

# Cities Alive

Rethinking the Shades of Night



ARUP

This report is a product of collaboration between the Foresight + Research + Innovation and Lighting teams at Arup. It involved a wide range of internal and external experts.

### **Arup Lighting**

Arup's lighting designers create thoughtful, sustainable and award-winning concepts with light. We work at a strategic level to design solutions for today's constantly evolving urban places. Our designs are driven by a keen desire to understand the way people use places, the unique cultural context, the overall vision and ambitions of places, designers and users, and the fundamental role that lighting plays in creating these experiences. From sensitive historic interventions for existing cities to ambitious new urban developments, we combine creativity with technical expertise to propose strategic solutions that enhance the way cities work from day to night.

### **Arup Foresight + Research + Innovation**

Foresight + Research + Innovation is Arup's internal think-tank and consultancy which focuses on the future of the built environment and society at large. We help organisations understand trends, explore new ideas, and radically rethink the future of their businesses. We developed the concept of 'foresight by design', which uses innovative design tools and techniques in order to bring new ideas to life, and to engage all stakeholders in meaningful conversations about change.

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 #lightnight

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# Foreword

*“...our lives are inextricably mixed up with those of our fellow human beings, and that there can be no real happiness in isolation...”*

—Sir Ove Arup, “The Key Speech”, 1970

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. Night-time presents challenges to cities globally, be it for reasons of safety and fear, lack of destination or attraction.

While the urban renaissance of the last 20 years has increased the number of people living in city centres, this has not always successfully translated into the notion of a ‘24 hour’ city. 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.

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’.

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.

—Florence Lam, Arup Fellow | Global Lighting Design Leader



# Key Opportunities

The rapid growth and expansion of cities, emergence of new technologies, and the increasing recognition for healthier, more sustainable and resilient urban environments creates a wide range of opportunities to rethink the design and function of cities at night.

## People

Create intelligent lighting environments that are sensitive to the behaviour of people and responsive to changes in the environment

Identify, quantify and communicate the diverse social benefits of lighting, including non-visual impacts on health and wellbeing

## Technology

Assess the potential of emerging technologies and design approaches in the context of human factors to move beyond pure functional performance

Invest in smart lighting infrastructure that has the capability to be reprogrammed according to future needs and developments

## Space

Explore the spatial, social, functional and historical context of urban spaces to identify how design opportunities relate to local requirements

Consider the diversity of end-user requirements of spaces at night and anticipate a broad range of use patterns in the early stages of projects

## Process

Encourage cooperation between stakeholders, harness shared knowledge and establish interdependencies between different parties

Employ a strategy to manage the ownership of light, with a focus on integrating private and public sources of light





# Light in Cities

*“In order to understand lighting in cities you need to understand the city in general.”*

—Susheela Sankaram, Lighting Designer, Amsterdam, 2015

The United Nations has proclaimed 2015 the ‘International Year of Light’, which focuses on the interdependence between social development and effective application of lighting infrastructure, in both emerging and developed economies.<sup>1</sup> Urban lighting offers a unique opportunity to address economic, environmental and social challenges, and can help us reimagine the use and function of our cities at night.<sup>2</sup>

*Cities Alive: Rethinking the Shades of Night* defines ‘urban lighting’ as the totality of all lighting in a city’s public realm. This includes traditional forms of street lighting and other publicly provided illumination as well as ambient light from advertising, building interiors or other artificial sources. All forms of artificial lighting—including lighting inside buildings—currently account for 19% of global electricity consumption.<sup>4</sup> By 2030, demand for artificial lighting is expected to increase by 80% worldwide, compared to 2006 levels.<sup>5</sup> The lighting systems control market alone is estimated to grow by 20% per year between 2012 and 2020, driven by a focus on more energy efficient technologies and the adoption of smart LED systems.<sup>6</sup>



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NASA satellite image illustrating the distribution of global city lights

Despite continued technological advances, access to light is by no means equal across cities and regions. As David Nye puts it in his foreword to *Cities of Light: Two Centuries of Urban Illumination*, “satellite photos suggest the extent of urban lighting, but do not reveal the symbolic meanings or the socio-economic forces at work in electrification...The homogeneity of the night satellite proves an illusion. It is a useful but incomplete fiction”.<sup>7</sup>

This is because even today, one fifth of the world’s population do not have access to electric light. As a consequence, after-dark study, recreation and public space usage are curtailed.<sup>8</sup> According to UN Secretary General Ban Ki Moon, “widespread energy poverty still condemns billions to darkness, ill health and missed opportunities for education and prosperity”.<sup>9</sup>

*Cities Alive: Rethinking the Shades of Night* explores the future of cities at night, and the role lighting solutions can play in enabling healthy, inclusive and sustainable urban lifestyles. It focuses on the human factor and ways to enhance the experience and use of public space during the hours of darkness.



THE NICHOLS BRIDGEWAY

Prudential

# Urban Night-times and the 24h City

*“The night-time condition is not uniform...we need to embrace the complexity of night-time...and recognise the difference in the segments of night.”*

—Jeff Schnabel, Portland State University, 2015

Cities are incredibly complex systems. They are made up of an enormous variety of components, all operating within unique cultural, economic and climatic contexts. A city’s structural and environmental diversity is further complicated by an increasing diversity of citizens—from children and young adults to disabled and elderly, from ethnic minorities to tourists and commuters. Policy makers, planners and designers are responding to this diversity through a greater focus on human-centred design, where people and their needs sit at the heart of design and policy decisions.

The 24h city is a phenomenon that increasingly shapes the way we experience urban life. A growing percentage of social and economic life now takes place in the hours after dark. Current developments towards 24h cities tend to blur our perception of day and night. 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.<sup>10,11</sup> 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

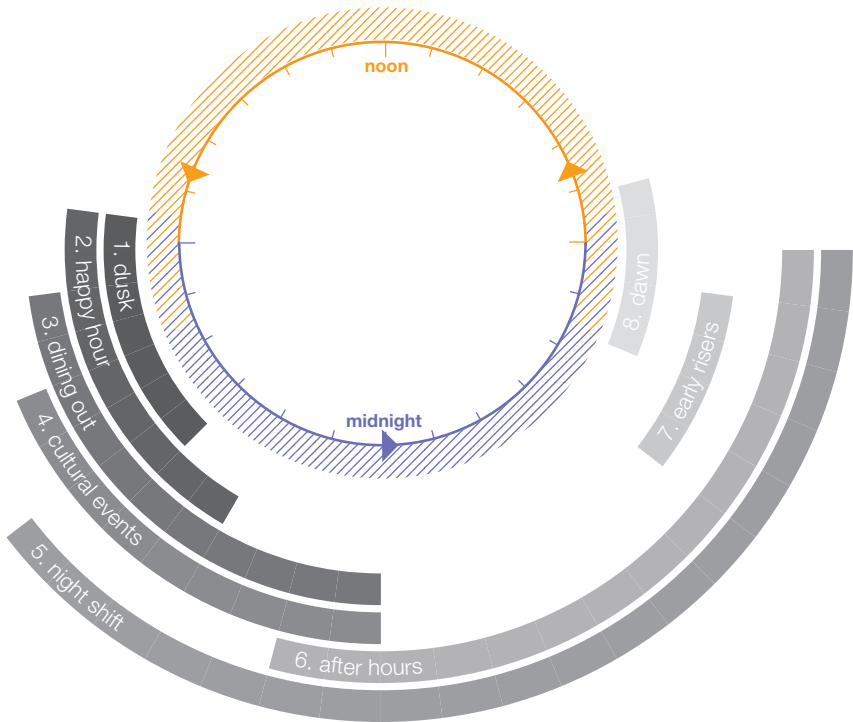


Lighting installation *Lichtgrenze* celebrating 25 years since the fall of the Berlin Wall

entertainment, stimulating economic and social activity, and generating vital and vibrant urban environments.

A truly 24h city will be defined as a city that takes a holistic approach to the 24h cycle; a city in tune with natural rhythms and people's ever changing personal and public needs and desires. 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—from smart LEDs to OLEDs (Organic Light-Emitting Diodes)—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.<sup>12,13</sup>

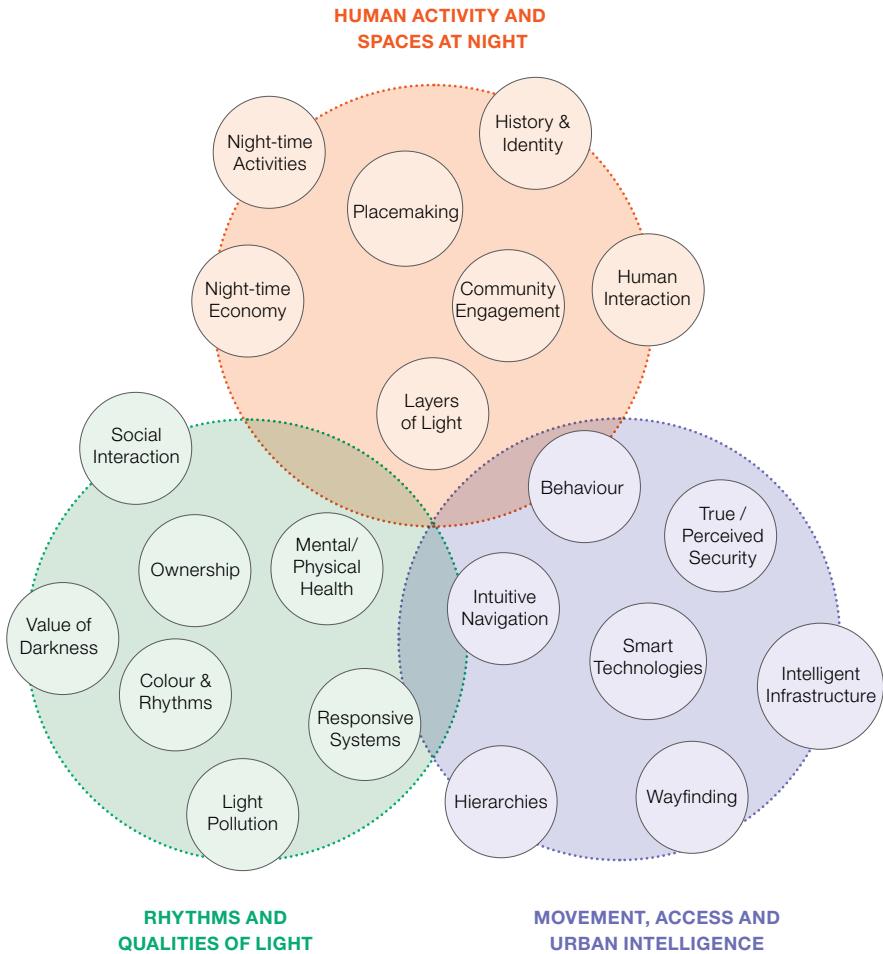
The advent of smart LEDs and their intelligent integration in city systems can enable lighting that is responsive to specific situations and contexts, while a growing understanding of the hidden impacts of light on human behaviour can help us design inclusive and more liveable urban environments.<sup>14,15</sup> 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'.



The eight shades above typify an urbanised area in the Western hemisphere such as New York. Cities and their seasonal, cultural and climatic variations will chart their own shades of night dependent on local usage.

1. **Dusk:** as the sun sets, depending on season, either the work day extends into the night, or daylight extends into the post work hours
2. **Happy hour:** the social extension of the work day, decompression time
3. **Dining out:** the date, the business meeting, the special event, window shopping, strolling, meeting friends
4. **Cultural events:** going to the movies, theater, the ballet, concert or opera
5. **Night shift:** factory workers, cleaning crews, around-the-clock services, such as transit, and emergency repairs and services begin
6. **After hours:** nightclubbing and after-hours clubs
7. **Early risers:** the first shift arrives, outdoor markets set up, newspapers arrive
8. **Dawn:** the commuters begin to arrive, school starts

**Figure 1:** Shades of Night – Public Space during the Darkened Hours is a framework that identifies activity shades, or zones, within districts of a city. It helps match future illumination according to changing street life and commercial and institutional opening/closing hours.



**Figure 2:** This diagram identifies the key points around light and the human experience as covered in the report's three key themes.



# Light and the Human Experience

*“The traditional idea of sustainable urban lighting is based just on economic and environmental-technical aspects. Because lighting is primarily intended for people, urban lighting should be focused on the human experience with a qualitative social engaging role.”*

—D. Casciani, M. Rosso, “Experience of Lighting Sustainability in the Environment”, 2012

By recognising the human experience as a driver for design decisions and acknowledging night-time design as an opportunity for meaningful solutions, the stage is set to create more liveable cities. This section is divided in three key themes for urban night-times through which future needs and requirements for lighting and the human experience are explored.

- **Human Activity and Spaces at Night**

Enjoyment, engagement and fun in the night-time public realm; how can the public realm cater for inclusive experiences, while considering work and leisure requirements?

- **Movement, Access and Urban Intelligence**

Places and spaces for improved night-time mobility and social behaviour; how can light act as an enabler to make spaces more accessible and usable at night?

- **Rhythms and Qualities of Light**

Socially and environmentally sustainable places; how can light help in creating environments that promote wellbeing and respond to current and future social needs?



## Human Activity and Spaces at Night

*“Public spaces play a vital role in the social and economic life of communities...They act as a ‘self-organising public service’, a shared resource in which experiences and value are created”*

—Joseph Rowntree Foundation, “The social value of public spaces”

### Facilitating the night-time economy

A considerable amount of modern life takes place after dark. Many industries operate across 24/7 timespans, necessitating adequate urban accessibility and mobility for those working at night. 18% of China's, 19% of the UK's, and 27% of the United States' working population are performing some kind of night work during the hours from 10 pm to 6 am.<sup>16,17</sup> Many cities and businesses already understand the economic implications of a flourishing night-time economy. In 2009, the UK's night-time economy was estimated to generate 27% of total urban turnover, while Sydney was able to create \$2.7bn of economic benefits with only \$127m spending on night-time management.<sup>18</sup> When designing for night-time, we need to consider the necessity for streets and places to enable a complex set of economic and social uses, and see lighting as the enabler of thriving urban economies.

### Enabling human interactions within the public realm

Depending upon demographic, climate and geographic context, night-time activities differ vastly throughout the shades of night. Many of the world's fastest growing cities and their inhabitants are continually reinventing themselves.



The interactive and temporary light installation *Marling* by Umbrellium illuminates the public realm based on people's voices and gestures

In her seminal book *The Public Realm: Exploring the City's Quintessential Social Territory*, sociologist Lyn H. Lofland defines the public realm as that social entity within the physical settings of a city that is made up of interactions between strangers—a successful public realm enables human interaction to take place.<sup>19</sup> The Department of the Environment, UK, found that meaningful public realm improvements can help generating investments from the private sector, while increasing trade in urban areas by up to 40%.<sup>20</sup>

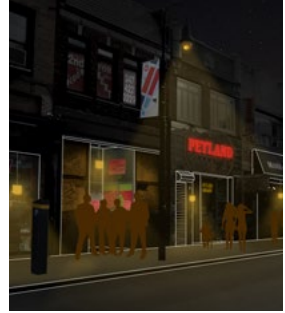
Public realm considerations are our most powerful tool in designing cities that work for their inhabitants. In order to create and enhance vital, functional public spaces, we need to gain a better understanding of the way different demographic groups want to use and experience the city. With his design for an 'interactive urban spectacle' in Eindhoven, the Netherlands, Usman Haque was able to give control of the urban realm to the people. In a project called *Marling*, he enabled citizens to creatively visualise social life in a public square only through the use of their voices. By combining microphones, custom-made software and lasers, the installation created colourful illuminations that revealed new definitions of the space and let people interact dynamically with each other and the environment.<sup>21</sup>

## Understanding local needs and desires

Public interaction with urban lighting can also focus on the planning stage. New York’s 82nd Street Partnership requested proposals for an enhanced lighting strategy for two main street corridors, with Roosevelt Avenue being confined by an elevated railway with several walk-up subway stops. Arup proposed a participatory process that would educate stakeholders and help develop a joint plan for action. A *NightSeeing, Navigate Your Luminous City* programme enabled participants to experience the area at night. Stakeholders highlighted a particular desire to enjoy the streets at night—through food trucks, shopping, lingering and an appreciation of colour and friendships. The importance of a site-specific lighting programme to enhance legibility, safety and city enjoyment, was clarified during the process. Through the integration of stakeholders into the lighting plan, the proposed creative solutions responded to the context, locality and users of the space.

## Designing for a myriad of activities and social interactions

Arup’s redesign of *Bradford City Park* in the United Kingdom takes a carefully balanced, layered lighting design approach to deliver a flexible public space whilst maintaining the functional requirements for a city centre. The project succeeds through the design of a responsive space that allows for a broad range of events, activities and social interactions. As a main connector between Bradford’s visitor attractions and transport hubs, the public space is designed to cater for pedestrian use both day and night. Lighting systems are chosen to create a functional yet playful night-time setting that aids navigation through the emphasis of primary routes and directional decision points. The project’s key feature, a large ‘mirror pool’ water feature, incorporates over 100 illuminated fountains and delivers lighting from ten 17m-tall feature columns, developed in collaboration with artist Wolfgang Buttress. The feature columns incorporate lighting equipment alongside lasers and interactivity sensor equipment which



82nd Street Partnership creative proposals: 82nd Street (above), Roosevelt Avenue (below)

**Case Study:**

# Leicester Square, London

Arup's recent collaboration with Burns + Nice for the lighting and urban design regeneration of Leicester Square Garden in London sought to breathe new life into its night-time environment. New lighting features were installed to increase visibility on pathways, create visual excitement, improve contrast and create an overall more inclusive experience. A comparison of pre- and post-redesign analysis has shown a more evenly spread occupancy of the space, improved movement patterns throughout the square, and greater use of space after dark.





Bradford's *City Park* provides a catalyst for regeneration

create Haque Design and Research's interactive *Another Life* art installation. The fountains and integrated colour changing LEDs add a dramatic and dynamic feel to the space. Arup designed the lighting to provide a subtle and understated lit backdrop to the park, to avoid over lighting of the space and allow the interactive colour and feature lighting to shine. *City Park* has become a vibrant, high quality space that has, particularly at night-time, changed public interactions and the overall experience for residents and visitors alike.

*"Light has the power to completely change the experience of a place"*

—Francesco Anselmo,  
Lighting Designer and  
Technologist, 2015

### Utilising the different layers of light

At night, the impression of a city is created through what is illuminated. Light and art are powerful tools to create an atmosphere for a place; they greatly shape the sensorial experiences of our surroundings. Successful placemaking creates a canvas for people to explore and fill with life. In *The Endless City*, Geetam Tiwari highlights the importance of planning spaces for uncertain uses. Tiwari notes that "the growth of future cities depends upon how well we are able to plan for the 'unplanned'"<sup>24</sup>

Illumination acts as a backdrop for the spectrum of human activity after dark. Its immense power includes the ability to 'effortlessly' alter spaces; as a medium, it allows designers to play with shades, colour and intensities. Many lighting strategies follow established regulations and mainly

**Case Study:**

# Bruum Ruum, Barcelona

BruumRuum by artec3 Studio and David Torrents, is an intuitive, interactive lighting installation at the Plaza de Glories in Barcelona, creating a dialogue between people and the public space. Sensors respond to ambient noise and the sounds of passers-by. The lighting elements change colour in response. This is an example of social light and sound interaction, where the square takes on a human quality by reacting to sounds of the city. The sensors capture and integrate the sounds caused by pedestrians and vehicles passing through. The lighting installation transforms a standard plaza by day into an engaging public space at night.<sup>22,23</sup>







Illumination of Toronto's Goderham Building after the implementation of the city's Historic Interpretation and Lighting Strategy

consider the horizontal layer of light—how much light reaches the ground plane. In contrast, the *Urban Design Compendium* highlights lighting as one of five elements for the creation of a thriving public realm, pointing out the importance of planning illumination for pedestrians by utilising different layers of light sources, from street lighting to ambient lighting emitted by advertising boards.<sup>25</sup> Planners need to move away from a narrow concern with lighting roads to a holistic approach to illuminating places.

### Illuminating the history and identity of a space

In 2013, the City of Toronto developed a *Heritage Interpretation Masterplan for Old Town Toronto*. A complementary *Heritage Lighting Masterplan* recognised the key role light can play in communicating urban history and identity. Lighting now serves as one of the key interpretive media used to tell stories about Toronto's Old Town. Lighting is used to highlight key structures and buildings and to facilitate a greater understanding of the broad range of historic buildings and past uses. The night-time environment is painted by layers of light that emphasise the city's history, purposely reducing illumination in less relevant surrounding areas and allowing them to function as a backdrop.<sup>26,27</sup>

*“People now migrate to urban areas for a whole host of reasons; for employment, but also for the vibrancy and culture of the city, experience and connection. With this comes the need for a new aesthetic function and identity in cities. In the future, the challenge for urban planning will not just be in squeezing the most out of the space, but in squeezing the most out of the experience of urban life.”*

—Arup, “Cities Alive: Rethinking green infrastructure”, 2014





The temporary light installation *Great Street Games* invited the public to interact with their environment by participating in games projected onto the public space

### Temporary lighting as a powerful tool for urban regeneration

Improving night-time lighting in cities does not always require permanent solutions. Temporary installations are a powerful way to transform spaces in urban areas and use light as art. Temporary events, such as light festivals, draw people to cities, thus enhancing city promotion as well as commercial activity. Nocturnal illumination of cherry blossom trees is a common feature of many of Japan's traditional cherry blossom festivals. Lighting further emphasises the blossoms' meaning and enhances a sense of cultural identity. At one event at *Fukuoka Castle* the illumination of more than 1000 cherry blossom trees is combined with illumination of the castle walls. Events such as these have become a magnet for local communities and tourists alike by offering a unique and distinct experience.<sup>28,29</sup>

*“Lighting is the flower or blossom of an otherwise invisible infrastructure”*

—Sandy Isenstadt,  
University of Delaware,  
2015



## Movement, Access and Urban Intelligence

*“As urban life continues to attract people with legitimate expectations for a high quality of life, cities will face increasing pressure to provide access to well-designed open space.”*

—Mark Hough, “Urbanism and the Landscape Architect”, 2013

### The link between light and positive human behaviour

Wilson and Kelling’s ‘broken windows theory’ highlights the importance of a maintained urban environment for combating anti-social behaviour.<sup>30</sup> They highlight a close connection between crime and the physical condition of a neighbourhood. The more physical dereliction and disrepair is experienced—damaged bikes, litter, or broken street lights—the more likely people are to care less about their surroundings. In this context, researchers at Eindhoven University study the application of interactive lighting to “de-escalate aggression” and anti-social behaviour. Lighting scenarios are developed to better understand how varying colour, intensity and dynamics of interactive lighting can influence people’s social interactions and perceptions. The research shows that lighting can trigger positive behaviour—for example by lowering of arousal levels, shifting and broadening attention, or inducing a positively balanced mood. The lab-based scenarios are now being tested and rolled out at a psychiatric care facility and a busy urban nightlife district.<sup>31,32</sup> As our knowledge of the ‘hidden’ benefits of lighting increases, new strategies to increase informal social

control, reverse the ‘broken window’ effect, and nudge people towards certain ‘desired’ behaviours, can be developed.<sup>33,34</sup>

## Perception of safety as a critical component for urban life at night

A review by the UK Home Office of 13 UK and US studies on the interrelation between improved street lighting and crime levels documented an overall decrease in recorded crime of on average of 20% across experimental areas. This reduction was observed across day- and night-time, supporting increased social control and community pride through improved lighting as a reason, instead of increased surveillance through higher illumination.<sup>35</sup>

People’s perception and feelings of safety in a night-time environment often differ substantially from actual risks. Generally speaking, lit places are safer than dark areas; however, whether light above a certain illuminance further increases the safety of a place is less clear.<sup>36</sup> In fact, overly lit nightscapes can reduce the eyes’ ability to adapt to darkness and spot danger, especially in areas with varying light levels across adjacent spaces and could subjectively be associated to unsafe places. When considering Jane Jacobs’ urban theory on the importance of ‘eyes on the street’,<sup>37</sup> the ability of more lighting to make spaces safer can be further questioned: rather than seeing lighting as a direct enabler for safety, enhanced illumination should be seen as a means to attract more people to a space, thus creating safety through presence and activity. This highlights that effective lighting for safety requires more than a simple illumination of space.

## Connecting destinations and enabling wayfinding

Safe transport experiences, easy navigation and legible wayfinding are crucial elements of any urban night-time experience. It is important to recognise that night-time wayfinding and navigation are shaped by fundamentally different factors to those of daytime. At night, the strategic integration of light sources into the urban fabric can significantly improve people’s orientation, providing guidance



London's *Olympic Park* during the 2012 Olympic Games

and direction. Night-time wayfinding offers the possibility to maneuver people's attention towards a certain direction or destination.

The aim of Arup's proposed lighting strategy for the Olympic Park in London, was to allow for the integration of art and wayfinding, increasing the opportunity for pedestrians to interact with the park. The concept focused on the use of nodes and clearly highlighted destinations in combination with well-lit pathways. People's responses to light and darkness were harnessed to gather or dissipate people, adopting a natural approach to people flows management. The aim was to create an environment of 'intuitive navigation' and the creation of a strong sense of identity for the park at night, focusing on creating a sense of spectacle, and aiding wayfinding for visitors through clearly lit routes.

Melbourne's lighting strategy specifically focuses on improving pedestrian wayfinding across the city. It ensures that all forms of lighting highlight the city's core network of paths, nodes, edges and landmarks. Illuminating a selected number of landmarks enhances people's understanding of the city and provides simple orientation. The strategy also encourages avoidance of excessive illumination. Lighting design must consider the unique quality and distribution of all light sources within a given space prior to making an intervention.<sup>38</sup>

Another vision for urban wayfinding and accessibility is community-based adaptable lighting. In the not-too-distant future, we will have tools to provide programmatic recommendations for nuanced brightness levels based on business open hours, crime hotspots, evening and late night recreation, parking routes and transit hubs. The town of Dörentrup in Germany, for example, has trialled a scheme that incorporates the early switching off of street lighting with individual community control. Residents are given the option to turn on the illumination of individual streets for 15 minutes via their mobile phone. *Dial4Light* is expected to save the town up to 12 tonnes of carbon emissions per year.<sup>39</sup>

### Lighting cities for people instead of cars

Many of our current city structures and systems have evolved to serve car-based urban mobility; street lighting in particular often services the needs of cars and their drivers, and not pedestrians. Public lighting applications, for example, are often focused on the amount of light that reaches the street, paying little attention to the pavement and pedestrian experience. With a growing shift towards integrated multi-modal transport systems, and an increase in walking and cycling, this approach needs to be rethought. Urban lighting systems need to be tailored more towards the needs of pedestrians and cyclists. This applies to the redesign of cities in developed regions and the rapid expansion of cities in emerging economies, where the growing influence of the car is still the prevailing transport trend.

Looking further ahead, autonomous or driverless vehicles are likely to become an integrated component of city transport systems. This emerging technology poses interesting and complex questions for the design of urban environments and infrastructures. According to IHS Automotive, there could be nearly 54 million autonomous vehicles on the road by 2035.<sup>42</sup> This will impact the allocation and utilisation of road space, potentially freeing up space for pedestrians and allowing for more shared use of road surfaces. Lighting design can become a key enabler for the safe integration of autonomous vehicles into our cities, and support the better utilisation of streets by people and vehicles.

*“If you plan cities for cars and traffic, you get cars and traffic. If you plan for people and places, you get people and places.”*  
—Fred Kent, “Project for Public Spaces”



## Case Study:

# Intersection Signalétique, Montréal

As part of its lighting strategy, Montréal's Quartier des Spectacles has experimented with wayfinding that goes beyond the functional aspect of getting from A to B. Realised as a pilot, Intersection Signalétique explores the potential of light projections on the pavement to create signage and express identity within the urban landscape. An interplay between projections and the traffic light system is created. Limiting illumination to crosswalks indicates safe crossing to pedestrians through rows of animated circles. When lights turn red, projections change to display directions to nearby venues and current event programmes, highlighting the quartier's cultural activity.<sup>40,41</sup>





Strategically lit stations and illuminated connecting routes have improved public safety, use and accessibility of Bogota's *TransMilenio*

## Facilitating public transport, walking and cycling

Beyond private personal mobility, lighting also plays a key role in the delivery of effective and safe public transport. In 2000, the *TransMilenio Bus Rapid Transit* system (BRT) in Bogota, Colombia, was launched. The aim was to increase the safety of the system in a city where public transport would have not been considered the safest transport option at the time. Today, the *TransMilenio* is the world's largest BRT system with 12 lines covering a distance of 112 km. The lighting strategy played a key role in increasing the attractiveness of the scheme by making sure that large parts of the network were lit at night, increasing safety for passengers and operators.<sup>43,44</sup>

In the Netherlands, a team of designers has created an innovative lighting design intervention that creates a unique cultural experience for pedestrians and cyclists. The *Van Gogh Cycle Path* is a collaboration between Daan Roosegaarde and Heijmans. The path incorporates 'light stones' that harvest sunlight during the day and emit illumination at night. Located near Vincent Van Gogh's historical residence, stones create patterns that relate to his paintings, creating a unique cultural reference to the artist's life and work. ProTeq is working on a similar technology called *StarPath*, a sprayable coating of daylight-absorbing particles that emit glow at night and can be

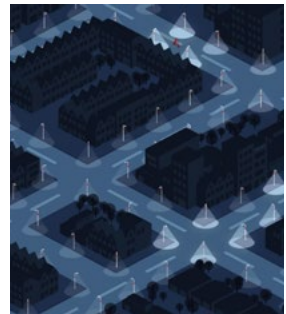
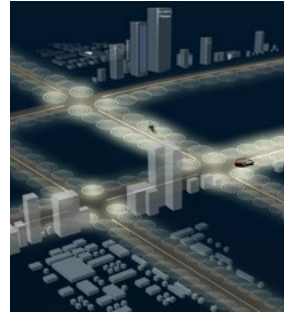
applied to nearly any solid surface.<sup>45,46</sup> Such novel lighting solutions, once perfected for robustness and glow-time, could reduce the need for electric lighting and decrease the operating costs of city lighting systems.

## Recognising the opportunities of smart technology

One dominant technology trend of the 21st century is the continuing revolution of information and communication technology. As processors, sensors and the analysis of data become cheaper and more efficient, lighting systems and solutions will exist as smart and connected components of the Internet of Everything. Coupled with advances in lighting technology itself, smart and responsive lighting environments are emerging, where the level, intensity and impact of light can be carefully controlled and adapted to environmental cues, behaviours or pre-programmed schedules. While these adaptive lighting environments are already an emerging trend within buildings, at the city-scale smart lighting systems are still in their infancy.

A pilot trialled in three European cities, for example, uses LED-based intelligent street lighting to create night-time illumination that responds to the natural environment. The project called *Lites* incorporates intelligent dimming control that combines a system of automatic and active dimming with a set of embedded sensors, responding to light, motion, temperature and current. The lamps are configured as nodes of a network that allow for comprehensive control whereas the collection of relevant output data allows for optimum regulation of luminance levels. The trial aims to understand possible reductions in energy consumption through the application of new lighting technology, while complying with European standards of security for lighting public places.<sup>47</sup>

The potential opportunities for smart lighting systems are enormous. Smart lighting could be integrated with other city systems, such as traffic management, or have the capability to gather data on user behaviour and the status of the city. Copenhagen, for example, is planning to integrate a dynamic street system that can respond to the changing demands of traffic during the day, by 2025. LED lights in the road surface



Tvilight's *City Sense* intelligent outdoor lighting control system

*“Cities of the twenty-first century may well be designed around the mobile phone in the way that cities in the twentieth century were designed around the car”*

—Ben Hammersley, “64 things you need to know now for then”, 2012





In Copenhagen's *Green Waves* scheme cyclists benefit from traffic light solutions that intelligently respond to the number of cyclists, indicating best route options

will signal which mode of transport has priority at what time, widening or reducing lane width according to the current traffic situation. *Green Waves* is one part of the scheme which has already been implemented. Here, traffic light systems direct cyclists to best possible route options. The number of cyclists are registered through sensors imbedded in the road surface, which can trigger traffic lights to switch to green when cyclists reach a certain volume. Both strategies aim to enable safer, more efficient and enjoyable urban cycling and will enhance traffic flows, intelligently using smart systems in combination with LED lights.<sup>48</sup> When implementing smart systems, it is beneficial to invest in advanced systems upfront, while making sure they are adaptable and reprogrammable in the long-term.



## Rhythms and Qualities of Light

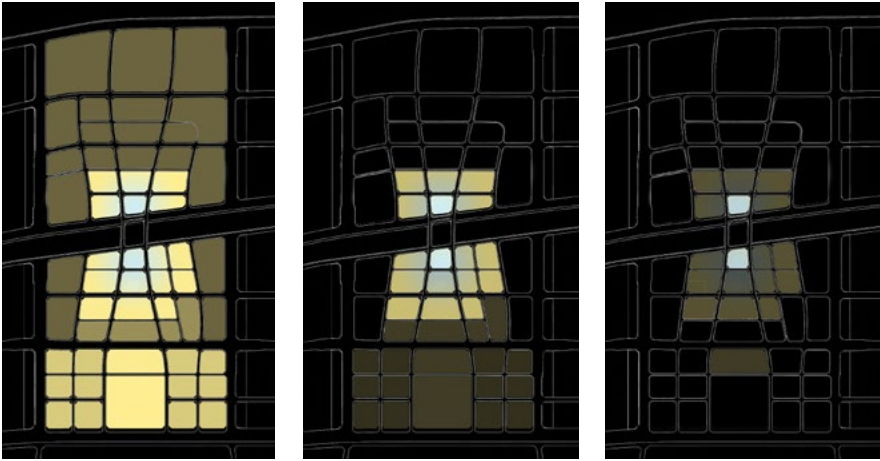
*“Light is critical for our health and wellbeing. Ensuring that we receive adequate light levels at the appropriate time of day benefits our alertness, mood, productivity, sleep patterns and many aspects of our physiology.”*

—Dr Victoria Revell, University of Surrey

### The challenge of disconnected light sources and excess illumination

Urban lighting consists of a wide range of layers and sources of light. Public sources include street lighting, traffic lights and the illumination of public buildings, monuments and spaces. Private sources can include illumination from advertising boards to light emitted from the interior of buildings. Public and private sources are usually separated through ownership and control paradigms. Currently, public authorities are only responsible for public lighting, which is often designed in isolation from adjacent private contribution of lighting. This frequently results in excess illumination conflicts and redundancies between public and private light.

The City of Glasgow, Scotland, conducted an experiment to see how a new way of lighting urban space could be developed, taking into account all lighting sources in the specific location. The main aim was to minimise the prevalence of badly or over-lit spaces. This experiment was put in place to demonstrate how George Square, the city’s main square, could be lit by solely using reflected light from building facades while suppressing the square’s streetlights. The successful experiment created a very pleasant quality of light, improved perception and highlighted the architectural form of the space. While the trial was successful, a proposal to expand the concept was never taken forward.<sup>49</sup> The main issues hindering



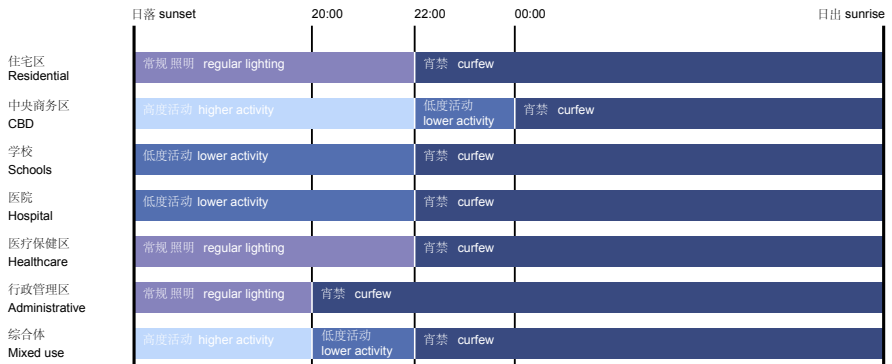
Xixian's *Lighting Masterplan* regulates and times the intensity and spread of lighting within the city's districts according to time of day and use

the implementation of these kind of approaches revolve around regulation, ownership and control conflicts. New lighting guidelines should consider such conflicts and create frameworks that enable a more carefully curated combination and management of all light sources to ensure that quality and perception are the main objectives rather than prescribed luminance of a surface.

### Light as an enabler for thriving human communities

Arup's *Lighting Masterplan for Xixian Great City* is based on the concept of social life and community, culture and history, sustainability, and preserving the rich past of the area. In the plan, lighting elements respond to changing uses over time and area. Lighting in residential areas, for example, is delivered through public space lighting, with little or no facade lighting. 'Curfews' on lighting times ensure low light disturbance during the night. In the central business district, lighting is programmed according to levels of human activity, turning the district into a distinct landmark at night when human activity is low. The city's lighting controls also adapt to different seasons according to the duration and intensity of daylight and the predicted use of exterior spaces.





Night light programming responding to the local rhythms and needs. *Xixian Lighting Masterplan, 2014*

## The link between light and human health

All light triggers physical and behavioural reactions in the human body. Illumination can have both beneficial and detrimental impacts on a person, depending on the quality, type and intensity of light. Especially during the winter months, with shorter days and longer nights, artificial light is a powerful tool in fighting seasonal affective disorder, a type of depression caused by a lack of stimulation of the hypothalamus via sunlight.<sup>50</sup> Innovative lighting solutions offer the opportunity to supplement daytime lighting during times when the intensity and availability of sunlight is low.

*“The 24-hour light-dark cycle is the most important environmental time signal.”*

—Steven W. Lockley, Russell G. Foster, “Sleep: A Very Short Introduction”, 2012

## Understanding the different colours and rhythms of light

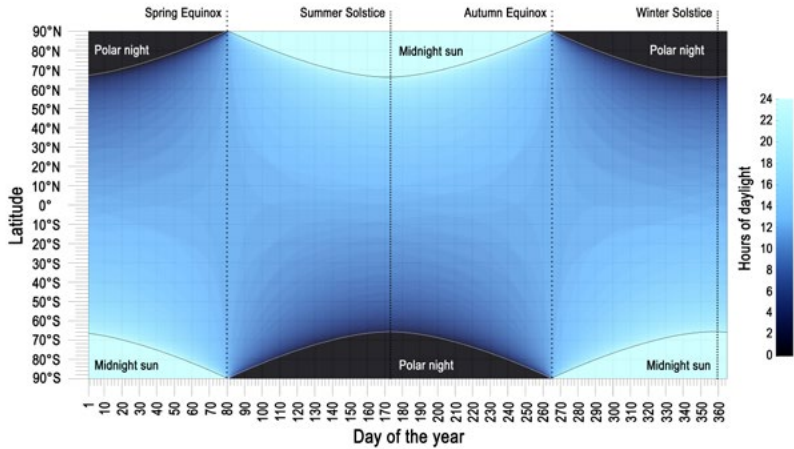
The colour of light is another factor that has a huge influence on people’s wellbeing. The full range of white light spectrum is important for mental health, with different parts of the spectrum having positive impacts at different times of day. While blue light helps people wake up in the mornings, it also suppresses the production of melatonin, a vital hormone for helping us get to sleep at night. LED screens, smart phones and computers emit mainly blue light, meaning that their use should be restricted during the evenings in order to prevent disruption of quality sleep patterns.<sup>52</sup> Instead, in the evenings,

**Case Study:**

## Bus Stop Light Therapy, Umeå

In Malmö, Sweden, sunlight simulating light boards were installed at bus stops. The boards provide commuters with infrastructure-integrated light therapy specifically designed to combat seasonal affective disorder. The lights filter out harmful UV rays, preventing potential eye and skin damage. Winter bus use in the city doubled after the lights were installed. Since their installation, the bus stops have become more than just shelters; they contribute to residents' health and wellbeing during the dark winter months.<sup>51</sup>






Duration of daylight hours across latitudes

warm red light provides the right signals to help us the transition to sleep. As a consequence, traditional ways of measuring light through the lux rating will be insufficient as we design human-centric lighting solutions. In the future, there will need to be a greater focus on the colour of light and its effect on specific spaces and contexts.

A growing understanding of different parts of the light spectrum on human behaviour, sleep cycles, performance and health will pave the way for novel lighting solution and spaces that encourage specific physical and behavioural responses. In office buildings, for example, circadian lighting systems are emerging that can actively support more creative, healthy and productive employees. Such systems adapt light wavelengths and colour spectrums according to location, time and task.<sup>53</sup>

Cambridge, Massachusetts, is one of the first cities to develop a street lighting strategy based on circadian cycles. Controlled through a wireless system, lighting infrastructure within a specific street can autonomously dim or brighten according to a pre-defined set of criteria and environmental triggers. Individual lights can dim down to 35% of their maximum illuminance. The system is projected to consume only a quarter of the energy the previous street lighting system required, while creating an improved colour rendition to the night-time environment, which in turn is perceived brighter.<sup>54</sup>



*“We suggest that estimating the night’s value is not nearly as important as simply recognising that it does have enormous value and then trying to preserve this value and put it to good use.”*

—J. Meier, U. Hasenöhrl, K. Krause, M. Pottharst, “Urban Lighting, Light Pollution and Society”, 2014

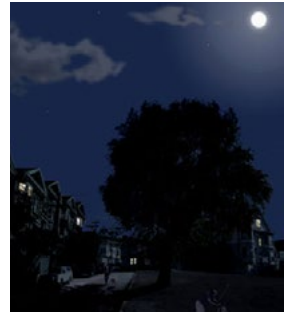
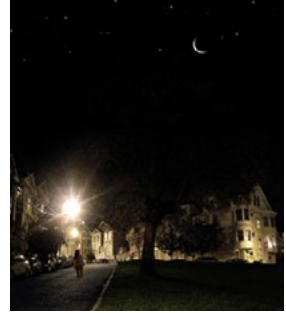
## Recognising the need for both light and darkness

Light and darkness are equally important to our health and wellbeing. With the shift towards 24h cities, the value of darkness needs to be reconsidered. We should not aim to simply recreate the day at night, but should carefully consider the role of night-time lighting, including how much light is required and desirable.

Light pollution and the increasing illumination of our cities has fuelled a debate on the necessity of dark skies and their validity for urban areas. Research shows that night-time lighting has increased by an average of 6% per year, with increases of up to 20% in certain areas such as Mexico and Tokyo.<sup>55</sup> In the United States, excess light through unshielded outdoor lighting fixtures contributes up to USD 2.2bn of wasted electricity per year, while producing 14.7m tons of carbon.<sup>56</sup> A better consideration of the local context and actual needs—including public and private light sources—instead of blind reliance on standards alone to design public lighting, could help reduce many ‘unnecessary’ light and excess light sources.

## Integrating urban night-time lighting with environmental rhythms

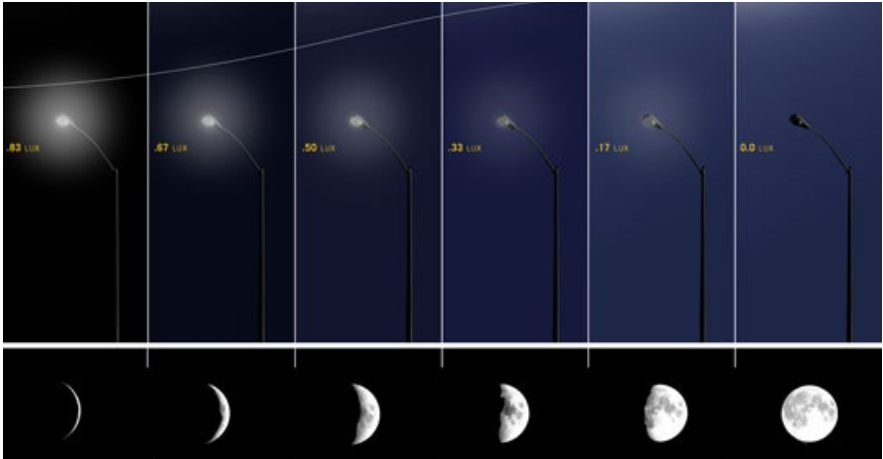
*Lunar-Resonant Street Lights* is a concept for smart streetlights that enable a better integration of lighting within environmental rhythms. The concept—by Design Collective Civil Twilight—utilises sensors to adjust brightness levels in accordance to the moon’s luminance, dimming or turning off lights completely as the moon gets brighter. According to the creators, the technology could result in energy savings of up to 95%. According to Civil Twilight, streetlights alone account for 38% of the electricity used for lighting in the United States, resulting in around 300m tons of carbon emissions a year. Streetlights are also a huge source of light pollution, preventing two-thirds of Americans from seeing stars at night. “Utilising available moonlight, rather than overwhelming it, saves energy and mitigates light pollution, while facilitating the urban experience of one of the most fundamental and beautiful cycles of nature,” according to Civil Twilight Design Collective.<sup>57</sup>



Demonstration of Civil Twilight’s *Lunar-Resonant Street Lights*

Left: Satellite image of Berlin showing the difference in lighting technologies illuminating East and West Berlin. The West uses fluorescent lamps—mercury arc or gas lamps—with a whiter colour while the East uses sodium-vapour lamps with a yellower colour.





Civil Twilight's prototype of *Lunar Resonant Street Lights*. The system responds to the intensity of the moon and adjusts light levels accordingly.

## Dark habitats for the benefit of people and nature

Over 30% of vertebrate species and 60% of invertebrate species on the planet are nocturnal.<sup>55</sup> To support urban biodiversity, lighting in parks should be partially turned off at night. This shift would create valuable dark areas for the natural environment, while enabling easier management of parks at night. With a growing focus on sustainability and environmental resilience, night-time design will increasingly have to consider the needs and requirements of both people and the natural environment. Dedicated 'dark routes' throughout a city, in conjunction with green infrastructure corridors, could be an effective strategy for increasing the resilience and quality of life in cities, while preserving the natural environment and urban habitats.





# The Case for Night-time Design

*“The objective is to define a fresh, inclusive night-time design discipline to arrive at truly dynamic, after-dark public spaces.”*

—Leni Schwendinger, “Cities of Light: Two Centuries of Urban Illumination”, 2015

It is time to re-draw city design visions to include the hours of darkness. Urbanists who believe in the value of diverse space usage want to create places that are welcoming and heterogeneous—spaces that are inclusive. Urban lighting itself has expanded into a re-envisioned profession of ‘night-time design’. The objective of this new profession is to increase opportunities for citizens to inhabit and utilise public space at night.

Social research, digital technologies, urban design considerations and visual design methodologies are needed to support varied and complex social relationships in our cities. This will empower the design of outdoor spaces that are truly conducive to social interaction: after-dark places that encourage activity and psychological wellbeing; that welcome people of different backgrounds; and that provide a feeling of security and confidence. Safer spaces would include protection from cars, enhanced ability to see physical impediments, and increased visual comfort for the elderly and vulnerable.

Thanks to social research for public spaces, we now understand much better how people use our cities after dark; by engaging citizens in the design process we can better envision how they aspire to use the public realm, and design illumination of spaces

that reflect those wishes. Existing pilots for the application of innovative city-oriented prototypes already range from temporary art-installations to complete re-routing of traffic. Such prototyping should expand to novel lighting technologies and spatial concepts in order to gain a quicker and deeper understanding of their potential application and benefits.

More local authorities will need to work with night-time designers to undertake research into the usage of space in their districts and neighbourhoods throughout the different shades of night. The goal will be to develop integrated and holistic lighting programmes and strategies that go beyond a focus on public safety and pure engineering solutions. It is envisioned that public and private lighting—including shop fronts, advertising boards and private institutions—will merge into a sensor-driven network of responsive and intelligent lighting assets, a network that can adapt to constantly changing functional and aesthetic criteria. More studies and prototypes are urgently needed to help develop this vision, including the policies and protocols required to support it.



## Achieving Integrated Urban Night-time Design

The following actions and opportunities highlight steps towards a more human-centred night-time design approach and lighting experience. They enable deeper conversations about the application and benefits of different lighting solutions, while assisting in the development of forward-looking approaches.

### People: human experience and needs

We are no longer limited to purely functional considerations in the planning and design of cities. A better understanding of lighting requirements enable us to give greater consideration to the quality of human experiences. Moving from the conception of ‘the more light the better’ to a more granular and refined understanding of the qualities and characteristics of light offers opportunities to create lighting solutions that respond to context, people and locality.

### Actions and opportunities

1. Create intelligent lighting environments that are sensitive to the behaviour of people and responsive to changes in the environment
2. Identify, quantify and communicate the diverse social benefits of lighting, including non-visual impacts on health and wellbeing
3. Consider the multiplicity of user groups, activities and anticipated future demands from an early project stage
4. Design inclusive environments for a wide demographic profile, including strategies to foster positive behaviour and minimise anti-social actions
5. Rethink standard approaches to lighting with a shift in focus from lighting roads to lighting places—from car- to people-centric solutions

## Technology: smart and responsive systems

LEDs and smart technologies—in combination with an ever-growing understanding of the impacts and qualities of different types of light—equip us with the tools to address complex urban challenges in new ways. Night-time lighting can become more responsive to environmental, social and contextual needs through smart technologies. Sensors and the Internet of Things pave the way for intelligent solutions that can directly respond to local activities and conditions.

## Actions and opportunities

1. Assess the potential of emerging technologies and design approaches in the context of human factors to move beyond pure functional performance
2. Invest in smart lighting infrastructure that has the capability to be reprogrammed according to future needs and developments
3. Incorporate non-visual impacts of light in lighting fixtures and raise awareness of the potential interplay between health and smart technology
4. Utilise the full potential of advancing technologies to reduce excess light and glare in response to city light levels and street hierarchies
5. Design lighting control systems that are able to respond to changing light levels and that can effectively integrate public and private light sources

## Space: context and place

Understanding context is fundamental to effective placemaking. A move away from uniform implementations, standardised lighting technologies and universal norms is needed for cities to develop a distinctive night-time character. Locality-responsive design should consider all the different layers and conditions that make a space unique: spatial qualities, current and future users and their activities, context, history, functions and environmental factors.

## Actions and opportunities

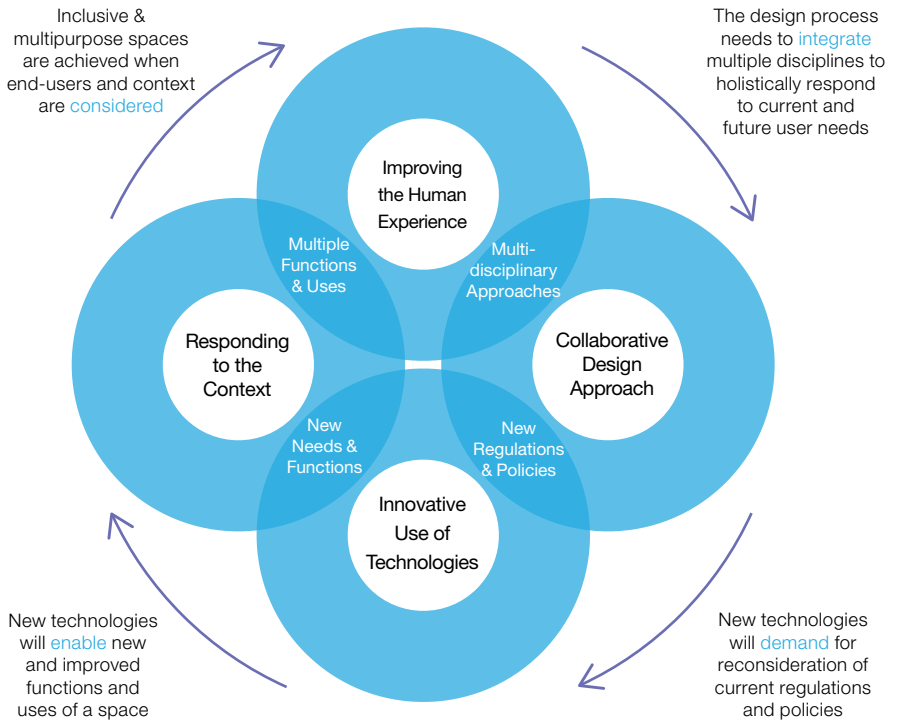
1. Explore the spatial, social, functional and historical context of urban spaces to identify how design opportunities relate to local requirements
2. Consider the diversity of end-user requirements of spaces at night and anticipate a broad range of use patterns in the early stage of projects
3. Incorporate spatial overlays between internal and external, public and private light sources into design strategies and concepts
4. Re-evaluate light and darkness through considering light hierarchies and layers within a space, including options for dedicated 'dark routes'
5. Assess the potential of underused or forgotten spaces for temporary light installations and architectural illuminations

## Process: collaborative and integrated design

Lighting considerations need to be a core requirement of planning policy, rather than being a separate initiative or strategy. This integration should reflect the immense impact light has on our experience of night. The interdependencies between lighting, urban design, human experience and other practices need to be recognised in order to make full use of this potential. Collaboration across disciplines, stakeholder groups and management systems is essential to escape the current disconnected working culture. Lighting designers should prepare for a more active role in shaping socially sustainable places.

## Actions and opportunities

1. Encourage cooperation between stakeholders, harness shared knowledge and establish interdependencies between different parties
2. Employ a strategy to manage the ownership of light, with a focus on integrating private and public sources of light
3. Engage citizens and stakeholders in design and decision-making processes to understand public and business needs and requirements
4. Re-evaluate and redesign existing policies and regulatory frameworks to enable prototyping, innovation and people-centric design
5. Integrate lighting considerations at an early project stage and develop lighting strategies in conjunction with wider city development plans



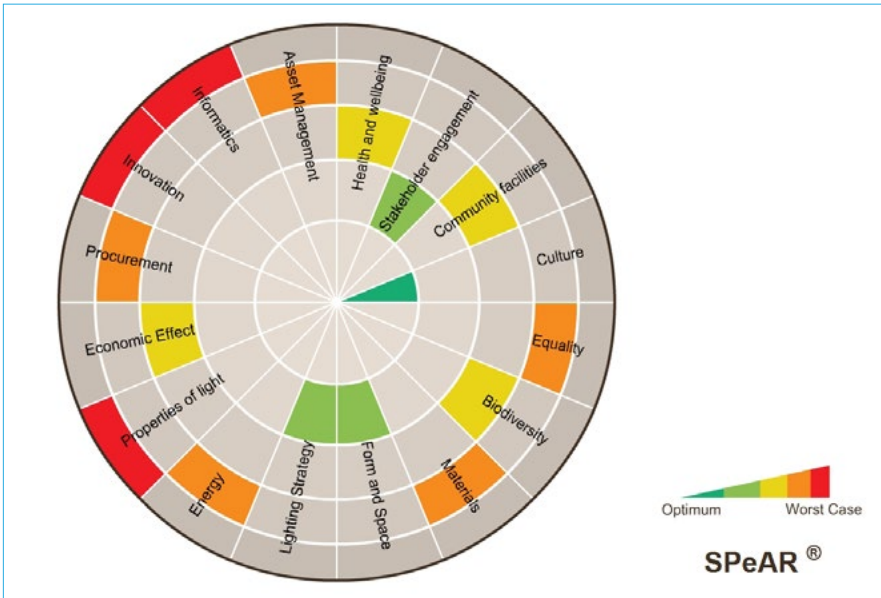
**Figure 3:** This diagram maps the flow and relationship between the strategies outlined in this report

# Tools for Urban Night-time Design

The following are examples of existing tools for improving approaches to night-time design.

## SPeAR for Night-time Design

SPeAR for Night-time Design is a version of Arup’s digital SPeAR® (Sustainable Project Appraisal Routine) tool that focuses on night-time lighting. This version has been adapted to examine specifics of night-time design within social, economic and environmental contexts. It assists in evaluating how lighting can support these goals and contributes to build a community that supports and evaluates the project from the beginning to the end. Results are presented graphically on the unique SPeAR® diagram—an intuitive colour traffic light system that indicates performance in each area. The tool allows for performance to be evaluated before, throughout and after completion of a project.



SPeAR for Night-time Design. A tool to define objectives and measure progress of night-time initiatives. Illustrated is an in-progress analysis of research Arup is undertaking in Colombia.



## Social Research and Community Engagement

Social research techniques can be utilised to better understand the specific set of considerations and requirements of a place as well as to engage communities in shaping their environments. Generated insights translate into well-informed and relevant project outcomes. Aimed either towards community engagement, or informing and educating practitioners and local authorities, education programmes such as the London School of Economics' *Configuring Light / Staging the Social* or Leni Schwendinger's *NightSeeing, Navigate Your Luminous City* help to raise awareness of lighting and night-time design and its relevance in the greater urban context.<sup>58,59</sup>



*NightSeeing* Light Walk and workshop. Impressions of a community engagement project undertaken in collaboration by Arup, LSE and Despacio in Colombia.

## Temporary Installations and Prototypes

Temporary installations create engaging environments over a limited period of time, while offering the opportunity to test concepts and prototypes in a real-life setting. A temporary realisation of a project can prove a concept with hard facts, or highlight areas that require improvement and refinement. Success or failure can be assessed, and economic, social, environmental and other benefits evaluated and clearly demonstrated. As test-bed for potential permanent installations, temporary projects are particularly interesting for the realisation of more innovative and experimental proposals, likely to be rejected by decision-makers. Lighting festivals are particularly relevant in this area.



Up and Away! Sydney Vivid Festival 2012

## Quantitative and Qualitative Assessments

Aiming to move beyond the traditional quantitative approach of designing for night-time environments, Arup adds qualitative dimensions to understand attributes such as visual comfort and safety by use of High Dynamic Range (HDR) imaging to explore how complex relationships of brightness and luminance influence our subjective perceptions of spaces. Information gathered through site, user and HDR surveys is utilised to create a series of visual tools which seek to explain through quantitative and user feedback analysis exactly why and how perceptual experiences occur. A 'data web' tool allows the stakeholders and designers to evaluate subjective as well as measurable conditions such as light quality, energy efficiency and acceptance that both marries our analytical ability to understand the science of light with our attention to subjective experiential conditions that help inform notions of space.



Arup's 'data web' tool illustrating an evaluation of a project undertaken in Porto Antico, Genoa



# Conclusion

*“Light is fundamental to all social life, yet public realm lighting can often focus on prescriptive design standards, rather than designing with social relevance for the way that humans interact in a modern 24 hour city.”*

—Arup, “24:00:00—Lighting in the urban age” exhibition, 2015

The future of urban night-times is increasingly shaped by a focus on the human experience. Lighting is moving beyond a focus on functional performance towards a much more granular, location-specific and holistic consideration of lighting solutions with specific urban context. It is recognised as a fundamental component of healthier, safer, more resilient and more enjoyable urban environments.

In the past, the attitude of ‘the more light the better’ has led to a general abundance of light, especially in urban areas. We now know that it is crucial to rethink the value of darkness, to understand the different shades of night and to allow the night to have its own unique set of characters.

Rapid advances in lighting, information technology and intelligent systems offer immense opportunities for radical new approaches to urban night-times. The success of lighting in the future, however, will rely on our understanding of the adequate use of

this technology. Technology should never be a singular driver for change, but should always react and respond to a clear social or environmental need. Only through an understanding of how to use these complex sets of technologies in an intelligent way, solutions, truly beneficial to citizens, the environment and the economy, are possible.

Increasing demand for human-centred night-time experiences have inspired the emergence of more contextual lighting research and design practices. Understanding the complex and perpetually changing demands of people and cities will be the key important factor in designing solutions that work in accordance to the needs and desires of people, and the different shades of night.

## References

1. *Light in the Built Environment*, by International Year of Light 2015. 2015. Available from: <http://www.light2015.org/Home/Why-LightMatters/Light-in-the-Built-Environment.html>.
2. *In the Shade: lighting local urban communities*, by Helen Hamlyn Centre for Design, Royal College of Art. 2012. Available from: [http://www.hhc.rca.ac.uk/CMS/files/1.IN\\_THE\\_SHADE\\_+cover.pdf](http://www.hhc.rca.ac.uk/CMS/files/1.IN_THE_SHADE_+cover.pdf).
3. "Life in 2050: How we invent the future today", by Ulrich Eberl. 2011. Beltz GmbH.
4. *Lighting the Clean Revolution*, by The Climate Group. 2012. Available from: [http://www.theclimategroup.org/\\_assets/files/LED\\_report\\_web1%283%29.pdf](http://www.theclimategroup.org/_assets/files/LED_report_web1%283%29.pdf).
5. *Light's Labour's Lost: Policies for Energy-efficient Lighting*, by International Energy Agency. 2006. Available from: <http://www.iea.org/publications/freepublications/publication/light2006.pdf>.
6. *Lighting the way: Perspectives on the global lighting market*, by McKinsey&Company. 2012. Available from: [http://www.mckinsey.de/sites/mck\\_files/files/Lighting\\_the\\_way\\_Perspectives\\_on\\_global\\_lighting\\_market\\_2012.pdf](http://www.mckinsey.de/sites/mck_files/files/Lighting_the_way_Perspectives_on_global_lighting_market_2012.pdf).
7. *Foreword*, by David Nye in "Cities of Light: Two Centuries of Urban Illumination", by Sandy Isenstadt, Dietrich Neumann and Margaret Maile Petty. Routledge. 2015.
8. *Study after Sunset*, by International Year of Light 2015. 2015. Available from: <http://www.light2015.org/Home/LightForDevelopment/Study-after-Sunset.html>.
9. *Light & Education: Providing better, brighter environments for studying*, by Solarway. Available from: <http://www.solarway.com/en/lighteducation>.
10. *Public Lighting Theory - developing the nexus of lighting and urban design*, by Leni Schwendinger. 2010. Available from: [https://lenischwendinger.wordpress.com/2010/01/02/public\\_lighting\\_theory/](https://lenischwendinger.wordpress.com/2010/01/02/public_lighting_theory/).
11. *Comment > Leni Schwendinger lights the way*, by Leni Schwendinger. 2010. Available from: <http://archpaper.com/news/articles.asp?id=4936#.VOE23bUo6P8>.
12. *lighting: The Columbia Encyclopedia, 6th ed.*, by Encyclopedia.com. 2014. Available from: <http://www.encyclopedia.com/topic/lighting.aspx>.
13. *A Brief History of Light*, by International Year of Light 2015. 2015. Available from: <http://www.light2015.org/Home/ScienceStories/A-Brief-History-of-Light.html>.
14. *The Time is Right for Connected Public Lighting Within Smart Cities*, by James Crowther, Christoph Herzig and Gordon Feller. 2012. Cisco, Philips. Available from: [https://www.cisco.com/web/about/ac79/docs/ps/motm/Connected-Public-Lighting\\_Philips\\_Cisco.pdf](https://www.cisco.com/web/about/ac79/docs/ps/motm/Connected-Public-Lighting_Philips_Cisco.pdf).
15. *Circadian Rhythms: Influence of Light on Humans*, by Steven W. Lockley. 2009. Encyclopedia of Neuroscience, vol. 2, pp. 971-988.
16. *Americans work too long (and too often strange times)*, by Daniel S. Hamermesh and Elena Stancanelli. 2014. Available from: <http://www.voxeu.org/article/americans-work-long-and-strange-times>.
17. *Working Time Around the World: Trends in working hours, laws and policies in a global comparative perspective*, by Sangheon Lee, Deirdre McCann and Jon C. Messenger. 2007. Routledge. Available from: [http://www.ilo.org/wcmsp5/groups/public/@dgreports/@dcomm/@publ/documents/publication/wcms\\_104895.pdf](http://www.ilo.org/wcmsp5/groups/public/@dgreports/@dcomm/@publ/documents/publication/wcms_104895.pdf).
18. *The Evening & Night-Time Economy: Realising the potential for Destination Organisations*, by Association of Town Centre Management and VisitEngland. 2012. Available from: [http://www.visitengland.org/Images/VE\\_TheEveningNightTimeEconomy\\_tcm30-34984.pdf](http://www.visitengland.org/Images/VE_TheEveningNightTimeEconomy_tcm30-34984.pdf).
19. "The Public Realm: Exploring the City's Quintessential Social Territory", by Lyn H. Lofland. 1998. Transaction Hub.
20. *The Value of Public Space: How high quality parks and public spaces create economic, social and environmental value*, by CABE Space. 2014. Available from: <https://www.designcouncil.org.uk/sites/default/files/asset/document/the-value-of-public-space.pdf>.
21. *marling*, by umbrellium. 2015. Available from: <http://umbrellium.co.uk/portfolio/marling/>.
22. *BruumRuum*, by artec3. 2014. Available from: <http://www.artec3.com/BruumRuum>.
23. *Color and light show in Torre Agbar*, by Elisabet Gómez, 2014. barcelona city blog. Available from: <http://www.barcelonacity-blog.com/en/2014/11/05/color-light-show-torre-agbar/>.
24. "The Endless City: The Urban Age Project by the London School of Economics and Deutsche Bank's Alfred Herrhausen Society", by Ricky Burdett and Deyan Sudjic. 2007. Phaidon Press.
25. *Creating Healthy Environments: Practical Tools for Increasing Walking in the Built Environment*, by Living Streets. Available from: <http://www.livingstreets.org.uk/sites/default/files/content/library/toolkits/creatinghealthyenvironments/3.8publicrealmdesignguidance.pdf>.

26. *Heritage Interpretation Master Plan for Old Town Toronto*, by City of Toronto Heritage Preservation Services. 2013. Available from: [http://www1.toronto.ca/city\\_of\\_toronto/city\\_planning/urban\\_design/files/pdf/heritage\\_interpretation\\_master\\_plan.pdf](http://www1.toronto.ca/city_of_toronto/city_planning/urban_design/files/pdf/heritage_interpretation_master_plan.pdf).
27. *Heritage Lighting Master Plan For Old Town Toronto*, by Toronto Heritage Preservation Services. 2011. Available from: [http://www1.toronto.ca/city\\_of\\_toronto/city\\_planning/urban\\_design/files/pdf/hert\\_final\\_report.pdf](http://www1.toronto.ca/city_of_toronto/city_planning/urban_design/files/pdf/hert_final_report.pdf).
28. *Fukuoka Castle Sakura Festival 2015*, by Japan Attractions. 2015. Available from: <http://japan-attractions.jp/illumination/fukuokajyo-sakurafes2015/>.
29. *City in Bloom*, by National Cherry Blossom Festival. 2015. Available from: <http://www.nationalcherryblossomfestival.org/get-involved/cityinbloom/>.
30. *Broken windows theory*, by Wikipedia. 2015. Available from: [http://en.wikipedia.org/wiki/Broken\\_windows\\_theory](http://en.wikipedia.org/wiki/Broken_windows_theory).
31. *Human-Technology Interaction*, by Technische Universiteit Eindhoven. 2014. Available from: <http://www.tue.nl/universiteit/faculteiten/industrial-engineering-innovation-sciences/onderzoek/onderzoeksgroepen/human-technology-interaction/nieuws/11-12-2014-eindhoven-de-escalate-project-wins-national-safety-prize/>.
32. *de-escalate: Defusing Escalating Behaviour through the Use of Interactive Light Scenarios*, by de-escalate. 2014. Available from: <http://www.de-escalate.nl/>.
33. *Enlightened Cities: illuminations for urban regeneration*, by Nona Schulte-Römer in “Understanding the Post-Industrial City”, by Frank Eckardt and Sofia Morgado. 2012. Königshausen und Neumann.
34. *The effects of improved street lighting in crime: a systematic review*, by College of Policing. 2013. Available from: <http://library.college.police.uk/docs/what-works/What-works-briefing-improved-street-lighting-2013.pdf>.
35. *Effects of improved street lighting on crime: a systematic review*, by Home Office Research, Development and Statistics Directorate. 2002. Available from: [https://keyssso.net/community\\_news/May\\_2003/improved\\_lighting\\_study.pdf](https://keyssso.net/community_news/May_2003/improved_lighting_study.pdf).
36. *Lighting Use & Design*, by Project for Public Spaces. Available from: <http://www.pps.org/reference/streetlights/>.
37. “The Death and Life of Great American Cities”, by Jane Jacobs. 1992. Vintage.
38. *Best Practices in Placemaking through Illumination*, by Jamie Brätt, Gareth James, Ryan Price and Jeremy Sewall. 2010. Urban Affairs and Planning Program - Virginia Tech. Available from: <http://www.arlingtonvirginiausa.com/index.cfm/linkservid/CEE2E4DA-1D09-08FB-3B47F13AFF97AA20/showMeta/0/>.
39. *Lights down as heat sensitive lampposts come to the streets of Toulouse*, by Jason Burke. 2009. The Guardian. Available from: <http://www.theguardian.com/world/2009/oct/26/toulouse-heat-sensitive-lampposts>.
40. *Experimenting with the Future of Urban Signage in Montreal's Quartier des Spectacles*, by Quartier des Spectacles Montreal. 2010. Available from: <http://www.quartierdesspectacles.com/en/blog/108/experimenting-with-the-future-of-urban-signage-in-montreal-s-quartier-des-spectacles>.
41. *History and Vision of the Quartier des Spectacles*, by Quartier des Spectacles Montreal. 2015. Available from: <http://www.quartierdesspectacles.com/en/about/history-and-vision/>.
42. *Self-Driving Cars Moving into the Industry's Driver's Seat*, by IHS Pressroom. 2014. Available from: <http://press.ihs.com/press-release/automotive/self-driving-cars-moving-industrys-drivers-seat>.
43. *TransMilenio*, by Wikipedia. 2015. Available from: <http://en.wikipedia.org/wiki/TransMilenio>.
44. *Telephone interview Urban Nighttime Lighting*, Carlosfelipe Pardo. 2015.
45. *Van Gogh-Roosegaard cycle path*, by Marieke Swinkels-Verstappen. 2013. heijmans. Available from: <http://www.heijmans.nl/en/news/roosegaard-van-gogh-bicycle-path/>.
46. *Cities Alive: Rethinking green infrastructure*, by Arup. 2014. Available from: [http://www.arup.com/Homepage\\_Cities\\_Alive.aspx](http://www.arup.com/Homepage_Cities_Alive.aspx).
47. *Lites*, by The LITES Project. 2013. Available from: <http://www.lites-project.eu/>.
48. *Good, Better, Best: The City of Copenhagen's Bicycle Strategy 2011-2015*, by The City of Copenhagen The Technical and Environmental Administration. 2011. Available from: [http://kk.sites.itera.dk/apps/kk\\_pub2/pdf/823\\_Bg65v7UH2t.pdf](http://kk.sites.itera.dk/apps/kk_pub2/pdf/823_Bg65v7UH2t.pdf).
49. *Interview Urban Nighttime Lighting*, Riccardo Marini. 2015. London.
50. *Seasonal affective disorder*, by NHS. Available from: <http://www.nhs.uk/conditions/Seasonal-affective-disorder/Pages/Introduction.aspx>.
51. *Light Therapy*, by Reprogramming the City. 2013. Available from: <http://reprogrammingthecity.com/light-therapy/>.
52. *Smartphones Ruin More Than Your Sleep - They May Also Be Destroying Your Vision*, by Kevin Loria. 2014. Available from: <http://www.businessinsider.com/smartphones-effect-on-vision-and-health-2014-9?IR=T>.
53. *Circadian workplaces: Can curated working experiences help improve work wellness and productivity?*, by Rebecca Goldberg and Josef Hargrave. 2014. The Journal of Space Syntax, Vol 5, No 2 (2014), pp. 227-231. Available from: <http://joss.bartlett.ucl.ac.uk/journal/index.php/joss/article/view/223/pdf>.

54. *Cambridge Streetlight Conversion Fact Sheet*, by Cambridge Electrical Department. 2014. Available from: [http://www.cambridgema.gov/~media/Files/electricaldepartment/LED%20Conversion%20Fact%20Sheet\\_FINAL.aspx](http://www.cambridgema.gov/~media/Files/electricaldepartment/LED%20Conversion%20Fact%20Sheet_FINAL.aspx).
55. *The Dark Side of Light: A Transdisciplinary Research Agenda for Light Pollution Policy*, by Franz Hölker, Timothy Moss, Barbara Griefahn, Werner Kloas, Christian C. Voigt, Dietrich Henckel, Andreas Hänel, Peter M. Kappeler, Stephan Völker, Axel Schwöpe, Steffen Franke, Dirk Uhrlandt, Jürgen Fischer, Reinhard Klenke, Christian Wolter, and Klement Tockner. 2010. *Ecology and Society* 15(4):13. Available from: <http://goedoc.uni-goettingen.de/goescholar/bitstream/handle/1/7268/ES-2010-3685.pdf?sequence=1>.
56. *IDA Practical Guide - PG1: Introduction to Light Pollution*, by International Dark Sky Association. Available from: <http://www.darksky.org/assets/documents/PG1-light-pollution.pdf>.
57. *Lunar-Resonant Streetlights*, by Civil Twilight. 2007. Available from: <http://www.civiltwilightcollective.com/lunar1.htm>.
58. *Configuring Light / Staging the Social*, by LSE Cities. 2015. Available from: <http://www.configuringlight.org/>.
59. *NightSeeing: Navigate Your Luminous City*, by NightSeeing. 2015. Available from: <http://www.nightseeing.net/>.

## Further Reading

- Berman, M., "All That Is Solid Melts Into Air: The Experience of Modernity". Verso. 2010.
- British Astronomical Association, *Campaign for Dark Skies (CfDS): Blinded by the Light?*. 2009. Available from: <http://www.britastro.org/dark-skies/pdfs/HANDBOOKTEXT.pdf>.
- Crary, J., *24/7: Late Capitalism and the Ends of Sleep*. Verso. 2014.
- Dewdney, C., "Acquainted with the Night: Excursions Through the World After Dark". Bloomsbury USA. 2005.
- Illuminating Engineering Society of North America, *Light and Human Health: An Overview of the Impacts of Optical Radiation on Visual, Circadian, Neuroendocrine, and Neurobehavioral Responses*. 2008
- Isenstadt, S., Maile Petty, M., Neumann, D., "Cities of Light: Two Centuries of Urban Illumination". Routledge. 2014.
- Jakle, J. A., "City Lights: Illuminating the American Night". The Johns Hopkins University Press. 2001.
- Lockley, S.W., "Sleep: A Very Short Introduction". OUP Oxford. 2012.
- Meier, M., Hasenöhl, U., Krause, K., Pottharst, M., "Urban Lighting, Light Pollution and Society". Routledge. 2014.
- Melbin, M., "Night as Frontier: Colonizing the World after Dark". The Free Press. 1987.
- Roberts, M., "Planning the Night-time City". Routledge. 2009.



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## Publications



*Living Workplace* focuses on the future of the workplace. It investigates the impact of growing cultural and generational diversity, the role of new technologies and working patterns and the importance of creativity and collaboration for organisational success.



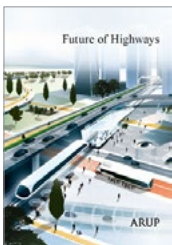
Moving beyond static objects in glass cases, *Museums in the Digital Age* outlines how future museums will see personalised content, new levels of sustainability and a visitor experience extended beyond present expectations of time and space.



The ideas being developed in *Cities Alive* seek to capture not only the beauty of nature but also the sustainability of balanced ecosystems. These are challenges for landscape designers creating new cities that meet our increased expectations for access to clean water, cheap and plentiful supply of food, and fast and effective transport systems, with the need to reduce the impact on natural resources.



The *Future of Rail 2050* focuses on the passenger experience and sets out a forward-looking, inspiring vision for rail. The user journeys imagined here are intended to generate a conversation about the future and provide the big-picture context for future planning and decision making ts and the rail industry.



*Future of Highways* considers a range of trends that are likely to shape the future of roads and highways. The report explores the implications of these and imagines a series of future user experiences. These plausible user journeys provide a window onto a connected, low-carbon future where intelligent mobility solutions put users at the heart of design.

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While the urban renaissance of the last 20 years has increased the number of people living in city centres, this has not always successfully translated into the notion of a ‘24 hour’ city. 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.

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.

—Florence Lam, Arup Fellow | Global Lighting Design Leader



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