LIGHTSAVERS CANADA

Building Intelligent Communities with Advanced Streetlighting

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1. INTRODUCTION

1.1 PURPOSE

This primer provides an introduction to how networked streetlighting employing light-emitting diodes (LEDs) can be used as an expandable platform for intelligent communities. It is intended to as a resource for building capacity, overcoming barriers and guiding implementation for creating connected smart communities.

1.2 INTELLIGENT COMMUNITIES

The term Intelligent Community is generally used to refer to applying digital information technology through the built environment to improve the overall quality of life for people at home, work and play. The technology is used to provide opportunities for economic development and enhance urban services, resource conservation and cost effectiveness. Key attributes often include:

- Fostering innovation in industries and neighbourhoods;
- Creating and attracting talent;
- Advancing urban infrastructure, transportation, and utility performance; and
- Improving community services[1].

Digital masterplans are emerging as a tool for municipalities to outline a comprehensive set of initiatives for deploying digital technologies at the community level, including smart city applications. The existing and pervasive infrastructure of streetlight poles provides a backbone for a digital city, enabling accessible and connected community-wide solutions.

1.3 LED STREETLIGHTING

LED technology is now the primary choice for new streetlight luminaires. It is replacing incumbent high intensity discharge (HID) in many full-scale retrofits globally. LED streetlights are more efficient, reliable and long-lasting than HIDs, and provide the additional opportunity of building networked intelligent infrastructure. Existing installations have demonstrated LED technology provides the following benefits:

- Reduced energy consumption by 40-70%;
- Reduced maintenance requirements through product lifetimes upwards of 100,000 hours and improved performance predictability;
- More effective light distribution and colour rendering that improves public safety and security; and
- Suitability to adaptive controls that provide additional energy savings upwards of 20% and provide smart city capabilities.

It is estimated that over 30% of Canadian streetlights have been converted or are committed to be converted to LED. However, these conversions do not often include full-scale adoption of intelligent lighting controls, meaning additional benefits are available from the lighting upgrades that are not being realized.

[1] *http://kitchener.ca.granicus.com/MetaViewer.php?view_id=2&clip_id=489&meta_id=28042*

2. INTELLIGENT STREETLIGHTING

2.1 LED STREETLIGHTING CONTROLS

Unlike HID lamps, LEDs are particularly well suited to controls. LED technology is dimmable, rapidly turns on to full illumination and does not decrease in service life from frequent ON/OFF operations. Adaptive streetlighting control can be considered the first generation of smart streetlighting. Adaptive controls can automatically adjust light output in response to daylight conditions or motion detector triggers, as well as be scheduled to adjust output during specified periods of the night. By using these controls, municipalities can save energy by ensuring only the required light output is emitted.

2.2 INTELLIGENT NETWORKS

Control systems have advanced beyond just adaptive functionalities and are now becoming platforms for building intelligent applications by leveraging the existing community-wide infrastructure of streetlight poles. Smart city solutions are supported by communication networks that service the Internet of Things (IoT) technology. IoT delivers machine-to-machine (M2M) and machine-to-person communications. The extent of these opportunities depends on the network model and sensors implemented.

The evolution of control networks can be summarized across four tiers, increasing in versatility for lighting and community services:

Tier 1: No Network
Tier 1 streetlighting is comprised of individual controls on each streetlight with no network connectivity. The streetlight is a single purpose device with a photocell that is individually controlled based on light levels. The luminaire control is basic ON/OFF functionality.

Tier 2: One-way Communication Network
At Tier 2, streetlights are connected to each other but not a central management system. The connectivity is a low bandwidth communication network such as a power line carrier (PLC) or a wireless radio frequency (RF) mesh network. The system consists of a base controller and individual modules in each luminaire. The base controller can be programmed to adjust light output of each streetlight based on the time of day. This network is one-way communication, from the base controller to the light modules, and typically does not enable implementation of additional sensors or actuators.

Tier 3: Bidirectional Communication Network
Tier 3 streetlighting connects segments to a central management system (CMS) using a gateway at the base controller and a cellular modem at the CMS platform. As in Tier 2, the controller uses PLC or RF to control each luminaire. With the cellular modem, backhaul communication is enabled and the streetlight network can communicate with the CMS to report on performance (e.g. hourly usage data) and provide real-time fault monitoring.

Tier 4: Unified Communication Network for Smart City Applications
At Tier 4, streetlight poles can individually support higher bandwidth applications, while collectively, they are all on a single network servicing as a gateway to the IoT, building the backbone for an intelligent community. It uses bidirectional communication for full control and monitoring, as well as communication with mobile clients. There are a variety of network configurations used by smart streetlighting solution providers, including: cellular, low power wide area networks (LPWAN), PLC and RF mesh. Each configuration has varying benefits relating to service range, installation costs and complexity, power

consumption, security and data carrying ability. The most appropriate configuration will vary between municipalities based on existing infrastructure conditions and smart city objectives.

2.3 SENSORS

Deploying a network configuration that supports IoT technology enables the use of IoT devices, such as sensors and actuators, in addition to adaptive controls, developing the platform for a connected intelligent community. The range of conditions that can be monitored by IoT devices is ever expanding, but existing sensor applications relating to smart streetlighting include:

- Ambient and ground temperature
- Humidity
- Seismic
- Wind
- Precipitation
- Particulate matter
- Ambient light
- Power monitoring
- Motion
- Audio
- Video
- Radiation
- Sewer levels
- Real-time locating system (RTLS)
- Oxygen & carbon dioxide
- UVA/UVB
- Ultrasound

An example of intelligent streetlighting that uses a unified communication network to relay data from sensors is presented in Figure 1.

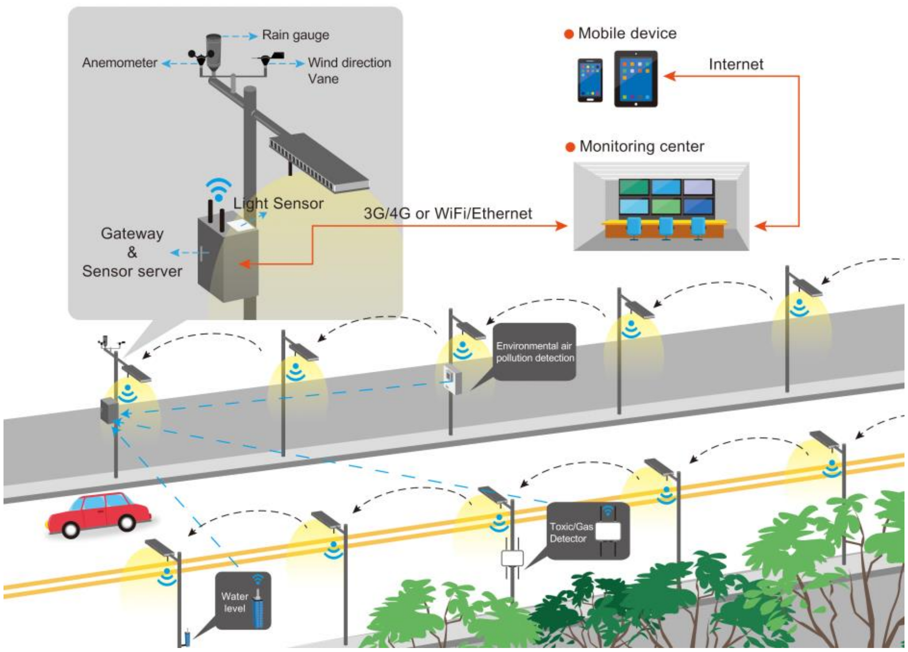

Figure 1: Example of an intelligent streetlighting network with various sensors that communicate to the CMS and mobile devices[2]

The LightSavers Primer *Adaptive Controls for Roadway and Parking Lighting* provides more information on issues relating to integrating networks and controls into streetlighting systems[3].

[2] http://www.cens.com/cens/html/en/news/news_inner_48111.html

3. THE VALUE PROPOSITION

3.1 INTELLIGENT STREETLIGHTING OPPORTUNITIES

The opportunities and value proposition of an intelligent streetlighting network are continuously advancing. Because an intelligent network integrates with other systems and community services, the potential benefits go further than improvements to the efficiency and quality of lighting to include enhanced services and revenue generators. Developing streetlighting as digital infrastructure also has the unique value of future-proofing the built environment by providing a platform for the future integration of new technologies as they come online. The data provided by connected lighting and smart infrastructure can support many services within a municipality, including law enforcement, environmental improvement, transportation and natural disaster preparedness. The benefits of intelligent streetlights with sensors can be summarized into the following seven categories:

3.2 ENERGY AND OPERATIONS

Typically, the improved energy conservation and maintenance efficiency is the most attractive benefit to implementing an intelligent streetlighting control system because of the direct cost savings. Connected adaptive controls help reduce maintenance requirements and light output to save energy and money while optimizing lighting conditions based on site-specific needs. As described below, a controls system:

a) Improves Energy Efficiency

Additional energy savings, and associated greenhouse gas (GHG) reductions, are possible through adaptive dimming and ON/OFF control. Dimming is used to control light output to avoid over-lighting. Because roadway luminaires are designed to meet lighting design standards up until the end of service life, newly installed lighting often exceeds requirements by up to 40 percent[4]. By controlling light output to only meet design levels, energy consumption is reduced and the service life is extended. Dimming and luminaire extinguishing can also be used during off-peak hours, depending on the type of roadway. The sample manufacturer dimming/extinguishing schedule provided in Figure 2 shows examples of possible variations in light output designed to respond to different uses and requirements. These light schedules may not all follow RP-8 recommendations for lights levels, which municipalities should reference when designing dimming or extinguishing schedules.

[3] *https://static1.squarespace.com/static/56cdde5262cd94f3e9cffd8e/t/57b5cca41b631bc0993745a7/1471532197587/LSIV%2B2-3%2BControlPrimer.Final.For%2Bwebsite.pdf*
[4] *Boyce, P.R., Fotios, S., and Richards, M., "Road Lighting and Energy Saving," Lighting Research and Technology, 41(3), 2009, pp. 245–260.*

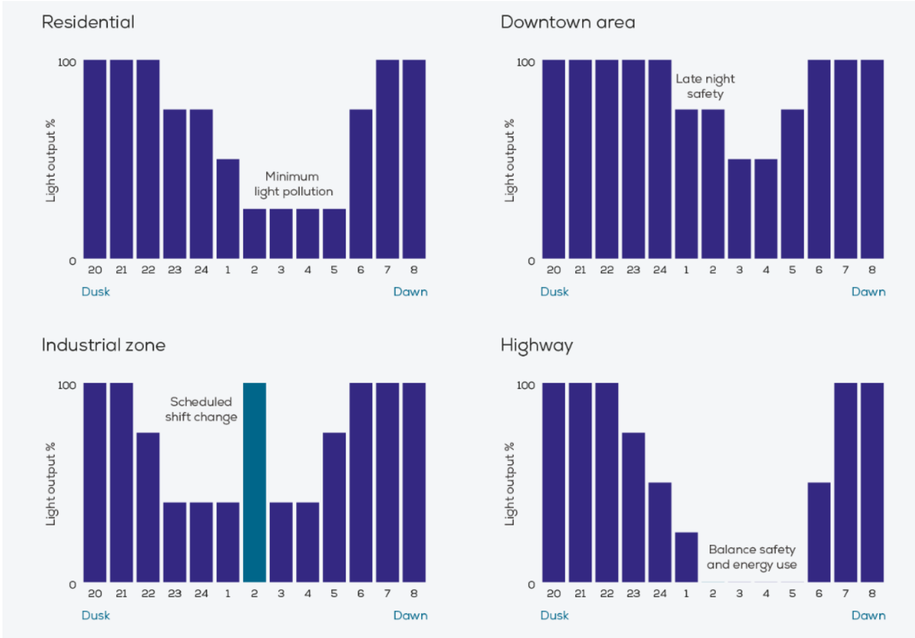

Figure 2: Sample dimming schedules for residential, downtown, industrial and highway areas of a community[5]

To realize the cost savings of a dimming schedule, electricity billing or rate changes will have to be negotiated with the local utility (further discussed in the sections below). If energy monitoring is needed for billing, smart controls with meter grade accuracy may be required.

b) Reduces System Operational Costs

The real-time monitoring and analysis of luminaire performance through central management reduces installation and maintenance costs. The control network provides communication to automatically identify when and where a fault occurs, thus reducing the number of on-site trips required. The use of mapping software for hosting the luminaire database enables easy identification, tracking and locating of maintenance issues, optimizing the required response and minimizing costs.

c) Improves System Safety and Efficiency

Safety and efficiency is also improved by the real-time monitoring. In many municipalities, streetlight failures are reported by citizens. In Kitchener, Ontario, for example, one in four faulty luminaires is replaced based on citizen reporting[6]. Central management allows maintenance crews to respond faster and with more comprehensive information on the system failure. This results in less time with ‘dark’ areas, improving the safety of the system.

Case Study: Clermont-Ferrand, France

The City of Clermont-Ferrand deployed an intelligent streetlight management system with the main objective to improve overall maintenance and reduce energy consumption. The City chose to implement a cellular network because a wireless solution was more feasible for installation than a PLC network. With implementation, the City now monitors its 16,000 streetlights in real-time and is able to notify maintenance crews almost as soon as a failure

[5] http://www.telensa.com/smart-lighting/
[6] http://kitchener.ca.granicus.com/MetaViewer.php?view_id=2&clip_id=489&meta_id=28042

is experienced. This has reduced response times from within a week to within a couple of hours. Clermont-Ferrand also implemented the following dimming schedule:

- During the week:
    - 22:00 to 06:00 – 50% light output
- During the weekend:
    - 22:00 to 00:00 – 75% light output
    - 00:00 to 06:30 – 50% light output

The overall energy saved from the system deployment is approximately 35 percent and total operating costs have been reduced by 40 percent.[7]

3.3 TRAFFIC OPTIMIZATION

Traffic congestion is major issue in most large municipalities. It is both costly and damaging to the environment. Intelligent applications can monitor vehicle traffic in real-time using video and/or magnetic road sensors and optimize vehicle flow. The smart sensors can adjust traffic by leveraging the streetlight communication network to control smart traffic signals to optimize flow through intersections or to re-route drivers through digital signage and mobile applications.

Case Study: Los Angeles, United States

In 2013, Los Angeles implemented a central management system to control 4,500 traffic lights based on real-time traffic data it receives from an array of magnetic road sensors and roadway cameras. After two years, the project has increased travel speeds by 16% and reduced delay times at major intersections by 12 percent.[8]

3.4 PARKING OPTIMIZATION

Sensors integrated in a connected streetlight network can monitor availability of parking spaces and the length of time they have been occupied, while also scanning for parking infractions, advancing the functionalities of ground sensors. The parking and violation data can be communicated to commuters, potential commuters and city staff, including law enforcement. It can also be used to develop a tiered rate structure based on the busiest areas and/or times to incent drivers to park on less congested streets at less busy times. Smart parking provides opportunities for additional revenue opportunities for a municipality with improved violation data and tiered rates.

Case Study: San Francisco, United States

San Francisco installed wireless sensors in 8,200 on-street spaces to monitor parking availability in real time. This pilot project, called SFpark, was conducted to determine the most effective parking costs to meet availability targets. As a baseline, three control neighbourhoods were also integrated with parking sensors. After two years, SFpark reported the following results:

- Reduced weekday GHG emissions by 25%;
- Reduced traffic volume;
- Reduced search time for drivers by almost 50%; and
- Increased revenue by $1.9 million by making it easier to pay for parking, enough to offset the revenue lost to decreased parking tickets.

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[7] https://www.sierrawireless.com/resources/case-study/city-of-clermont-ferrand/
[8] http://smartcitiescouncil.com/article/battling-traffic-jams-smarter-traffic-signals

Although this smart city application is not connected to the streetlight infrastructure, it demonstrates the potential of the evolving smart parking solutions developed to be integrated in the luminaire network. For example, as part of San Diego's smart streetlighting pilot involving almost 50 poles, sensors were implemented in select fixtures in the downtown area that could monitor where and how long cars were parked. Using this information, parking enforcement and operations were optimized based on the data gathered. Initial results have shown not only that San Diego had many missed opportunities for parking enforcement, but also that the City had more opportunity to optimize traffic flow. In addition, real time parking availability applications will be deployed in spring 2017 for the public.

3.5 ENVIRONMENTAL MONITORING

Available environmental sensors for networked streetlights provide the opportunity to monitor and report weather conditions, air quality, ground conditions and noise. Air pollution sensors, including those that monitor carbon dioxide, sulphur dioxide, particulate matter and others, can provide important information on the health and environmental risks of ambient conditions. Conventional air pollution monitoring systems have typically been implemented with low spatial resolution due their significant size, weight and cost. Sensors mounted on streetlight infrastructure greatly increase the resolution and can relay data to public users, policy makers and researchers within minutes. The public can then take appropriate action based on individual health needs, and will also be more aware of their contributions to pollution. When considering the deployment of air quality sensors, municipalities should consider engaging staff responsible for health and the environmental initiatives.[9]

Case Study: Various Deployments

The use of environmental sensors is in the early stages, however, there are various pilots being conducted throughout the world including:

- **Glasgow, United Kingdom**: the City has implemented air quality and noise sensors along the River Clyde bike path and outside the Glasgow Central railway station as part of a Future Cities demonstrator[10];
- **Chicago**, **United States**: the joint research project, Array of Things, conducted by the University of Chicago and Argonne National Laboratory has been deploying data sensor nodes on utility poles since 2016 to monitor air quality and pollutants, light, noise, user movement and more[11];
- **Chattanooga, United States**: in 2016, UT Dallas researching began implementing the pilot project " Geolocated Allergen Sensing Platform (GASP)" that is deploying similar units as Chicago to detect particulate matter and pollen, as well as temperature, pressure, humidity and six other air pollutants[12];
- **Hamburg, Germany**: in March 2016, the Hamburg Port Authority launched an IoT pilot of environmental sensors to record emissions of sulfur dioxide, nitrogen dioxide and fine dust, along with temperature, air pressure and humidity[13].

3.6 SAFETY AND SECURITY

Intelligent streetlighting has the potential to improve community safety and security, not only by using light output controls, but also by the use of sensors, such as ground condition and noise monitors, and the communication network. Opportunities will be maximized through engaging with the appropriate law enforcement officials to ensure alignment of objectives and identify opportunities.

[9] *Yi, W.Y., Lo, K.M., Mak, T., Leung, K.S., Leung, Y., and Meng, M.L. "A Survey of Wireless Sensor Network Based Air Pollution Monitoring Systems", Sensors, 15, 2015, pp. 31392-31427; doi:10.3390/s151229859 .*
[10] *http://futurecity.glasgow.gov.uk/intelligent-street-lighting/*
[11] *http://www.chicagotribune.com/news/local/politics/ct-chicago-big-data-sensors-20150914-story.html*
[12] *https://www.utdallas.edu/news/2016/3/7-31941_Project-Aims-to-Make-Breathing-Easier-by-Mapping-A_story-wide.html*
[13] *http://technews.co/2016/12/06/the-port-of-hamburg-embarks-on-iot-air-quality-measurement-with-sensors/*

Dimming, brightening or flashing luminaires can be used for security purposes. This can involve emergency vehicle interfaces that can control light output for the purposes of emergency services. In some cases, law enforcement may need to extinguish lights during an operation. With legacy fixtures, the light is often extinguished by firing at the bulb, however, with an intelligent controls system, a luminaire can be turned off remotely without ending its service life.

Streetlighting can also be equipped with acoustic detection for gunshots or accidents which can trigger an image capture and alert emergency responders. Responders can be directed by flashing streetlights to the specified site, minimizing response times. Video may also be used for identifying missing or wanted individuals with minimal on-site investigation.

Intelligent streetlight networks can also be used as part of natural disaster preparedness. Seismic sensors can detect earthquakes and alert public and emergency response. Streetlights can be controlled to flash or change colour to indicate emergency evacuation routes in the event of flooding or other disasters, as is set up in Eindhoven, Netherlands[14].

Case Study: Glasgow, United Kingdom

As part of Glasgow's Future City demonstrator program, the city implemented a pilot of streetlight sensors to detect loud disturbances and unexpected movement in two lighting systems in the city center. The network then alerts authorities with the specific location, optimizing response time.[15]

3.7 MAINTENANCE OPTIMIZATION

Data from intelligent streetlight networks can be used to optimize municipal maintenance service delivery. Waste management, salt/gritting applications and sewer level monitoring are example services that have been involved in smart city solutions and discussed in the case studies below. However, municipalities are not limited to these service solutions and should identify the maintenance services that would have the greatest impact on the community if optimized through digital infrastructure and explore future opportunities.

Case Study: Bristol, United Kingdom

As part of Bristol's Smart City Project, the city has connected road temperature sensors into its network of intelligent LED luminaires. These sensors alert gritting crews when the road surface is reported at 3ºC and ensure grit application is limited to areas at this temperature. This targeted application significantly reduces grit use and associated maintenance costs.[16]

Case Study: Glasgow, United Kingdom

Following successful implementation of other smart city applications, Glasgow is now planning waste management optimization. The city will install underground large-volume bins with fullness sensors. The bins will be connected to litter receptacles above ground. The waste collectors will only be sent for collection when the fullness sensor alerts maintenance services.[17]

[14] *http://www.lightinglab.dk/_files/Dokumenter/presse/2015decembersmartcitiescouncil.pdf*
[15] *Ibid.*
[16] *http://www.computerweekly.com/feature/Evolving-Glasgows-Future-City*
[17] *Ibid.*

Case Study: Shawinigan, Canada

In 2016, the city installed 6,000 wireless controllers in each of its LED fixtures connected through a bidirectional RF communication network. Although initially installed for lighting control, the network can also be used for other City applications, including powering and monitoring time-based or event based sensors. Shawinigan has begun using sensors to monitor sewer levels because, during heavy rain or snow, sewers are at risk of flooding. The sensors continuously monitor water levels and send data and alerts to City staff. Prior to the streetlight sensors, staff had to check weekly if an overflow mechanical signal had been triggered since the last visit. The sewer monitoring system reduces City maintenance requirements and can also store data when overflows do occur, including water volumes and episode durations.[18]

3.8 REVENUE GENERATION

Intelligent streetlighting applications can provide opportunities for additional revenue generation either for municipalities or partners. Two applications currently available are Wi-Fi access points and electric vehicle (EV) charging stations.

Wi-Fi hotspots installed on poles can generate revenue through data access leases, advertising and usage fees. In can also improve internet availability in public buildings, such as libraries and community centres, and promote digital inclusion by providing free access in low-income areas.

Demand for EVs is growing faster than the availability of charging stations in many major municipalities. Charging stations can now be added to streetlights, along with associated payment processing, as demonstrated by BMW's "Light & Charge" pilot program in Munich[19]. The pole is fitted with a standardized connector to allow any EV model to charge and an integrated control unit for contactless operation using a smart phone app or RFID card. Not only will this generate revenue for the municipality but it will encourage greater uptake of EVs and support lower carbon emission targets.

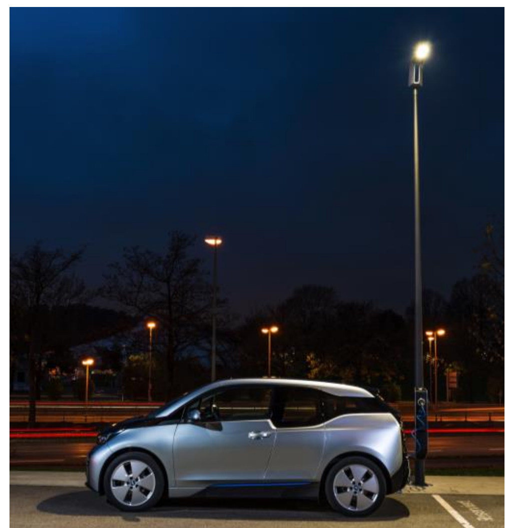

Figure 3: Example EV streetlight charging station by BMW

Case Study: London, United Kingdom

In 2006, the City of London partnered with The Cloud, a wireless network operator, to launch a free public Wi-Fi program in London's business and financial centre. Hotspots are installed on street furniture, including streetlighting poles, and have provided service for over 50,000 users. The cloud recently completed a full network upgrade, increasing the wireless capacity by four times and becoming the largest gigabit Wi-Fi network in Europe.[20]

London was awarded a share of £40 million from the UK government to install EV charging stations in streetlights across the city. Details on when this project will begin or how many stations are being implanted are not available.[21]

[18] http://www.dimonoff.com/
[19] http://www.bmwblog.com/2016/01/05/future-mobility-solutions-light-and-charge/
[20] https://www.cityoflondon.gov.uk/business/commercial-property/utilities-and-infrastructure-/Pages/wi-fi.aspx
[21] https://thenextweb.com/uk/2016/01/25/uk-to-get-electric-car-charging-points-embedded-in-street-lights/

4. OVERCOMING BARRIERS

LED streetlight adoption has increased significantly over the past 10 years and continues to expand. The platform for smart city solutions is therefore growing accordingly. However, as with any new technology, municipalities still face challenges to implementation.

Potential barriers specific to adaptive controls are discussed further in the LightSavers primer *Adaptive Controls for Roadway and Parking Lighting*, including: utility rate structures; interoperability with hardware and software; low utility prices; the waiting game; technological comfort; potential legal issues related to safety and dimming; and IT security[22].

4.1 INTEGRATION OF MUNICIPAL AGENCIES

Potential impacts of advanced streetlighting with smart city applications have the opportunity to engage various municipal agencies. Streetlighting infrastructure no longer involves just the transportation or roadway department. Benefits could be as far reaching as reductions to healthcare costs because residents are able to better manage their exposure to air pollution. To understand the full potential of data sharing from the digital initiatives, municipalities should unify their agencies during the design and procurement phases. This will likely require a champion, as discussed below, who understands the importance of integrating services and the value added of sharing data.

4.2 LIABILITY & RISK

Any lighting application must address the liability and risk issues resulting from changes in lighting levels and schedules and whether this affects safety. Legal concerns may come from an agency's justification for implementing a new lighting application or from the legal liability of owners and designers if there is a personal injury lawsuit attributed to the lighting system. Existing standards and design practices typically have not been modified to reflect the advancements in lighting control technologies. However, the following resources can help in developing policies and standards to reduce the liability and risk of implementing control technologies:

- *Design Criteria for Adaptive Roadway Lighting* by the Federal Highway Administration (FHWA) presents research in the frequency and severity of crashed related to illumination level[23];
- *Light Reduction and Energy Efficiency Guide* by the Transportation Association of Canada provides information on adaptive lighting applications for specific road types[24]; and
- *Guidelines for the Implementation of Reduced Lighting on Roadways* by the FHWA establishes criteria to apply to a roadway environment to identify appropriate lighting levels based on roadway characteristics and usage[25].

4.3 INITIAL CAPITAL COST

Implementing an intelligent networked control system will increase initial capital cost of a streetlighting conversion project, highlighting the importance of understanding the full extent of benefits across municipal services.

Municipalities should consider streetlights as a networked asset and change its perception from being an operational expense to it being a revenue potential or cost offset potential. Furthermore, as many of the potential benefits are realized in the long-term, the cost-benefit analysis should reflect the time period over which the benefits will accrue, rather than just the "payback period". For example, comparing projects based on the payback period will only

[22] https://static1.squarespace.com/static/56cdde5262cd94f3e9cffd8e/t/57b5cca41b631bc0993745a7/1471532197587/LSIV%2B2-3%2BControlPrimer.Final.For%2Bwebsite.pdf
[23] https://www.fhwa.dot.gov/publications/research/safety/14051/14051.pdf
[24] http://www.tac-atc.ca/en
[25] https://www.fhwa.dot.gov/publications/research/safety/14050/14050.pdf

consider benefits occurring within that timeframe and not the returns achieved after costs are covered. Municipalities should evaluate smart city applications based on economic indicators that evaluate the total costs and gains across a reasonable prediction of the product's lifetime. Possible financial analysis tools include: Total Cost of Ownership (TCO), Return on Investment (ROI) and Internal Rate of Return (IRR), discussed further in *LED Streetlight Scale-up: A LightSavers Guide*[26].

4.4 INTEROPERABILITY

For future-proofing intelligent infrastructure, the software systems and products should be interoperable. Interoperability of streetlighting technologies is important for improved functionality, scalability and flexibility of the applications. Requiring interoperability of devices at the poles is important for use of one common central management system to see and operate various vendors' solutions. By not being locked into proprietary technologies, municipalities can future-proof new technology by ensuring long-term viability of products and cost-competitiveness. Although newer to the streetlighting market, interoperability is not a unique concept, for example, in the building automation market where there are a variety of vendors, system integrators and subsystems communicating through a common protocol and connection configuration.

To promote interoperability of roadway lighting, municipalities should endorse global open standards. Major initiatives are:

- **The TALQ Consortium:** developed in 2012 to establish a globally accepted standard for management software interfaces specific to outdoor lighting networks, although not yet mandatory, products of participating vendors can be integrated between manufacturers[27];
- **LonMark International:** an industry authority for certification, education, and promotion of interoperability standards that defines common profiles for smart streelighting devices that vendors can voluntarily follow[28]; and
- **National Transportation Communications for ITS Protocol (NTCIP):** a joint standardization project of the United States that develops recommended design standards for interoperability and interchangeability, including the report: NTCIP 1213 Object Definitions for Electrical and Lighting Management Systems (ELMS)[29].

Municipalities can drive adoption of interoperability within the IoT and streetlighting markets by requiring applications to follow standards as above and use a standardized management software interface to allow integration of other systems and components.

4.5 PUBLIC PERCEPTION

When considering the implementation of sensors, it is important to be proactive and transparent with the community about mitigating intrusion into private activities and promoting improvements to safety. For example, the Array of Things research project in Chicago abandoned the initial plan of using sensors that counted cellphones and other mobile devices to track human movements due to public concern. As a replacement, the pilot project will use cameras to monitor movement through images that will not be stored or transmitted beyond the nodes of the utility poles. In this case, the public in Chicago had a high sensitivity to government projects having any interaction with mobile devices but are more comfortable with cameras and are more familiar their proliferation in public spaces.[30]

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[26] https://static1.squarespace.com/static/56cdde5262cd94f3e9cffd8e/t/57e03479197aea2b560ad2aa/1474311293803/5.LS.StreetlightGuide.160210.pdf
[27] http://www.talq-consortium.org/
[28] https://www.lonmark.org/
[29] https://www.standards.its.dot.gov/Standard/410
[30] http://www.businessinsider.com/key-challenges-to-growth-for-smart-cities-2015-11

4.6 COMPLEXITY OF NEW TECHNOLOGY

With new digital technologies, there is a learning curve for early adopters when the end user may not be initially comfortable with the proposed functionalities or requirements for installation. Furthermore, public agencies often require a Request for Information (RFI) or meetings with the private sector to help scope these new technologies, generally making the procurement processes longer than in the private sector. In some cases, municipalities find it difficult to attract the required IT talent to efficiently and effectively adopt new technologies. Municipalities should hold manufacturers accountable for the products by including warranty provisions in contracts and work directly with them to become familiar with the technology and knowledge for successful implementation. If an agency is completing a full-scale conversion of legacy streetlight luminaires to LEDs but does not feel comfortable to include a full-scale smart control network, the luminaires should be future-proofed with appropriate control receptacles and a pilot project should be conducted. A pilot can demonstrate the implications of intelligent lighting networks and provide an opportunity to develop in-house capacity.

4.7 SECURITY

As new digital infrastructure and smart technologies are being adopted, there needs to be a balance between the gains of increased infrastructure connectivity and management of the new security, safety and performance risks. A connected streetlight network can be vulnerable to cybersecurity attacks at varying threat levels. In response to these new concerns, standards are being developed by organizations including National Electrical Manufacturers Association (NEMA) and the Underwriters Laboratories (UL)[31]. Generally, municipalities need to ensure confidentiality and integrity of the network data in the hardware, software and connectivity. Secure sockets layer (SSL) encryption mechanisms should be considered for hardware and firmware. In software and back-end, features such as two-factor authentication are recommended to prevent unauthorized disruption of the system. For connectivity, an Internet Protocol security (IPsec) site-to-site Virtual Private Network (VPN) tunnel from the gateway to the corporate perimeter should be required. Finally, ongoing maintenance is needed to ensure the implemented security parameters are being maintained.

[31] http://www.ul.com/inside-ul/street-smart-security-for-connected-lighting-infrastructure/

5. IMPLEMENTATION

5.1 KEY COMPONENTS FOR SUCCESS

Successful implementation of outdoor lighting networks with intelligent applications requires a project champion who engages key stakeholders, develops a robust business case, fosts a utility partnership, and advocates for good public procurement and effectively monitors and reports results, as discussed below.

5.2 CHAMPION

Overcoming the barriers to implementation requires, most importantly, a project champion with decision-making authority to help initiate and sustain the proposed changes to public service. The champion has to be committed to leading system change to improve quality of life and resolving challenges. The champion must understand the potential opportunities of an intelligent and connected community and be able to effectively communicate these to stakeholders. One main champion in streetlighting can invoke a municipal- or provincial-wide change.

The champion will engage the right team to:

- Build a strong business case (considering all economic and non-economic benefits over the entire service life);
- Hold effective discussions and build relationships with utilities to modify tariffs and/or purchase streetlights;
- Identify appropriate system specifications for effective procurement; and
- Carry out project delivery and commissioning, including reporting results and lessons learned.

5.3 BUILD THE BUSINESS CASE

A business case typically involves comparing the benefits, costs risks and feasibility of implementing a given project or different options for a proposed project. There are many resources available, which outline the components of a typical business case, including the Government of Canada Public Services and Procurement Business Case template[32]. This section provides guidance on some of the unique considerations for creating a business case for intelligent streetlighting.

Since intelligent streetlighting projects can provide significant non-economic benefits to a municipality, these should be captured and quantified, where possible, in the business case. Additionally, the development of intelligent streetlighting as a backbone for intelligent community infrastructure can enhance the services provided by many city departments who should be engaged in the development of the business case.

[32] https://www.tpsgc-pwgsc.gc.ca/biens-property/sngp-npms/ti-it/etivcarmd-idsfvbctp-eng.html

a) Set the Strategic Context

The first step in building a business case is to set the strategic context by identifying the problem or problems the proposed project will address. The case for converting to LED streetlighting from traditional HID lighting is usually driven by the intent to reduce municipal energy and maintenance costs as well as GHG emissions reductions and improve lighting quality.

Developing streetlighting as digital infrastructure, enabled by the use of networked controls and sensors, can deliver additional benefits to a municipality beyond those delivered by converting to LEDs alone, as discussed in more detail in the Value Proposition section of this primer. These can include additional energy and maintenance savings, improvements to traffic flow, parking optimization, environmental and safety and security benefits. Because these potential benefits of intelligent infrastructure can impact many of the services delivered by a municipality, it is important to involve all relevant municipal agencies in the business case development to ensure the project aligns with their objectives and to assess opportunities for funding and staff support in other departments.

Municipal departments to consult could include: traffic and transportation services (including road maintenance, and parking services), law enforcement services, solid waste management services, health services, and information technology. Individuals or departments leading the overall digital planning efforts for the City should also be involved. For example, some larger cities are appointing Chief Digital Officers or Chief Innovation Officers to consolidate the municipality's approach to technology deployment at a community level. These individuals will be key members of the objective-setting discussions for intelligent streetlighting projects.

b) Identify Scope Options

Based on the established objectives, identify the scope of the project or scope options. For example, different options for the use of controls and IoT applications in streetlighting projects can be established. Options can also include the use of different technologies; the scale of the roll-out (a best practice for new technology installation is to begin with smaller scale pilot projects); or the decision to implement lighting that is ready to incorporate additional controls and sensors at a later date.

c) Identify Performance Measures

Once the project objectives and scope have been set, performance measures for each objective should be established. These are the indicators that need to be monitored or assessed in evaluating the success of the project. For example, performance measures for LED conversions typically include targets for energy conversation, maintenance savings and GHG emissions reductions. Example performance measures for streetlighting systems that incorporate controls and IoT applications are provided below.

Service Provided by Intelligent Network	Sample Performance Measure
Lighting Controls	• Additional energy savings • Additional GHG emissions reductions • Additional maintenance savings
Traffic Optimization	• Reduced delay times at major intersections • Reduced travel times • Reduced weekday GHG emissions from traffic
Parking Optimization	• Reduced weekday GHG emissions from traffic • Reduced traffic volume • Reduced search time for drivers • Increased parking revenue
Environmental Sensors	• Amount of data collected • Reliability • Delay • Data Resolution and detection probability • Reduced health services costs
Maintenance Services	• Reduced road salt/grit use and truck operation • Reduced snow clearing costs • Reduced waste collection costs • Reduced sewer maintenance costs
Provision of Wi-Fi Hotspots	• Number of users • Revenue (if through a paid service)
Provision of EV Charging Infrastructure	• Number of uses • Revenue (if through a paid service) • Reduced GHG emissions

d) Conduct a Technical and Cost Analysis

For each scope option identified perform a cost analysis. As discussed under *4.2 Initial Capital Costs*, a simple payback analysis should not be used because it ignores operating and maintenance expenses over the life of the asset, which are key components in evaluating long-lasting technology.

The value of non-economic benefits that accrue to all stakeholders should be defined where possible. This will require collaboration and buy-in with different municipal groups. The system benefits determined by a LCCA will vary depending on site-specific features, including: community needs; roadway type; land-use and pedestrian activity.

Adaptive Controls for Roadway and Parking Lighting: A LightSavers Primer provides more information on completing a LCCA for a networked streetlighting control system[33].

[33] https://static1.squarespace.com/static/56cdde5262cd94f3e9cffd8e/t/57b5cca41b631bc0993745a7/1471532197587/LSIV%2B2-3%2BControlPrimer.Final.For%2Bwebsite.pdf

e) Identify Funding Options

Likely the greatest barrier to implementation is sourcing funds. Public agencies often require investors and financial institutions willing to finance intelligent infrastructure projects. Similar to LED streetlight conversion projects, financing for smart applications can be costly and requires creative approaches focussing on both short- and long-term objectives. Financing options used for upgrading streetlighting systems include:

- **Self-financing:** municipalities use their own annual capital budgets. All municipal departments that will benefit from the project should ideally contribute to its development;
- **Government infrastructure financing:** funding and loans available from federal and provincial governments for municipal capital investment in infrastructure;
- **Leasing:** operating or capital leasing options from manufacturers and suppliers for municipalities to rent the lighting assets;
- **Energy performance contracting:** private energy service companies (ESCOs) provide turnkey solutions at a price based on expected energy savings;
- **Public Private Partnerships (P3):** the municipality grants a long-term license to the private sector to finance, implement and operate an infrastructure asset; and
- **User fees:** municipalities impose fees that are paid by choice, for example through tolls, EV charging stations or Wi-Fi hotspots.

More information on funding options for streetlighting networks is provided in *LED Streetlight Scale-up: A LightSavers Guide*[34] and *Smart Cities Financing Guide*[35] developed by the Smart Cities Council.

5.4 UTILITY ENGAGEMENT

It is important to engage the local utility during the early stages of a streetlighting project, specifically to ensure reduced energy use will be captured in cost savings. Furthermore, electricity for lighting is the responsibility of the utility, whereas making sure streets are safely lit is responsibility of the municipality, but ownership of the streetlights varies. If not already the case, municipalities should consider the option of obtaining streetlight ownership. This will provide the municipality more control of the lighting and network design, full benefits of potential revenue generators, potential long-term maintenance and operation savings and a channel to more easily overcome tariff challenges.

The main tariff challenge arises from the flat rate tariff utilities use for energy billing of the typically unmetered streetlight infrastructure. The flat rate structure is based on assumed energy usage and requires renegotiation to capture expected energy savings from installing advanced streetlighting systems. Networked controls with meter grade accuracy can measure power consumption providing the opportunity for Time of Use (TOU) billing. Although not yet certified by Measurement Canada, utilities, municipalities and manufacturers are working with Measurement Canada to develop a way to bill electricity using adaptive controls within the parameters of the law. In the meantime, municipalities should work directly with their local utility to develop an agreement that allows electricity to be billed based on control measurements or develops a tariff to reflect the expected reduction in energy use. For example, the City of Mississauga installed a full-scale adaptive controls system with its LED streetlight conversion in 2014 and worked with Enersource, the utility, to develop a method for demonstrating the metering integrity of the controls. The City installed smart meters along with the controls at select poles to allow for regular comparisons between readings[36].

[34] *https://static1.squarespace.com/static/56cdde5262cd94f3e9cffd8e/t/57e03479197aea2b560ad2aa/1474311293803/5.LS.StreetlightGuide.160210.pdf*
[35] *http://smartcitiescouncil.com/resources/smart-cities-financing-guide*
[36] *http://www.dimonoff.com/news/mississauga-led-streetlight-update-article-light-savers-canada*

Utilities are becoming more comfortable with and prepared for adaptive controls and smart lighting applications, but initial pilot demonstrations may be required to help facilitate this conversation and educate on how to incorporate controls into the billing system.

5.5 PROCUREMENT

Procurement of intelligent streetlighting networks is more complex than simple luminaire replacement because of the extensive list of potential opportunities that involve various public agencies. To future-proof communities, municipalities should at minimum be implementing a platform for smart city solutions by including a control network in the procurement of a full-scale LED streetlight conversion project.

a) Delivery Models

The delivery model for the project should be established based on the funding analysis conducted in the previous step and following an assessment of the internal capacity of the municipality to deliver the project.

Example arrangements include:

- Contracting with a single provider for financing, design, installation and maintenance of the entire intelligent streetlighting system (LEDs, controls and IoT applications). In some cases, vendors and service providers now offer the Lighting as a Service (LaaS) turnkey model that provides agencies the option to upgrade legacy streetlights to an integrated system of LED luminaires and smart controls. Lighting is treated as a monthly service that is billed as saved energy based on reductions in electricity use.
- Two or more separate contracts for the above services
- Purchase of luminaires only, to be installed by municipal staff and separate contract(s) for the installation of controls and IoT applications.

b) Procurement

The U.S. Department of Energy (DOE) Municipal Solid-State Street Lighting Consortium (MSSLC) maintains the *Model Specification for Networked Outdoor Lighting Control Systems* living document that includes modular reference for drafting Requests for Qualifications (RFQs), RFIs and Requests for Proposals (RFPs) for lighting control systems[37]. Adaptive control requirements will vary depending on the jurisdiction, so although is document is useful for modelling bid documents, the model specifications should be customized based on the specific end-user.

The Illuminating Engineering Society of North America (IESNA) has develop another useful resources for control system procurement, design and installation: *Guide for Selection, Installation, Operations and Maintenance of Roadway Lighting Control Systems* (DG-28-15).

For procurement of intelligent community solutions that are supported by a controls network, the European Innovation Partnership on Smart Cities and Communities, supported by the European Commission, makes the following recommendations for municipalities:

- Establish comprehensive and robust economic frameworks that identify the need for low-carbon economies fostered through innovative public procurement mechanisms;
- Engage with other public agencies to understand lessons learned and promote collaborative governance;

[37] https://energy.gov/eere/ssl/model-specification-networked-outdoor-lighting-control-systems

- Organize collective procurement processes to engage multiple municipal agencies with common objectives;
- Work with industry, for example through working groups, market-soundings and information forums, to exchange market knowledge and share community objectives;
- Promote public-private partnerships;
- Ensure procurement frameworks are flexible to allow for innovation but also require global open standards for interoperability and warranty provisions and/or maintenance contracts to respond to issues with new technologies;
- Inform public of proposed solutions and encourage/enable feedback prior to installation; and
- Adopt clauses, terms and conditions, evaluation criteria and sub-contracting guidance that have all been standardized.[38]

5.6 ONGOING MONITORING & COMMUNICATION

For emerging technologies such as networked streetlight for intelligent communities, the greatest catalyst to increase adoption can be knowledge sharing about existing projects. Public agencies engaged in intelligent streetlighting applications should monitor and communicate lessons learned throughout each of the following project phases: pre-design; design; construction; and occupancy and operations. For effective reporting, projects should evaluate common and repeatable performance measures, as listed under Building the Business Case, which can be universally understood. Collaborating with other jurisdictions can be an efficient and cost-effective method to evaluate various streetlight applications if each agency implements different options and reports results. Sharing lessons learned from early adopters will ultimately advance technology, which increases public and government understanding and comfort and promotes adoption of new intelligent applications that foster a connected community and enhance quality of life.

[38] https://eu-smartcities.eu/sites/all/files/Guideline-%20Public%20Procurement%20for%20smart%20cities.pdf