the concept of 'open data' (that is, city performance data openly released for public consumption and innovation) is emerging as a key strategy for cities across the globe. Some cities, such as New York for instance, have over 1,600 datasets on traffic performance, crime, air quality, etc.

The most famous example of open data innovation is likely Citymapper, which used real-time public transport and traffic information to enable citizens to determine the optimum route across the city at any given time. The company has now taken the open data concept further, with the launch of its Citymapper Smartbus service. This is the first bus service of its kind in the sense that its routes are not static, instead they are determined by demand. At present, routes are identified using open data to determine underserved corridors. In future, this concept could feasibly transfer to incumbents to create a public transport system that is determined by real-time demand and has the potential to become more efficient.

The next industry shift, based on the foundation of open data, will be the emergence of MaaS (Mobility-as-a-Service).

While on demand transport solutions already exist in the form of Uber, Lyft and so on, these do not solve any congestion issues in the city. In fact, given that in cities where such services operate their numbers are not regulated, the increase in vehicles roaming around the city in anticipation of fares may even lead to an increase in congestion. Meanwhile, these services function only as a single piece of the urban transport 'pie', offering users no visibility outside their walled garden.

MaaS differs in the sense that all urban transport solutions are integrated into a single platform by which users can determine the best price across several services and modes according to real-time data, such as traffic conditions, time of day, demand and other variables. Demand is particularly important here, as it will enable providers to increase the number of shared transport services, an extension of the Citymapper Smartbus service. This will lead to an urban transport situation where price and availability is shaped by real-time demand and will likely reduce congestion. This is not only due to the aforementioned increase in shared transport options, but by the fact that transport services become more attractive to the customer versus personal vehicles.

Indeed, in San Francisco's smart city vision, it foresees that MaaS cities would enable every citizen will be able to select their journey across the city, on demand within 2 minutes, with journey times across the city taking no longer than 20 minutes. The net result of this would be to shave a third off of the current average San Francisco one-way commute time.

i. Next Steps

The proliferation of MaaS will almost certainly be determined by changes, or lack thereof, in policy. At present, most cities are focused on technologies (such as dynamically phased traffic lights and smart parking) that increase the average speed of vehicles in the city by virtue of more efficient management of the extant traffic volume. Few cities, save for outliers such as Oslo and Singapore, aim to deliver solutions that render owning a private vehicle obsolete. Indeed, this view is nowhere more apparent than in North America, where the motor vehicle is a symbol of independence.

However, the example of San Francisco shows that the situation is beginning to change. While MaaS is largely viewed as a European concept at present, Juniper believes that interest will undoubtedly spread across to major cities in North America and Asia, particularly as driverless vehicles will drive down private ownership levels in cities.

Indeed, for driverless vehicles to thrive (the aim now for many cities around the globe), the establishment of MaaS platforms will be critical, given they will first be used as a public transport solution as opposed to a private transport solution.

Case Study

BoldIQ

Juniper Research interviewed Roei Ganzarski, CEO BoldIQ, September 2017

BoldIQ's key solution focuses on the ability to optimise resource scheduling (assets and people) and services where timescale constraints and high level of dynamic complexity limit the use of traditional optimisation tools.

In the context of smart cities, BoldIQ's provides a scheduling system that enables on-demand and shared transport services, thus reducing congestion and removing the need for parking, essentially forming one of the components of a MaaS platform.

MaaS will require real-time, or near-real-time route and mode optimisation to deliver a useful end-user experience. Although not mathematically perfect (which could be achieved using traditional, time-consuming optimisation tools), the company's technology could prove invaluable as a solution to the high volume demand of urban transport.

2.6 Smart Traffic & Parking Regional Prospects

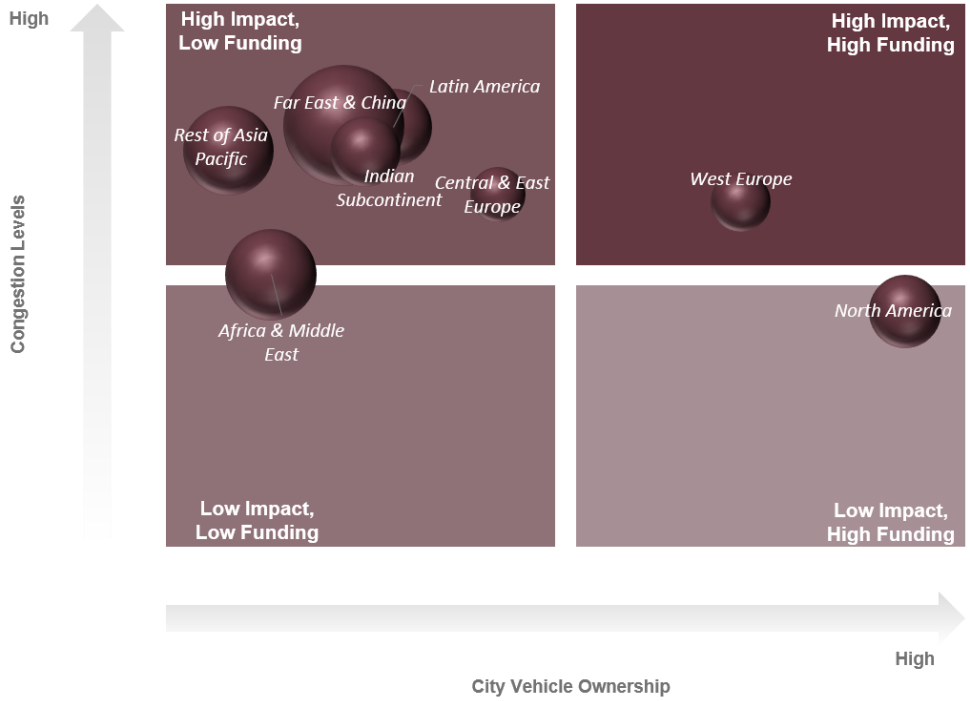
Smart traffic management and smart parking in cities are unavoidably linked. Indeed, an efficient management system will have oversight and control of both the traffic flow on arterial roads as well as parking space availability. Combining datasets will enable cities to manage the overall traffic situation as efficiently as possible.

The following figure evaluates various regions' city car ownership levels versus the overall congestion suffered in cities. The size of the bubble indicates the total city population for that region.

- Despite North America having infamously congested cities, this is in fact restricted to a relatively small number of densely populated agglomerations, such as New York, Los Angeles, San Francisco and others. In many cases, investment has already been poured into attempting to ease the congestion problem, so near-term opportunities will be localised at present.
- Of the developed regions, it is likely that West Europe is the region where smart traffic and parking initiatives will have the most impact, as they are issues of key concern in cities and many cities were not designed with high car ownership in mind.
- Far East & China, Rest of Asia Pacific, Latin America and Indian Subcontinent all suffer from very high congestion levels in their cities, while vehicle ownership is low compared to West Europe and North America. As these regions grow economically, it is likely that crippling congestion will hamper any further economic growth, despite there being room to do so. Therefore, smart traffic and parking initiatives are likely to have a very high impact.

  Nevertheless, many cities in these regions are unlikely to have the budget to implement city-wide projects, which leaves them in somewhat of a chicken-and-egg situation, as city budgets are unlikely to grow quickly without smart city initiatives fostering growth. It may therefore be possible to strike long-term deals with cities in these regions with a view to achieving ROI in a longer timeframe, although naturally this carries an element of risk.

Figure 2.10: Juniper Strategy Quadrant: Regional Smart Traffic & Parking Prospects Evaluation



Source: Juniper Research

'Emerging regions are very focused on improving the overall competitiveness of their cities and leapfrogging the European and American cities that previously drove their economies. Europe is interested in sustainability and quality of life, while the US is driven predominantly by economic growth.'
Munish Khetrapal, Cisco[16]

[16] Juniper Research interviewed Munish Khetrapal, Managing Director - Global Head of Solutions, Smart Cities at Cisco Systems, October 2017

2.7 Smart Street Lighting

Street lighting is undoubtedly one of the pain points for cities. Citizens demand it, while in the interests of safety it is highly beneficial that ample lighting is provided on city streets.

This lighting comes at a high price. Traditional lighting fixtures, using HPS (high pressure sodium) or LPS (low pressure sodium) lamps are inefficient, produce an unpleasant colour cast while simultaneously containing chemicals toxic to the environment. The following table evaluates the commonly used lamp technologies:

Table 2.11: Street Light Technology Evaluation

	Lifetime (hours)	Lumens per Watt	Proximity to Natural Light (100 is best)	Issues	Benefits
Incandescent	1,000-5,000	11-15	40	Highly Inefficient, Short Lifespan	Lowest initial cost
Mercury Vapour	12,000-24,000	13-48	15-55	Inefficient, toxic, UV radiation	Bright
Metal Halide	10,000-15,000	60-100	80	UV radiation, toxic, risk of bursting	True white light
High Pressure Sodium	12,000-24,000	45-130	25	Poor colour, toxic	Efficient
Low Pressure Sodium	10,000-18,000	80-180	0	Very poor colour, toxic	Efficient
Fluorescent	10,000-20,000	60-100	70-90	UV radiation, toxic, diffuse light emission	Efficient
Compact Fluorescent	12,000-20,000	50-72	85	Slow start-up, toxic	Efficient
Induction	60,000-100,000	70-90	80	High initial cost, toxic, heat-sensitive	Rapid start-up
LED	50,000-100,000	70-150	85-90	High initial cost	Efficient, directional light

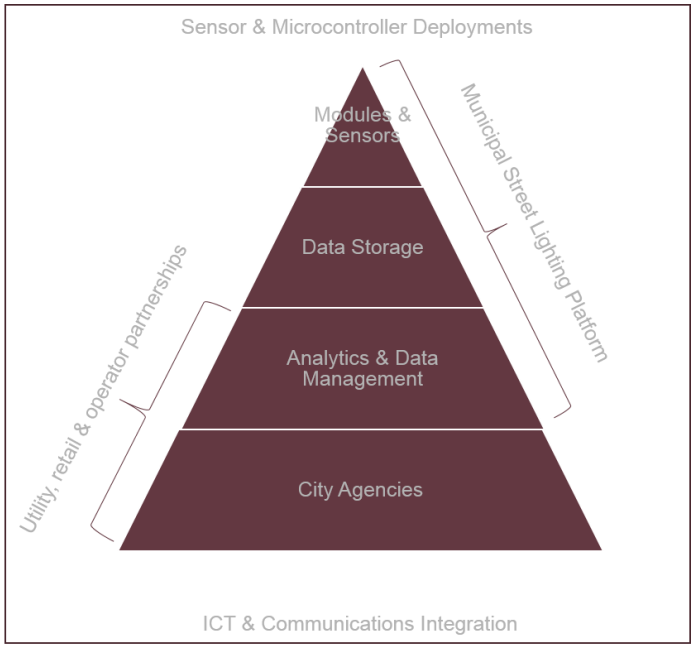
Source: Adapted from Grah Lighting

While LED lights only triumph over all others where proximity to natural light is concerned, rapid development in LED technology has meant this type of light has become a viable street lighting option over others, as ROI can be expected well within the light's expected lifetime.

2.7.1 Smart Street Lighting Strategies

In the first instance, the goal of a city will be to reduce its street lighting energy bill. Owing to price falls in LED fixtures, alongside its benefits as shown in table 2.11 above, LED has become the technology of choice for low-energy street lighting. However, the potential for LED fixtures reaches further than pure energy consumption reduction. We will therefore examine the value chain for smart street lighting to understand the various market components and opportunities.

Figure 2.12: Smart Street Lighting Value Chain



Source: Juniper Research

i. Modules & Sensors

This part of the value chain is particularly important to the value proposition offered by smart street lighting solutions. Here, not only are LED modules themselves included which will, of course, provide a source of light, but sensors integrated with the module can offer an array of possibilities, many of which allow street lighting services to cross over into other smart city service areas:

- Traffic measuring sensors can be placed on top of modules, which enables smart street lighting to be combined with smart traffic management.
- Meanwhile integrated sensors are able to detect whether the light itself is functional or not, which can be of enormous benefit in cities. Historically, non-functional lamps could only be identified visually by inspection teams or by notification from the public. In the case of visual inspection, this meant a low-efficiency, high-cost strategy owing to the number of vehicle miles and man hours required to manually inspect all street lights. Additionally, rapid identification and repair of non-functional lights has the benefit of reducing crime rates in some cases, although its effectiveness depends on a number of variables beyond the scope of this research.[xxv]
- In areas of high pedestrian traffic, measurement of pedestrian volumes in proximity of the street light offers a number of opportunities, not least as it offers the possibility of turning the lamp off or dimming it and thus saving more energy if there are no citizens walking in the surrounding area.

ii. Data Storage

Data storage capabilities are useful for information regarding the lamp's status, brightness and burn time. Data collected from onboard sensors can offer greater insight into the overall lighting system. It also gives cities the opportunity to work with third parties if data is integrated into an analytics layer.

iii. Analytics & Data Management

The analytics layer of the smart street lighting platform is crucial in not only the management of the lighting system itself, but also in opening new service channels that could lead to revenue streams to reduce the time required to achieve ROI, such as:

- Utility partnerships to offer smart grid services, such as EV charging stations;
- Retail partnerships where footfall data from integrated sensors can offer retailers additional business insights from an external location;
- Operator partnerships, where the addition of Wi-Fi access points (also useful for traffic monitoring) to the fixture offer MNOs (Mobile Network Operators) the opportunity for increased data offload, while ISPs can extend their out-of-home networks and reduce churn.

Case Study: Kansas City

As part of a 10 year smart city project, Kansas City has partnered with Cisco and Sensity Systems to install 125 smart street lights equipped with network-connected cameras and weather sensors.

The cameras are principally used to control light luminosity according to nearby motion, although they are also able to capture other data, such as obstacles on the adjacent streetcar track, while the provision of retail analytics services to merchants is also a possibility.

Meanwhile Sprint has installed a municipal Wi-Fi network on the lamp fixtures to provide citizens with connectivity.

Although the total investment required amounted to $15 million, the city contributed $3.7 million, with the remainder coming from deals with partners.

iv. Caveats

It is important for cities to consider that, until recently, the smart street lighting market has been characterised by a lack of standardisation, with most vendors adopting their own proprietary protocols. This in turn may limit future service expansion in terms of plugging additional control and communications modules into the fixture. Reliance on a single vendor for critical infrastructure such as street lighting is unwise.

The ability for any given system to interoperate with products from other vendors is therefore, in Juniper's opinion, essential. The requirements for interoperability (best achieved via open standards) apply to:

- Communications: data reporting and fixture control should be managed via a standardised communications protocol, such as IP (Internet Protocol) or ZigBee, alongside standardised transport, such as PLC (powerline communications) or 3G/LTE.

Software: Additionally, lighting point controller support for open profiles such as LonMark will help ensure data transferability between management systems from disparate software vendors.

- Hardware: standardised hardware is also desirable in terms of future planning, where some cities may not immediately commission networked street lighting. Thus it is desirable that lighting controller hardware conform to standardised design to be physically compatible with parts from multiple vendors.

Despite falling costs for LED fixtures, many cities continue to face hurdles where conversion to energy-efficient street lighting is concerned. On the one hand, municipal budgets may struggle with the up-front payment required for fixture conversion (in many cases ageing poles and brackets may need to be replaced, adding further cost), despite the clear long-term business case for LED street light installation.

Meanwhile the lighting infrastructure is not always owned by the city itself, but by the serving utility. Therefore, conversion to smart street lighting is likely to form part of the utility's smart grid strategy, where various regional effects (as described in section 2.2.4) may hamper adoption.

Case Study: NEMA

In February 2014 a breakthrough happened in the smart street lighting industry following NEMA's (National Electrical Manufacturers Association) release of the ANSI (American National Standards Institute) C136.41 standard targeted at street light units.

The standard specifies mechanical, electrical, and marking requirements for dimming control and the addition of further hardware on top of the controller unit. In essence, cities are now able to choose from numerous vendors when examining options with regard to communications and other features installed over new lighting units.

Where lack of standardisation and cost had remained barriers to greater adoption of smart street lighting, rising demand for LED lamps have continued to reduce costs, with the availability of standardised equipment, notably from Philips and Acuity Brand.

2.7.2 Driving Investment: 2017 Market Developments & Emerging Opportunities in Smart Street Lighting

At present, one of the primary drivers for cities to install smart street lighting has been to reduce energy costs by virtue of greater lamp efficiency and reduced maintenance costs. Thus far, there have been relatively few cases where street lighting has been used as a revenue source for the city.

Nonetheless, this situation will undoubtedly change in the future. City appetite for monetising these assets is on the increase, although for the moment these opportunities are directed primarily to projects such as smart parking, where the street light is able to monitor parking space occupancy.

Near- and long-term technology developments however will likely spur the business case for monetisation of municipal street lighting:

- The first commercialised 5G networks, which will likely be ready in 2019, will rely on a far greater number of cells in dense areas such as cities. One of the logical placement zones for these new small cells will be in the will be in the lighting fixture. In this way, communications will not only be supplied to the

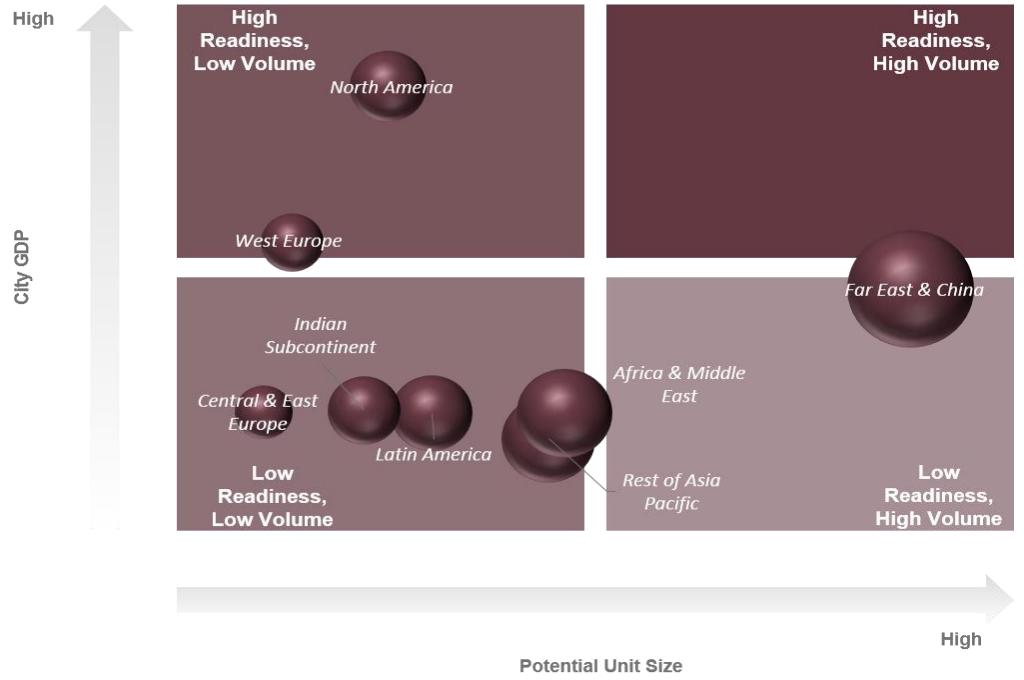
light, but will also enable cities to generate revenue (through leasing agreements with mobile operators), or absorb the costs of smart street lighting infrastructure build-out through some form of PPP agreement with operators.

- Driverless vehicles cannot rely on the cloud to process real-time information owing to the relatively high latency of using that technology. Communications and analytics must be made available to vehicles at the city local-level. In turn, this will generate opportunities with regard to edge computing analytics, as well as V2I (vehicle to infrastructure) communications modules. This opportunity is unlikely to emerge before 2025 however.

2.7.3 Smart Street Lighting Regional Prospects

The following quadrant shows the expected regional prospects for smart street lighting initiatives (ie networked and micro-controlled lighting, rather than solely LED lighting); the bubble size reflects regions' city populations. Regions' readiness to implement large-scale smart street lighting projects is gauged according the city productivity in that region, where higher city GDP creates a feedback loop enabling municipalities to initiate smart city projects.

Figure 2.13: Juniper Strategy Quadrant: Regional Smart Street Lighting Prospects



Source: Juniper Research

i. North America

North American cities have the highest GDP in the world, creating an environment where smart street lighting projects are high on the agenda. However, in some municipalities, street lighting is owned by the incumbent utility, which may create a barrier where conversion to smart LED is concerned.

ii. Latin America

This region is characterised as one where city wealth is rather unevenly distributed, although the overall potential in terms of total units to be converted is relatively high. Commitment to the UN's SE4ALL (Sustainable Energy for All) initiative means that a greater proportion of the budget will now be allocated on projects such as smart street lighting, with projects already underway in cities such as Rio and São Paulo. The continued fall in LED fixture prices will therefore be important to market growth in this region.

iii. West Europe

With smart street lighting being closely related to the smart grid, Juniper believes that climate goals and energy reduction initiatives make West Europe one of the leading markets for smart street lighting uptake. City wealth is relatively high, although the region's volume size in terms of units to convert is larger only than Central & East Europe.

iv. Central & East Europe

Juniper believes that Central & East Europe is one of the smaller markets in terms of smart street lighting investment potential. Many cities in the region do not have similar energy efficiency goals to West Europe, alongside a relatively low average city wealth index, meaning that conversion to smart street lighting is likely to be restricted to larger cities in the near-term.

v. Far East & China

Owing to enthusiastic investment in LED technology thus far, the very high unit volume potential and relatively high economic output from cities, Juniper believes that this region is likely to be a leader in smart street lighting for the foreseeable future. While overall budgets may mean that individual project sizes are not as large as in North America, this region likely is a good long-term bet.

vi. Indian Subcontinent

Traction in this region is likely to be dominated by India, where the government recently announced its intention to convert the entire country's street lights to LED over the next 2 years.[xxvi] As per the quadrant, cities overall are not in prime position to fund such projects; so EESL (Energy Efficiency Services Limited), operating as a joint venture between 4 central government utilities, will raise initial capital requirements. Nevertheless, while the path to LED is clear, the path to connected smart lighting incurs additional cost, which makes prospects for complete smart street lighting solutions less clear.

vii. Rest of Asia Pacific

Similarly to Latin America, city wealth in this region is unevenly distributed, so smart street lighting projects are likely to be restricted to wealthier cities in countries such as Australia, New Zealand and Singapore.

viii. Africa & Middle East

Overall city wealth in this region is inflated owing to the economic output generated from wealthy cities in the UAE, Israel and South Africa, so smart street lighting projects are likely to be restricted to these areas in the near-term.

3. Smart City Stakeholder Analysis & Leaderboard

3.1 Introduction

Given the breadth of vendors involved in the smart city landscape, this section is a select profile of the vendors aiming to generate revenue from the smart city market and should not be seen as an exhaustive list. It profiles some of these players and, in as far as possible, compares them using criteria such as company size, breadth of service offering and funding.

Companies profiled here include:

- ABB
- Accenture
- Cisco
- Hitachi
- IBM
- Intel
- Nokia Networks
- Schneider Electric
- Siemens
- SIGFOX
- Silver Spring Networks
- Streetline.

3.2 Juniper Leaderboard

Our approach is to use a standard template to summarise vendor capability. This template concludes with our views of the key strengths and strategic development opportunities for each smart city vendor.

This technique, which applies quantitative scoring to qualitative information, enables us to assess each vendor's capability and capacity and its product and position in these markets. The resulting Leaderboard shows our view of relative vendor positioning. Readers should note that criteria for assessing positioning in the Juniper Leaderboard are markedly different from those for its predecessor, the Vendor Matrix, and thus positioning in the former cannot be compared directly with positioning in the latter.

We have assessed each vendor's capabilities against the following criteria:

Table 3.1: Vendor Capability Assessment Criteria

Category	Criteria	Weighting	Description
Corporate Capability	Financial Performance in Sector	20%	In assessing this factor we considered the smart city solutions performance as measured by revenues, employees and investments.
	Experience in Sector	15%	Experience of the vendor, as measured by the length of time smart city solutions have been offered. Acquisitions and its experience were also taken into account here.
	Operations & Global Reach	10%	This factor considers primarily the overall extent of geographical penetration of the vendor based on numbers of countries, regions, customers and offices to measure global reach.
	Marketing & Branding Strength	25%	The strength of the vendor's brand and marketing capability.
	R&D Spend	30%	An indicator of the investment a vendor is making to deliver best-in-class solutions; M&A is also considered here as a measure of investment.
Product & Positioning	Smart City Range & Features	10%	This factor relates to breadth and the features that are a part of that product range.
	Customers & Deployments	15%	We evaluate here the vendor's success to date measured by the number of customers to whom it has sold its smart city products or services.
	Industry Partnerships	30%	The extent to which a vendor has been able to achieve partnerships in the segment, with a view to augmenting its smart city capabilities.
	Creativity & Innovation	15%	This factor assesses the vendor's perceived innovation through its flow of new features, products, developments and enhancements.
	Dependency on Smart City Solutions	30%	The company's overall dependency on the success of its enterprises in the smart cities space, as well as the ability of the company to react with agility in competitive markets

Source: Juniper Research

3.2.1 Leaderboard Scoring Results

We have mapped out the results of our assessment, displaying 12 stakeholders on the Leaderboard.

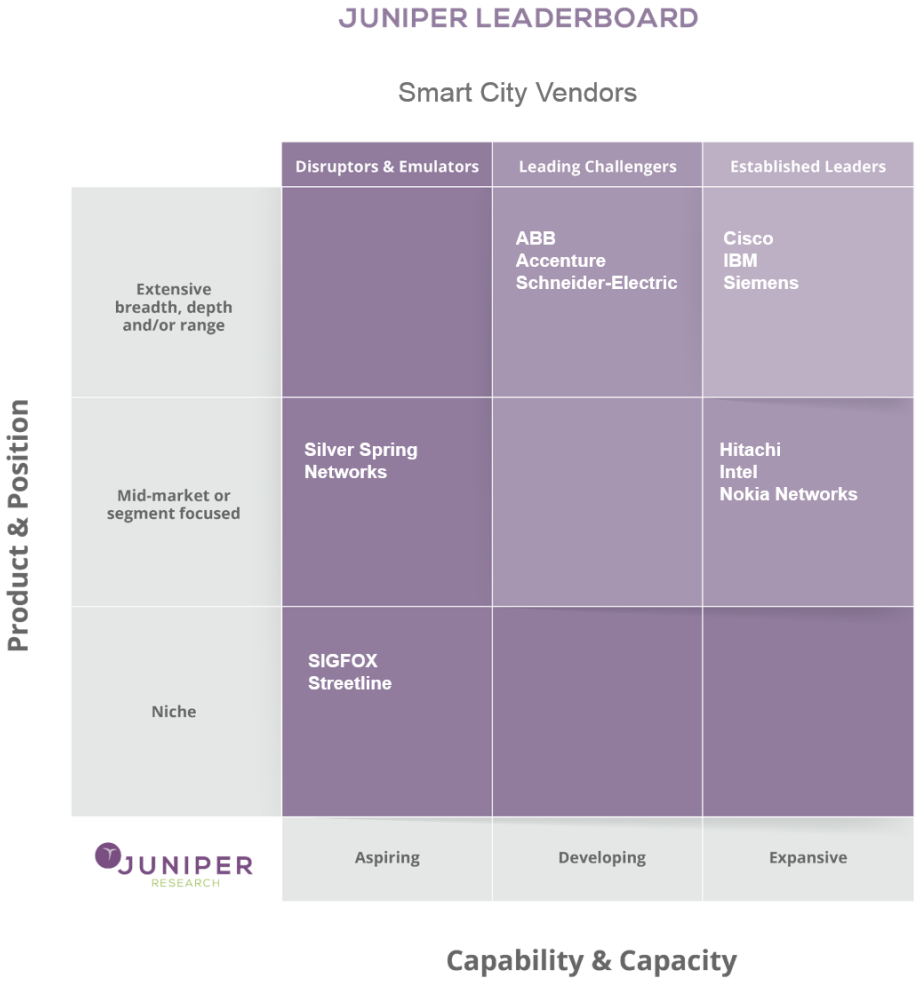
Table 3.2: Juniper Leaderboard: Smart City Vendors

	Corporate Capability					Smart City Product & Positioning				
	Financial Performance in Sector	Experience in Sector	Operations & Global Reach	Marketing & Branding Strength	R&D Spend	Smart City Service Range & Features	Customers & Deployments	Partnerships	Creativity & Innovation	Dependency on Smart City Solutions
ABB										
Accenture										
Cisco										
Hitachi										
IBM										
Intel										
Nokia Networks										
Schneider Electric										
Siemens										
SIGFOX										
Silver Spring Networks										
Streetline										

HIGH LOW

Source: Juniper Research

Figure 3.3: Juniper Leaderboard: Smart City Vendors



Source: Juniper Research

3.2.2 Vendor Groupings

Our analysis enables us to conclude that, from this particular list of vendors, there are essentially 3 main groups.

- Established Leaders
- Leading Challengers
- Disruptors & Emulators

i. Established Leaders

These are typically corporate scale vendors, complemented by a segment wide or market wide position in the IoT and will have substantial overlap into the smart city market. Typically they will also have augmented their capability through an acquisition, a joint venture and extensive partnership deals.

- Cisco has long been a player in the smart city field, having been one of the pioneers of the concept's potential. The company's presence, experience and ability to play across several areas in the smart city market puts Cisco in a leading position.
- IBM has, according to Juniper's estimates, the highest sector revenues of all companies analysed in this Leaderboard and offers comprehensive services to stakeholders looking to implement smart city projects. This, together with real-world experience of large-scale smart city projects, leads us to designate the company as an established leader.
- Siemens has significant technical experience in the type of projects being brought to smart cities and is able to rely on high revenue generation from its business operations. The company is a prominent smart city partner in several areas, with solutions offered across a wide range of city components.

ii. Leading Challengers

This group is formed principally of vendors who have yet to fully develop their solution, or of those targeting specific user groups or product segments as opposed to the entire market.

- ABB is certainly one of the larger players in the wider smart city market, with a value proposition heavily linked to the development of the smart grid and energy solutions. The company is in a tremendous position to capitalise on long-term smart energy efforts which, at present, are mostly embryonic in global cities.
- Accenture has a wealth of experience helping clients achieve their goals. The company is able to play across several smart city segments, despite the service being one of sourcing and strategy rather than implementation.
- Hitachi has a presence in resource delivery, software and communications, coupled with high brand awareness thanks to a long, distinguished history.
- Intel is undoubtedly a company with vast resources behind it. Nevertheless, with the PC market in decline, Intel recently decided to cut 12,000 jobs by mid 2017. Its search for new revenue streams is therefore very dependent on its success in the IoT and also how successful it can be in the smart city market, particularly in the face of rising competition from alternative silicon providers.

- Nokia Networks enjoys a vast partner network in the form of operators worldwide and its position as a supplier of communications solutions for smart city projects looks strong. Nevertheless, competition is fierce, and branding alongside an array of proven case studies may play a more significant role than usual to gain market advantage.
- Schneider Electric has an extensive network of customers, as well as partnerships with major smart city stakeholders, while the number of smart city projects in which the company has been involved is impressive.

iii. Disruptors & Emulators

This group is formed of players who have developed disruptive solutions for their target industry, but have not yet established a diverse client base or partner network.

- Silver Spring Networks has successfully raised its profile in recent years and offers a wide range of solutions geared to smart grid and smart street lighting services. Meanwhile, it has a number of important partnerships already in place.
- SIGFOX is a relatively new player in terms of the service offering, while global rollouts of its product have yet to be achieved. Nevertheless, it offers an attractive solution for cities looking to achieve low-cost communications for smart city sensors, while it offers a business model geared to the IoT.
- Streetline has taken advantage of being one of the early movers in the smart parking market, with a number of successful projects in the US. Its move to Europe, alongside a vision for Asia, allied to the ability to reduce deployment costs for stakeholders, means the company is positioned to retain a market leading proposition.

3.2.3 Limitations & Interpretations

Our assessment is based on a combination of quantitative measures where they are available (such as revenues and numbers of employees) that will indicate relative strength, and also of qualitative judgement based on available market and vendor information as published. In addition we have improved our in-house knowledge from meetings and interviews with a range of industry players. We have used publicly available information to arrive at a broad, indicative positioning of vendors in this market, on a 'best efforts' basis. However, we would also caution that our analysis is, almost by nature, based on incomplete information and so for some elements of this analysis we have had to be more judgemental than others. For example with some vendors, less detailed financial information is typically available if they are not publicly listed companies.

We also remind readers that the list of vendors considered is not exhaustive across the entire market but, rather, selective. Juniper endeavours to provide accurate information; whilst information or comment is believed to be correct at the time of publication, Juniper cannot accept any responsibility for its completeness or accuracy: the analysis is presented on a 'best efforts' basis.

The Leaderboard compares the positioning of vendors based on Juniper's scoring of each company against the criteria that Juniper defined. The board is designed to compare how the vendors position themselves in the market based on these criteria: relative placement in one particular unit of the board does not imply that any one vendor is necessarily better placed than others. For example, one vendor's objectives will be different from the next and the vendor may be very successfully fulfilling them without being placed in the top right box of the board, which is the traditional location for the leading players.

Therefore, for avoidance of doubt in interpreting the board, we are not suggesting that any single box implies in any way that a group of vendors is more advantageously positioned than another group, just differently positioned. The board is also valid at a point in time: November 2017. It does not indicate how we expect positioning to change in the future or, indeed, in which direction we believe that the vendors are moving. We caution against companies taking any decisions based on this analysis: it is merely intended as an analytical summary by Juniper as an independent third party.

3.3 Smart City Movers & Shakers

Rowan Trollope

Cisco

Senior Vice President and General Manager, IoT and Applications

Rowan Trollope is Senior Vice President and General Manager of Cisco's IoT and Applications.

Trollope joined Cisco in 2012. Since then, he has reinvented Cisco's collaboration business and made design, simplicity and exponential improvement the guiding principles of product development.

Most recently, Trollope was also appointed to lead Cisco's IoT efforts as the company focuses on helping its customers and partners create value in a highly connected, digital world. In this role, he leads a worldwide organisation responsible for technology solutions across IoT market segments, including manufacturing, industrial, transportation, public sector and many others.

Marcus Weldon

Nokia

Corporate Chief Technology Officer and President of Nokia Bell Labs

Marcus Weldon has global responsibility for defining the technology strategy for Nokia, driving the implementation of that strategy with the Nokia Business Groups and leveraging innovations from Nokia Bell Labs.

Before the Nokia transaction Weldon had global responsibility for the technology strategy and Bell Labs in Alcatel-Lucent and, prior to that, the global responsibility for the technology strategy for a number of business units in Alcatel-Lucent and Lucent Technologies.

Weldon has a PhD (Physical Chemistry) degree from Harvard University and a Bachelor of Science (Computer Science and Chemistry) joint degree from King’s College London.

David Kenny

IBM

Senior Vice President, IBM Watson and Cloud Platform

David Kenny is senior vice president, IBM Watson and Cloud Platform, spearheading the Watson technology platform development, as well as optimising IBM’s public cloud for data and cognitive workloads.

Kenny was most recently General Manager, IBM Watson, responsible for the Watson platform, its global ecosystem of business partners and developers, and emerging solutions. Prior to joining IBM he was Chairman and Chief Executive Officer of The Weather Company (Weather)

Kenny was previously president of Akamai.

Paul Daugherty

Accenture

Chief Technology & Innovation Officer

Paul Daugherty is Accenture's Chief Technology & Innovation Officer, leading the company's Technology Innovation & Ecosystem group. He is also a member of Accenture's Global Management Committee. In addition to overseeing Accenture's technology strategy, Daugherty has responsibility for driving innovation through R&D activities in Accenture's Labs.

Daugherty developed the Digital Business vision and helped shape Accenture's early moves to establish its digital business leadership. He founded Accenture's cloud computing business and was instrumental in launching Accenture's SaaS, Big Data and open source businesses. Daugherty played a key role in the company's technology business during the major transitions to client/server computing and Internet-based computing.

Sabrina Soussan

Siemens

CEO, Mobility Division

Sabrina Soussan joined Siemens in 1997 and was the Project and Segment Head for Siemens VDO Automotive in France, the UK, Japan and Germany.

From 2009 to 2011, she had various leadership positions in Building Technologies. Most recently, starting in 2013, she headed the commuter rail business in Siemens Mobility.

Before starting work at Siemens, Soussan was employed as an engineer in research and engine development at Renault in France. She studied mechanical engineering and aerospace technology in France and completed an MBA program in Ireland.

Dan Rabinovitsj

Ruckus Wireless

COO

As COO of the Ruckus Wireless Business Unit, Rabinovitsj manages day-to-day operations for Brocade's wireless networking products and solutions. He joined Brocade in May 2016 with the acquisition of Ruckus Wireless, where he was COO.

With a career spanning more than 25 years in communications and wireless technology, Rabinovitsj has extensive experience driving new ideas from vision to reality and a passion for building disruptive technology with great teams.

Rabinovitsj joined Ruckus from Qualcomm, where he was the Senior Vice President and General Manager of its Wired and Wireless Networking group .

3.4 Stakeholder Analysis

3.4.1 ABB

i. Corporate Profile

The ABB Group was formed through a merger between Asea and BBC Brown Boveri in 1988, with a lineage that can be traced back to 1883. Based in Zürich, the company has 4 distinct business divisions: Electrification Products; Robotics and Motion; Industrial Automation; Power Grids.

Approximately 132,000 individuals worked for the company at the end of December 2015. The company's Electrification Products division generates the greatest revenues for ABB, with a 28% share of total operating division revenues in 2016, having risen from 26% in 2015.

Table 3.4: ABB Financial Snapshot 2014-2016 ($m)

	2014	2015	2016
Revenue	$39,830	$35,481	$33,828
Net Income	$2,718	$2,055	$2.034

Source: ABB

Key executives include Ulrich Spiesshofer (President & CEO); Timo Ihamuotila (CFO); Claudio Facchin (Power Grids Division).

ii. Geographic Spread

ABB operates in approximately 100 countries across the globe and has a business presence across the Americas, Europe, the Middle East, Africa and Asia.

iii. Key Clients & Strategic Partnerships

- In April 2017 ABB teamed up with IBM to combine its ABB Ability tool with IBM's Watson platform, allowing industrial customers to combine asset data with machine learning analytics.
- The company announced a partnership with Microsoft in October 2016 with the aim of leveraging the latter's Azure cloud infrastructure for utility customers.
- ABB was a key partner in the EU-funded Grid4EU smart grid research programme, which ran from November 2011 to January 2016.
- The company announced a partnership with the Italian city of Venice in April 2016, to build an electrical and automated flood barrier system to protect the city against high tides and storm surges.
- In October 2015 ABB and Microsoft announced a collaboration for a worldwide EV fast-charging charging services platform, connecting ABB EV charging stations to Microsoft's Azure cloud platform, enabling value-added services to be offered by service providers.
- A strategic partnership between ABB and Hitachi was announced in December 2014 for a joint venture for high voltage direct current system solutions in Japan.

- ABB and BYD announced a collaboration in September 2014 to develop battery storage solutions for grid-connected, micro grid, solar and marine storage applications.
- In May 2014 a partnership was announced between ABB, Cofely, Alliander, Mitsubishi Motors, ASC and the Amsterdam University of Applied Sciences for the development of a Vehicle2Grid pilot programme in the city of Amsterdam. The project aimed to enable locally produced energy, ie distributed generation, to be transferred to the grid, used immediately or stored in an EV battery to drive the car or run household appliances. The pilot was scheduled to run for 3 years.

iv. Products & Services

ABB has extensive capabilities in the smart city arena. The company is able to supply wireless communications infrastructure, both for mesh networked devices as well as connected smart city devices, such as smart meters and SCADA systems, via its Tropos wireless network. Performance, security and Quality of Service can be altered according to the use-case. As part of the company's IT portfolio, analytics are also offered alongside control operations, asset management and workforce management.

ABB's solutions extend beyond communications infrastructure to the following smart city segments:

- Electricity Grids: In its role as the world's largest supplier of electricity grids, ABB is heavily involved in establishing smart grids. The company supplies solutions for grid automation, demand response, renewable energy integration and energy storage.
- Water Networks: ABB enables city water supply optimisation through the provision of distribution, treatment and desalination solutions.
- Transport: Solutions in this segment include EV charging, electric buses and DC electric rail.
- Buildings: Energy management, use and control solutions are provided for deployment in homes, commercial buildings, industry and data centres.
- District Heating & Other Energy: The company offers heating and cooling services, alongside waste to energy conversion.

v. Juniper's View: Key Strengths & Strategic Development Opportunities

- ABB claims to be the global market leader in the power grid market. It is therefore in a strong position to capitalise on the global trend to EV transportation demand, for which substantial infrastructure and management software will be required.
- Another key area for ABB will be in the smart buildings space, where high growth of renewable energy spend and traction in building energy management systems will drive demand.
- AMI, while ABB is not a competitor, is on the agenda for many cities in the first instance. Nevertheless, with key competencies in distribution automation and renewable energy integration, the company looks set to capitalise on smart grids over the long-term, in particular in emerging markets such as India, which has a strong focus in that direction.

3.4.2 Accenture

i. Corporate Profile

Accenture is a global market leader in management consulting, technology and outsourcing services. The company has a workforce of more than 373,000 individuals. Key executives include Pierre Nanterme (CEO); David P Rowland (CFO); Omar Abbosh (CSO).

Based in Dublin, Ireland, the company operates across numerous industries including Communications, Media and technology; Financial services; Health and public services; Products, including consumer goods, retail and travel services, Industrial and life sciences; Resources, including energy and utilities.

Table 3.5: Accenture Financial Snapshot 2014-2016 ($m)

	2014	2015	2016
Revenue	$30,002	$31,048	$32,883
Net Income	$3,176	$3,274	$4,350

Source: Accenture

ii. Geographic Spread

Accenture has offices in the world's major financial hubs, including Boston, Chicago, New York, San Francisco, Frankfurt, London, Madrid, Milan, Paris, Rome, Bangalore, Beijing, Manila, Mumbai, Sao Paolo, Shanghai, Singapore, Sydney and Tokyo, among others. In total, the company has workspace in more than 200 cities across 55 countries.

iii. Key Clients & Strategic Partnerships

- The UK city Ipswich selected Accenture as a partner to help develop its smart city transformation strategy and implementation plan in May 2016.
- Accenture is a strategic partner in Amsterdam's ASC project.
- In May 2015 NASSCOM (National Association of Software and Services Companies) partnered with Accenture to find ways of implementing ICT in different aspects of a smart city.
- The company announced an alliance agreement with Hortonworks in July 2014, to bring knowledge to governments and enterprises aiming to make sense of Big Data from operational, video and sensor data.
- In October 2013 a joint venture company, called Omnetric Group, was formed by Accenture and Siemens. Combining the 2 companies' knowledge, the aim is to work with utilities striving to develop smart grids.
- In August 2013 Accenture finalised the completion and deployment of a demand-response billing system for energy customers in the Yokohama Smart City Project
- Accenture's client list includes 89 members of the Fortune 100 and more than 75% of the Fortune 500.
- The company has established alliances with 165 market leaders including ABB, Cisco, VMWare, General Electric, Microsoft, Oracle, SAP and IBM.

iv. Products & Services

Accenture offers numerous solutions for businesses and governments looking to realise smart city projects. The business portfolio is organised as follows:

- Intelligent Cities Strategy: Consulting services to help businesses and governments streamline processes and develop low-carbon, sustainable infrastructure.
- Citizen Services: Provision of technology for citizens and city employees to facilitate working from home or other locations, lessening the need to travel to the workplace to reduce congestion and energy consumption.
- Smart Grid Services: Helping utilities and communities in the transition to a smart grid, providing expertise in the field of smart metering/AMI, grid operations, transmission and distribution asset management as well as work, field and resource management.
- Smart Building Solutions: A suite of energy management services aimed at reducing energy consumption in buildings. Energy consumption information is captured and analysed with opportunities to save energy highlighted through the service. The solutions are the convergence of building controls technology and information management, highlighting the opportunity to save over 25% costs from HVAC (Heating, Ventilation, Air Conditioning) systems.
- Intelligent Transport: Helping clients to develop and implement low-carbon transport systems and infrastructure in relation to urban mobility, EV and recharging networks, as well as mass transit systems.
- Urban Applications & Operation Systems: Helping the transition of services from traditional delivery to one enabled by the Internet. The service aims to implement a strategy based around an open architecture to improve the ability to manage services over ones enabled by proprietary architectures.
- City IT & Network Services: Addresses the need to develop municipal systems that are easily integrated across agencies with a view to reducing maintenance and service costs. The service is based on the creation of an open and scalable platform.
- Infrastructure Analytics: Provides data-driven analysis of building performance in terms of energy consumption and sustainability. The service delivers both analytics and performance assessment of measures implemented.

v. Juniper's View: Key Strengths & Strategic Development Opportunities

- Accenture has powerful alliances with the likes of Cisco, Siemens and Hortonworks, while its client base is impressive.
- However, as more experience is gained in the smart city field, the company could face greater competition from project implementers.

3.4.3 Cisco

Juniper Research interviewed Munish Khetrapal, Managing Director - Global Head of Solutions, Smart Cities at Cisco Systems, October 2017

i. Corporate Profile

Based in San Jose, US, Cisco was founded in 1984. With its roots firmly in communications networking, the company also offers a range of services related to the delivery of smart digital technologies.

Table 3.6: Cisco Financial Snapshot FY 2015-2017 ($m)

	2015	2016	2017
Revenue	$49,161	$49,247	$48,005
Net Income	$8,981	$10,739	$9,609

Source: Cisco

Some 70,000 individuals work for Cisco. Key executives include Chuck Robbins (CEO); Joe Cozzolino (SVP, Services); Chris Dedicoat (Executive Vice President, Sales).

ii. Geographic Spread

Cisco's EMEA and APJC headquarters are in Amsterdam and Singapore respectively. Further operations are located across the US, Asia, and Europe, with field sales offices in 93 countries and over 400 offices in total worldwide.

iii. Key Clients & Strategic Partnerships

- Cisco has established numerous strategic alliances with major players in the smart city space including Accenture, Citrix Systems, Intel, Microsoft, Oracle, SAP, Tata and VMWare.
- The company has been selected as a partner in numerous smart city projects, including those based in Amsterdam, Bangalore, Barcelona, Hamburg, Newcastle San Francisco and Songdo. Some 72 cities have deployed Cisco solutions at the time of writing.
- In March 2016 the company signed an agreement with the Senate Department of Economics, Technology and Research in Berlin to develop smart city solutions in telemedicine, security and network infrastructure.
- A joint agreement was signed between Cisco, Sprint and Kansas City in June 2015 to deploy Cisco hardware and software from selected partners alongside Sprint connectivity solutions for a number of projects in the city.
- In 2014 a smart city global strategic alliance was formed by AGT International and Cisco, with joint solutions focused on smart traffic incident management and city safety. The alliance aims to rollout solutions to up to 1,000 cities within the next 5 years.

iv. Products & Services

Cisco's networking hardware solutions have a global reputation and the company has long been a market leader. Cisco has adopted a horizontal strategic approach, as opposed to a vertical one, with the intention of allowing partner companies to integrate with its solutions. Leveraging the

technical expertise gained through the expanding need for digital communications technologies and promoting a vision for the 'Internet of Everything', Cisco is addressing the smart city market through its 'Smart+Connected City' solutions.

In November 2017, Cisco announced the launch of its City Infrastructure Financing Programme, a $1 billion fund aimed at accelerating smart city projects. Financing solutions are flexible, ranging from traditional loans, to as-a-service consumption, to equity and revenue share finance programmes.

- Cisco DNA (Cisco Digital Network Architecture): This is an open, extensible, software-driven architecture that aims to create greater efficiency in enterprise (and city) network management. Built over an SDN (software defined networking) controller, the solution includes contextual analytics and network virtualisation.

  Key benefits include the ability to automate network functions based on a single policy, simplifying overall management. Meanwhile, the architecture leverages machine learning aimed at predicting network performance, making adjustments to ensure continued efficient operations based on data analysis.

  Furthermore, Cisco DNA includes important tools relevant to IoT security concerns, offering network managers the ability to mitigate threats using segmentation; network analytics help detect suspicious activity.

- Cisco Kinetic: This is the company's IoT operations platform, which aims to integrate connection management across a range of communications technologies. The platform is compatible with the company's fog computing concept, as well as Cisco DNA. Meanwhile, the platform is able to integrate video data. In the context of smart cities, data from services such as traffic, parking, Wi-Fi, lighting and waste management can be integrated. Meanwhile, the open nature of the platform allows third party actors to plug services into the platform via APIs.

  The overall goal of the platform is to deliver simpler integrations between smart city services; for example, the re-routing or rescheduling of waste collection as a result of a detected traffic incident.

- Smart+Connected City Wi-Fi: Establishment of a network infrastructure for city digitisation, allowing citizens ubiquitous access to Internet services, while simultaneously enabling a communications network for the implementation of other smart city services, such as smart traffic and parking, utilities and location-based services.

- Smart+Connected Lighting: The solution combines with the Smart+Connected Multi-Sensor Node to create a light-sensory network. These standards-based systems gather a wide variety of data from the environment, including levels of humidity, CO_2 and O_2, UVA and UVB light, particulate matter, motion and seismic activity, video, sound and more.

  Transmitted over the network, this data is capable of supporting many city services across a common infrastructure; from law enforcement to environmental improvement, transportation oversight and earthquake preparedness, among others.

- Smart+Connected City Parking: A solution aiming to combine the rollout of ubiquitous Wi-Fi access as detailed above, with a network of IP cameras, sensors and smartphone apps. As well as providing citizens

with real-time parking information to reduce time wasted looking for an empty space, the system also aims to communicate with traffic officers, as well as provide analytics to authorities and enable new pricing models.

- Smart+Connected Traffic: Leveraging the Wi-Fi network along with IP cameras, connected sensors and applications, this system aims to improve visibility of real-time traffic flows enabling long-term planning for urban authorities. Moreover, the solution enables faster incident response due to automation which, in turn, reduces traffic congestion caused by incidents.
- Smart+Connected City Safety & Security: This solution aims to integrate video surveillance, social media, citizen reports and sensors to create a networked overview of the city with the aim of improving citizen safety. Data is collected on crime type and location, along with data from social media. Analytics are supplied to predict crime patterns and help city planning.
- Smart+Connected Operations Center: The solution's end-to-end integrated platform and software synchronises the control of high-resolution blueprints, images, streamed camera data and system alerts, which allows interaction between all relevant data in real-time. It simplifies control room operations, reduces the total cost of ownership and improves efficiency to support rapid decision making for critical city infrastructure assets.

v. Juniper's View: Key Strengths & Strategic Development Opportunities

- Cisco is one of the market leaders in the smart city space, having established a prominent presence and wide portfolio of solutions.
- Meanwhile the company's avoidance of proprietary solutions is likely to help accelerate the market overall.
- The company benefits from being able to showcase a number of successful smart city projects.

3.4.4 Hitachi

HITACHI

i. Corporate Profile

Hitachi was founded in 1910 and is based in Tokyo, Japan. A multinational operation, the company has recovered from a slump during the first decade of the millennium to reach record high operating incomes in 2013 and 2014; record high net income was achieved in 2011.

Table 3.7: Hitachi Financial Snapshot (¥ billion) 2014-2016

	2014	2015	2016
Revenue	¥9,774.9	¥10,034.3	¥9,162.2
Net Income	¥217.5	¥172.1	¥231.2

Source: Hitachi

The company currently employs 303,887 people. Key executives include Toshiaki Higashihara (president & CEO); Keiji Kojima (SVP & Executive Officer, CEO, Services & Platforms Business Unit); Keizo Kobayashi (Vice President and Executive Officer, CEO, Urban Solutions Business Unit and General Manager of Urban Solutions Business Division, Social Innovation Business Division).

Segmented into 11 business divisions, Hitachi's Social Infrastructure & Industrial Systems segment was responsible for the highest proportion of overall 2016 revenue (23%), followed by Information & Telecommunication Services (20%)

The company has made several smart city related acquisitions in recent years through its subsidiary Hitachi Data Systems, including Avrio, Pantascene, oXya, and Pentaho, with the acquisitions targeted at strengthening the company's analytics and systems integration portfolio.

In September 2017, Hitachi announced a major reorganisation of its IoT strategy, with Hitachi Data Systems, Hitachi Insight Group and Pentaho consolidated under a single subsidiary called Hitachi Vantara.

ii. Geographic Spread

As a multinational conglomerate, Hitachi has operations covering all continents of the globe, with divisions in 45 separate regions.

iii. Key Clients & Strategic Partnerships

- In May 2016 the company announced a partnership with Copenhagen, Denmark. Via its Hitachi Insight Group subsidiary, the partnership aims to develop a platform solution for smart city application development and information access for businesses and citizens.
- Hitachi joined the AT&T Smart Cities Alliance in February 2016.
- Hitachi Data Systems' Indian subsidiary is partnering with the central and state governments to participate in the ongoing Smart City Mission.
- An agreement was concluded between Hitachi and the City of Yokohama in July 2013 for the former to contribute to the latter's ongoing smart city project
- Hitachi was commissioned by the Kashiwa-no-ha smart city in Japan, in collaboration with government agencies, universities, research institutions, Mitsui Fudosan and other entities, to help with the integration of disparate energy management solutions through the creation of an area energy management solution smart centre.
- Hitachi partnered with NEDO (New Energy and Industrial Technology Development Organisation), Mizuho Bank and Cyber Defense Institute to begin a smart grid demonstration site on Maui Island, Hawaii.
- During 2011 a partnership between Hitachi and Living PlanIT, developer of the UOS (Urban Operating System), was announced. UOS was implemented as a demonstration project in London City Airport in 2013.
- Hitachi was involved in a Japanese smart city pilot programme, running from 2010-2015, with deployments in Yokohama, Toyota City, Keihanna Science City (Kyoto Prefecture) and the city of Kitakyushu.

iv. Products & Services

Hitachi is involved in several technologies important to the development of smart cities.

- Energy: Focused on the smart grid, Hitachi offers solutions for power grid analysis, grid stabilisation, distribution management systems, storage battery systems, connection technology for disparate systems and energy management systems.

- Mobility: Hitachi has formed a consortium of companies from inside and outside the Hitachi group to provide a wide range of solutions for smart mobility. These include information and control platforms, urban management infrastructure (data monitoring, state estimation) as well as the provision of applications for vehicles, payment services and information services.
- Water: Solutions for realising smart water infrastructure include a treatment system, an information control system and an energy saving system. These 3 components aim to reduce power consumption and bring improvement in the reliability of water supply, while simultaneously reducing costs.
- Communications: Numerous solutions are provided by Hitachi to enable communications between humans and machines. These include gateway technologies to connect disparate networks, wireless communications technologies and network virtualisation technology.
- IT platform: Vision for the creation of a central platform from which to manage various public infrastructure processes in the smart city. The platform enables data processing and management, communications management, digital security and operations management.

v. Juniper's View: Key Strengths & Strategic Development Opportunities

- The company appears to have overcome a difficult period, with operating income reaching record levels, despite relatively flat revenues. Its recent acquisitions have enabled it to launch a competitive public safety offering, which will be of interest to any city.
- The company should leverage experience gained from smart city projects in the Far East to boost its profile across global markets.
- Its move to consolidate its IoT operations under a single subsidiary should considerably improve service delivery and reduce inefficiencies. The company should therefore be able to offer a much stronger smart city play.

3.4.5 IBM

i. Corporate Profile

IBM was founded in 1911 and has a long history of suppling computing technology. Based in New York, US, the company had 377,757 employees at the end of December 2015. Key executives include Virginia M Rometty (President & CEO); Erich Clementi (SVP Global Markets); Dr John Kelly III (SVP Cognitive Solutions and IBM Research).

The majority of the IBM's revenues are generated from industries in Financial services; Public sector; Industrial, including electronics; Service and product distribution; Communications.

IBM spent approximately $5.6 billion in R&D in 2016.

Table 3.8: IBM Financial Snapshot 2014-2016 ($m)

	2014	2015	2016
Revenue	$92,793	$81,741	$79,919
Net Income	$12,022	$13,190	$11,872

Source: IBM

ii. Geographic Spread

IBM is present on global scale, operating in more than 175 countries. Major markets include Canada, France, Germany, Italy, Japan, the US and the UK, plus Austria, the Bahamas, Belgium, the Caribbean region, Cyprus, Denmark, Finland, Greece, Iceland, Ireland, Israel, Malta, the Netherlands, Norway, Portugal, Spain, Sweden and Switzerland.

iii. Key Clients & Strategic Partnerships

- In February 2017 Vodafone announced a partnership with IBM to develop smart city solutions using the former's connectivity, devices and sensors and the latter's Watson analytics solutions. Initial services aim to deliver energy, waste and lighting efficiencies.
- IBM was announced as a partner for AT&T's smart cities initiative in January 2016; initial project cities include Chicago, Dallas and Atlanta.
- Carnegie Mellon and IBM announced a cloud-based analytics partnership for smarter buildings in March 2015.
- Veolia and IBM announced a new partnership in November 2014, including new solutions that integrate intuitive and powerful digital technologies into urban services to improve the efficiency of municipal systems around the world, transforming water, energy and waste management services for cities.
- In June 2014 IBM partnered with the Indian city of Palava to establish an integrated platform, from which disparate city agencies are able to work together and share data. Particular focus is placed on public safety, intelligent operations and participative governance.
- AT&T announced a partnership with IBM in February 2014 with the intention of deploying M2M solutions for IoT, with a particular focus on deployment in smart cities and utilities. Key targets will include those who are obliged to manage the large volumes of data produced by connected devices in the scope of vehicles, utility meters, video cameras and transport infrastructure.
- Miami-Dade county partnered with IBM in 2013 to focus on cutting across organisational boundaries to provide better services to residents, by improving the predictive management capabilities of systems related to water management services, transport solutions and intelligent policing.

iv. Products & Services

IBM offers a wide portfolio of solutions for stakeholders looking to deploy smart city projects. Key to the overall portfolio is its so-called 'intelligent operations centre', a central hub to which several agencies are connected, as well as a monitoring and analytics station.

IBM's 'smarter cities' offerings can be broadly categorised as follows:

- Planning & Management: This includes solutions for improving public safety, emergency management and smart buildings. Fundamental to these is the collection and analysis of data to drive intelligent actions, improve efficiency and lower costs.
- Infrastructure: This includes solutions for water management through digital technologies and smart grid solutions. Emphasis is placed on the management of assets and operations, along with the optimisation of processes through analytics.

- People: IBM is also involved in the drive to improve quality of life through the development of social programmes, healthcare and education solutions, where systems are deployed to handle high volumes of transactions and combined with analytics. As ever, collection, analysis and management of data is integral to IBM's solutions.

  At the core of the company's present and future efforts is the Watson platform, which incorporates machine learning technology across a range of service areas. The platform is envisioned as a transformative tool in that it offers predictive and automated capabilities for smart city service delivery across transport, healthcare, public safety and energy.

v. Juniper's View: Key Strengths & Strategic Development Opportunities

- The company's Rio de Janeiro project has widely been considered a success, while the ability to play across several market segments makes IBM a leader in the smart city arena.

- IBM has increased its emphasis on its Watson platform, with the company reporting that the number of Watson users and developers had doubled during 2016. Indeed, the company has over 6,000 clients and more than 50,000 developers.

3.4.6 Intel

i. Corporate Profile

Intel was founded in 1968 and is credited with creating the world's first commercial microprocessor. Widespread consumer recognition of the brand was gained during the 1990s as its family of Pentium microprocessors was widely distributed in household PCs.

The company employed 106,000 people at the end of December 2016; 51% of whom are located in the US. Key executives include Brian M Krzanich (CEO); Sohail U Ahmed (SVP General Manager, Technology & Manufacturing Group); Douglas L Davis (SVP General Manager, Internet of Things Group).

Intel's business is divided in to the following segments: Client Computing Group; Data Center Group; Internet of Things Group; Intel Security Group; Programmable Solutions Group; Non-Volatile Memory Solutions Group; All Other.

55% of 2016 revenues were attributable to the Client Computing Group.

Table 3.9: Intel Financial Snapshot 2014-2016 ($m)

	2014	2015	2016
Revenue	$55,870	$55,355	$59,387
Net Income	$11,704	$11,420	$10,316

Source: Intel

ii. Geographic Spread

Intel operates production facilities in the US, Ireland, Israel and China, while assembly and test facilities can be found in Asia and North America. Sales and marketing offices are located worldwide.

iii. Key Clients & Strategic Partnerships

- Intel became a partner for AT&T's smart cities initiative, announced in January 2016; initial project cities include Chicago, Dallas and Atlanta.
- In September 2015 Intel partnered with Connode and Reliance Energy to supply Intel gateways for a smart communications solution for smart meters, streetlights and distribution automation equipment in Mumbai.
- Intel announced a partnership with INRIX during November 2014, investing some $10 million in the latter. Intel will licence INRIX data and analytics services, while INRIX has opened its APIs to Intel partners and developers.
- In June 2014 Intel announced a partnership with the city of San Jose to participate in a 6 month smart city pilot programme. The project has involved the deployment of multiple sensors across the city, measuring and analysing data provided by transportation networks, energy and communications systems, as well as environmental data.
- Intel announced an 'Internet of Things Installation' in April 2014 in collaboration with Dublin's City Council. The pilot will establish Dublin as one of the most densely sensed cities in the world, while data will also be crowdsourced directly from social media. The partnership with the city was extended in May 2017, with sensors deployed across the city to monitor rainfall, weather conditions and river levels.
- The company partnered with Imperial College and University College London in 2012 to establish a smart city lab to undertake smart city experiments using crowdsourced data.

iv. Products & Services

Intel's vision for smart cities involves the establishment of a city-wide IoT architecture involving sensors and analytics to improve processes. The company offers a portfolio of products for the development and deployment of IoT solutions:

- Hardware & Software for IoT Device Development: Provision of processors and SoCs (system-on-chip), security software, network connectivity hardware as well as operating system software from embedded systems vendor Wind River.
- Gateway Solutions for Connected Devices: Enabling connectivity of legacy and new devices with other systems through the integration of technology and protocols.
- Network & Cloud: Processors, development and security platforms alongside network software and hardware enabling device management through APIs and the establishment of SDN and NFV practices.
- API Management Solutions: API management, security and brokerage, tokenisation brokerage, creation, monetisation and go-to market solutions, using a platform approach to device management and control.

Furthermore, the company offers a cloud-based analytics platform allowing multi-protocol communication of data across a Hadoop-based architecture. Event processing can be achieved in near-real-time, while the platform also has the ability to leverage machine learning algorithms.

v. Juniper's View: Key Strengths & Strategic Development Opportunities

- Intel has established a strong partnership with analytics services company INRIX, while it also has a large portfolio of hardware solutions, allowing it to compete in many smart city verticals.
- The company should look to partner with cloud computing service providers interested in the smart cities space, to extend the capability of its own platform.

3.4.7 Nokia Networks

NOKIA

Juniper Research interviewed Marc Jadoul, Market Development Director, Internet of Things, Marketing and Corporate Affairs, Nokia, October 2017

i. Corporate Profile

Finnish company Nokia has its headquarters located in Espoo. Approximately 101,000 individuals worked for the company at the end of 2016. Key executives include Rajeev Suri (CEO); Marc Rouanne (President, Mobile Networks); Kathrin Buvac (CSO).

In 2015 Nokia acquired networking and communications company Alcatel-Lucent for $16.6 billion. Meanwhile the company's wholly-owned subsidiary, Nokia Networks, now operates as the company's Networks business, with 4 business groups operating under that umbrella: Mobile Networks; Fixed Networks; IP/Optical Networks; Applications & Analytics.

Table 3.10: Nokia Financial Snapshot 2014-2016 (€m)

	2014	2015	2016
Net Sales	€11,762	€12,499	€23,614
Nokia Networks Net Sales	€11,198	€11,487	€21,800
Profit (loss)	€3,476	€2,468	€(927)

Source: Nokia

ii. Geographic Spread

Nokia has sales teams active in approximately 130 countries across the globe, covering the 6 major continents.

iii. Key Clients & Partnerships

Nokia Networks' key clients are operators across its various service areas.

- In October 2017 the city of Sendai in Japan sign an MOU (memorandum of understanding) with Nokia to establish the latter as a strategic partner to the city.
- In May 2017, the Rwandan government announced that Nokia had been selected as a partner to develop smart city solutions across the country.
- In October 2016 the company joined the Bristol is Open project, with Nokia supplying networking equipment and research capabilities to the initiative.
- In April 2016, Zain KSA and Nokia signed a MOU to collaborate on a major initiative to transform Jeddah into a smart city by 2018.

- The Dubai government security networks operator Nedaa select Nokia in March 2016 to deploy a smart city solution based on a 5G-ready next-generation network to enable high-bandwidth voice, video and other data applications for mission-critical services and IoT applications.
- Nokia and Oi Brasil signed a partnership agreement in November 2015 to develop smart city and other IoT solutions in Latin America.

iv. Products & Services

Nokia Networks' portfolio includes solutions for:

- Mobile Networks: technologies and services for access and core technologies, with support for 2G to 5G standards.
- Fixed Networks: copper, fibre and coax solutions for fixed broadband networks, including high-speed solutions for legacy networks as well as next-generation deployments. The business also includes a solution for smart home services.
- IP/Optical Networks: routing and optical technologies for communications service providers, with the company identifying energy, transport and the public sector as key vertical end-customers.
- Applications & Analytics: software platforms and applications for communications service providers; includes device and network management solutions.

Nokia's solutions for smart cities include technologies from different divisions, including major software and services components. The company's smart city framework is based on a horizontally layered architecture, encompassing:

- City-wide connectivity to provide both fixed and mobile access to connect all people, devices, machines and sensors;
- A city-wide network, a single converged IP-based network for operational efficiency and lower costs;
- A city cloud with a virtualised software-defined network to flexibly connect sites, people and applications quickly and securely;
- •A city IoT platform to manage sensors and devices, and collect, analyse and expose data to a wide variety of smart applications;
- City applications developed within an innovation ecosystem of trusted partners.

Recently, Nokia also launched its Integrated Operations Center to enhance situational awareness and command centre decision-making by aggregating data sources in use by emergency services. The Operations Center is able to use automated workflows in reaction to data feeds and thus generate efficient emergency services response.

- Nokia's IMPACT IoT platform forms the basis for the company's data aggregation and application delivery strategy for smart cities. The platform is open for third party applications, but also pre-integrated with a number of applications, including video analytics, smart parking and smart lighting. Here, edge computing technology is employed to reduce reliance on a centralised cloud. Indeed, where video is concerned, data is actually converted to IoT events, such as direction, velocity and so on, using machine learning technology. In this manner, the full bandwidth of the video data does not need to be processed and stored; it also means

that events can be easily integrated with other applications integrated with the platform.

- Solutions are designed to support both mobile and fixed line, as well as LPWA (Low Power Wide Area) connectivity.
- The company is heavily involved in the development of 5G technologies, as well as NB-IoT (Narrow Band-IoT).
- Solutions offer end-to-end security and high scalability.

v. Juniper's View: Key Strengths & Opportunities

- The company has achieved a significant boost following the acquisition of its former competitor, Alcatel-Lucent. Nevertheless, companies such as Cisco and Huawei present strong competition, with both able to achieve global scale.
- Nokia's vast partner network is likely to prove invaluable when competing at the infrastructure level is concerned.

3.4.8 Schneider Electric

i. Corporate Profile

Schneider Electric was founded in 1836 and incorporated in 1981. Based in Rueil-Malmaison, France, the company had 181,362 employee in 2015. Key executives include Jean-Pascal Tricoire (CEO); Prith Banerjee (EVP, Technology); Daniel Doïmo (EVP, Global Solutions).

Schneider Electric currently has customers in 4 principal markets: Residential and non-residential buildings; Utilities and infrastructure; Industries and machine manufacturers; Data centres and networks.

Supplied service offerings to these market segments primarily consist of energy management, electrical power distribution and supply, building control and automation and industrial control and automation solutions.

Table 3.11: Schneider Electric Financial Snapshot 2014-2016 (€m)

	2014	2015	2016
Revenue	€24,939	€26,640	€24,693
Net Profit (loss)	(€467)	(€446)	(€462)

Source: Schneider Electric

ii. Geographic Spread

The company has customers in over 100 countries worldwide. It is organised into 8 regional operations covering Europe, CIS (Commonwealth of Independent States), China, India, Asia, North America and South America.

iii. Key Clients & Strategic Partnerships

Schneider Electric has over 30,000 OEMs (Original Equipment Manufacturers) on its books, alongside a network of retailers, contractors, systems integrators and design specialists. Direct dealings are also conducted with utilities, governments and local public authorities.

The company has participated in more than 200 smart city projects around the globe.

- Schneider Electric has combined forces with Cisco, Accenture, IBM and Microsoft in the delivery of smart city projects.
- In March 2016 the company partnered with Wipro to develop convergent smart city solutions for the Indian market.
- In December 2014 UAE buildings systems integrator BMTS announced a partnership with Schneider Electric to educate the region's infra-development sector on 'the technology-driven shift towards a smart and connected future'.
- The city of Boston selected Schneider Electric as a partner in its smart city effort in September 2013, with the latter planning to collect and analyse data from the city's 350 commercial buildings, 850 traffic lights, 64,000 street lights and a 3,100 vehicle municipal fleet, to help advance its efficiency and environmental goals.
- Schneider Electric was selected as a key designer for the Masdar Institute of Science and Technology to implement smart buildings and power management systems.
- The company has been commissioned as the key manager of Abu Dhabi's Demand Side Energy Management Project.

iv. Products & Services

Schneider Electric offers solutions across the smart city landscape:

- Smart Energy: Distribution automation, load shedding schemes, end-to-end smart metering solutions and data management tools are offered under this segment.
- Smart Mobility: Real-time adaptive traffic management portfolio through collection and management of data, alongside services to notify travellers. Tolling solutions are also offered.
- Smart Water: Network optimisation, along with river and storm water management, remote monitoring and control, are offered as part of Schneider's portfolio for smart water networks.
- Smart Buildings & Homes: Remote and on-site energy management services, integration of distributed generation, as well as building security solutions.
- Smart Public Services: Analytics for connected services, where data is pulled from street lighting, video surveillance and weather intelligence systems to drive useful actions.
- Smart Integration: Services offered to bridge connections between disparate digital city services. Tools, dashboards and analytics services are supplied.

v. Juniper's View: Key Strengths & Strategic Development Opportunities

- The company has a strong presence in the APAC (Asia Pacific) region, which offers the largest growth opportunity for smart city projects.
- The company should look to capitalise on knowledge gained through its involvement in the Masdar City project to differentiate from its competition.

3.4.9 Siemens

SIEMENS

Juniper Research interviewed Martin Powell, Head of Urban Development, Siemens, October 2017

i. Corporate Profile

Based in Berlin and Munich, Siemens was founded in 1847. Approximately 348,000 individuals work for the company, with 33% of the workforce located in Germany. Meanwhile 51% of the company's revenues are generated from operations in Europe, CIS and MEA.

Operations at Siemens are divided into 9 sectors: Power & Gas; Wind Power & Renewables; Energy Management; Building Technologies; Mobility; Digital Factory; Process Industries & Drives; Healthcare; Financial Services.

Table 3.12: Siemens Financial Snapshot 2014-2016 (€m)

	2014	2015	2016
Revenue	€71,227	€75,636	€79,664
Net Income	€5,507	€7,380	€5,584

Source: Siemens

Siemens's Wind Power & Renewables, Energy Management and Building Technologies segments were responsible for 31% of the company's revenues for 2013.

Key executives at Siemens include: Joe Kaeser (President & CEO); Markus Tacke (CEO Wind Power & Renewables); Ralf Christian (CEO Energy Management).

ii. Geographic Spread

Siemens operates 289 major production and manufacturing plants worldwide. In addition, office buildings, warehouses, research and development facilities or sales offices are present in almost every country in the world.

iii. Key Clients & Strategic Partnerships

- Siemens has recently held talks with Indian Urban Development Minister M Venkaiah Naidu with regard to integrating Siemens's solutions into India's Smart City Mission.
- In February 2015, the company was selected as a technology partner for the 'Triangulum' project with the aim of applying smart city solutions to urban quarters of the cities of Manchester, Eindhoven and Stavanger. Learnings and successes are intended to be applied in 'follower' cities as part of the project, including Leipzig, Prague, and Sabadell.
- Siemens is a project partner in the ongoing ASC project.
- Siemens signed a partnership in July 2013 with local power companies and development associations to launch a smart city project in Vienna. The project aims to integrate power grids with information and communications technologies to optimise district energy use, leveraging a connection between buildings and the low-voltage network through a control system, while integrating distributed power generation and storage technologies.

- Smart parking solutions vendor Streetline partnered with Siemens in April 2012, enabling the integration of Siemens's parking meters with Streetline's sensors and applications
- In 2010 Siemens partnered with Californian utility Burbank to enable AMI through software, installation and commissioning services.

iv. Products & Services

Siemens has a broad range of solutions for smart city projects and is considered one of the market leaders in terms of smart grid technologies. The company's smart city portfolio is divided into the following categories:

- Building Technologies: Solutions are available for building automation, fire safety and security. Focus is placed on HVAC and energy management via automated processes.
- Mobility: Siemens supplies operational support systems for rail and road systems, while offering numerous solutions for smart traffic management, including a platform for traffic control, smart parking systems, toll systems and infrastructure for urban traffic control.
- Power Distribution: Siemens is highly active in the power grid space and so has hardware solutions for medium and low voltage distribution automation, as well as a 'Totally Integrated Power' software solution for complete integration between distribution lines and buildings.
- Smart Grid: Consulting, services, automation, security, monitoring and control solutions serving the smart grid from end-to-end. Siemens' smart grid products cover both hardware (sensors and controllers) as well as software (management and control technologies).

The company launched its City Performance Tool in September 2015, designed to help cities identify solutions that increase efficiency, reducing emissions and job creation. The system leverages 70 different technologies to advise the most appropriate solution to use for various projects.

In March 2016, the company launched the Mindsphere IoT platform which extracts data from systems to a common platform on a cloud base level, obviating the need to connect different systems together. Martin Powell noted that the company aims to co-create applications on top of the analytics layer with partners like utilities, transport operators and cities themselves: 'You could integrate data from Uber for example with air quality, schools and so on and establish new policies as a result of analysing this data.'

The platform is also connected to the City Performance tool which helps show a city what its emissions are, its air quality and technology choices that will enable job creation.

Additionally, Siemens has developed a methodology for cities that wish to monitor how they are performing against the Paris Agreement as a percentage of the national contribution. This is envisioned as a useful catalyst for connecting infrastructure elements together and making them more efficient through a platform approach, noted Powell.

v. Juniper's View: Key Strengths & Strategic Development Opportunities

- Siemens has a massive global presence resulting in increased brand profile, while it has some 70 city account managers positioned across the Americas, Asia, India and Europe. Combined, this enables Siemens to be highly competitive in the smart city market.

- Its new City Performance Tool could prove invaluable, as many cities may struggle with their existing datasets and future planning projects, with the new software able to help the decision-making process.

3.4.10 SIGFOX

Juniper Research interviewed Maxime Schacht, Marketing Analyst, SIGFOX, April 2016

i. Corporate Profile

SIGFOX was founded in 2009 as a privately held company, with headquarters in Labège, France. The company has specifically targeted IoT communications by utilising antenna and base station infrastructure that can operate independently of other wireless networks.

Although the company does not reveal its financial performance publicly, some $151 million has been raised to date through funding rounds. heavyweight players such as Intel, NTT DoCoMo, SK Telecom and Telefónica contributing to the latest $115 million series D funding round, concluded in February 2015.

SIGFOX currently employs 215 people, the majority of whom are engineers. Key executives include Ludovic Le Moan (CEO); Christophe Fourtet (Scientific Director); Roswell Wolff (President, APAC).

ii. Geographic Spread

Aside from its Labège headquarters, offices are located in France, Spain, UAE, the US and Singapore. Operations are currently focused on expanding services all across the world, priority being given to Europe, the US, Latin America and Asia. Large country coverage has been achieved in the Netherlands, the UK, Spain, Portugal and France while rollout is ongoing in the US, Belgium, Czech Republic, Denmark, Ireland, Italy, Luxembourg, Australia, New Zealand and Oman. SIGFOX aims to cover 60 countries by 2018.

iii. Key Clients & Partnerships

- Partnerships are in place with numerous silicon and module vendors, such as Libelium, On Semiconductor, Amtel, Samsung, Texas Instruments, Silicon Labs and Telit. SIGFOX has made its IP available at no cost to silicon and module vendors to rapidly expand the compatible device ecosystem.
- SIGFOX network operator partnerships have been established with Thinxtra (Australia), Engie M2M (Belgium), WND (Brazil), Simple Cell (Czech Republic), IoT Denmark, IDEO Caraïbes (French Antilles), VITI (French Polynesia), VT Networks (Ireland), NetTrotter (Italy), RMS (Luxembourg), Thinxtra NZ (New Zealand), Omantel (Oman), Narrownet (Portugal), IO Connect (Réunion/Mauritius/Mayotte), Cellnex (Spain), AEREA (Netherlands) and Arqiva (UK)
- The company announced a partnership with Microsoft in March 2016, with SIGFOX connecting to the Azure IoT hub, enabling a cloud-based visualisation and analytics platform for connected devices.
- Also in March 2016 a partnership was established between SIGFOX, Altice and the latter's subsidiary SFR, to offer SIGFOX as a LPWA connectivity solution for M2M customers.
- Further telco partnerships are in place with the likes of Tele2 and T-Mobile.

iv. Products & Services

SIGFOX has focused on providing wireless communications technology for IoT applications, where the understanding is that most devices do not transmit large data frames during their duty cycle, so do not require a high-bandwidth network to operate efficiently. Its long range and signal propagation qualities mean that SIGFOX is classified as a LPWA technology, with correspondingly low power consumption suitable for long-term operation of battery-powered devices.

The core of SIGFOX's solution centres on the establishment of narrowband wireless communications networks for IoT devices, with the technology based on World War 1 submarine signalling technology. The network itself, therefore, only requires investment measured in millions of dollars to cover a country, while traditional cellular network investment runs into billions of dollars.

The technology itself, as noted, is supplied *gratis* to hardware OEMs; the business model operates through the on-boarding of devices to the SIGFOX network, where revenue is generated per device and by messaging volume.

- Operating in the globally-available ISM bands (licence free), the technology operates using ultra narrowband radio technology with a star-based cell infrastructure.
- Device management and configuration is enabled via the SIGFOX cloud and API.
- SIGFOX operates as a single network, thus devices deployed across regions can be managed simply. This also means that all devices are governed by a single contract and can therefore be freely moved between regions or where coverage is desired.

v. Juniper's View: Key Strengths & Strategic Development Opportunities

- SIGFOX's key strengths lie in the fact that infrastructure deployment, as well as total cost of ownership, is very low compared with alternative solutions. Meanwhile, the business model offers a far simpler solution to manage than cross-regional cellular M2M subscriptions. It will need to leverage these advantages to establish its network before cellular technologies such as eSIM and NB-IoT are ubiquitous, as these will offer very strong competition.
- Meanwhile, the fact that SIGFOX is the single owner of the network creates an element of risk for stakeholders as, at this nascent stage of the IoT, the future of connectivity solutions is not set in stone. Guarantees must be offered, if possible, to safeguard the continued operation of the network to ensure that the solution is future-proof.

3.4.11 Silver Spring Networks

Juniper Research interviewed Brandon Davito, VP Smart Cities business, Silver Spring Networks April 2016

i. Corporate Profile

Silver Spring Networks was founded in 2002 and began life as Real Time Techomm before changing to the present company name shortly thereafter. The company was privately held until its stock market floatation in 2013; its headquarters are San Jose, US.

652 individuals work for the company, 90% of whom are located in the US. Key executives include Michael Bell (President & CEO); Jim Burns (EVP & CFO); Eric Dresselhuys (EVP Global Sales).

In May 2014 the company announced the acquisition of Streetlight.Vision for an undisclosed sum. The acquisition enables Silver Spring to offer software and control solutions for networked street lighting.

Table 3.13: Silver Spring Networks Financial Snapshot 2014-2016 ($000)

	2014	2015	2016
Revenue	$191,288	$489,559	$311,008
Net Income (loss)	$(89,170)	$79,986	$(21,629)

Source: Silver Spring Networks

ii. Geographic Spread

The company operates from offices in Brazil, Australia, the UK, Singapore and the US, with customers located in the US, Canada, Australia, New Zealand, South America, Asia and Europe.

iii. Key Clients & Partnerships

Silver Spring has a number of important partnerships in place across various elements of the smart grid, a selection of whom are listed below:

- AMI: Itron, Landis+Gyr, Master Meter
- Demand-Side Management: AutoGrid, Tendril
- Distribution Automation: Advanced Control Systems, Dynamic Ratings, Sentient, Siemens
- Software: Bidgely, SmartGridCIS
- Street Lights & Smart Cities: Acuity Brands, Philips, Rongwen, SELC, Samsung, urbancontrol

Meanwhile the company received strategic investment from Hitachi and EMC prior to its IPO in 2013.

iv. Products & Services

Silver Spring's core business revolves around the deployment of an open standards-based solution suite, SilverLink, provides connectivity and control on a unified multi-application network purpose built for the IoT. Targeted at utilities and cities, SilverLink offers solutions for electricity, gas, water and smart city applications. According to Silver Spring's VP of Smart Cities, Brandon Davito, the company has connected over 23.6 million devices across 5 continents thus far.

- SilverLink Network Platform: A combination of access points, bridges, relays, edge routers, street lights and SilverLinkOS network operating software. The platform is designed to provide a connectivity solution for intelligent infrastructure devices and applications. The SilverLink Network Platform leverages IPv6 to ensure future-proof interoperability with third party devices and software using IP networking.

  Silver Spring recently launched Starfish, an international, public wireless IPv6 network service for the IoT. Starfish provides secure, reliable and scalable connections to devices and sensors by building on the IEEE 802.15.4g wireless protocol (Wi-SUN). Starfish enables commercial

enterprises, cities, utilities and developers to access data created by endpoints and to create insights from these data to improve efficiencies and quality of life.

- SilverLink Control Platform: A network management solution used to provision, operate and troubleshoot a Silver Spring network. The SilverLink Control Platform includes back-office tools for managing network performance, upgrading device firmware over the air and administering end-to-end security across each device and application layer of the network.

- SilverLink Data Platform: A data warehouse solution that ingests, organises and visualises data for analysis. The SilverLink Data Platform provides access to near-real-time and historical data using standard APIs, enabling a variety of advanced analytics applications from Silver Spring, third party solution developers and internal analytics teams. Working in concert with Silver Spring's SensorIQ technology, the SilverLink Data Platform creates parallel data pathways to pull data from any smart grid or smart city device without affecting critical business processes.

- SilverLInk Applications: An ecosystem of applications developed by Silver Spring, third party solution providers and internal utility/city IT teams. SilverLink Applications offer a range of solutions for utilities and cities, covering all aspects of operations from consumer engagement and grid management to street light control and smart parking.

v. Juniper's View: Key Strengths & Development Opportunities

- Silver Spring is able to compete across several elements of the value chain, where its partnerships are key in strengthening its position.

- Its decision to use an open standards based platform is less risky for cities which have shied away from smart city projects in the past due to proprietary solutions. This is particularly important in the street lighting sector, where the potential versatility that smart street lighting offers in terms of services means that open approaches are fundamental.

3.4.12 Streetline

Juniper Research interviewed Kurt Buecheler, SVP Business Development, Streetline, April 2016

i. Corporate Profile

Streetline was founded in 2005 and is owned by Kapsch of Austria, so its financial performance is not revealed individually.

Its headquarters are in Foster City, US. Key executives include Manny Krakaris (President and CEO): Mark Noworolski (CTO); Scott Dykstra (VP, Operations).

ii. Geographic Spread

Streetline operates from offices located in the US, the UK and Germany.

iii. Key Clients & Strategic Partnerships

- Streetline has several partnerships with key smart city service providers, including Cisco, Citi, IBM, Siemens and Telefónica, among others.

- In July 2013 the company partnered with Orange Business Services, with the latter responsible for the commercialisation, deployment and support of the service in France.
- Streetline partnered with IBM, Eseye and Amey in January 2013 with the aim of deploying a smart parking solution in the city of Birmingham, UK.

iv. Products & Services

Streetline has taken a platform approach to smart parking, offering a combination of hardware, software and analytics to provide a full smart parking solution.

At the heart of the portfolio is Streetline's sensing hardware, consisting of magnetometer sensors combined with light variance detectors, designed to be embedded into the road. The platform is also able to integrate with various other forms of parking space monitoring, including:

- Cameras, which also offer cities the option of adding surveillance for security purposes;
- Wi-Fi and Bluetooth detection, analysing the movement of mobile devices to determine occupancy levels;
- Sensor inputs can be integrated and analysed to determine the probability of a space being occupied. Owing to the system's high level of accuracy, deployments of expensive embedded road sensors can be reduced to a ratio of 1:10 across monitored parking spaces.

The company also distributes its own app, Parker, which advises drivers of real-time parking space availability and cost. Access to the data is not closed however, with third parties able to access occupancy and price via an API.

Meanwhile merchants and enforcement can leverage tools to integrate parking data into their websites or internal systems, enabling the former to potentially increase footfall, while the latter is able to reduce the number of man-hours required to monitor parking space violations.

v. Juniper's View: Key Strengths & Development Opportunities

- Although Streetline has not reached the scale of many other vendors profiled in this section, it has the advantage of being an early mover in the smart parking market, alongside proven technology showcased by its partners.
- While smart parking solutions were predominantly deployed in North America, Streetline has identified Europe and Asia as key growth markets for these services, so its move into Europe can be viewed as a key opportunity to securing a market-leading position in this region.

Endnotes

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