Public Lighting Group.

Smart Lighting Feasibility Study.

Draft
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Contents.

Background and Purpose

The Public Lighting Group has identified knowledge gaps surrounding the role and feasibility of introducing smart street lighting in Victoria. This feasibility study will help address gaps in this knowledge, and ultimately help Victorian local governments understand whether they might introduce smart lighting programs.

Since 2002, a number of metropolitan and rural Councils have participated in the Victorian local government network formerly known as the Street Light Group. In July 2016 this was renamed to the Public Lighting Group (PLG). The PLG has a vision of 'connecting Councils to deliver smart public lighting'. Its mission is to move public lighting into the 21st century by enabling member councils to better identify opportunities and respond to challenges.

In its endeavour, the PLG identified a gap in local government knowledge of Smart Lighting and the role it could play in the Smart City. This document titled **Smart Lighting Feasibility Study**, unpacks the feasibility of smart lighting as a connectivity option for the smart city by exploring the following issues:

- What is Smart Lighting?
- How can Smart Lighting be leveraged to deliver a Smart City?
- What are the technology options to enable Smart Lighting?
- What are some of the considerations that could impact the use of Smart Lighting?
- What are potential pathways for implementing Smart Lighting?
- What other options are available for delivering a Smart City?

This feasibility study sits alongside a **Smart City Concept Deck**, which provides smart city inspiration for Council including some developed concepts addressing the specific challenges of the Councils. Two of these concepts have been progressed further to **Mini Business Cases**.

These documents together set out to answer two questions, what could smart lighting be used for, and does smart lighting provide suitable connectivity to support smart city uses?

5x Resources

- Smart Lighting & Smart Cities
- Smart City Concept Deck
- On-Street Community Participation: Mini Business Case
- Smart Parking Spaces: Mini Business Case
- **Smart Lighting Feasibility Study** ← You Are Here

Smart Lighting Overview

Smart Lighting is lighting that is connected to each other, or the Internet through networking devices. This enables more efficient lighting management using a Central Management System. The network connectivity inbuilt into smart lighting can also provide Internet access for other smart city uses (e.g. smart parking sensors).

Councils in Victoria are in the process of upgrading their street light networks to LED lighting. This has been largely driven by Council's desire to reduce the cost of street lighting by benefiting from more energy efficient LED lights.

'Smart Lighting' is a term used by lighting and networking companies to describe LED lighting which has the ability to be controlled by a **Central Management System** (CMS) in order to provide functional and flexible lighting. The CMS is a system that enables two way communication of information on the lamp life of individual lanterns to be relayed back to a control centre, informing the operator whether or not any given lantern is operational. Therefore, unnecessary day burning of lamps can be prevented, and costly night time inspections of installations may be avoided.

CMS systems also provide operators with intelligent and flexible lighting control, individual control to street lights, dimming, and asset management. Smart lighting allows cities to adapt their lighting strategies to suit specific conditions - for example different colour lights or lighting profiles at different times, or in different places. Having a CMS system in place increases energy savings with additional dimming and enables a greater monitoring of the entire system.

In addition to the lighting efficiencies associated with smart lighting and a CMS, many smart lighting products have inbuilt connectivity that can help connect other **Smart City** uses and products to the Internet. For example, a smart parking system (that monitors how long cars occupy a parking bay) can connect to the Internet via a smart lighting system to send data back to council officers or to car park users.

The cost associated with adding this type of smart city functionality on-top of a lighting controller and CMS functionality is generally incremental. In one study, Arup found that adding smart city connectivity on top of a smart lighting system would increase capex costs by around 8%. Therefore, for the purposes of this research, the feasibility of smart lighting includes the benefits of CMS functionality as well as smart city connectivity.

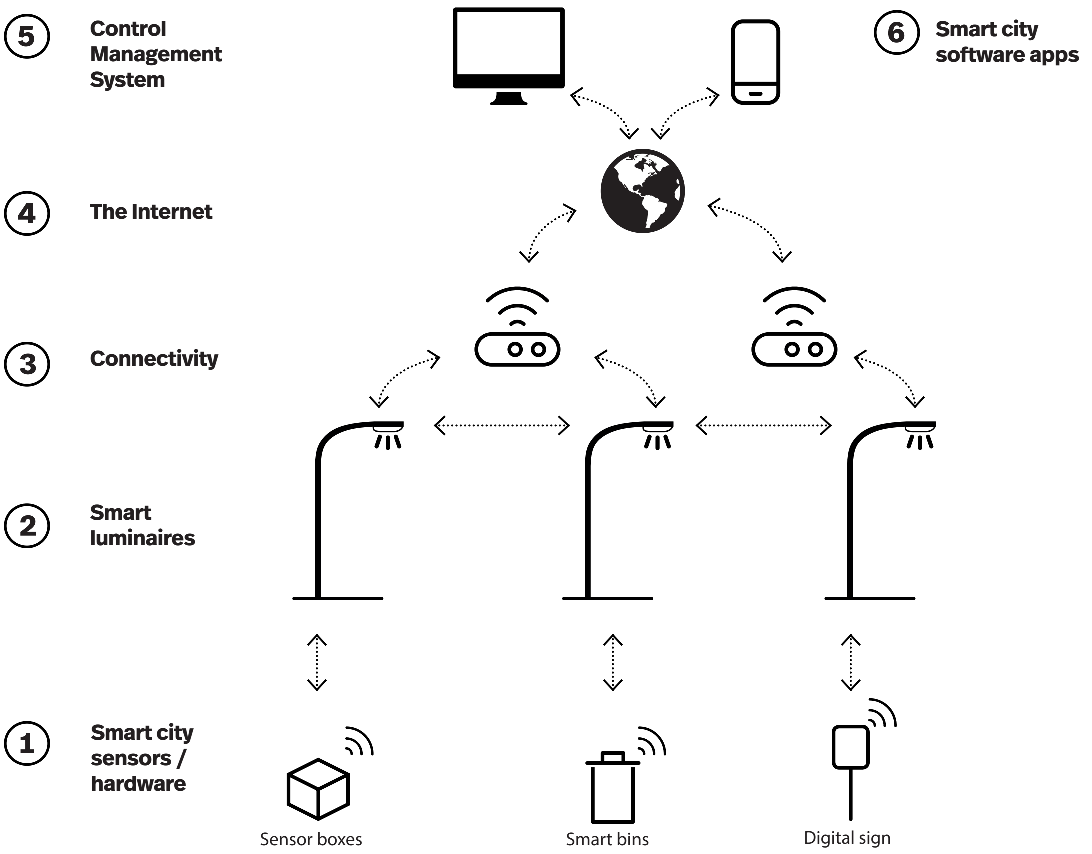
Smart Lighting Overview

An overview of smart lighting, compared to traditional or LED street lighting is provided below. This feasibility study considers moving from Level 1 or 2, traditional lighting or unconnected LED lighting, to Level 3 and Level 4, to include smart lighting, and potentially with smart city network connectivity.

Level 1	Level 2	→	Level 3	Level 4
Traditional Lighting	**LED**		**Smart Lighting**	**Smart Lighting with Smart City Connectivity**
Generally, traditional sodium lighting.	Replacement of LED's creates notable energy savings, changes in lighting profile, compared to sodium lighting. These efficiencies and advantages are well understood, and are not the focus of this study.		Connecting lighting (generally LED lights) to each other and to the Internet to enable operational efficiencies for lighting owners. Incorporates a lighting Control Management System (CMS).	Connectivity can also be used to provide network connection for other smart city uses and products (e.g. smart parking). Street lighting can be an enabler of these sensors/hardware, due to cities being conveniently scattered with light poles, attachment locations and a reliable power supply.

Smart Lighting
Tech Options

This section describes the general configuration and components of a smart lighting system. The different configurations help to understand how a smart lighting system might be procured, and the considerations to take into account.



A general, high-level architecture of a smart lighting system with smart city connectivity is provided above. The main elements are:

1. **Smart city sensors/hardware** (e.g. smart bins, smart parking sensors) that can be connected using smart lighting systems. Smart street lighting can be an enabler of these sensors/hardware, due to cities being conveniently scattered with light poles - providing an attachment location, connectivity and a reliable power supply.
2. **Controllers** embedded in the street lamp luminaire, that can manage the individual lighting profile of that street light, and potentially provide connectivity and attachment for other sensors.
3. **Connectivity** to and between the street lights, including gateways where applicable.
4. Connection to the **Internet**.
5. A lighting **Control Management System (CMS).** The piece of software that allows control, customisation and monitoring of individual street lights or groups of street lights.
6. **Smart city software and applications**, connected to the Internet. Examples include smart bin monitoring software, or car parking mobile applications that show where the best place is to park a car.

Artwork credits: Surya, Lucan fhne, Edward Boatman, Prakruti, Andreas and Mello

Smart Lighting Tech Options

Connectivity Options

With regards to connectivity, individual smart lights can be connected through several different technologies:

- Hard-wired (e.g. fibre or Ethernet) generally underground. More applicable to greenfield installations than retrofits.
- Direct wireless connection. Each street light is directly connected to the Internet through a wireless technology (e.g. 3G, or Low Power Networks).
- Wireless mesh networks. Each smart luminaire can talk to nearby luminaires - passing on messages between them.
- Communication over power lines. Carrying messages across existing power lines.

With regard to the two wireless typologies identified above, there are different ways to connect street lamps. Different smart lighting providers might utilise different connectivity protocols or methods. Different connectivity types can cost different amounts (both initial and ongoing costs) and have different functionalities (e.g. different data speeds or data bandwidths). It is therefore important to consider the connection type carefully from the outset.

Smart Luminaire Options

With regards to Smart Luminaires, these are the general options available for installing smart lighting on street light poles. The options exclude standard LED luminaires without connectivity (or those that exclude the potential for future connectivity).

- **LED + NEMA 7 Pin (dimmable driver)**. Specified with DALI (Digital Addressable Lighting Interface) dimmable drivers and with a NEMA (National Electrical Manufacturers Association) 7 pin connector that allows for future connectivity. DALI allows individual control of luminaires.
- **LED + NEMA 7 Pin + Connectivity**. Specified with a smart NEMA node module which enables wireless communication and benefits of smart lighting such as CMS, feedback and monitoring.
- **LED + NEMA 7 Pin + Connectivity + Other Sensors**. Specified with a smarter NEMA node module which enables third party sensors and more inputs.

Example of Phillips Street Lighting system that allows for future connectivity and integration of sensors through NEMA 7 pin outlet.

CIMCON's Plug & Play Wireless Lighting Controller (iSLC) with Remote Monitoring, Dimming, GPS, Metering and Sensor Input Capabilities. Integrates into NEMA 7 pin. Connects to Silver Spring network.

Procurement Options

There is more than one approach to procuring lighting. The Institute of Public Works Engineers (2017) has identified two different approaches to procuring a smart lighting configuration:

1. **Turn-key solutions**, where one provider is responsible for implementing all (or almost all) of the layers in the configuration identified on the previous pages. In other words, one provider would be responsible for providing smart lighting controllers, connectivity, and CMS in an integrated product. Increasingly these providers also provide some limited smart city uses/products (e.g. environmental sensors, public Wi-Fi) in turn-key solutions.

2. **Modular procurement,** where different layers are procured separately. For example, different providers could provide connectivity, lighting controllers, CMS and/or smart city applications. In these instances, there is a need to ensure the interoperability of each component in the system. In other words, each component needs to be able to talk to each other, despite being provided by different groups.

Costs & Benefits
Overview

Smart Lighting can provide direct benefits through cost savings associated with lower energy consumption and a reduction in operations and maintenance costs. Indirect benefits include environmental and public safety benefits, as well as the potential to leverage the benefits of the IoT.

This section includes an overview of the costs and benefits associated with Smart Lighting that Council would need to consider, based upon research and case studies of smart lighting proposals and installations.

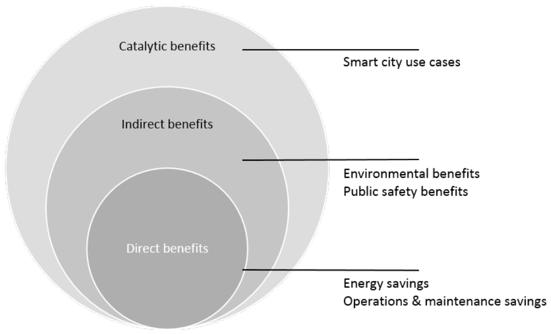
As the Smart Lighting concept is still in its infancy, and there are very different models of delivery available, it is difficult to articulate costs and benefits with accuracy. Where there are benchmark quantified costs and benefits available, they are included as a general indication, rather than definitive guide.

A summary of the benefits and costs is provided below. More detail is provided on the following pages.

Benefits	Costs
Energy efficiencies associated with smart lighting controls	Lighting controller costs
Operational efficiencies associated with smart lighting controls	Lighting CMS costs
Environmental benefits as a result of lower greenhouse gas emissions	Connectivity costs
Public safety benefits associated with more responsive lighting levels	Smart city hardware and application costs
Enabling Smart City use cases and products	Potential costs for installation of smart city hardware

The below framework can be used to highlight the benefits associated with Smart Lighting.

- Direct benefits are financial benefits such as an increase in revenue or a reduction in cost.
- Indirect benefits are benefits that are not as easily quantified in financial terms and are typically less measurable.
- Catalytic benefits are the wider economic benefits that have been enabled.



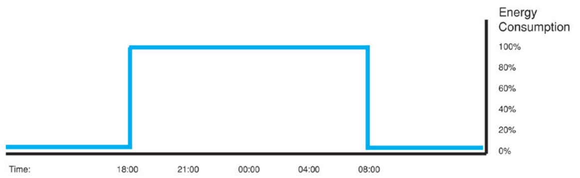
Costs & Benefits Overview

<u>Benefit:</u> Energy efficiencies associated with smart lighting controls

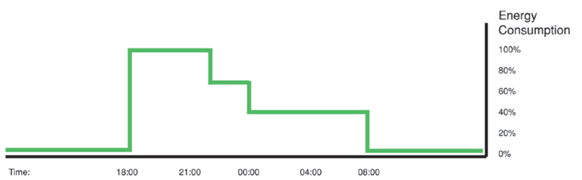
There are substantial energy efficiencies and cost savings associated with LED lighting. However, Smart Lighting only provides a marginal benefit over LEDs through the addition of lighting controls, as most of the benefit is realised in the LED itself.

A study by Auckland Transport estimates that a further energy saving of 15% is possible through a shift from LED lights to integrated smart lighting (with a CMS). In Scotland, business cases for smart lighting have proposed to dim lights by 50% during 11pm and 6am. A study undertaken for Dublin City Council estimated a 7% energy saving when transitioning from unconnected LED street lights.

LED lighting (without smart controls) energy consumption profile



LED lighting (with smart controls) energy consumption profile



<u>Benefit:</u> Operational efficiencies associated with smart lighting controls

Council staff have noted that community complaints about street lights not working are an issue for the City. When a community member contacts the City to report a broken street light, it is difficult to find the exact light that they are referring to and attend to the issue. Lights with embedded sensors can address this issue, potentially reducing operational costs (e.g. routine light checks during the night) and provides higher levels of community satisfaction.

A Feasibility Study for smart lighting in Ireland estimated that a city-wide smart lighting CMS would enable a 15% saving in non-routine maintenance costs. Non-routine street light maintenance includes lights that have been knocked down during weather events, vandalised or become faulty.

In addition, there is expected to be other administrative and maintenance efficiencies associated with a CMS. For example lighting management, night patrols, billing and other administrative costs, and maintenance planning optimisation (predictive maintenance) should all benefit from the data generated by a lighting CMS.

<u>Benefit:</u> Environmental

Environmental benefits are the reduction of greenhouse gas emissions directly linked to the reduced energy consumption of Smart Lighting. A study undertaken in Germany, found a reduction of 0.14 tonnes of CO2 per light per annum when upgrading to a CMS controlled LED street lighting system from traditional lighting. Similar to the energy efficiency benefits, the incremental benefit of Smart Lighting above LEDs is only marginal through the addition of lighting control as most of the benefit is realised in the LED itself.

<u>Benefit:</u> Public safety

Higher levels of real or perceived public safety may be experienced by adjusting lighting levels using smart lighting. Examples might include:

- Increasing lighting levels in high crime areas
- Increasing lighting levels during emergency events
- Increasing lighting levels in response to loud noises or elevated activity around a street light

We are unaware of any studies that demonstrate or quantify these benefits conclusively, however this is one of the major benefits espoused by many smart lighting suppliers.

Costs & Benefits
Overview

<u>Benefit:</u> Smart City products and use cases

Smart lighting systems provide the potential connectivity and power infrastructure for deploying other smart city technologies, as detailed in previous chapters.

The deployment of connected sensors and technology (Internet of Things) via the Smart Lighting network could present a number of opportunities to promote social, environmental, and economic benefits for the community, and financial efficiencies for councils

There are a multitude of smart city technologies that might be supported by connected, smart lighting systems. The *Smart City Business Cases* and *Smart City Concept Deck* that can be read alongside this feasibility study provide examples of these.

The benefits stemming from the smart city products and use cases cannot be quantified. Firstly, there are a myriad of applications available, and each council will select only some of these. Secondly, future applications that do not yet exist, but will come to market in the coming years (with rapid development of the Internet of Things), are speculative and therefore unproven at this stage. Finally, many smart city technologies that exist are not reliant upon smart lighting for connectivity and power, and therefore it is not possible to attribute benefits to smart lighting. This is discussed further in the 'Considerations' chapter.

<u>Cost:</u> Smart lighting controller costs

Installing a lighting controller, which is an additional technical component, to each street light will create an additional cost. The exact cost of installing a controller will depend upon the model of procurement (e.g. scale of rollout) and the exact product specifications (e.g. connectivity options, as detailed in previous chapters).

There will also be ongoing costs associated with adding these controllers to each street light. For example, maintenance/replacement costs associated with replacing smart lighting controllers will be a new cost to consider. Again, the exact cost will depend upon factors such as the procurement model selected, the scale of a roll-out, and technical components/models selected.

<u>Cost:</u> Smart lighting Central Management System (CMS)

From reviewing practice elsewhere, CMS systems can be charged at a fixed cost, or an ongoing service provided with a subscription fee. The cost will vary significantly between geography, scale of the roll-out, and packaging options (e.g. whether the CMS is included as part of a turn-key solution, or is it standalone).

<u>Cost:</u> Connectivity costs

There will be fixed and/or ongoing costs associated with network access/connectivity. These could be associated with the use of an existing network (e.g. a Sigfox network or a standard 3G network will involve monthly data costs). Some suppliers (e.g. SilverSpring, provide a Network as a Service (NaaS) model, which would require direct negotiations with the supplier. With more custom networks, there might be no ongoing costs, but a higher initial fixed cost.

The cost of network connectivity is complex, as it will depend upon the interaction of many factors - how much data needs to be transmitted, how often it needs transmitting, the procurement model and agreements with connectivity providers, the scale of the street lighting network etc.

<u>Cost</u>: Smart city hardware and application costs

There are costs associated with rolling out sensors, actuators or other smart city applications. These costs, again, will vary significantly depending on the exact application being rolled out. As a matter of reference, a standard Libelium Smart City Sensor (which measures things such as noise, pollution, temperature) costs in vicinity of $4,000 (without installation and systems integration costs). In this context, achieving large scale sensor roll-outs is still not cheap, however the cost is expected to drop dramatically in the coming years as the Internet of Things matures.

<u>Cost</u>: Installation of smart city hardware

We understand that councils would need consent from DNSPs for the attachment of additional devices (e.g. sensors or security cameras) to their infrastructure. DNSPs could charge a leasing fee for access to their infrastructure however it would need to be negotiated with the DNSP on a case by case basis.

Costs & Benefits
Case Studies

The table below provides a summary of benefits, costs and financial payback periods associated with various international smart lighting case studies. The table is intended to provide a high level overview of the types of costs and benefits associated with different types of installations. The case studies show very different periods of return on investment, depending on upon local circumstances (e.g. labour costs, energy costs).

Title/Source	Change	Description	Financial Costs	Financial Payback Period	Other Benefits
Aurich	Level 1 to 3	Installation of CityTouch CMS	Unknown	Unknown	0.14 tonnes of CO_2 saved per light annually
Silver Spring Report (supplier commissioned)	Level 1 to 2	LED replacement only	Unknown	8 years	Unknown
Silver Spring Report (supplier commissioned)	Level 1 to 4	LED replacement with connected lighting	20% more expensive compared to normal LED replacement over lifetime (but higher benefits as well)	6 years	Additional financial savings driven by operational savings as well as increased energy savings from dimming and reduced nightly burn time enabled by the network.
Greater Geelong City Council	Level 1 to 4	Rollout of smart lighting in Ocean Grove shopping area	Unknown	Unknown	Public Wifi, public USB charging points - helping to activate Ocean Grove shopping area
San Diego	Level 1 to 4	Installation of LED luminaries, with connectivity and lighting control system (using GE LightGrid), associated smart city applications	Unknown	13 years	Dimming schedules to reduce light use
Dublin City Council	Level 1 to 3	Installation of LEDs with connected lighting	Unknown	8.6 years	7% energy saving compared to normal LED installation
Dublin City Council	Level 1 to 4	Installation of LEDs with connected lighting and connectivity for smart city uses	Unknown	9.1 years	7% energy saving compared to normal LED installation
Adelaide (Pirie St)	Level 1 to 3	Installation of LED luminaries in pedestrian area with dimming feature, pedestrian sensors	Unknown	Unknown	15% energy savings reported

Considerations
Ownership

The ownership of the street lights will generally influence the feasibility of transitioning to smart lighting. In Victoria, street lights are generally owned by a DNSP, Council or VicRoads.

The opportunities for smart lighting will vary depending on who owns lighting assets. We have considered the impact of ownership models based on the following questions:

- Who receives the direct benefits of Smart Lighting, such as the energy cost savings and operations and maintenance savings?
- Who owns the connectivity of Smart Lighting and the data collected by utilising the connectivity?

DNSP owned.

DNSPs manage energy networks - Australia's energy networks provide the final step in the delivery of electricity to households, businesses and industries. DNSPs are largely responsible for maintaining and managing street lighting in most areas of Australia. Considering that DNSPs own the majority of street lighting in Victoria, it is essential that Councils continue to negotiate with the DNSPs and aim to work collaboratively to deliver Smart Lighting if pursued.

As part of this ownership, the DNSP is responsible for undertaking the operation, maintenance and replacement (OMR) of these street lights. DNSP owned street lights are normally unmetered with the customer typically being charged based on the number and type of street lights and the hours of operation.

In the case of Smart Lighting on DNSP owned assets, while it is expected that the benefits associated with energy savings through lighting control and optimised operation and maintenance would be passed onto the consumer (i.e. the relevant council), in reality the full savings are not always passed on. This is due to the DNSP owning the technology and therefore controlling what level the technology is utilised. Similarly, it is expected that the DNSP would own the data connectivity through Smart Lighting and Council would need to negotiate with the DNSP to access the data or connect sensors to its network.

If Council wants to own, operate and maintain the Smart Lighting technology on DNSP owned assets, it would need to involve the DNSP transferring or selling the whole street lighting asset to the Council. Victorian councils that have enquired about purchasing DNSP assets have noted the costs can be prohibitively expensive, and therefore have not proceeded with these plans.

It has been established, through previous legal cases, that a Council cannot own the luminaire on a DNSP asset, without owning the entire pole/section of network.

With the potential for DNSP revenue to be challenged with new technologies (e.g. distributed energy grids), there is the potential for DNSPs to seek new revenue sources from their assets. In the future, this might include the DNSP providing connectivity for smart city technologies, or deploying their own sensor network and then on-selling data.

Council owned.

Council owned street lights are usually located in open space and public areas such as parks, sporting grounds, car parks, and activity centres and are normally metered with the customer being charged based on the energy consumed.

Councils may elect to own new public lighting and are free to choose who provides the operation, maintenance and replacement services of these new assets. However, new public lighting assets are generally built by Council and then vested to DNSPs. This requires the Council and DNSP to agree that after construction and commissioning of the public lighting asset that the ownership of the asset is transferred to the DNSP.

Considerations
Ownership

In terms of Smart Lighting on Council owned street-lights, assuming that the technology can be connected to the network, Council will own, operate and maintain the Smart Lighting. As such, it would be expected that the benefits associated with lower energy consumption and reduced operations & maintenance, would flow directly to the council. Additionally, it would be expected that any data collected through the Smart Lighting network would be accessible to Council.

VicRoads funded.

VicRoads pays the full cost of installation, operation and maintenance of all road lighting on freeways (excluding pathway lighting). For lighting on arterial roads, ongoing operation and maintenance costs are shared between VicRoads (60%) and the relevant Council (40%). Generally, the initiating party for arterial lighting will fund the installation costs.

VicRoads guidelines state that new road lighting on arterial roads shall be installed as DNSP operated and that a combination of VicRoads owned and DNSP operated lights should be avoided in the same location, suggesting that the asset is vested to the DNSP. If this is the case then the overview provided for DNSP owned assets would need to be considered.

Conclusion.

Considering the limited control that Councils have over DNSP owned assets, it would be suggested that Councils should first pursue investigating Smart Lighting on their own assets before DNSP owned assets. Since many of the Council owned assets are actually located in activity centres, these assets are already the most credible option to leverage smart lighting for IoT.

Considerations
Lighting Standards

There is yet to be a specific set of unified standards, terminology, or specification which governs smart lighting. The implementation of lighting standards is typically linked to the Australian Standard AS/NZS1158 series of P and V Category Lighting. Other standards can also influence smart lighting rollouts.

Lighting for streets and public spaces is subject to numerous technical requirements to ensure that the desired outcomes are met. The AS/NZS1158 standards state that the performance criteria for such lighting schemes to help address the following:

- Facilitation of safe movement of vehicles and people
- The discouragement of illegal acts
- Contributing to the amenity of an area through increased aesthetic appeal
- Minimising glare and light spill into sky and neighbouring areas

Due to the prevalence of modern LED lighting, the AS/NZS1158 series of standards are undergoing change as the technology is moving quickly. The standards were originally written based on traditional discharge lamp types such as High Pressure Sodium (HPS), Mercury Vapour (MV) and Fluorescent, which have largely become superseded by LED as efficacy has rapidly increased.

The series divides public lighting into the following two broad categories:

1. Category V lighting - Lighting that is applicable to roads on which the visual requirements of motorists are dominant, e.g. traffic routes.
2. Category P lighting - Lighting that is applicable to roads on which the visual requirements of pedestrians are dominant, e.g. local roads and lighting that is applicable to outdoor public areas, other than roads, where the visual requirements of pedestrians are dominant, e.g. outdoor shopping precincts.

V Category Lighting

The objective of V Category (road lighting) is to provide an illuminated environment, which is conducive to the safe and comfortable movement of vehicular and pedestrian traffic at night, and the discouragement of illegal acts. To accomplish this, the lighting should reveal necessary visual information. This consists of the road itself, the course of the road ahead, kerbs, footpaths, property lines, road furniture and surface imperfections, together with the road users including pedestrians, cyclists and vehicles and their movements, and other animate and inanimate obstacles.

The V Category standard requires minimum levels of lighting to be applied to roadways. These limits are set at a relatively high level, designed to ensure adequate light is provided for higher traffic flows.

It is possible for smart lighting to reduce it intensity, when there are low levels of traffic (or no traffic). However, there is some speculation that there might be legal implications (e.g. liability risks) if a council or DNSP provided lighting levels below those directed in the Australian standards.

This means that, despite the possibility of dimming lighting for energy and cost savings when there are lower levels of need (e.g. lower levels of traffic), this may create a legal risk. This creates a significant barrier to fully implementing smart lighting features in areas covered by the V Category Lighting standard.

P Category Lighting

The major purposes of the lighting covered in this Standard are to assist pedestrians to orientate themselves and detect potential hazards and to discourage fear of crime and crime against the person while protecting the integrity of the night time environment through control of light spill and glare. The lighting may also be used to enhance the prestige and amenity of the location but should be designed to minimise any obtrusive effects. The lighting, with certain exceptions, is not meant to provide drivers with adequate visibility if motor vehicle traffic is present at the location; for this the vehicle headlights are used.

Considerations
Lighting Standards

The exceptions is when there is interactive pedestrian and vehicular activity present in designated areas, e.g. transport interchanges, car parks.

Due to lower risks (compared to V Category Lighting areas), P Category Lighting areas would provide an opportunity to pilot and explore the full potential of smart lighting.

Lack of Smart Lighting Standards

Currently smart lighting's various additional components do not have an AS/NZS style standard that governing rollouts. There are not currently any standards for an entire smart street lighting luminaire or pole. Smart street lighting and smart poles will bring together areas that have not previously co-existed including street lighting, dimming, communications, metering, controls, sensors, displays, photovoltaic systems, connection sockets, EV charging and potentially other components. It is clear that the Australian Standards do not account for the more complex environment and customisation enabled by smart lighting systems.

DNSP Approved Luminaires

With regard to the design of smart lighting, the DNSP's only accept a small selection of "approved" luminaires to be used within their jurisdiction (since they are required to operate and maintain the system following installation).

Often a DNSP will only approve a limited catalogue of luminaires for installation on their infrastructure. This limits the ability to achieve good or more custom lighting outcomes that are suited to the specific context of a lighting installation (e.g. the colour profile, or dimming profile).

Luminaire Control Standards

Various protocols already exist to control lighting systems and the NEMA ANSI C136.41 standard is gaining acceptance as a 7 pin connection base standard for mounting sensors and other accessories.

Considerations
Regulatory Context

The regulatory context influences the feasibility of introducing smart lighting in different contexts. This section provides an overview of key regulation of public lighting in Victoria.

Regulatory bodies

Essential Service Commission (ESC). The ESC promotes the long-term interests of Victorian consumers by regulating essential services such as energy, including public lighting through the Public Lighting Code. The purpose of the Public Lighting Code is to regulate the provision of public lighting or the arrangements for such provision by specifying minimum standards and certain obligations of DNSPs and public lighting customer.

Australian Energy Regulator (AER). The AER regulates the DNSPs in accordance with the Public Lighting Code and the National Electricity Rules. The AER has the power to issue licenses, codes and guidelines and make price determinations which includes the provision of some aspects of public lighting including the operation, maintenance and replacement (OMR) charge.

Regulatory influence

Councils may attempt to influence change of the current regulatory frameworks by engaging with both these regulatory bodies to ensure that there are clear regulatory guidelines associated with Smart Lighting and DNSP owned assets. It should be noted, that this approach can be slow, costly and have a low probability of success. If councils own and operate their own infrastructure, then this should not be a barrier.

Considerations

Alternative Options

While Smart Lighting can provide both power and connectivity, there are a range of alternative options for both. Alternative power sources and connectivity forms are provided below. These should be considered when thinking of deploying smart city use cases and products, as they may often be cheaper or more convenient.

Alternative power sources

The table below articulates other power sources that might be considered when planning to deploy smart city technologies. They provide an alternative power source to that provided by a smart lighting system.

Tech	Good when	Not good when	Considerations
Mains power (e.g. from a building)	Large quantities of data are to be sent and/or frequency is high (as this requires a lot of power)	Don't have access to mains power You don't have approval to connect to mains power You want to decommission the sensors after a short time	May need special approvals and certified specialists to connect your sensors
Solar power	Have access to open space with sun exposure	Higher density areas of the city that have overshadowing When sending a lot of data, or are sending data very frequently using a high power consuming connectivity type	Solar panels can be bulky
Battery only	Sending small amounts of data The project is short, or your sensors are portable Using a connectivity type that doesn't use much	When sending a lot of data, or are sending data very frequently using any connectivity type	If they are not self-charging batteries, someone will have to replace them periodically

Considerations
Alternative Options

Alternative Internet connectivity sources
The table below articulates other connectivity sources that might be considered when planning to deploy smart city technologies. They provide an alternative connectivity source to that provided by a smart lighting system. They should be considered as alternatives when planning rollouts.

Tech	Description	Range	Considerations
Wi-Fi	Public Wi-Fi systems might be deployed that provide connectivity for smart city technologies. Often already deployed, or more feasible to deploy, in activity centres (density of activity/users). Sometimes provided by other infrastructure (e.g. smart bins, or Telstra phoneboxes)	Low Approx 50m	Requires stable Wi-Fi network (public Wi-Fi networks often not stable). Security and encryption on Wi-Fi can be a larger concern. Councils often own secure, directional Wi-Fi or similar for CCTV and other networks, that may be able appropriated for other sensor uses
Cellular (3G and 4G)	Mobile phone-like SIM card inserted in sensor to communicate with mobile network. Covers most areas of cities.	High Kilometres	The cost of frequently sending large amounts of data can be considerable (mobile phone company subscription costs) Not suitable for very high bandwidth smart city uses
Cellular Narrowband	Upcoming technology, uses existing mobile network.	High Up to 30km	Currently in pilot in Australia Not suitable for higher bandwidth smart city uses (e.g. CCTV, public Wifi)
Sigfox	Proprietary sensor network provided by Thinxtra in Australia.	High Kilometres	Requires access to a gateway. Commercial providers such as Thinxtra provide connectivity. Not suitable for higher bandwidth smart city uses (e.g. CCTV, public Wifi)
LoRaWAN	Long-range connectivity that requires special configuration	High Kilometres	Requires access to gateway. Commercial providers and open access providers active in Melbourne market Not suitable for higher bandwidth smart city uses (e.g. CCTV, public Wifi)
Cables (e.g. Ethernet)	Would require Ethernet access. Probably most relevant if attaching sensor to council building that already has Internet access.	Direct contact required	Power can be provided over Ethernet (PoE)

Considerations
Risks

There are a number of risks associated with Smart Lighting that needs to be considered when planning an installation.

DNSP risks. It is our understanding that councils cannot own networked LEDs installed on DNSP assets, and instead they would need to be vested to the DNSP. This could include the connectivity enabled by the smart lighting infrastructure, meaning that the DNSP would capture the benefits of the infrastructure investment, with a risk that the full benefits are not passed on to councils and the community.

Mitigation options: install smart lighting on council owned lighting assets as a priority over DNSP assets.

Vendor lock-in. Proprietary smart lighting solutions can make a customer dependent on a vendors products and services. This is a higher risk with 'turn-key' solutions (see 'technology options' section). While a proprietary solution may provide the Council with the requirements it needs in the short-term, they must ensure that their solution is adequately future proofed. This can be achieved by ensuring that the solution integrates with other devices and technology.

Mitigation options: Procuring smart lighting through a modular approach (see 'technology options' section), or ensuring interoperability is guaranteed in supplier contracts.

Data management. When generating and collecting data, it is essential to maintain security and privacy where more sensitive data is collected. This can particularly become sensitive when collecting data that relates to individuals. Additionally, there may be issues around who owns the data, especially in the context of Smart Lighting on DNSP owned assets or when using proprietary technologies.

Mitigation options: Ensure contracts provide for data ownership vested with councils, ensure adequate security/privacy controls are in place when collecting potentially sensitive data from smart lighting systems.

Funding. Councils have traditionally relied on internal funding, however there area a range of alternative funding options including Federal Government grants for Smart City initiatives that could be considered.

Mitigation options: Council's should properly understand their funding options before pursuing investment.

Resourcing. To successfully deliver a project councils must ensure that they have adequate capacity, capability and expertise. This is particularly applicable to technology projects which generally have a higher level of complexity.

Mitigation options: build internal knowledge by running small-scale pilots of smart lighting systems and smart city use cases/products. Use this knowledge to inform larger scale rollouts. Alternatively, engage with other councils or consultants where there are evident knowledge gaps before procuring smart lighting or smart city technologies.

Benefits realisation. Many of the Smart Lighting and Smart City concepts are in their infancy. As such, the benefits associated with these concepts are speculative and are at higher risk of not being realised relative to mature technologies.

Mitigation options: undertake small scale trials to test the benefits and costs associated with smart city use cases and products prior to wider adoption.

Considerations
Risks

Adequate technical specifications. Many smart city applications (e.g. a well-functioning public Wifi system or CCTV system) require high-level technical spec's (e.g. bandwidth). Not all smart lighting systems will provide sufficient bandwidth or capacity to service their needs. It is important to ensure that a deployed network is sufficient for future uses a council may wish to pursue.

Mitigation options: Ensure smart lighting system provides sufficient technical specifications to meet future needs. Consider alternative network options (see below). A smart city strategy or IoT strategy should assist in understanding future connectivity needs more definitively.

Alternate networks. There are alternative communication networks that could be used to implement smart city use cases and products in many cases. There is a risk that, after investing in smart lighting as a connectivity platform, there are cheaper ways to achieve power and connectivity for smart lighting.

Mitigation options: Fully consider all connectivity options, not just smart lighting, to enable smart city products and use cases. Consider the strategic interrelationship of smart city technologies through the development a smart city strategy for each council.

Recommendations
Next Steps

While Smart Lighting is in its infancy, the preliminary findings in this study suggest that the concept does have merit. This section outlines Arup's recommendations should the PLC wish to further pursue the Smart Lighting concept.

Implementing Smart Lighting

Our recommendations for proceeding with Smart Lighting are outlined below:

1. Undertake small scale Smart Lighting pilot projects in order to test and ratify the issues identified in this study that are relevant to each Council.
2. These smart lighting pilots should be undertaken on council owned lighting assets (rather than DNSP assets).
3. These pilots would ideally achieve Level 4 smart lighting capabilities, allowing councils to test additional smart city technologies that might connect to the lighting. The pilots would ideally be located in activity centres
4. Use the lessons learned from the Smart Lighting pilot projects to evaluate and develop a pathway forward for each Council.
5. Any future investment in Smart Lighting, particularly at scale, should be subject to a formal business case.

The findings of the Feasibility Study and workshops have informed this recommendation. During the Discovery Workshop (see *Smart Lighting & Smart Cities* document) the problem identification highlighted activity centres as a key area of interest, particularly focused on the desire to increase levels of activity in these areas.

Additionally, investigation of the technical standards illuminated the complexities of testing smart lighting in areas requiring V Category lighting standards on public roads, further lending a pilot to a pedestrianised environment (P Category areas).

Similarly, and of greatest significance, is the challenges associated with DNSP owned assets. Particularly, the limited negotiating power, prohibitive costs, insecure business models and inadequate protections for ensuring councils can capture the benefits associated with using or purchasing DNSP assets for smart lighting. With this in mind, the simplest way to start testing the benefits of smart lighting is on Council owned assets in activity centres.

Removing the ownership complexities from the equation gives councils the autonomy to focus on quantifying the costs and benefits, evaluating how well the chosen solution responded to a given problem, to build capabilities in council and test a specific tech concepts. From there, councils can build a case for a roll out, on council assets or DNSP assets in the longer term, and start experimenting with smart lighting and smart cities.

Additional Recommendations

Throughout the engagement the team noted that among the Councils there is a need to consider the following:

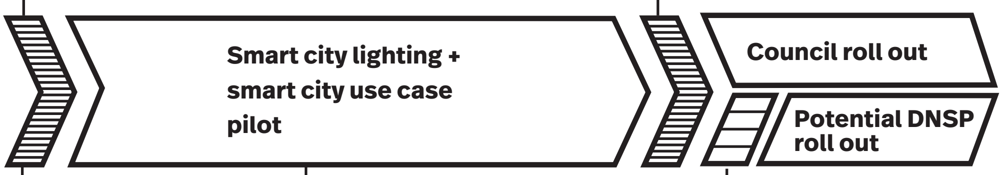
- Public Lighting Group Initiatives. The collective interest of this group was strongly demonstrated in this project, and should be maintained and fostered wherever possible. Including, exploring the regulatory barriers and barriers presented by the technical standards. As outlined in the Feasibility Study
- Lighting Masterplan to ensure lighting, smart or otherwise, fits its context and delivers a legible and high quality experience for residents.
- Smart Cities Strategy to develop a coordinated approach within councils to approaching smart, finding the efficiencies, ensuring the interoperability of concepts, taking advantage of the right resources, identifying required capabilities and skills and any gaps.
- Smart City Pilot. The PLG could explore the interest from each Council in pursuing other concepts contained in the Smart City Concept Deck, particularly those that are independent of smart lighting.

Recommendations
Pathways to Implementation

The councils would ideally proceed with a turnkey smart lighting pilot. Arup recommends that this is located in an activity centre on council owned lighting assets and tests one of the concepts from the concepts deck or mini business case.

Investment Logic Map

Evaluation

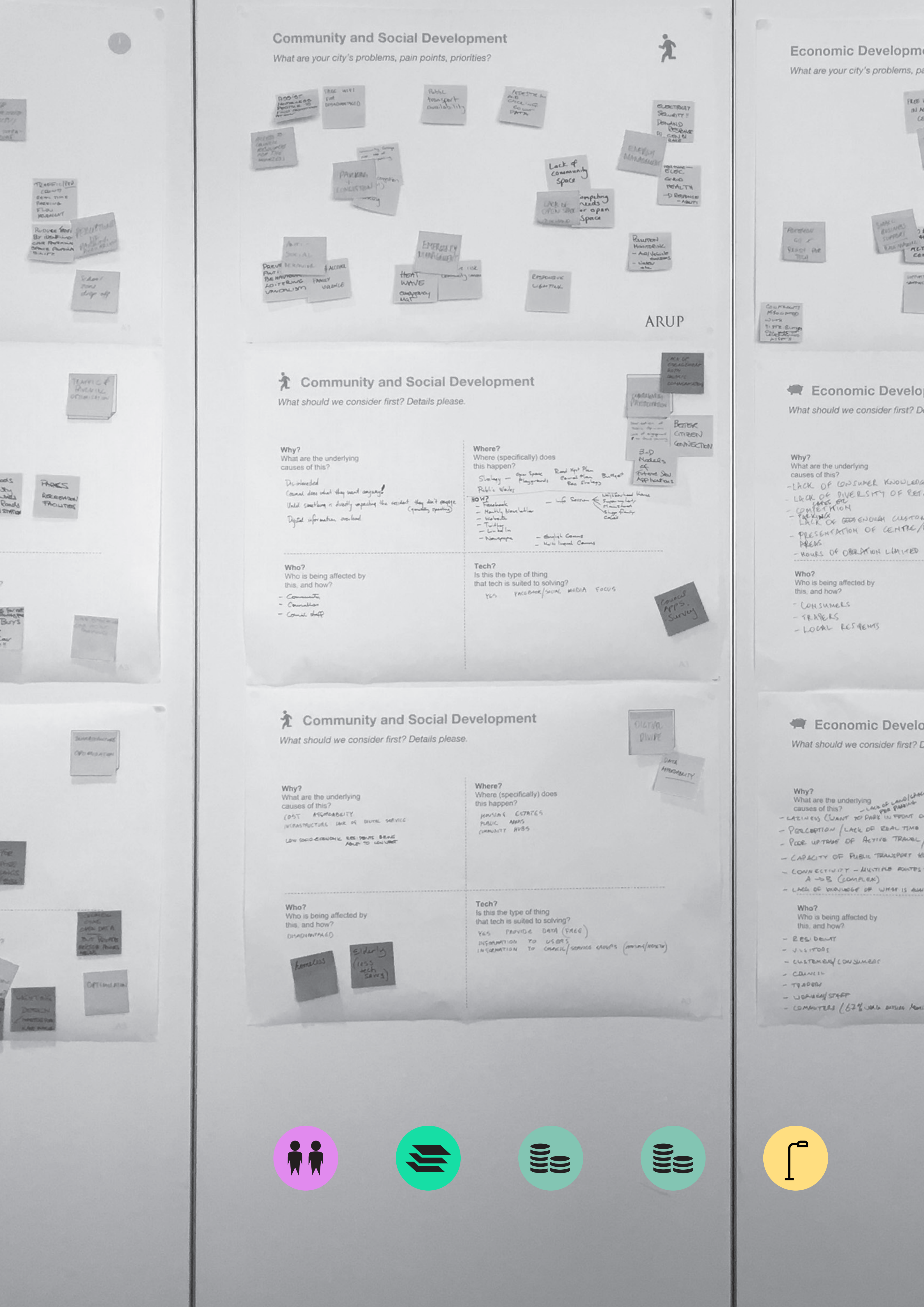


Establish KPIs from the outset of the project in accordance with the Department of Treasury and Finance investment framework.

Use turnkey procurement for smart lighting component, given the skills and capacity limitations of council. The turnkey tech that is selected must have reasonably interoperable network connectivity to enable smart city use cases.

Negotiations

Consider options for rolling out across DNSP assets, this may require negotiating the regulatory and technical standard limitations.


Community and Social Development
What are your city's problems, pain points, priorities?
ARUP
Community and Social Development
What should we consider first? Details please.
Why?
What are the underlying causes of this?
Where?
Where (specifically) does this happen?
Who?
Who is being affected by this, and how?
Tech?
Is this the type of thing that tech is suited to solving?
Community and Social Development
What should we consider first? Details please.
Why?
What are the underlying causes of this?
Where?
Where (specifically) does this happen?
Who?
Who is being affected by this, and how?
Tech?
Is this the type of thing that tech is suited to solving?

Appendix 1
Tech Catalogue

The technology outlined on the following pages are examples of a selection of players in the smart lighting market, their connection protocols, benefits and things to consider as a purchaser/operator. Many appear similar, however there is subtleties in their offerings which make them different and could have huge implications for councils after install – both positive and negative.

Tech Options

Example	Description	Connection	Benefits	Considerations
Philips City Touch	CMS systems provide operators with intelligent and flexible lighting control, individual control to street lights, dimming, and asset tracking along with many other features.	Luminaire must have 7 pin NEMA socket, sensor is connected and transmits via wireless 3G / 4G / GPRS Connection.	Retrofitting to almost any luminaires. Plug and play through standard lighting connection sockets, Remote monitoring, accurate lighting operating data, automatic outage notification	Deploying a CMS network will require a robust, scalable, IT infrastructure. Consideration must also be given to the volume of incoming data, where the collected data will be stored and who will have access to it. Data could either be hosted internally or by an external data centre. Closed protocol could inhibit scalability in the future
TVILIGHT	Sensor based presence detection technology with web based management software to control network in real time.	2G/3G/4G Used in most projects (via Sim-Card), Wi-Fi requires WPA2 encryption to secure the connection, Ethernet via cable.	Retrofitting to existing pole network, powered by the street poles. Sensors can be external to the luminaires and link to form a mesh network capable of adding open source sensors to its system.	Open source. Layered approach to choose what level of smart technology your project requires. How to deal with 3rd party software and hardware
Schreder Shuffle Lighting System	Module based lighting system where you have a basic pole and then select your lighting, sensor and external power outlet modules to suit each configuration.	Can be wired or wireless using the propitiatory Owlet Nightshift CMS system with web based interface. Two way communication.	Standard system with off the shelf components. Allows you to configure the basic pole, then add modules such as lighting, brackets, WLAN, CCTV, speakers, EV charging points. Appearance is very modern and sleek.	The product is a new build focused and better suited to city centres and public spaces than roads, as it wont be suitable for general street lighting. Single source supplier. Cant easily expand the system to include bespoke items other than whats offered in the product catalogue at present.
Schreder Owlet CMS	Owlet is a range of smart controllers offered in three levels which allows for standalone, autonomous and interoperable control.	Standalone control needs to have a specific driver to control dimming. Wireless connection is based on the ZigBee protocol.	Using the wireless connection the luminaires can connect together forming a mesh network. This can have 3rd party sensors that are compatible with ZigBee added to the system. Future ability to adapt.	Compatibility with existing luminaires and ownership. Layered approach gives levels of smart capability. Potentially only work in direct view with other sensors.

Example	Description	Connection	Benefits	Considerations
inteliLIGHT	Street lighting remote management and smart city platform	Power line communication (LONWorks protocol) or Radio frequency between luminaires. IP based between power supply cabinets and mainframe.	Compatible with all types of drivers. Standard software gathers and stores data in great detail, giving better analytics in real time than other systems. Software has basic, professional and enterprise level options for specific user needs. Security cameras and sensors, Smart grid and traffic control can run over the inteliLIGHT system.	Need to add a specific driver to each lamp so that the luminaires can be managed by the control system. Very comprehensive capabilities, but unclear who becomes responsible for compatibility of each sensor and additional equipment type within the system. Could be more suited to large citywide deployment.
ST Electronics	Smart lighting and intelligent communications control system	Two way communication of commands routed through a data concentration gateway and internet, sent directly back to the office application over 3G.	Plug and play network automatically connects for scalability. Also self healing to ensure reliability. Secure encrypted data communications. Low cost operation using public data bands. Can be set up to control lighting autonomously. Preprogrammed alarms via sms.	Every luminaire requires a smart control unit to be installed into them. This could be challenging in the current street lighting ownership models in Australia. Very lighting focused, does not provide much information with regard to smart cities or future expansion of system.
Harvard LeafNut	Wireless lighting controls for the smart city ecosphere - CMS / Smart CMS / Smart City	WiMAC protocol which uses a combination of GPRS and RF wireless communication. Remote server connects to a web based interface. Zigbee is used in other sensors. MoRLiCs adapts to traffic flow systems to control light based on traffic flow.	Scalable system which is proven through 400k nodes in operation. Node system is offered in new and retro fit solutions, including to fit the NEMA 7 pin. This allows for automated or central control, including system expansion.	Harvard offers a range of ways to connect to most luminaires, but assessment is required to ensure that existing luminaires can operate in unison with new ones.

Appendix 2 Lighting Masterplans

Light plays a vital role in our daily lives. It is fundamental to our existence, linking cultural, economic, social and political aspects of our global society. More than half the world's population currently lives in cities and the United Nations estimate this figure to rise towards 70% by 2050.

Despite this increasing urbanisation, we are not using our cities and towns to their fullest potential. Once shops and offices close for the evening, levels of activity in urban centres drop. Traditionally, cities have been planned and built around the daytime experience; night-time design has often been an afterthought. Much of this "daytime bias" can be linked to the development of life and light over time. Historically, most economic activities took place during the day. It was the advent of the oil lamp, then gas powered lighting, electricity and the invention of the incandescent light bulb that opened the doors to expanding human activities into the hours after dark. Current advances in lighting technologies - smart LEDs - are fostering a new wave of innovation that has the potential to once again transform the way humans utilise and experience spaces in the hours of darkness.

We must rethink urban lighting beyond just a functional add-on for safety or beautification and recognise it as an opportunity and fundamental solution to improve the quality of life for urban citizens. Properly considered, lighting can positively impact our cities' 'total architecture', reinforcing urban design principles, enhancing cultural experiences and encouraging social interaction.

New technologies have opened up a realm of fresh opportunities. Despite ground-breaking innovations such as LEDs, we believe the most exciting future development to be about responsive lighting to changing nightscapes. We will see city's lights change depending on time and usage patterns of the public realm after dark–articulating what we call the different 'shades of night'.

With investment in urban real estate, infrastructure and renovation becoming the driving force behind economic growth, the physical and social landscapes of the city are changing at an astonishing rate. What this means for lighting design, and in particular urban lighting, is that all cities are not alike, nor should they be. In addition to respecting and enhancing the local culture and local identities, it is fundamental to acknowledge that the governmental structures are different, levels of crime vary, investment in 'green strategies' are unique, and the demands on the population, whether increasing or decreasing, is also very different. Different design responses are required for different cities.

What has been missing is a considered approach to strategic planning and design for the night time. A holistic approach to urban lighting could help create vibrant, prosperous, safe, and inclusive places for those who live, work and play in cities–at all hours. As we start to understand the importance and distinctiveness of the different shades of night–from dusk till dawn–we shift away from seeing light as a purely functional element.

Time and effort should be placed at the start of all urban design and regeneration efforts to explore and define a dynamic narrative that embraces the night-time. This includes engaging with relevant stakeholders when considering the nocturnal context in order to harness the full potential of light's attributes, new technologies and the chance to create meaningful design for places after dark. Cities that work for people are understood as complex adaptive systems. Urban lighting is not the end in itself; it is a means by which we can deliver improved community and economic outcomes. Our challenge is to extend a truly human-centric urban design and planning approach to include the after dark hours and the people and positive experiences that thrive within them.

Lighting equipment, lighting control, and renewable technology advances at a rapid pace. This knowledge is critical when providing strategic advice to cities, planners and architects. Technology has the power to drive the changes towards designing cities and systems of power in a remarkably efficient way. This understanding paves the way for night-time illumination that is more relevant and meaningful to the specific context: bus shelter lighting that improves health and wellbeing of commuters; interactive lighting installations that encourage human interaction; or street lighting that is programmed to enable different levels and types of illumination throughout the night. Such systems go beyond the generic provision of illumination, enabling entertainment, stimulating economic and social activity, and generating vital and vibrant urban environments.

The advent of smart LEDs and their intelligent integration in city systems can enable lighting that is responsive to specific situations and contexts, while a growing understanding of the hidden impacts of light on human behaviour can help us design inclusive and more liveable urban environments. This will be a powerful factor in the transformation of our approach to urban lighting from ‘the more the better’ towards ‘the right kind of light’.

With or without smart lighting, it is recommended that every council at the very least consider a lighting masterplan vision for their respective cities. This give the best chance that over time when each individual intervention is designed and installed, it ends up being one cohesive outcome. It also gives the council a powerful tool to examine opportunities for focal points at night time such as main streets, highlighting local history and creating an identity to encourage patronage. It also serves as a communication tool to the public and local business, showing the vision and commitment to the long term future of the community.