THE FUTURE OF STREET LIGHTING

The potential for new service development

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INTRODUCTION

Public street lighting is an essential element of urban environment. It affects residents’ sense of safety and social inclusion, improves visibility for motorists, and also creates an inviting environment for business and tourism after dark. While street lighting is undeniably important, one third of the world’s roads are still lit by technology dating back to the 1960s (1), typically consuming approximately 40% of a city’s overall electricity costs. (2)

In recent years, many cities have started to replace their sodium streetlights with energy efficient Light Emitting Diodes (LEDs) based lights, driven by sustainability targets, emerging government standards and the need to reduce costs. When compared to legacy street lighting technologies, LEDs offer longer lifetimes, lower energy consumption and reduced maintenance expenses. LEDs are an economically beneficial alternative to traditional streetlights when energy savings are considered, despite their higher upfront cost. Typical payback periods range from 4 to 12 years. (2) The Northeast Group estimates that 280.2 million LED streetlights will be added over the next ten years, reaching a penetration rate of 89% by 2026. (3)

Unfortunately, switching to LED lighting alone will not be enough to meet cities’ energy consumption and reduction targets. Adaptive, interoperable lighting solutions are needed to bring savings to the next level, facilitated by connecting LED bulbs with a central management system (CMS) over the internet. These networked streetlighting systems allow operators to monitor and regulate light levels in unprecedented ways, resulting in increased energy savings and lower operational costs. The 50% energy savings that are realised by switching to LEDs increase to 80% when connectivity and a central management system (CMS) are added. (2) With a proven business case, a number of vendors are entering the market and many of the world’s largest cities including London, New York, Hong Kong and Sydney are already implementing these connected street lighting systems.

While the energy and cost saving benefits are driving adoption, cities are increasingly seeing infrastructure. With an even and widespread distribution across urban areas, readily available power and integrated connectivity, smart street lighting is being used to form the technology foundation of a city. Through the addition of data collection devices such as...
sensors and cameras, street lighting infrastructure is being used as a platform to host a variety of applications in the areas of environmental monitoring, traffic optimization, smart parking and public safety. Furthermore, street lighting infrastructure is being used to host charging points for electric vehicles, and as a base for public Wi-Fi and communication networks.

Brian Buntz of the Internet of Things Institute provides a useful metaphor: ‘Lamp posts may well follow a trajectory similar to that of mobile phones. It wasn’t so long ago that mobile phones were suited for one purpose only – making calls. Now, making a phone call has become almost secondary to all of a smart phone’s other capabilities. Similarly, while the lamp posts of yesteryear provided only illumination, modern-day lamp post can serve as multi-functional smart-city nodes, capable of monitoring everything from crime to parking to weather.’ (4)

The humble lamp post may well become the most valuable real-estate in the city for future deployment of smart city services. Many pieces of the smart lighting puzzle are already available including low cost, low-power LED lighting, multiple methods of connectivity, multiple sensors and the applications to support them, however, the true potential of the smart lighting infrastructure remains relatively underrated.

This report will discuss the progression of smart lighting infrastructure from the adoption of LED bulbs, to the creation of a distributed smart city platform. It will investigate a number of applications that can be hosted through street lights, detailing use-cases, benefits and potential business models, as well as providing examples of real-life case-studies wherever possible.

Progression of Smart Lighting Infrastructure:
STAGE 1: SWITCHING TO LED BULBS

One-third of the world’s roads are still lit by technology dating back to the 1960s. These streetlights are notoriously expensive, and typically account for approximately 40% of a city’s overall electricity costs. With the threat of crime and anti-social behaviour, turning the lights off is not an attractive option.

In recent years, local authorities are starting to make the switch from traditional sodium bulbs to LED lights, which provide the same amount of lighting, whilst significantly reducing energy usage, and therefore energy costs. LED lights provide a number of benefits including:

**Increased life-expectancy**
LED lights typically last between 20-25 years, compared to just three to six years for conventional lighting. This translates into reduced maintenance costs, fewer lamp renewals and less physical monitoring.

**Demonstrable health and safety benefits**
LED lights are more focused, which improves night-time visibility, reduces light spillage onto residential properties and can reduce vehicle accidents and crime.

**Cost savings**
Significant overall savings are generated from reduced energy usage, protection against rising energy prices, and lower maintenance and inspection costs.

**No upfront costs**
Increasingly financiers are providing funding packages into which all upfront costs are absorbed and repayments are made from energy savings. Typical payback periods range from four to 12 years (including finance costs). Within the UK, the Green Investment Bank has created the Green Loan for Local Authorities, a value for money financing product which can finance all LEDs and CMS capital expenditure including columns. [5]

Progression of Smart Lighting Infrastructure: Stage 1
2.1 MARKET SIZE AND PENETRATION

Global investment in public LED streetlights is expected to reach $57 million over the next decade, with penetration rates expected to reach 89% by 2026. (3) In terms of cost benefits, Philips estimates that a complete switch to LED technology can generate savings of approximately €130 billion. (1)

Many cities are already making the switch. As of 2016, the Northeast Group has identified more than 1,000 unique LED streetlight projects in over 90 countries. Examples of projects include:

- **Boston, USA** converted 40% of its streetlights in 2012, saving the city $2.8 million annually in electricity costs. When factoring in reduced maintenance costs and other savings, the city expects a payback period of less than three years.

- **Peterborough, UK** replaced 400 low-pressure sodium lights with new LEDs, halving its energy costs and reducing CO₂ emissions by nearly 27 tons per year.

- **Madrid, Spain** is retrofitting 225,000 streetlights with energy efficient lamps. The project is expected to cut power consumption by approximately 44% and those savings will be used to finance the investment. (2)

As well as adoption of older street lights, the use of LED streetlights in new streetlights is also gaining traction. In 2012, 10% of new public streetlights were LED based, and this figure is expected to rise to 80% by 2020. (1) In the near term, the largest markets will be North America, Europe and South Asia, with adoption being driven by cities looking to reduce high energy and labour costs.

2.2 BUSINESS MODEL

Currently, the upfront costs of LED street lighting are slightly more than their traditional counterparts. However, when viewed from a lifetime perspective, LED street lighting offers significant cost savings. Therefore, authorities are moving from traditional tendering approaches which have focused on initial costs, and subsequently inexpensive but not necessarily sustainable solutions. Cities are now taking a total cost of ownership (TCO) approach when tendering and investing in infrastructure. TCO takes into account all costs linked to new infrastructure, from initial investment (CapEx) to the operating costs (OpEx) such as maintenance, re-lamping, energy costs and disposal. (1)
STAGE 2: CONNECTED STREET LIGHTING

Switching to LED lighting alone will not be enough to meet cities’ energy consumption and cost reduction targets. Adaptable, interoperable lighting solutions are needed to bring savings to the next level.

Conduct remote monitoring
Control system can reduce maintenance costs by detecting when there is a problem with an LED and raise a service alert. Technicians only have to visit a light when there is a known problem, which removes the need for labour intensive surveillance.

More accurately meter electricity usage
Control systems can also record the power use at each light so the city only pays for the power it uses.

An independent global trial of LED technology in 12 of the world’s largest cities found that while LEDs can generate energy savings of 50%, these savings reached over 80% when LED lighting was coupled with smart controls. (2) A total of $12.6 billion is expected to be invested in smart networked streetlights from 2016-2016 in addition to the $57 billion expected to be invested in LED lighting. (3) Cities that have already invested in connected streetlight systems include:

The city of Eeniend in the Netherlands uses a system which dims LEDs to 20% power when no one is in the area. When a sensor detects movement, the lights switch to full power and alert other lights in the person’s path to brighten as well.

All LEDs are essentially electronic devices that can be connected to central control systems in order to give operators the ability to monitor and regulate light levels in unprecedented ways. Different networks are being used to connect these devices with a CMS including wireless internet connections, radio frequency, GPRS, 3G, power lines and IP. Most commonly network connectivity is low bandwidth, allowing small amounts of information to be sent back to management server at regular intervals.

These communication networks allow lighting network operators to:

Change light levels
Using a control system operators can ‘tune’ their street lights to switch on when fog or rain creates low daylight levels, or conversely dim them when there is too much reflected glare from snow cover. LED street lights can be integrated with motion sensors to switch on lights when pedestrian or cars pass by and public safety personnel can raise lighting levels, or have LED lights flash, at locations where accidents or emergencies have occurred. (2)
A two-and-a-half-year pilot involving some of the world’s largest cities, including New York, London, Hong Kong, Toronto and Sydney, found that combining LEDs with smart controls could result in savings of 85%. (2)

3.1 CONNECTED LIGHTING VENDORS

<table>
<thead>
<tr>
<th>VENDOR</th>
<th>DESCRIPTION</th>
</tr>
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<tbody>
<tr>
<td>Philips</td>
<td>Philips is a global smart public lighting vendor, with its CityTouch management platform deployed in cities around the world including London, Buenos Aires, Rio de Janeiro and Los Angeles. Philips supplies lights, control units for power lines or wireless networks, and a lighting control system.</td>
</tr>
<tr>
<td>Echelon</td>
<td>Echelon is a vendor of generic control platforms, therefore does not supply luminaires, but rather the control systems that work with them. Echelon developed the LonWorks standard, which is used for the automation of various functional within buildings and cities, for example, lighting. By 2010, approximately 90 million devices were installed with LonWorks technology.</td>
</tr>
<tr>
<td>Telensa</td>
<td>Telensa is a specialist provider of street lighting control systems. Similarly to Echelon, Telensa does not supply luminaires, instead providing its own wireless technology and PLANet Central Management System that allows management of lighting infrastructure. The company is also active in parking and vehicle tracking applications.</td>
</tr>
<tr>
<td>Silver Spring</td>
<td>Silver Spring has predominantly been involved in smart meter deployments, however it has recently acquired Streetlight.Vision, a provider of CMS systems for street lighting. Their CMS system can control lights using either power lines or wireless communication networks, and is widely deployed across Europe and Asia.</td>
</tr>
<tr>
<td>GE Lighting</td>
<td>GE provides all components of a smart street lighting system, including luminaires, control nodes, wireless mesh networks and central management systems. Its proprietary platform for managing public street lights is called LightGrid.</td>
</tr>
<tr>
<td>Osram</td>
<td>Osram is a spin-off of Siemens and supplies luminaires as well as full lighting solutions including a management platform called Street Light Control (SLC) which is based on Echelon’s LonWorks technology. Osram’s street lighting solutions have been deployed around the world in cities like Milan.</td>
</tr>
<tr>
<td>Cisco</td>
<td>Cisco offers a Smart+Connected Lighting solution which combines with its Smart+Connected Multi-Sensor Node to create a light-sensory network (LSN). As well as acting as a lighting control system, the resultant platform is capable of gathering a wide variety of data from the environment including levels of humidity, CO₂ and O₂, particulate matter, motion, video and sound. The solution has been piloted in cities including Amsterdam and Nice.</td>
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</tbody>
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Table adapted from Machina Research: The financial case for smart street lighting is strong, and the secondary benefits are extensive (6)
CASE STUDY: FUTURE GLASGOW (29)

In 2013, Glasgow City Council won a Future City Demonstrator competition run by the UK government’s Technology Strategy Board. The city received £24m to showcase a number of smart city projects that aimed to improve the local economy, increase quality of life and reduce the impact on the environment.

The project within the demonstrator programme that has attracted most attention is the city’s smart street lighting trial. The Intelligent Street Lighting Project demonstrated how the city can use smarter streetlights to improve lighting quality, reduce energy usage, improve public safety and make maintenance more efficient.

Gary Walker, Programme Director of the Future City Glasgow Demonstrator, explains that the city ‘replaced the sodium lights with LEDs, then looked at connecting the lights to a central management system over the internet to monitor their performance and trim light levels based on circumstances.’

The lights were deployed in three locations:

- Riverside Walkway: a dynamic lighting system was integrated with movement sensors that reacted to the presence of citizens. Lights would be set to 20% brightness, but would increase to 100% when movement was detected. This aimed to increase safety around the nearby cycle path and open spaces, promoting active travel within the city.

- Merchant City: a dynamic lighting system was deployed in the city’s premier entertainment district to boost the night-time economy by providing a safer environment.

The demonstrators were successful and the resultant business case is so strong that the council is now progressing a project that will retrofit approximately 3,500 columns across Glasgow’s city centre’s street lighting network with more efficient, controllable LED lighting. The project will also incorporate communications infrastructure that will form a Wi-Fi network across the city centre, as well as being used to support SMART systems including Internet of Things (IoT) and Machine-to-Machine communication. The key objective underpinning the project is to create an open standard network which will allow the connection of everyday infrastructure such as bins, vehicles, air quality monitoring and footfall counters, to gather real-time data. The data will be sent to the Council’s data analytics team, and will be used to inform decisions around service provision.

The city also plans to create a Living Lab within the corridor zone of the city.

The project is expected to start and complete in 2018 and will cost around £4m. 40% of the required funding has been secured from ERDF, and the city will fund the remaining 60% via the City Deal Programme.
Cities all over the world are already adopting intelligent street lighting systems. However, they are now starting to see the wider potential of the humble lamp post. Both traditional lamp posts and more advanced smart lighting installations have the potential to act as a smart city platform, enabling a range of other smart city applications through the integration of data collection devices such as sensors and cameras. Lighting infrastructure is being used as a basis for solutions in many areas, however, this report will discuss applications in the following areas:

- Environment monitoring
- Transport optimisation (traffic management and parking)
- Public safety
- Electric vehicle charging
- Wi-Fi and internet provision
- Digital signage and public communication

Street lighting is being used as a platform for these solutions for a number of reasons:

Firstly, they are connected to the power supply, therefore they can provide electricity for attached devices. They also allow sensitive devices to be placed high above the ground, while also providing a bird’s eye view of the surrounding landscape. In the case of intelligent street lighting installations, some degree of connectivity is already in place, which data collection devices can use to communicate. This greatly reduces the cost of deployment for many of the solutions listed above.

Secondly, streets and the majority of street based assets are typically owned by public bodies and are therefore amenable to legislative change. In cases where street assets are managed and operated by private companies, licences are granted for discrete periods of time (usually five years). Within this timeframe change can be ‘mandated’ across the entire network through tendering requirements. (7)

Finally, streets are ubiquitous. They connect the city and are used every day by pedestrians, drivers and users of public transport. Within urban areas lamp posts line the vast majority of streets, providing a dense network of power-enabled, publicly-controlled infrastructure that can host data collection devices.

This report will provide an overview of how street lighting infrastructure is being used to host the solutions listed above, discussing use-cases, benefits, business models and providing examples of real-life deployments wherever possible.
THE FUTURE OF STREET LIGHTING
The potential for new service development

- SMART LIGHTING
  - LED
  - Photocell control
  - 0-100% dimming
  - On-demand lighting

- CONCEALED SPEAKERS
  - (music, alerts)

- IMAGE SENSING
  - Image sensing
  - Proximity
  - Parking monitoring
  - Public security

- ENVIRONMENTAL SENSING
  - (Air quality, noise)

- WI-FI, MOBILE & MESH

- DIGITAL SIGNAGE
  - Way finding
  - Traffic direction
  - Civic direction
  - Revenue potential

- CHARGING POINT
  - (eVehicle / eBike)

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THE FUTURE OF STREET LIGHTING
The potential for new service development

4.1 ENVIRONMENT MONITORING SOLUTIONS

A common starting point in a city’s journey to develop new services on top of smart lighting infrastructure is to integrate sensors. Utilising existing infrastructure significantly reduces the cost of deployment for dense sensors networks, and can provide the sensors with power removing the need for expensive battery replacement programs.

The sensors, coupled with high-bandwidth networking, enable researchers to collect, monitor, analyse and make decisions based on granular, real-time information. This information can be used not only to make lighting improvements, but also for environmental monitoring purposes. A range of sensors have been integrated into street lighting infrastructure including:

- Lighting: ambient light and UVA/UVB
- Temperature
- Motion
- Pressure
- Humidity
- Noise
- Air quality
- Radiation
- Precipitation
- Wind

Business cases are still emerging for many of these sensor types, however many sensors types, such as air quality sensors, are already being integrated into lighting infrastructure, driven by legislative requirements.

Use-Case 1: Air Quality Sensor Integration

The World Health Organisation (WHO) has revealed that more than 80% of people living in urban areas that monitor air pollution are exposed to air quality levels that exceed safe limits. (8) Air pollution is a major environmental risk to health, with approximately 40,000 deaths in the UK being attributed to outdoor pollution every year. Therefore, by reducing the level of air pollution, cities can reduce the burden of diseases such as stroke, heart disease and lung cancer, as well as chronic and acute respiratory diseases. Health problems caused by air pollution have a high cost to society, businesses and the health service, totalling over £20 billion every year. (9)

In Europe, all countries in the European Union are required to comply with Directives, such as the Air Quality Framework Directive, which describes the basic principles for assessing and managing air quality in the member states, as well as listing the pollutants for which air quality standards and objectives will be developed and specified in legislation.

In response to these directives, conventional approaches to air quality monitoring are based on networks of static and sparse measurement stations. However, these stations are not able to capture temporal-spatial heterogeneity or identify specific pollution hotspots, which are required to develop robust real-time strategies for exposure control and interventions. (10)

In order to gather more granular data on air pollution, many cities around the world are adopting mobile laboratories to collect air quality data for specific purposes such as for testing the implementation of a mitigation plan, evaluating a traffic management plan or carrying out feasibility studies. (10) While this approach is an improvement, it is often only used for specific purposes and there remains a need to have access to continuous, real-time data on air quality.

Recently, cities have been implementing dense networks of low-cost sensors. This is expected to provide more accurate data around conditions, leading to more robust and reliable conclusions about air quality levels, and more informed decisions about required interventions. These dense sensor networks can be created by attaching air quality sensors to smart lighting infrastructure, as lamp posts are distributed throughout urban areas, and are typically next to roads which are pollution hotspots.

The use of lighting infrastructure also solves another problem in that it can increase the lifetime of the air quality sensor as power can be provided. Previously, the lifetime of an air quality sensor was between six months and three years before battery replacement or maintenance activities would have to be conducted. (10) In addition to creating dense networks of air quality sensors using street lights, cities have also been investigating attaching sensors to moving vehicles such as buses in order to get a more complete dataset.
Use-Case 2: Noise Sensor Integration

Noise can have a detrimental effect on health, wellbeing, productivity and the natural environment. It is estimated that the annual social cost of urban road noise in England is £7-10 billion. For comparison, this places it at a similar magnitude to road accidents (£9 billion). A report published by the World Health Organisation in March 2011 identified environmental noise as the second largest health risk in Western Europe. (11) For these reasons, the business case for the deployment of noise sensors across cities is gaining prominence, and integration into existing street lighting infrastructure allows for a low-cost deployment of a dense network of sensors.

Use-Case 3: Motion Sensor Integration

Motion sensors are increasingly being hosted on lamp posts due to the wide variety of applications they enable. Firstly, they are being integrated with smart lighting systems to enable lighting levels to be automatically adjusted based on pedestrian and vehicle flows. For example, Dubai has fitted their smart lighting luminaires with motion sensors which detect traffic movement and react accordingly. If there are no vehicles, the lights remain at 25% output, but if cars approach, the output is increased to 100%. As all the lights are wirelessly linked to each other, the surrounding lights also come on, and only go back to 25% once the vehicle has passed (12). This builds on the original smart lighting business case, increasing energy savings and reducing associated costs. Similar applications have been developed that react to pedestrian movements as well as vehicle traffic. Motion sensors are also being used for more advanced applications such as counting pedestrians, cyclists or cars, monitoring for congestion, or even triangulating gunshots. These applications will be discussed in more detail in the following sections.
CASE STUDY: CHICAGO ARRAY OF THINGS (30)

The Array of Things (AoT) is an urban sensing project in Chicago. Launched in summer 2016, a network of interactive modular sensor boxes will be installed on lampposts around Chicago to collect real-time data on the city’s environment, infrastructure and activity. With 500 nodes expected to be installed by the end of 2018, the Array of Things will essentially serve as a ‘fitness tracker’ for the city, measuring factors that impact liveability such as climate, air quality and noise.

The nodes will initially measure temperature, barometric pressure, light vibration, carbon monoxide, nitrogen dioxide, sulphur dioxide, ozone, ambient sound intensity, pedestrian and vehicle traffic and surface temperature. Continued research and development will help create sensors to monitor other urban factors of interest such as flooding and standing water, precipitation, wind and pollutants.

The data collected will be made publicly available to allow researchers, policymakers, developers and residents to work together and take specific actions that will make Chicago and other cities healthier, more efficient and more liveable. In order to alleviate privacy concerns about the data collection effort, the project is making its data available for review to citizens through the city’s data portal.

As the data will be made freely available, it is also hoped that it will support the development of innovative applications. Examples of applications that could be created include:

- An application that combines air quality, sound, vibration and temperature data to suggest the healthiest and unhealthiest walking times and routes.

- An application that determines which areas of the city are heavily populated at different times of day to suggest safe and efficient routes for walking late at night.

The Array of Things is being delivered by a team including the City of Chicago’s Department of Information and Technology and Department of Transportation, as well as organisations such as Cisco and Qualcomm. The project is being funded by a $3.1 million grant from the National Science Foundation and additional investments from Argonne and the Chicago Innovation Exchange.
4.2 TRANSPORT OPTIMISATION SOLUTIONS

A Smart street lighting infrastructure is increasingly being used to facilitate a number of smart transport optimisation solutions, that aim to reduce congestion and increase the efficiency of urban transport systems.

Congestion is a growing issue in urban areas. A study from INRIX and the Centre for Economics and Business Research has found that between 2013 and 2030, the total cumulative cost of congestion to the UK economy is estimated to be £307 billion, with the annual cost of congestion expected to rise by 63% to £21.4 billion over the same period. (13) This rise is largely driven by an increased demand for road travel due to population growth and increasing GDP per capita as the UK economy continues to strengthen. While per capita car ownership is predicted to decrease over this period, population growth will still lead to a greater number of vehicles on the road.

In urban areas, 30% of all traffic congestion is caused by drivers looking for parking spaces, resulting in tons of extra carbon dioxide being released into the city environment. Furthermore, poorly managed parking has been shown to reduce the number of visitors to town centres, which in turn leads to lower revenues for local businesses. (14)

**Uses of Smart Lighting Infrastructure**

By installing cameras and sensors on lamp posts and utilising the available connectivity, a number of providers have developed innovative smart parking and traffic optimisation solutions.

**Use-Case 1: Smart Parking Solutions:** (15)

Specific capabilities of these solutions include:

- **Parking guidance:**
  - Provision of real-time parking availability information through the smartphones of drivers or digital signs
  - Provision of parking rates and policy information for drivers

- **Parking enforcement:**
  - Detection and reporting of payment and overstay violations using sensors, cameras and payment information.
  - Detection and reporting of no-parking zone and loading zone violations using video analytics.
  - Creation of optimum routes for enforcement officers to maximise effectiveness.

- **Parking analytics:**
  - Real-time maps and long-term data around parking occupancy, revenue and enforcement which can be used to inform parking policy and pricing decisions.

*Diagram from Cisco Smart+Connected Parking Solution Whitepaper (15)*

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Cisco Smart+Connected Parking Solution in Action
Use-Case 1: Smart Parking Business Case

Drivers:

- Increased revenue through increased parking space utilisation
- Increased revenues through improved capture rates and tickets issued for parking violations
- Higher enforcement officer productivity
- Improved success rates in parking ticket disputes
- Additional revenue from pricing changes evidenced by data gathered and analysed by the solution

City benefits:

- Increased revenue through increased parking space utilisation
- Increased revenues through improved capture rates and tickets issued for parking violations
- Higher enforcement officer productivity
- Improved success rates in parking ticket disputes
- Additional revenue from pricing changes evidenced by data gathered and analysed by the solution

Citizen benefits:

- Reduced time spent looking for parking spaces, leading to time and fuel cost savings
- Less congestion in urban areas and general improvement in quality of life.

Use-Case 2: Traffic Optimisation Solutions:

Through the installation of cameras and sensors (predominantly sound and movement) on lamp posts a number of traffic optimisation solutions can be enabled. Features of these solutions include:

- Traffic monitoring:
  Lamp post mounted cameras can be used to provide views of live traffic conditions. Information can be used to re-route drivers away from congested areas using digital signage.
- Incident Detection and Management:
  Cameras and video analytics can be used to detect and verify traffic incidents.
- Traffic analytics:
  Video data collected and analysed over time can be used to inform future transport planning decisions.

Diagram from Cisco Smart+Connected Traffic Management Webpage (16)
Use-Case 2: Traffic Optimisation Business
Case Drivers:
City Benefits:
• More efficient traffic flow
• Less pollution and other environmental impacts
• Better visibility into traffic conditions
• More informed infrastructure investments

• Automated incident detection and quicker responses

Citizen Benefits:
• Improved road safety
• Less congestion, leading to reduced frustration and fuel costs
• Better driving experience

CASE STUDY: EXETER (31)

Exeter City Council and Devon County Council are deploying IoT sensors in lamp posts with the aim of easing congestion and reducing emissions. The ‘Engaged Smart Transport’ project uses real-time traffic and weather data collected from sensors on lamp posts, combined with other data sources such as eyewitness and behavioural information to better understand the factors affecting people’s travel behaviour. In essence it is attempting to understand where and why congestion happens in order to identify potential solutions.

The project is being funded by InnovateUK and delivered by a consortium consisting of NTT Data, Imtech (intelligent transport system provider), Vaisala (environmental IoT sensor provider), the University of Exeter (behavioural research) and Black Swan (social media data analytics).

VENDOR PROFILE: CLEVERCITI (14)

Cleverciti Systems was founded in 2012 in Munich, Germany and its sensor technology allows cities and parking operators to manage their on-street parking in a smart and efficient way.

Patent-pending sensors are mounted on facades, lamp posts and masts, analyse parking spaces along a street and send real-time data about the availability states to the Cleverciti ‘cockpit’ and public facing smartphone app. A single Cleverciti sensor can cover up to 100 parking spaces with a range of up to 400m and 320-degree rotation capability. With average installation times of under 20 minutes, Cleverciti sensors are ‘plug and play’, meaning they are mobile and can be relocated with ease, requiring no roadworks. Cleverciti sensors are fully compliant with privacy rights.

With just over one year on the market, the Cleverciti parking sensors have proven to be effective for several cities. The first city to adopt them was Bad Hersfeld, Germany, where Cleverciti installed six sensors, covering the whole city centre. Since then, sensors have been installed in Rotterdam and will soon be deployed in The Hague, Helmond and Cologne.
4.3 PUBLIC SAFETY AND SECURITY SOLUTIONS

The British Crime Survey has stated in a recent report that crime trends in England and Wales have been decreasing over the past two decades, particularly in the two main crime categories of burglary and vehicle theft, where rates have fallen by 57% since 1995.

Despite these promising trends, it is still widely appreciated that urban areas suffer from higher levels of crime than rural areas. A recent report released by the UK government stated that the rate of violence against a person was 7.2 per 1000 people in predominantly rural areas, compared with 12.3 per 1000 people in predominantly urban areas. Similarly, the rate of sexual offenses, robbery, domestic burglary and vehicle offenses was also significantly higher in urban areas. (17)

Furthermore, with many countries across Europe and further afield on high alert due to threats of terrorism, many cities are adopting more advanced public safety and security solutions.

Use of Smart Lighting Infrastructure:
Public safety and security technologies such as CCTV cameras have long been commonplace in urban environments. Many of these installations will require upgrading in coming years, and many cities are choosing to leverage their smart lighting infrastructure to deliver public security and safety solutions in order to reduce deployment costs and deliver new services through integration with other data collection devices.

To meet this increasing demand for safety and security systems, some lighting providers now offer smart lighting systems with modules that incorporate surveillance cameras, audio recorders and various sensors. These tools enable authorities to record and review activity...
on city streets. For example, cameras can work with sensors embedded in lamp posts to detect suspicious sounds such as gunshots, or to detect abnormal airborne particulate matter from fires. These solutions are often deployed in frequently vandalised areas, accident-prone road junctions and high-crime neighbourhoods and their mere presence can act as a deterrent.

Other vendors are offering systems that integrate features that help authorities and citizens respond to emergencies. Vendors such as Lumewave and Intellistreets let cities add emergency call buttons to their lamp posts that allow someone witnessing a traffic accident or a crime to report the event. In the Dutch city of Eindhoven, the street lights can be programmed to flash red to warn residents of road incidents or poor road conditions. (2)

CASE STUDY: OTTAWA (2)

In response to vandalism and illegal drug use in Cahill Park, Ottawa, the city installed a light-pole mounted surveillance system which included an intrusion alarm panel, motion detector, loudspeakers and digital video recorder that activates once the park is closed. When the motion detector picks up activity within a defined area, it notifies the city’s security operations centre and directs the camera to focus on the activity. Operations centre personnel can then determine what type of response is required. Since the system has been installed, the number of calls to police related to the park fell to zero.
VENDOR PROFILE: SHOTSPOTTER CRIME DETECTION AND LOCATION SUITE (33)

According to the National Gunfire Index, only 1 in 10 shooting incidents in the USA are reported to the authorities. When incidents are reported, it is often too late to respond and the information provided is imprecise.

The ShotSpotter™ gunfire detection and location technology is developed by American technology company, STT Inc. GE Lighting recently signed an agreement with STT to incorporate the gunfire sensors into their LED street lighting systems. This integration is expected to differentiate GE in the market, while significantly reducing cost of deployment for the gunfire sensors.

ShotSpotter functionality:

- **Connection**
  ShotSpotter sensors and software are embedded in intelligent GE LED fixtures and deliver real-time and accurate gunfire detection information to cities.

- **Detection**
  Real-time gunfire detection provides critical event data to responders such as precise location of incident and number of shots.

- **Response**
  Alerts are broadcast to emergency and dispatch centres, patrol cars and even responder smartphones, enabling them to arrive on the scene swiftly with more precise and accurate information to better protect the community in an emergency situation.

Specific benefits of the system include:

- Real-time access to maps of shooting locations and gunshot audio
- Actionable intelligence detailing the number of shooters and the number of shots fired
- Pinpointing precise location for first responders aiding victims, searching for evidence and interviewing witnesses.

ShotSpotter is already working in more than 90 cities including New York City, Washington DC, San Francisco and Kansas City. Since the system was installed San Francisco have reported a 50% decrease in recorded firearm violence. (19) Initial installations are typically funded through grants and ShotSpotter provides funding consultants to help cities secure required grants. Before integration with GE’s LED lights, the technology was purchased using a subscription-based service model. It is unclear if this will change following the partnership with GE.
CASE STUDY: UNIVERSITY OF ILLINOIS (34)

The University of Illinois has developed two public safety applications using their smart street lighting infrastructure. The first is an integrated emergency response button, and the second is an application which determines the safest route to walk at night.

**Integrated Emergency Response**

The university has equipped streetlights with emergency buttons that are integrated with on-campus security response teams. The system comprises a physical button and corresponding software component. Once pressed, emergency responders are notified and the application helps responders to locate the emergency by pulsing nearby street lights. The lights pulse from 10% to 100% brightness, creating a visible signal to both pedestrians and emergency responders. The visual cue is designed to facilitate the faster arrival of responders.

**SafeWalks**

SafeWalks is a mobile application provided to University of Illinois students, faculty and staff that addresses the daily concern of people who may feel unsafe when walking at night. By utilising the network infrastructure from smart street lights and integrated pedestrian-counting video sensors, SafeWalks is able to determine the safest walking path through campus. SafeWalks uses Google Maps API for directions and maps the real-time pedestrian traffic data collected through Placemeter sensors. Placemeter uses public video feeds and computer vision algorithms to return real-time routing advice for pedestrians. The safest route is determined by the highest amount of pedestrian traffic. Lastly, SafeWalks sends the traffic data to the streetlight controller to ensure the streetlights on populous walkways emit greater brightness on the streets.

Future areas of development include:

- Incorporating crime rates and block-wise weather updates for each street
- Enhancing streetlight adaptive brightness capability by predicting pedestrian traffic using historical data.

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Placemeter generates pedestrian and vehicle counts and location intelligence by applying proprietary cloud-based algorithms to video sensor streams. (Right: Example of Placemeter in action in New York City)
4.4 PUBLIC WI-FI AND INTERNET PROVISION

Local governments are providing free public Wi-Fi for several reasons. Some cities, such as Aberdeen, are deploying a network with the aim of addressing the issue of social inclusion by bridging the digital divide. Others, such as Bristol, have created a wireless mesh network over which Internet of Things (IoT) devices can communicate, with ambitions of catalysing innovation. The second example is using lamp posts distributed across the city to host this wireless mesh network, citing cheaper deployment costs as a key driver behind this decision.

More recently, lamp posts have been used more innovatively to provide connectivity in urban areas. According to an Ericsson Mobility Report, mobile traffic data is expected to grow nine times by 2020 and current telecoms infrastructure is struggling to respond to this demand, due to difficulty in acquiring sites to host infrastructure in dense urban areas. (18) In order to support this traffic growth, mobile operators are offloading data to distributed small cells. It is projected that by 2020, mobile operators will offload 40-50% of data capacity for LTE (4G) and high-speed Wi-Fi by 2020. In the scenario where multiple service providers will be hosting from the same infrastructure, it is estimated that over 50% of 4G/5G traffic may be offloaded. (19)

These small cells have typically been hosted on their own masts, however, Siemens and Philips have created an innovative solution which integrates small cells with smart lighting infrastructure. The regular and dense distribution of lamp posts throughout urban areas provides an ideal framework for networks of small cells. In the future, this increased and consistent connectivity could be used to facilitate the deployment of autonomous vehicles.
CASE STUDY: LOS ANGELES (18)

Philips’ SmartPole street lighting infrastructure with fully integrated 4G LTE wireless technology from Ericsson. The collaboration aims to provide high quality, public lighting that is energy efficient, as well as improved network performance in dense urban areas.

Ericsson and Philips believe they have developed a solution to this problem by integrating Ericsson small cells within Philips SmartPoles to provide optimal urban coverage and a future-ready network. The solution makes bulk site acquisition possible in cities, enabling the widespread and consistent deployment of 4G LTE broadband services, with minimal visual impact.

The solution allows city authorities to sell space within their connected lighting poles to network service providers for mobile broadband infrastructure, creating a new revenue stream for the city and accelerating payback time of the initial investment. Therefore, this solution solves two issues simultaneously; offering city officials an innovative way to afford next generation energy efficient LED lighting to meet sustainability goals, and enabling network operators to offer improved city-wide mobile broadband and app coverage.

Furthermore, the availability of high-quality connectivity and the presence of the smart street lighting infrastructure facilitates the addition of other innovation applications. Potential applications include electric car charging systems, environmental sensors, surveillance equipment and digital advertising boards.
CASE STUDY: BRISTOL IS OPEN – IOT MESH NETWORK (35)

The Bristol is Open project is a joint venture between the University of Bristol and the city council. The project has created a sophisticated digital research infrastructure across the city. The network comprises a ring of super-fast broadband and an IoT ‘mesh’ network created from access points mounted on 1,500 street lamp posts across the city. It uses self-regulating advanced wireless technologies for extending connectivity. It is designed to accommodate high volumes of low bandwidth applications such as sensors.

The mesh will enable IoT devices to be implemented at scale, providing a test facility to network operators, application developers and device manufacturers. Partners in this project will be able to experiment and develop new solutions to address the challenges of modern life. These could involve leveraging machine-to-machine communications or internet of things technologies to control complex traffic signals or monitor the health of citizens. Ultimately, the project aims to create an open programmable city which can be used to develop new solutions to make the city work better.

4.5 ELECTRIC VEHICLE (EV) CHARGING

Electric vehicles (EVs) are those that use electric motors for propulsion. While conventional internal combustion engine (ICE) vehicles use the combustion of fuels (traditionally fossil fuels) for propulsion, EVs use an electric battery which must be recharged by plugging it into a socket.

The most obvious benefit of EVs is the reduction of Greenhouse Gas (GHG) emissions. In London, road transport is responsible for 66% of particulate emissions and 42% of NOx emissions. Research has shown that for each conventional car displaced by an EV, 1.5tons of CO2 per year are saved from being released into the atmosphere. This represents a 62% reduction compared to a petrol-powered car, and a 53% reduction compared to a diesel-powered car. Even when looking beyond emissions from exhaustion, and taking into account the full energy value chain (for example, electricity production for charging), EVs remain superior in terms of emission reductions (20).

Driven by these benefits, the global electric vehicle market is expected to reach $110bn (£72.7bn) by 2019 (21).

Regional Penetration (22)
Adoption of electric vehicles is being driven by several western European countries as well as the USA and China.

Norway:
Norway has the highest level of electric cars per capital in the world, with over 105,000 on the road as of May 2016. With its relatively small population of approximately 5 million people, this translates to 24% of cars in Norway being electric. This high adoption rate has been driven by compelling government incentives. For example: electric cars are exempt from traditional vehicle fees and taxes which, conversely, are very expensive for traditional ICE vehicles. These incentives make the price of owning an EV comparable to traditional cars.
Furthermore, energy production in Norway is almost 100% renewable, enabling free charging for all EVs.

Looking to the future, Norway has plans to ban sales of new diesel and petrol cars by 2025, and has also announced that from 2019, ICE cars will be banned from the centre of Oslo to reduce pollution.

**Germany:**

Germany has also announced plans to ban the sale of non-electric cars by 2030 with the aim of reducing emissions by 80-95% by 2050. As of May 2016, Germany has approximately 60,000 EVs on the road, however due to the country’s bigger population, electric vehicles account for less than 1% of the 45 million cars on German roads.

The German government aims to have one million EVs on the road by 2020, and has funded a €1 billion programme to subsidise the costs of EVs and to make the electric car ‘mass market capable.’ Subsidies of €4000 are available per EV and €300 million will be spent on upgrading electric car charging stations and expanding the network in German cities and on the autobahns.

**Netherlands:**

The Netherlands is another leader in the adoption of EVs. As of June 2016, the Netherlands has over 94,500 EVs registered in the country and is on track to meet its target of 200,000 electric vehicles by 2020. It has an overarching target of one million EVs registered on Dutch roads by 2025. In the same way as Norway, the Dutch are also planning to ban the sale of petrol and diesel cars by 2025. While these plans remain in the ideation stage in Norway, in the Netherlands the plans have already passed through the Parliament’s lower house, and are therefore likely to become law in the near future.

**USA**

As of June 2016, the USA has 474,000 registered EVs. With over 253 million cars and trucks on US roads (as of 2014), the electric vehicle market has a long way to go in order to make an impact on sales of traditional petrol and diesel vehicles. However, a real impact is being seen in the state of California, home to Tesla, which has over 200,000 EVs registered. This number is more than the number of EVs in the Midwest, Northeast and Southern areas combined. To encourage the adoption of EVs outside of California, the Obama administration planned to invest up to $4.5 billion in electric car infrastructure, including the creation of a coast-to-coast network of electric car charging stations. It is unclear whether this investment will continue with the new administration.

**China:**

In 2016, China emerged as the biggest market for EVs in the world, with sales expecting to reach 700,000 vehicles by the end of the year. Sales are expected to reach three million a year by 2025. Reducing emissions through encouraging the adoption of EVs is an important target for China in order to mitigate further environmental damage. In 2016, more than 80% of China’s underground water was deemed unsafe to drink due to pollution. Additionally, air pollution is proving costly for China, with the country losing approximately 6.5% of its GDP as a result of pollution-related costs such as low productivity and having to close factories when the pollution reaches untenable levels. In order to drive adoption, China is considering imposing mandates requiring carmakers to produce or import more EVs to meet CO₂ emission reduction targets.

**UK**

Approximately 80,000 EVs are registered in the UK as of June 2016, with numbers being boosted in recent years by the government’s Plug-in Car Grant which provides a 25% grant towards the cost of new EVs, capped at £4,500. London remains the only area of the UK that is not predicted to meet pollution level targets by 2025. To rectify this, London Mayor Sadiq Khan has announced plans to extend the Ultra-Low Emissions Zone to the North and South Circular roads from 2020, as well as impose additional charges on all petrol and diesel vehicles. In addition to penalising the ownership of traditional vehicles, London is also incentivising ownership of EVs through congestion charge exemptions and expansion of charging infrastructure.
Barriers to large-scale adoption of EVs
As demonstrated by the above, it is widely accepted that electric vehicles are the future of the motor industry, however there are a number of barriers inhibiting widespread adoption.

Upfront costs:
A policy options paper written for the Clinton Climate Initiative states that the biggest barrier to large-scale EV adoption is the high upfront cost of an EV in comparison with traditional alternatives. Despite Total Cost of Ownership (TCO) showing that EVs are more cost effective over time, it is often this initial outlay that deters adoption. In response to this, many governments are providing subsidies for EVs to counteract these initial costs. In the future, it is expected that EVs will reach price parity with traditional vehicles and this barrier will be reduced. (20)

Range anxiety:
The driving range of EVs on a single charge is a significant concern for drivers due to their fear of being stranded if the battery capacity is not sufficient to get them to their destination or a charging point. OEMs are responding by increasing battery capacities, with some allowing 100 miles to be driven on a single charge. Other OEMs have developed emergency mechanisms which allows for limited reserve battery power to be called upon if stranded. (24)

While increases in battery capacities will go some way to reduce this barrier, the most effective response is likely to be improvements in the public charging infrastructure network.

Availability of charging infrastructure
Closely linked with range anxiety, the availability of charging infrastructure is another significant barrier to large-scale adoption of EVs. Charging infrastructure for EVs is becoming more prevalent across the UK, however public options are typically limited to destination charging points with approximately 8,500 electric vehicle charges in the UK at 3,200 stations. By comparison there are more than 8,500 petrol stations, each with many refuelling points.

In addition to destination charging points, electric vehicle OEMs expect that most charging will take place at home, overnight. However, for households with no off-street parking this becomes more difficult. In the UK, less than 40% of urban households have access to off-street parking. Therefore, to address this barrier and encourage large-scale adoption in urban areas, a large investment in residential public charging infrastructure is required. (20)
The barrier of the upfront cost of electric vehicles is likely decrease over time as they reach cost parity with ICE vehicles. The range anxiety barrier is also expected to be eroded over time as the capacity of batteries increases, however some residual barrier will remain. This is expected to be addressed through the extensive provision of charging infrastructure, particularly in residential areas. While the lack of public charging infrastructure for those without off-street parking is well known, there are several barriers that are restricting the deployment of infrastructure.

Barriers to large-scale deployment of EV charging infrastructure:
There are a number of barriers to the deployment of widespread, public, residential EV charging infrastructure:

Finalisation of standards by international Standard setting bodies
While progress is being made, there is no single agreed upon standard for EV charging infrastructure, therefore private and public sector organisations are wary of investing large sums of money in systems with a particular plug design or voltage rating specification.

Policy uncertainty regarding the sale of electricity
It is still to be decided whether third-party charging providers become regulated entities, in the same way as electric utilities, when engaging in the sale of electricity. Legislation is being put into place in some markets, however some uncertainty remains, which is impacting business model decisions and the overall economics for third-party charging infrastructure providers. (20)

Viable business case
A critical driver for the participation of private investors in the EV charging infrastructure market is a viable business case. Currently there is uncertainty around levels of demand.

Use of Smart Lighting Infrastructure
Despite these barriers, city governments and local authorities are keen to provide charging infrastructure in order to encourage the adoption of electric vehicles and to meet their environmental targets.

Traditionally, authorities have provided charging infrastructure in residential areas by deploying stand-alone charging stations with an accompanying EV only parking space. This approach is causing concerns among non-EV drivers because of the decrease in parking for ICE vehicles. Formal objections are typically raised and in many cases, the charging station is not deployed. Therefore, it is often the parking implications that stop the widespread deployment of residential EV charging infrastructure. Furthermore, stand-alone charging points are expensive, ranging from £7,000 to £14,000 per point. (23)

This is leading authorities to investigate alternative methods to provide this infrastructure. These alternatives include:

Secured matting
A low-tech solution that enables users to plug in their car via domestic connections and trail their charging cable over a public footway.

Duct-and-chamber
Charging cables are securely channelled from a domestic connection, beneath a public footway within a covered chamber and fed through a lockable flap in the kerbside.

While these are both low-cost options, they still require that cars are parked very close to residences and may still require specific bays to be designated as EV only.

Portable chargers
A portable battery recharging unit which can be wheeled up alongside the EV and left to charge overnight.

This is another low-cost option however battery capacity would likely be constrained by weight and volume of the charger.

Induction charging
Wireless charging via electromagnetic induction pads embedded within the road and fixed to the bottom of the vehicle.

While this option minimises street-scene impacts and removes trip hazards, this technology is still developing and is unlikely to be a viable solution in the short to medium term. Issues remain with
standardisation and interoperability, and the technology suffers from reduced charging efficiency compared to cable based systems.

**Socket networks**: sockets retrofitted to lamp-posts and other everyday street furniture.

This option is proving to be the most attractive alternative option for a number of reasons.

Firstly, it is an innovative and low cost solution, with a socket-based charging point costing approximately 90% less than conventional charging points. (23) Socket networks are low-cost as the complexity associated with electricity metering and payments is not housed within the charging point. Users are expected to purchase smart cables which connect the user directly to the electricity provider, streamlining the business model and removing the need for an intermediary to collect payments.

Secondly, socket networks are versatile, in that they can be installed in a wide range of settings and can be easily scaled-up as demand increases. Also, due to their low cost, multiple sockets can be deployed in response to a single charging point request, giving the EV driver access to several charging points in their local area. It is hoped that by over-providing charging points the need for designated EV parking bays will be avoided.

Finally, socket-based networks minimise street clutter as sockets are integrated into existing street furniture. This leaves streets uncluttered and any charging points are unobtrusive.

However, it should be noted that there are some drawbacks to this method of charging point provision as lamp posts must have certain characteristics in order to be suitable. In terms of positioning, streetlights must be located in a front-of-footway location in order to avoid trip hazards caused by trailing cables. In some places this positioning is standard, however in other cities such as Berlin, lamp posts are typically placed at the back of footways, resulting in only 1-2% of lamp posts being suitable for EV charging sockets. (23) Lamp posts must also have a minimum diameter of 140mm to be able to accommodate the internal charging components. Finally, street lights must have an appropriate grid connection in order to safely charge electric vehicles.
CASE STUDY: HOUNSLOW

In recent years, Hounslow Council have started to receive requests from residents that are eager to buy an electric vehicle, however have no off-street parking, therefore require a charging point to be installed near their house in order to make the purchase viable.

Old process for requesting public charging infrastructure:
Traditionally, Hounslow would have had to wait for at least three residents in the same area to make a request before installing a stand-alone charge point and designating the adjacent parking space for EVs only. Not only was this approach expensive, with a typically installation costing between £7,000 and £10,000, the designation of a parking space for EVs only caused objections to be raised by other road users in the area who oppose the reduction in parking for ICE vehicles. This led to a lengthy consultation process and would often result in the deployment of the charging point being blocked.

Alternative approach – Streetlight charging points:
In search of an alternate approach, Hounslow council, along with a number of other London boroughs used funding from the Mayor of London's Air Quality Fund to commission some research into charging infrastructure solutions for residents without access off-street parking. The most attractive option that emerged was the provision of 'socket networks' that take their electricity supply from existing street furniture, such as streetlights.

Hounslow Council partnered with the German start-up company Ubitricity who produce EV charging sockets that can be integrated into existing lampposts. In line with other socket-based charging points, the sockets are simple, in that communication and metering functionality is assumed to be present in the smart cable, and low cost, with each charging point costing under £1000 for the socket and installation.

The council installed one socket and tested it with residents. During this test the council were aiming to test three things:

- The socket technology itself
- The practicality of retrofitting into streetlamps
- Whether the use of multiple sockets could negate the need for designated EV parking.

During this trial, the technology was found to be robust, and the installation of the technology into existing lampposts was found to be quick and easy, with one install taking only 30 minutes. The trial was considered a success and more sockets have been installed. A new process for requesting charging infrastructure was also implemented.

New process for requesting charging infrastructure:
Under the new process, residents contact the council to request charging points and are required meet some pre-set criteria. They must provide a receipt for an EV or hybrid, must have no access to off-street parking and must provide a £500 contribution towards the charging point. They must then select five streetlights on their street to be assessed. An engineer then inspects the lamppost to ensure it is suitable, and then sockets are installed on three of the five selected streetlights.

Hounslow have installed 20 lamppost-based sockets and have seven residents using them. Over the next three years, the council aims to have 75 sockets installed with 25 residents using them. This sample size should give a good amount of data around the success and longevity of the model.

Lessons Learned

Earthing readings
An issue found during the streetlight assessment process was the important of earthing readings at the streetlight. If an earthing reading exceeded 500 ohms,
copper mats or rods would have to be installed under the footway to make the lamppost safe to use for charging. Hounslow found that between 20-25% of lampposts were not suitable for use due to their earthing readings. Furthermore, as the readings were largely dependent on underground conditions, if one lamppost on a road was unsuitable, there was a higher likelihood of others being unsuitable as well.

Contributions from EV drivers
Hounslow requires that the EV driver that is requesting the charging point contribute to its costs. The reason for this is that, while everyone benefits from the cleaner air, there is currently a social equality issue. If general taxation is used to pay for charge points, then the council is subsidising facilities that will only be used, in the short term, by the wealthiest in society. The payment is aimed to supplement investments made on the part of the authority, however, aims to be small enough not to deter EV adoption.

Ensure charging points that are smart grid capable
The current electricity network in the UK is unsophisticated as there is no live monitoring of what loads are being put on the network. Therefore, the network planners operate on worst-case scenario model of planning in order to avoid potential overloading of the network, which means capacity is used inefficiently and the amount of charging points that can be installed is limited. Smart grid charging points will allow charge points to communicate with a central control panel that will ensure the network is not overloaded, however will allow more charging stations to be deployed. Load will then be balanced across these charging points.
BMW’s ‘Light and Charge’ system combines EV charging points into smart lamp posts, allowing cities to reduce their energy consumption by using LED lights, while also providing a simple and cost-effective way for local authorities to offer electric car charging, without installing the cabling required for separate charging stations.

The idea is to allow the charging of electric vehicles on city streets, removing the current necessity of finding charging stations or parking garages. With this system, virtually every city street in participating cities will have charging ports for electric vehicles; placing them under highly efficient LED street lights creates a safe environment to park and charge a vehicle.

While Light and Charge is integrated into the BMW iChargeNow network, the system will allow for the charging of any electric car, not just BMWs. There will be a standardised connector that will be available for the charging of electric cars from any manufacturer. The integrated control unit uses contactless technology to start the charging procedure using a smartphone app or RFID (Radio Frequency Identification Card).

The system is currently being tested on the streets of Munich and Oxford, and there are ongoing talks about pilots in London and Berlin.

The Munich ‘Light and Charge’ pilot is a result of a cooperation between the BMW Group, the city of Munich, the Stadtwerken Munich (Munich City Utilities) and German start-up Eluminocity. Launched in summer 2016, the pilot has integrated EV socket charging points in four smart lighting pillars across the city. All chargers are supplied with green electricity and access to the charging station is provided via an RFID card or by scanning a QR code with a smartphone. This mechanism allows the charging stations to be used by all standardised EV vehicles, rather than just BMW drivers.
CASE STUDY: LOS ANGELES (37)

The city of Los Angeles has spent $57 million over the past five years replacing 4,500 miles of streetlights with those that use LED bulbs. The system now saves $9 million a year in energy costs and 60,000 metric tons of CO₂ emissions. It has also left power plants with excess capacity, which the city intends to use to charge electric vehicles. The city has currently installed three lamp-post based charging stations, and has plans to add 27 more by the end of 2016. By the end of 2017 the city plans to have 100 charging points deployed across the city.

It took 18 months for the project to launch, due to the time needed to get buy-in from multiple agencies. The city Department of Transport agreed to surrender some parking meter revenue, while the Department of Water and Power agreed to provide the power.

The chargers supply 240 volts and typically provide 20 miles of range for every hour the EV is plugged in. They are operated by Chargepoint, the country’s largest EV charging provider. The city intends to enable credit card payments at all the stations, avoiding the need for membership with any specific vendor.

4.6 DIGITAL SIGNAGE AND PUBLIC COMMUNICATION

Building on existing solutions that use connected street lights as the basis for new services, cities are also starting to use the infrastructure to run dynamic digital signage systems. These systems display information on digital screens using displays or projectors in place of conventional printed signs. The connectivity from smart street lights enables the displayed information to be updated in real-time. In some instances, digital signage systems have been integrated with sensors and image recognition devices in order to adapt displayed content to passers-by or ongoing events.

Use-cases of dynamic digital signage systems include:

**Emergencies**
In emergency situations, dynamic digital signage provides the public sector with a single hub through which one consistent message can be fed.

**Wayfinding**
Digital signage can act as a navigation guide to help visitors move around a city, or can be used to direct crowds following an event.

**Traffic management:**
Digital signage can be used to direct traffic during certain times of day, or when there has been an accident.

**Advertising**
Cities have the option to rent out digital signage systems for advertising purposes. These dynamic systems can be used to display multimedia advertisements, as well as time-limited promotions and offers. In some cases, signage systems have been integrated with sensors and image recognition devices so that their content can be adapted based on who is passing by. Used in this way, digital signage has the potential to provide cities with a valuable new source of revenue.

**Public communication**
Digital signage systems can be used to communicate important public information or real-time information of interest. For example: the status of public transportation services or environmental readings such as pollution levels.

**BENEFITS (25)**

**Reduced costs**
Digital signs can be updated remotely and on-demand, eliminating costs associated with repetitive print production. Additionally, design time and expense can be reduced as many content management software applications provide easy-to-use templates.
Greater control
With printed signs, organisations must wait on their print supplier to reproduce and deliver the signs, and then must wait for the company responsible for hanging them to make the message visible. Digital signage internalises the processes of creating and delivering the messages, enabling faster delivery and greater control over when messages are communicated.

Greater flexibility
When using traditional signage, messages remain static and unchangeable for the duration of the sign’s lifespan. The dynamic nature of connected digital signs offers the ability to swap out messages as needed based on arising situations or changes in audiences.

Reduced environmental impact
Digital signage eliminates the waste, energy, water, ink and solvents needed to produce, transport and dispose of print signage. Digital signs featuring energy-saving LED backlit technology further reduces the sign’s carbon footprint compared to other types of displays.

Increased viewer engagement
Digital signage’s ability to offer a changing array of relevant messaging, compelling multimedia and eye-catching images is both more noticeable and more engaging than static signs.

In addition to using digital signage systems, cities are also improving their public communication capabilities by integrating loud speakers into connected lighting systems. Using network system controls, operators can turn a smart street light fixture into a sound system that broadcasts real-time and recorded audio messages. Loudspeaker equipped connected streetlights have been used to:

- Direct people to available parking at a public event
- Announce weather or transport alerts
- Play recorded music at festivals and events.

This approach is being used by several cities across the USA:

‘As you wander around Chicago’s Navy Pier – 50 acres of parks, promenades, gardens, shops, eateries and attractions on Lake Michigan – you might hear soothing music when you pass a street light. And at the Superdome Stadium in New Orleans, announcements to football fans entering and exiting the stadium emanate from street lamps. These are just a few of the ways embedded speakers in network-connected streetlights are being used to entertain and inform people passing by.’ (2)

Las Vegas is currently testing a streetlight system that can broadcast sound. The city has plans to use this system to control lighting and play music, but also to issue security alerts in pedestrian shopping areas. A representative from the Public Works Department said ‘We want to develop more than just the street lighting component. We want to develop an experience for people who come downtown.’ (2)
CASE STUDY: LinkNYC

Although not provided through street lighting infrastructure, the best example of the use of digital signage and connectivity to provide advertising revenues for cities is the LinkNYC kiosk system.

For several years, New York City has been developing a free public Wi-Fi project. Having tendered for a solution in 2014, the winning bidders have built the LinkNYC kiosk network; an ambitious effort to bring wireless internet access to all of the city’s residents.

The winning bid came from the CityBridge consortium consisting of four companies including advertising firm Titan and designer Control Group. Not long after winning the tender, Google created a company called Sidewalk Labs and acquired both Titan and Control Group, giving them a controlling stake in the deployment. (38)

The proposed solution involved building a network of 10,000 kiosks (or ‘links’) throughout the city that would be fitted with high-speed wi-fi routers to provide internet access, a phone allowing free calls within the USA, two USB charging ports for smartphones, as well as android tablet computers for accessing city maps and directions, and for making video calls.

The kiosks also provide the ability to use calling cards to make international calls, and each kiosk has one button to call 9-1-1 directly.

The Wi-Fi provided is free, however it requires users to agree to conditions stating that the companies providing the services can collect, store and analyse users’ personal, locational and behavioural data. Like many free internet products and services, LinkNYC is supported by advertising revenue, therefore the 2.9 metre kiosks feature two 140cm high-definition digital advertising panels on their sides. The data collected is used to better target these adverts to audiences, and to deliver ads to users’ smartphones. Due to this advertising potential, New York City does not pay for the system. Advertising is estimated to bring in over $1 billion in profits over 12 years, with the city expected to receive over $500 million.

Kiosks in lower-income and lower-traffic areas are not expected to display advertisements as the return on investment argument is not strong enough. Controversially, the kiosks that lack advertising are expected to exhibit network speeds that are up to 1/10 the network speeds of advertisement-enabled kiosks in wealthier areas of town.
LinkNYC launched in January 2016 and the kiosks have registered more than 671,000 Wi-Fi users, 34 million Wi-Fi sessions and tens of thousands of free phone calls made every week. Since the launch, the project has come under scrutiny by privacy advocates, who express concerns about their terms of service, the financial model and the collection of end users’ data, which could potentially lead to users’ movements being tracked throughout the city. There are also concerns that cyber criminals could hijack the kiosks, or rename personal wireless networks to the same name as LinkNYC’s network in order to steal users’ data.

In 2016, UK carrier BT announced that it had partnered with Sidewalk Labs’ Intersection, the Google/Alphabet-backed start-up behind LinkNYC, to roll out LinkUK which would provide free internet and phone hubs for London and the rest of the country. The partnership will be a three-way affair between Intersection, BT and advertising partner Primesight. The deployment is projected to start in 2017, however, the project is yet to get full approval from local authorities. If successful, 100 kiosks are expected to be rolled out in the first phase, with a further 750 being deployed across London in the long-term.

4.7 SUMMARY

As demonstrated by the applications discussed above, the potential for smart lighting infrastructure to be used for more than illumination is huge. Not only can networked streetlights enable the cheaper deployment of discrete applications such as sensor networks and transport optimisation applications, but they can also act as a wider smart city platform, enabling interactions to take place between hosted applications in response to real-time events. Furthermore, this section has illustrated how streetlighting infrastructure can also be used to reduce barriers to growth and penetration in other markets. An example of this is the use of lamp posts to host charging sockets for electric vehicles in residential and densely populated urban areas.

Increasingly, cities are using lamp posts and other street furniture to host communications networks that provide public Wi-Fi, improve mobile signal strengths or provide a platform for R&D activities. The use of streetlights in this way has the potential to provide a range of benefits. Socially, the provision of free public Wi-Fi has the potential to bridge the digital divide in communities. Economically, the provision of R&D networks and stronger, consistent mobile networks enables innovation and drives further economic growth. This approach has been taken by Kansas City in the USA, which has successfully used its connected streetlight implementation and wider smart city demonstration area to attract corporate investment and start-up accelerators to the city. (See case-study on next page).

Finally, LED streetlighting has already been proven to save cities money through reductions in energy usage and operational costs. However, networked streetlights also have the potential to generate significant revenues for a city in the form of digital advertising revenues and also through renting aspects of the infrastructure to third-party providers. While the mechanisms and complexities of this rental process still need to be explored, there is great potential for street lighting to move from a costly but essential public service, to a valuable, money-generating asset in the near future.
CASE STUDY: KANSAS CITY

In 2012, citizens approved funding for a two mile free-to-ride streetcar route through the centre of downtown Kansas City. The $102 million infrastructure investment aimed to increase mobility and support local tourism. However, as the project has evolved, it has become much more than a transit project.

The city also intends to include a $15 million investment in IoT technologies, including a network of sensors, kiosks and a smart parking solution. The project will be financed over a period of 10 years, with $12 million coming from partner organisations and $3.7 million coming from the city itself. The aims of this initiative are to expand connectivity, improve infrastructure efficiency, create new revenue streams and catalyse economic development within the city.

While Cisco has served as the primary partner, the project brings together many others. FastPark will provide in-street parking sensors, Sensity are delivering smart street lighting technology and Black and Veatch are expected to further enhance the project with a smart water system for leak detection and infrastructure asset management.

The use-cases specifically related to smart lighting infrastructure include:

• Deploying connected cameras on lampposts that will support a number of solutions in the transportation and energy verticals. The cameras, operated by Sensity, will register the presence of pedestrians and brighten or dim the lights to ensure the safety of residents while also conserving energy when the streets are empty. The cameras will also track streetcars and other vehicles to help the city understand traffic flows, optimise smart traffic signals and allow streetcar operators to anticipate road conditions. Video feeds from these cameras will also monitor weather conditions, helping the city plan weather responses such as snowplough deployment.

Once the project is live, the stretch of road will be one of America’s first urban areas truly enabled by the Internet of Things. Aside from creating a digitally-enabled downtown environment, the purpose of the investment is to foster the local technology industry. By building strong infrastructure for IoT and enabling data collection through sensors and cameras, Kansas City hopes to attract businesses to the region that are interested in experimenting with IoT, and provide direct access to new infrastructure for local start-ups. The city is already seeing results with local company Sprint building an accelerator to support start-ups that are keen to leverage the Wi-Fi network and the data it helps to collect.

A second initiative launched by Cisco, Sensity and entrepreneurship firm ‘Think Big Partners’ is working with the city to launch a Living Lab, which will provide a development data portal and program to support new companies developing commercial IoT products. With access to the Kansas City strip, participants will be able to test their ideas in a real-life IoT environment.
BUSINESS MODELS

Previous sections in this report have talked about authorities moving from traditional tendering approaches, which have focused on initial cost, to total cost of ownership approaches (TCO) which consider the entire lifetime cost of infrastructure. While this is appropriate when simply upgrading a system that will serve the same purpose, for example, upgrading sodium lights for LEDs lights, a new approach is required when additional services will be derived for the same infrastructure. In the case of smart street lighting infrastructure, there is the potential for the system to become a dynamic platform that enables continuous innovation. In this way, a total value of ownership approach is required. This involves not only taking into account the relative costs of the lighting infrastructure over its lifetime, but also the value of all other services that can be supported by it. This approach should not only strengthen the business case for investment in smart street lighting systems, but should also enable other solutions with less concrete business cases to be financed as well.

Looking to the future, aspects of lighting infrastructure could be rented out by cities to companies that are able to provide services in areas such as parking, traffic management and public safety. These public-private partnerships could pay for the cost of the street lamp and provide an additional revenue stream for the city.

BARRIERS

The deployment of smart street lighting infrastructure and the integration of the additional solutions described throughout this report often involve multiple vendors, numerous independent systems and complex technological interactions. This creates a number of barriers to the successful use of smart lighting infrastructure as the technological foundation of a smart city.

Operational barriers:

Silod nature of many city governments

The rigid vertical structures of many city governments can act as a barrier to implementing integrated solutions as technology investments are often made by individual departments, rather than collectively to support overall city objectives. In some cases, the communication channels and processes are not in place to allow effective and efficient cross-departmental working; something that is necessary to enable a piece of city infrastructure to be leveraged for several uses.

Cooperation of multiple stakeholders

Looking more widely at the actors involved in deploying these solutions, implementations will inevitably require the cooperation of different industries with diverse skills, competencies and working methods. In addition to manufacturers of lighting infrastructure, hardware vendors, software providers and connectivity service providers will all come together. Furthermore, business agreements will need to be negotiated with each of these providers based on the value of the service provided.

Security Barriers

Cyber attacks

While the added solutions provide many useful services and often improve daily life for citizens, their digital and connected nature makes them a potential target for malicious online attacks such as denial of service or unauthorised control attacks. The distributed nature of connected lighting infrastructure and sheer number of attached components vastly increases the available attack surface, therefore city authorities and system operators must ensure all networks and connected devices are secured appropriately.

Privacy

With increasing numbers of data collection devices such as sensors and cameras being deployed across cities, privacy is becoming a high priority topic for many citizens. Many cities...
deploying smart lighting-enabled camera solutions make it clear that video streams are analysed in real-time, on the device and reiterate that no data is stored. They also seek to stress the benefits that the devices will deliver such as improved safety and increased operational efficiency. From a citizen’s perspective, they will need to carefully manage which public service applications they use if they wish to keep their data private. It is expected that for many solutions, some level of privacy will be sacrificed for the benefit of services, however, this will need to be negotiated on a solution by solution basis.

**Infrastructure Barriers**

**Complexity**

Through the addition of multiple solutions to smart lighting infrastructure, there is a real possibility that systems will become overwhelmingly complex. A lack of integrated standards, mismatched interfaces and multiple proprietary systems that are unable to accommodate third-party applications could make connected lighting systems too difficult to implement. Additional solutions will need to be easy for the city or operator to manage and will need to be easily accessible and intuitive for end-users in order to be successful. (27) To mitigate this complexity risk, cities are deploying additional solutions in a modular, incremental fashion, ensuring they see value from one solution before adding another.

**Lifespan of Lighting Infrastructure**

Smart lighting infrastructure is likely be in operation for at least 20 years, therefore the embedded systems need to be adaptable over long periods of time and need to be able to support new applications. Cities are having to plan ahead in order to be prepared for options that are not currently available. For example, ensuring bandwidth is left available for unknown future applications. By planning ahead, cities will be able to leverage their smart lighting infrastructure to roll out an entire smart city blueprint over a period of time. (27)

In order to do this, cities require that software system used by smart lighting solutions needs to be remotely upgradable and based on open standards so that third-party solutions can be added over extended periods. Cities do not have the resources or money to upgrade software systems every couple of years, and are increasingly wary of vendor lock-in. Similarly, the applications developed will need to be compatible with the range of software programs that operate a city-wide lighting network.

**Financial Barriers:**

**Lack of proven business case:**

In the current economic climate, with many cities suffering from budget cuts, any solution they invest in must be affordable and have a concrete supporting business case. Cities are embracing the transition from traditional sodium street lights to LED lighting as the solution pays for itself through reduced energy costs in five to ten years. The reduced carbon footprint is also helping cities achieve their environmental targets. While the business case for the basic smart lighting infrastructure is robust and well proven, the evidence for other applications such as parking, security and charging infrastructure is still lacking. There is a risk that a lack of concrete business models will inhibit the adoption of many associated solutions.
CASE STUDY: THE HUMBLE LAMPPPOST (40)

In order to address a number of the barriers discussed above, a large European project called the ‘Humble Lamppost’ has been set up.

The Humble Lamppost is a ‘market making’ project launched by the European Commission. Rather than investing money directly into smart lighting infrastructure, the Commission aims to bring interested organisations together and to encourage them to develop the market themselves. The Commission has adopted this approach as it believes that the ‘humble lamppost’ is a simple and accessible way for cities to start their ‘smart’ journeys, however too many cities attempt this move individually. The objective of this project is to aggregate demand and achieve a large-scale EU smart lighting solution deployment. The project aims to have 10 million smart lampposts across EU cities by 2017.

The project is comprised of demand-side and supply-side clusters.

The demand-side cluster consists of several large cities and a broader community of smaller cities. Large cities include Paris, Madrid, as well as the borough of Greenwich in London. These cities are joined by clusters of smaller cities in the UK, the Netherlands, Italy, Switzerland, Finland and Estonia.
The project involves the following activities:

- A lengthy landscaping process looking at all ecosystem stakeholders from lighting engineers to city leadership
- Creation of city clusters to facilitate cross-city collaboration
- Creation of supplier ecosystem
- Convening of supplier ecosystem and demand clusters
- Definition of business models that leverage the certainty of LED lighting with the uncertainty of other smart initiatives.
- Engage funder ecosystem in order to finance this large-scale demand

This project aims to generate the following benefits for the various stakeholder groups:

For cities
the project expects to provide efficiencies in the areas of procurement, deployment and in realising return on investment. It also aims to improve the image of cities, and their confidence in adopting new technologies.

For industry
The project aims to create new markets, increase revenues, reduce sales costs and improve profit margins. Furthermore, the project aims to increase the export potential for European companies working in the project.

For the wider society
The project is aiming to provide a better experience for those living in areas with smart lighting systems, improve public safety and instil pride in communities.

The participants in the project predict that Europe could save Euro 2 billion a year on electricity bills by upgrading its 60–90 million streetlights to more efficient technology. It is hoped that by bringing city-clusters together around a modular design, adoption will increase at a local level. Following this, it is hoped that local adoption will create overall scale as leading cities disseminate learnings and funding becomes available from engaged financing communities.

(37)
While the Humble Lamppost project is aiming to address the barriers that are specific to smart lighting infrastructure, many of the barriers discussed above are true of the whole smart city field. Therefore, there is a high likelihood that many of these barriers will be overcome in coming years as the whole field progresses. The integrated nature of the smart city domain necessitates the cooperation of multiple stakeholders, and will require local governments to adopt a new way of working and move away from their traditional organisational structures. Similarly, concerns around the security and privacy of connected city applications are well known, and standards and technologies are rapidly emerging to address any threats or fears. The business case barrier is also encountered by the wider smart city domain and innovative financing models are emerging to support cities in adopting innovative solutions, while also transferring risk onto delivery partners. Examples of these financing models are outcome-based and performance-based contracting. With the finance barrier being reduced, more cities should be able to pilot applications, allowing business cases to be proven, or found unviable.

Lastly, the complexity barrier has the potential to cause significant damage if not addressed effectively. There is a risk that the market leaders attempt to use networked streetlights as a smart city platform and fail, discouraging others from trying. Furthermore, there is a risk that contractual arrangements between multiple stakeholders cannot be agreed, again inhibiting the exploitation of lighting infrastructure. Further research is required on this point to establish a viable solution.

Nevertheless, if the majority of these barriers can be overcome, there is huge potential for smart lighting infrastructure to serve as a versatile platform for current and future smart city applications.

**Supply-side: develop (national-specific) ecosystems**

Helping to bring multiple segments together to collaborate, innovate, and develop more common solutions

- Lighting
- Pole Manufacturers
- Electro-technical Systems
- CMS
- ‘Smart’ equipment
- Connectivity
- Data Brokers
- Operations & Maintenance
- Power & Utilities

Standards Development Organisation taking a growing interest
CONCLUSION

For over 30 years, LEDs have been used in a variety of areas, including industrial systems, vehicle lights and advertising. In recent years, the technology has been applied to outdoor lighting applications, delivering extensive benefits in the form of energy cost savings, operational efficiencies and CO₂ reductions. There are an estimated 7.4 million streetlights in the UK, however less than 10% are currently using low energy LEDs. (5) With the business case becoming ever more concrete, adoption is expected to increase rapidly in coming years, with global penetration rates expected to reach 89% by 2026. (3) Local authorities in the UK currently spend over £300million per year on electricity for streetlights and the Green Investment Bank predicts that authorities could enjoy annual energy cost savings of £200 million. (5)

While this is an encouraging start, switching to LED lighting alone is unlikely to be enough to meet cities’ energy consumption and reduction targets. This is leading cities to adopt adaptive, interoperable lighting solutions in order to bring savings to the next level. As LEDs are electronic devices, they can be connected to a central control system, giving operators the ability to remotely monitor and regulate light levels in unprecedented ways. These networked street lighting systems greatly increase energy savings, with the 50% energy savings realised by switching to LEDs increasing to 80% when integrated with a central management system (2). In response to this compelling business case, a number of traditional lighting vendors and innovative start-ups have brought solutions to market.

While the energy and cost saving benefits are driving adoption, cities are increasingly seeing the wider potential of smart street lighting infrastructure. With an even and widespread distribution across urban areas, readily available power and integrated connectivity, smart street lighting is being used to form the technology foundation of a city. Through the addition of data collection devices such as sensors and cameras, street lighting infrastructure is being used as a platform to host a variety of applications. Applications include:

- **Environmental monitoring**
  Cities like Chicago are integrating air quality, noise, motion, temperatures and precipitation sensors into streetlights in order to collect granular data about the day-to-day operations of the city. It is hoped that by making the data freely available, innovative applications will be developed that will improve the quality of life of those living in the city.

- **Transportation applications**
  Through the integration of motion sensors, counters and cameras into lighting infrastructure, innovative traffic optimisation and smart parking applications are being created by companies like Cisco and Cleverciti. These applications aim to reduce congestion in urban areas and improve the efficiency of transportation networks.

- **Public safety and security:**
  Through the use of sensors and cameras integrated with streetlights, a number of applications have been developed that aim to improve public safety. For example: motion sensors can detect when a pedestrian is approaching and lighting levels are automatically increased to improve visibility. Alternatively, pedestrian counters can be integrated into the distributed lighting network, which can feed real-time data to people walking home at night and suggest the safest walking path based on the number of other people on the route. In the USA, noise sensors have been mounted on lamp posts and can triangulate gunshots and automatically alert authorities.

- **Public Wi-Fi and internet provision**
  Due to the widespread nature of streetlights in urban areas, they are well placed to host distributed connectivity infrastructure that can be used to provide public Wi-Fi, or communication networks for IoT devices. Bristol has used lamp posts to create a mesh network that will enable IoT devices to be implemented at scale, providing a test facility to network operators, application developers and device manufacturers. Conversely, Los Angeles is allowing Ericsson to integrate small cells into their smart lighting infrastructure, with a view to renting out the additional capacity to mobile operators. While greatly improving connectivity
across the city, it is also hoped that this innovative approach will generate a new revenue stream for the city.

**Electric vehicle (EV) charging:**
It is widely accepted that electric vehicles are the future of the motor industry. However, lack of charging infrastructure is inhibiting adoption, particularly amongst those without off-street parking. An increasing number of companies are providing solutions which allow electric vehicle charging points to be integrated into lamp posts. This cost-effective method of providing EV charging infrastructure in dense urban and residential areas is being trialled by a number of cities including Munich, Oxford and the borough of Hounslow in London.

**Digital Signage:**
Lastly, due to their regular positioning, power and connectivity, smart streetlights provide an ideal base for digital signage solutions. Dynamic digital signage systems can be used for traffic management, pedestrian wayfinding, general public communication or in emergency situations to direct the public. There is also the potential for cities to rent out lamp post mounted digital signage space for advertising purposes, again generating another revenue stream for the city. This model has been proven successful by LinkNYC who are expected to generate over $1 billion in advertising revenues in their first 10 years of operation.

In terms of business model, cities have moved away from traditional tendering methods in favour of a Total Cost of Ownership (TCO) approach when procuring smart lighting infrastructure. With the potential of smart lighting infrastructure to be used as a platform that enables other smart city services and applications, a different approach is required once again. Not only should the cost of the lighting infrastructure over its lifetime be taken into account, but also the value of all other services that can be supported by it. This approach is being referred to as ‘Total Value of Ownership’ and is likely to become more prevalent in coming years. Finally, while the use of smart lighting infrastructure as a technological foundation for a smart city is an immensely promising prospect, a number of barriers remain.

**Operational barriers:**
Due to the number of services that could be hosted by smart street lights, operational barriers are likely to arise, caused by the siloed nature of many city governments, and the need to secure the cooperation of multiple industry stakeholders.

**Security barriers:**
As the number of connected components increases, the surface for cyber-attacks rapidly expands. Cities will need to ensure systems are secured appropriately in order to avoid malicious online attacks and maintain the trust of citizens. Secondly, with the proliferation of data collection devices, citizens have expressed growing concerns about privacy.

**Infrastructure barriers:**
Lastly, with the integration of multiple applications into smart lighting infrastructure, there is a real risk that the systems will become overwhelmingly complex and too difficult to implement. To mitigate this risk, it is recommended that cities deploy additional solutions in an incremental fashion, ensuring value is being delivered before adding another solution.

Despite these barriers, there is huge potential for smart lighting infrastructure to service as a multi-functional smart city platform, capable of monitoring everything from crime, to parking, to weather. Streetlights are ubiquitous in urban areas, can provide power to data collection devices and are increasingly enabled with connectivity capabilities. The promise of this approach is not so much in the generation of new data, but in the streetlight’s ability to converge previously disparate systems, and enable the development of solutions and services that combine data from a variety of sources to improve services and generate new revenue streams. While business cases for many applications still require strengthening, it is almost certain that lamp posts will be used for more than illumination in years to come.
THE FUTURE OF STREET LIGHTING
The potential for new service development

- WI-FI, MOBILE & MESH
- SMART LIGHTING
  - LED
  - Photocell control
  - 0-100% dimming
  - On-demand lighting
- CONCEALED SPEAKERS
  (music, alerts)
- IMAGE SENSING
  - Image sensing
  - Proximity
  - Parking monitoring
  - Public security
- ENVIRONMENTAL SENSING
  (Air quality, noise)
- DIGITAL SIGNAGE
  - Way finding
  - Traffic direction
  - Civic direction
  - Revenue potential
- CHARGING POINT
  (eVehicle / eBike)

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