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DYNAMIC LIGHT

Manual on Dynamic Lighting and Social Needs

DYNAMIC LIGHT—TOWARDS DYNAMIC, INTELLIGENT AND ENERGY EFFICIENT PUBLIC LIGHTING

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Dynamic Light: Manual on Dynamic Lighting and Social Needs

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DYNAMIC LIGHT

MANUAL ON DYNAMIC LIGHTING AND SOCIAL NEEDS

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Manual on dynamic lighting and social needs

The first idea behind light in public space was not to see the obstruction, obstacles or potential dangers but in fact to make oneself visible to other people and guards so as to avoid any suspicion. Soon this responsibility was taken up by the administration and then by the police, and the concept of public lighting developed. Light during the night came to be seen as a symbol of authority and order in the city.

The new public lighting from the late 17th century onwards, in addition to being intended for law and order also attempted and aimed at the beautification and decoration of the city, and provided convenience and social amenity by encouraging activities and traffic on the city streets and squares.

The hours from dusk until dawn were no longer seen as threatening time of criminal or illicit activity or supernatural danger; citizens began using night for respectable leisure and social activities [3].

The industrial revolution brought about a dramatic change in the public lifestyle. Instead of daylight oriented rhythm governing working hours, trading, business etc. artificial lighting allowed for longer working hours, shift works- at the same time giving rise to the clock based lifestyle. Public lighting was designed to bring workers to and from the industrial units- parameters like speed, efficiency and time saving found their way into public lighting as well; leading to the development of – Uniformity, general illumination and functional lighting as the chief characteristics of public lighting. Uniformity and general illumination was necessary to allow for quick and safe movement, avoiding obstacles etc. Even after almost 300 years of progress, these characteristics are still found in most public lighting solutions.

Light at now is almost omnipresent and it has come to a point to be associated with development, economic and technological advancement. The need has slowly given way to a demand; we expect light everywhere. Public lighting is now seen in even the smallest of the villages and towns

Chapter-1: Quality, Efficiency and Ecology: The Trinity of public lighting

Public lighting strategies must aim at achieving environmental, economic and social sustainability. The energy crisis along with the looming ecological disasters has firmly established sustainability as the top goal of any urban planning strategy.

The limited resources and the irreversible damage we have caused to the ecological systems are finally being realised. Unfortunately, all the effort and emphasis has been put on energy efficiency and savings.

Little or no thought is given for having the right quality of light, ecology or social sustainability. Such short term measures and strategies are not only disruptive and dangerous but are leading to "False Efficiencies".

1.1 Public lighting for quality, efficiency and ecology

Through various previous scientific studies and our own research for the deliverables, we have been able to establish and understand the relationships and interactivity between the physical urban environment, the human being (user), and light. The previous deliverables have shown that: light enables us experience and interact with the built environment. Lighting establishes social spaces, spaces

for interactions and exchange. It can encourage positive social behaviour and provide a safe movement. Public lighting thus creates:

a. Sense of security and safety
b. Sense of direction and orientation
c. Sense of scale and proportion
d. Sense of play and interaction
e. Sense of participation and belonging
f. Sense of value and heritage

Lighting also impacts the flora and fauna. Light at night is increasing light pollution to never seen before levels; a major contributor to this light pollution is public lighting.

Public lighting thus impacts not only our visual environment and functions, it influences flora and fauna, social interactions and behaviour, and of course energy consumption. Therefore any public lighting strategy needs to simultaneously address the questions of light quality, ecology and energy.

Taking our cue from Sustainability principles (see Fig. 1.1), through the various studies and research we can establish the three goals or pillars for public lighting, namely:

1. Quality of light: light for visual performance and comfort, right light at the right time for the right function and according to the user.
2. Ecology: Suitable light for all ecological systems, lower light pollution, human centric lighting.
3. Efficiency: Energy saving, lower carbon footprint and lower consumption of resources.

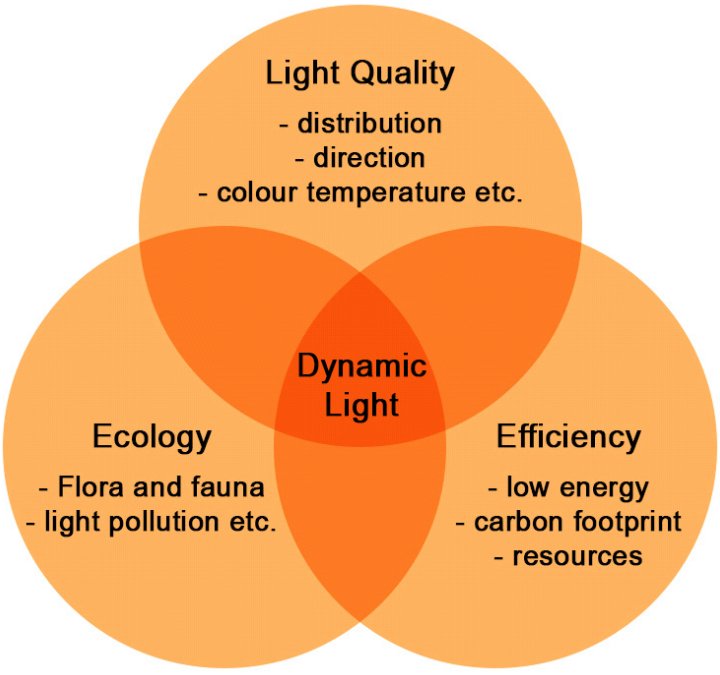
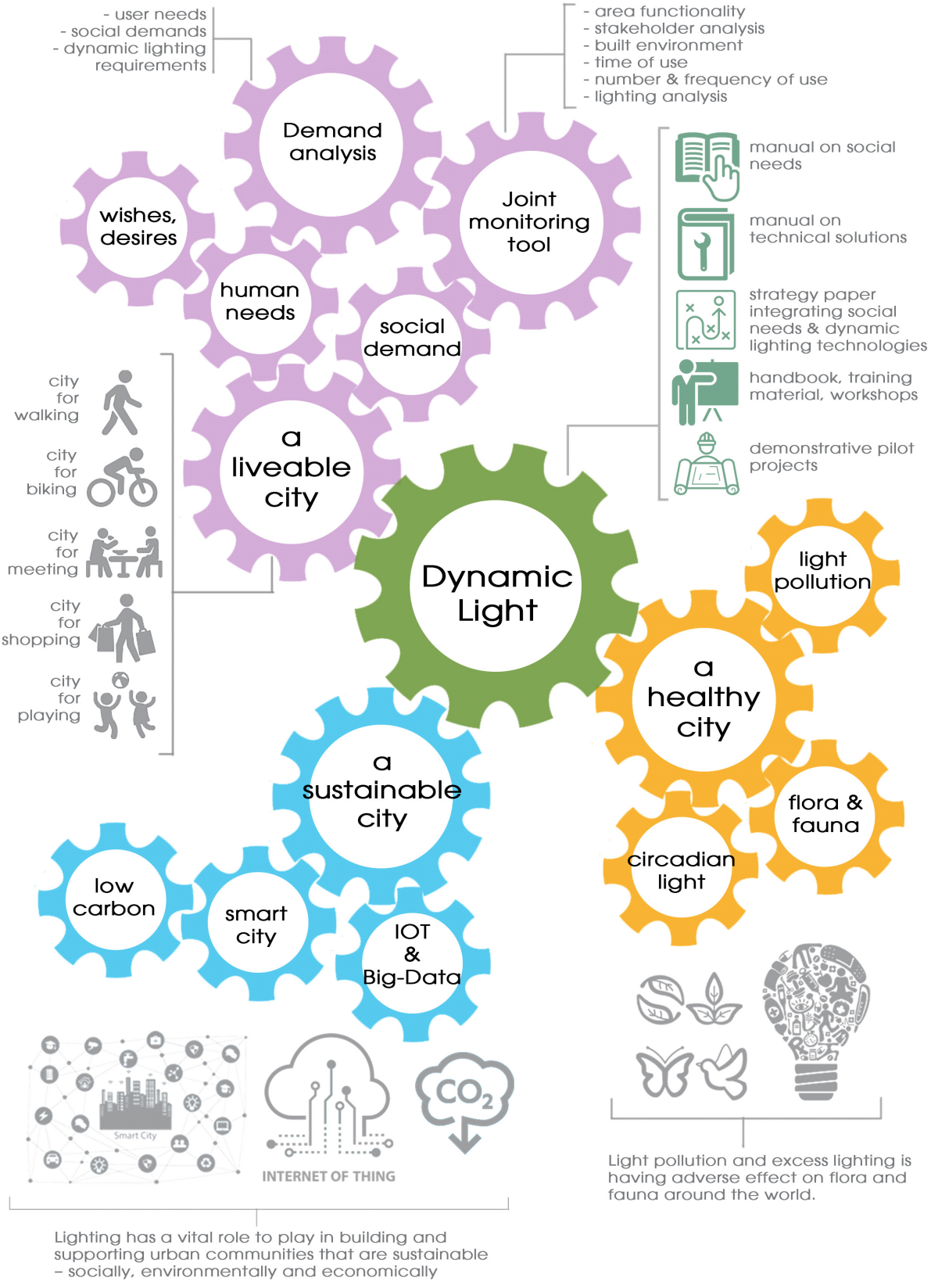


Fig.1.1: A representation of the 3 main dimensions of Dynamic light: Quality, Efficiency and Ecology

This Manual will aim to outlining the factors which are essential for light quality, ecology, energy efficiency and subsequently social sustainability.



1.2 False Efficiency

Energy efficiency and savings should not and cannot be at the cost of light quality resulting in poor visual environment. The urban realm today is confronted with challenges never witnessed before, like ever increasing population, pollution, pressure on housing, transportation and open spaces, climate change, ageing societies, and so on. Added to this the changing lifestyles and behavioural patterns bought on by new technology and media, combined with the impending environmental crisis are creating never before seen challenges for the urban spaces.

Light is an indispensible and the most critical component of the urban environment. Although the percentage share of the energy directly consumed by public lighting may be low, public lighting however does offer one of the best potential for energy saving.

Unfortunately, in order to save energy, a recent trend has been to completely switch off sections of public lighting. Instead of having the right quality and quantity of light at the right place, at the right time, for the right function; light is completely switched off. These results in visual environments that are unsuitable for the visual tasks, dangerous, create the fear of insecurity.

Through the previous deliverables (D.T 1.1.1) we have learned that public lighting can create positive visual environments, assist in safe public movement, elevates the sense of security, help in urban regeneration and a positive identity. Such a short term goal of energy saving by switching off public lighting randomly without any consideration to these various functions and users will adversely affect the visual environment, safe movement, feeling of safety, attractiveness and image of the space.

This is what can be best understood by the term "False Efficiency", wherein by having short term and narrow minded goals like "only energy saving" can result in massive losses in both tangible and intangible ways resulting in far more severe inefficiency than before. Energy saving hence cannot be at the cost of lower visual quality.

Thus the sensible approach is not just to replace conventional lighting with LED technology or switching off light but to use the new LED technology with dynamic lighting controls. Various lighting scenarios can be easily programmed to dynamically change the characteristics of the public light with changing requirements, uses, functions and frequency. Implementation of such lighting solutions can not only save energy but also at the same time provide suitable visual environment and quality.

Chapter-2: Dynamic Light: Definition and explanation

Urban lighting design has been the 'stereotypical night scene' created by floodlighting of every historical building and pouring excessive light on roads and pedestrian zones to increase safety and security furthermore, city governing authorities have chosen to adopt the "successful formula of the other city" over discovering the local needs. Therefore, urban lighting efforts have been overruled by blueprints of the prominent lighting schemes.

Consequently, urban lighting design has struggled to address the question whether the existing type of lighting design meets the needs of and feel pleasing to all segments of the society. [2]

The time has arrived to redefine urban lighting beyond just a functional add-on for safety or beautification and recognize it as an opportunity and fundamental solution to improve the quality of life for urban citizens. [2]

2.1 What is Dynamic Light?

Until very recently, street lighting commonly used high-intensity discharge lamps, often HPS high-pressure sodium lamps. Such lamps provided the highest amount of photopic illumination for the least consumption of electricity. However, in the past few years, new street lighting technologies, such as LED and control systems have become abundant.

Lighting control systems have long established themselves as an important tool for indoor lighting. Controls are often used not just for energy and cost savings but more for quality and user needs. The lighting controls have now since few years also found their way into European norms for indoor lighting.

Lighting controls for public lighting however are not mandatory. The on-going energy and sustainability discussions are putting ever more emphasis on lighting control for public lighting.

The three most common control strategies for public lighting are:

1. On-Off: switching at a pre-defined scheduled time.
2. Use of sensors (cameras, presence/absence sensors, IR etc.)
3. Other inputs like weather, traffic, noise etc.

The sudden evolution in technology has resulted in a number of lighting control strategies, but their mass use is still far from widespread with a low market penetration in Europe (McKinsey & Company 2012). According to several sources (E-Street 2008, E Soli 2012, Lites, and European Commission 2013) only 0.22% of installed lighting is with any intelligent lighting control.

Let us first understand the basics of lighting control in public spaces:

2.1.1 Tele-Management

It is the term given to a system that has the ability to automatically control and monitor an outdoor lighting system and is capable of a wide range of changes in lighting characteristics based on numerous

inputs such as time, traffic/ pedestrian volume and composition, weather conditions, ambient luminance to name a few.

Such a system can automatically send information about general performance, energy and light performance, maintenance etc. in a 2 way communication system (E-Street 2008)

New words and terminology is being added to this definition and the name has been upgraded to "Intelligent lighting".

2.1.2 Intelligent Lighting and Adaptive Lighting

The E-Street Project differentiates between intelligent and adaptive lighting as follows:

"Adaptive lighting only describes the performance of the light, adapting the light to various parameters such as time, volume, weather etc; while intelligent lighting also includes the operational elements, software, hardware and additional systems."

But both the terms are used interchangeably. A typical intelligent or adaptive lighting system consists of: luminaires with changeable lighting characteristics, lighting control systems, communication systems, and administrative tools.

2.1.3 Common Public lighting systems

The street lighting systems can be distinguished by being either fix or responsive.

A. Fix street lighting architecture: It is usually consist of a luminaire (with legacy/ conventional lamps), a power cable and a switch cabinet that allows one of 4 methods to switch on a luminaire- an astronomical clock with pre-determined on/off switching schedule, an individual photocell, a master photocell or a Tone Frequency (TF) remotely sent from administration. (E-Soli 2012)

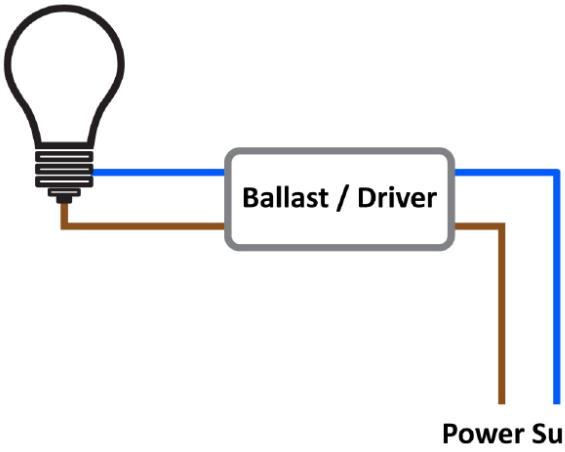


Fig.2.1: Conventional light source and ballast/ driver configuration. From Assessment of framework condition (WP 2 1.9) (p.14) [PDF], by Energy Saving Outdoor Lighting, 2012. Copyright 2010 by Esoli consortium. Retrived from http://www.esoli.org/images/stories/WP_2_Final_Document_VS_1.9.pdf. [50]

B. Adaptive lighting systems: It consist of the following components-

- Lighting Equipment (luminaires)
- Power supply systems- Electric power supply grid composed of a local power station, distribution power cabinets and power cables.
- Outdoor Light Controller unit (OLC) - It can be installed inside the luminaire or on the mast and allows communication between the segment controller (SC) and the ballast/ driver.
- Local segment control Unit (SC) - It allows communication between central control system and OLC. This allows for a dynamic change in lighting.
- Central control system – The central hub where the system is monitored and commands sent to one or more group of luminaires.
- Communication Network – Depending on various factors, networks like powerline communication (PLC), Radio Frequency (RF) or Wireless (Wifi).
- Sensors and actuators – Installed either in the OLC or SC depending on the type of system – Stand alone or real-time adaptive- The most common sensors are motion and presence-passive IR, Radar or Ultrasonic, Thermal and Video Cameras, Photocells, time clocks.

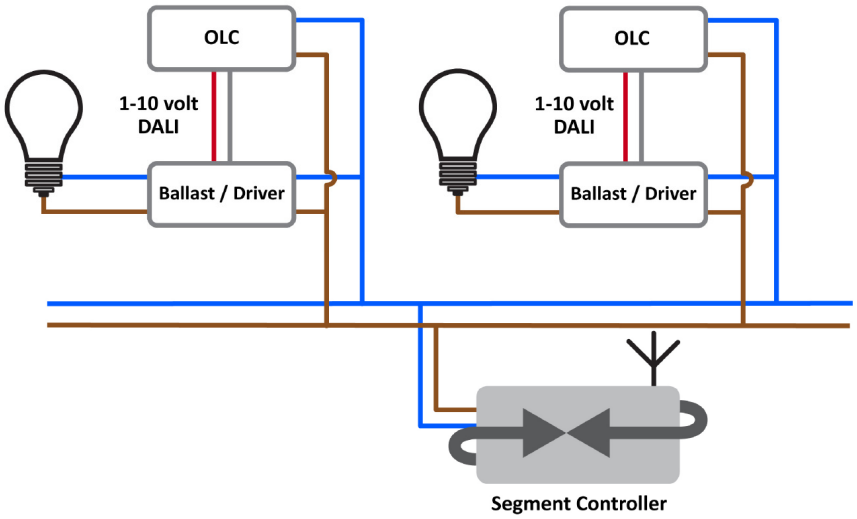


Fig.2.2: Generic architecture of an outdoor adaptive lighting system. From Assessment of framework condition (WP 2 1.9) (p.14) [PDF], by Energy Saving Outdoor Lighting, 2012. Copyright 2010 by Esoli consortium. Retrived from http://www.esoli.org/images/stories/WP_2_Final_Document_VS_1.9.pdf. [50]

2.1.4 Static and Dynamic Changes

Changes in light and its characteristics can either be static or dynamic.

- In a static change, the light changes in a pre-determined pattern and not based on real-time environmental information. The changes are pre-programmed in the system.
- In a dynamic system the light changes based on real-time or continuous information input.

The main distinction in communication therefore is that in a dynamic system there is a communication between the luminaires, control units allowing for a change in lighting characteristics based on real time information such as, volume, presence, weather, traffic etc.

The actual communication between components is ensured though a dimming protocol, allowing the controller unit to interact with the ballast/ driver. Current outdoor lighting standard protocols include 1-10 V, DALI, PLC, and more recently LON Mark and KNX.

2.2 Dynamic lighting: an improvement on Adaptive lighting

Adaptive lighting as we have seen is more or less "a reactive lighting control". The lighting reacts to changes in time, change in volume, change in weather or change in ambient luminance; the sensors detect a change and the lighting reacts to that change in a pre-determined way.

Dynamic lighting on the other hand is "a Pro-active lighting control". Dynamic lighting is dependent on the user behaviour, user needs and demands. It is also the expected and desired lighting situation for a particular function, activity, time, user, place etc.

Adaptive lighting is light adapted based on one or more parameters whereas dynamic light is the light adapted based on many parameters and respecting the user needs, demands and expectations.

Let us consider the concept of "dynamic light" using few examples.

Example-1: We shall assume the situation described in the deliverable D.T 1.1.2 & D.T 1.1.3 Joint monitoring tool and Demand Analysis in which a small public space in Wismar was studied and analysed.

The bus-stop is on a busy road for vehicular traffic and with a dedicated bicycle track. The bus-stop is adjacent to a public park and few retail outlets. The lighting of the bus-stop is based not just on the various visual tasks that need to be performed while waiting for the bus or boarding it. There are a lot more demands and expectations associated with lighting in the bus-stop.

The bus-stop signals where the bus will stop, it provides a place to sit and wait for the bus. There are maps and public transport network maps to help find connections. The bus-stop also symbolises a boundary between high speed vehicular movements, it provides orientation, way-finding, signals the end of working hours to name a few.

The bus-stop performs so many different tangible and intangible functions, but still the lighting for the bus-stop remains constant and does not cater to these changing and varied functions.

Now, consider the situation in which the brightness levels of the bus-stop increase 3-5 min before the bus is scheduled to arrive. The bus schedule and active GPS monitoring can be linked to the control systems that allow for increasing the light levels/ brightness of the bus-stop 5 minutes before the bus arrives. A simple gesture like this will have a series of implications:

- It will allow the people to see and reach the bus-stop before arrival of the bus.
- A bright bus-stop will provide an orientation for the users.
- It will assist in way-finding

Similarly, other environmental variables like closing and opening times of retail stores can be used to change the lighting for the bus-stop. For example, a warm colour temperature during the opening and evening times can signal the shops are open and a colder colour temperature can signal closing times.

Further on, such dynamic lighting control can also add to the sense of security and safety. The bus-stop as an orientation point and way-finding tool can help in promoting the psychological feeling of prospect and refuge. Previous scientific studies and the deliverables- D.T 1.1.2 & D.T 1.1.3 show the importance of these psychological factors in creating a sense of security and safety.

Example-2: The second example is taken from a student design project undertaken here at University of Wismar. The students undertook the task for designing light in the public spaces for a small theatre in the city of Rostock, Germany. Amongst the various analyses done by the students on the site was the analysis of movement in and around the theatre. This analysis of movement was further detailed out based on the climate and temperature around the year in the area.

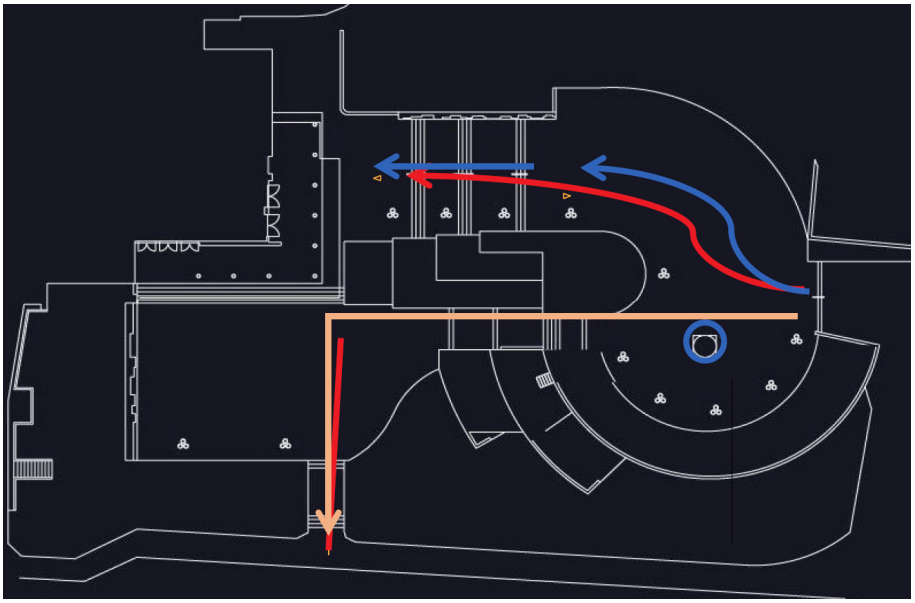


Fig.2.3: Analysis of movement in and around Theatre in Rostock. [51]

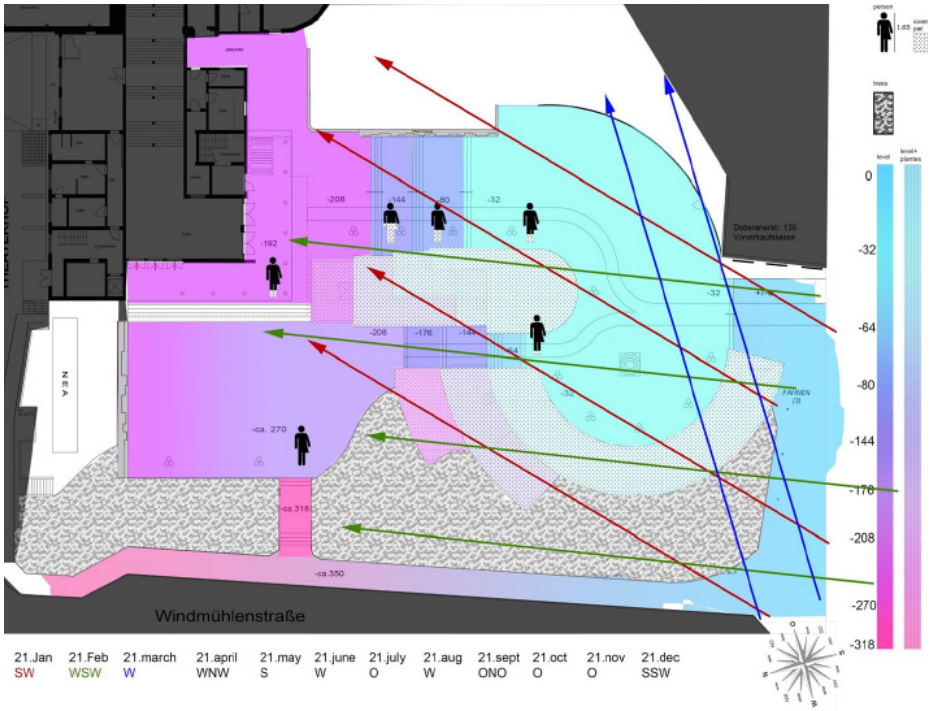


Fig.2.4: Analysis of use based on climate. [51]

Temperature allows to stay :

Jan-April: 5-30 min

Oct-Dec 15-25 min

to sit

May-Sep: 30-90 min

Main wind direction: SW

The students came up with some very interesting results, as seen in the images above. The students were able to identify the most used paths and understand how the people move around in the public space. They were also able to identify under what climatic and environmental conditions which areas of the public space are used.

This information then can be very easily used to design public lighting that caters to the needs and behavioural patterns of the different users. A simple adaptive lighting may only be able to dim up or down the light in certain areas based on sensors. Whereas a "**dynamic lighting approach**" will be able to not only predict where and when light is needed but it will also provide the right quality of light for the visual functions as well as for cognitive and psychological comfort.

Recent studies have shown that colour temperature can have an influence on the perceived temperature in a space. Taking these results, during cold weather, when people use the public space for a short period of time, a warm colour temperature light can be utilised to provide the user a sense of warmth and welcome.

Similarly, creating pools of light that encourage people to sit can be used to stay and use the spaces longer. As you see, a simple adaptive lighting will only be able to change based only on pre-defined and pre-determined algorithms. These algorithms cannot understand the user needs, demands and expectations. A "dynamic lighting" approach on the other hand will not only understand these needs, demands and expectations but will change the lighting situation to satisfy these requirements.

Light is one of the major factors in creating the human-made environment and its impact influences people's experience of the urban environment at night. The relation of light and urban environment in the night time involves psychological, aesthetic, and environmental discussions.

Such a simple application of dynamic lighting control as shown above based on user frequency and temperature can be easily extended to include sensors like proximity, user intensity, weather and climate sensors. These sensors could then be used to control more parameters like brightness, contrast, light colour etc.

Functions that earlier could not have been controlled like light distribution, colour rendering properties can now be controlled with the use of dynamic lighting controls. This allows for the optimum design for each and every use or function with the appropriate light quality; maximising the energy saving potential.

Chapter-3: Human needs, demands and expectations

A city is complex network of different political, economic and social environments; it is the mixing pot in which various different groups, cultures, classes, races, religions and communities constantly interact and grow.

A lighting strategy for a city therefore needs to not only cater to the different individuals and groups but also encourage a positive and healthy interaction between the various groups and assist in the development of the different groups.

The chief goal of public lighting is to ensure the satisfaction of the various user needs. Knowing and understanding people's need and preferences therefore is the key to a successful public lighting strategy. The following sections will shed some light on the concepts of needs, demands, expectations and preferences.

The changing lifestyle has created a scenario where in each and every individual will have their own needs and demands, the urban lighting has to be flexible and adaptive enough to be able to be modified according to the demands of the citizens.

Dynamic lighting controls will play a crucial role with the ability to have precise light distributions, different light distributions, on demand, controllable light colour and colour rendering qualities, on demand illuminance and luminance levels, and integration of sensors and other services.

3.1 Human Needs

Despite the individualistic and complex nature of human needs, goals, and aspirations – a number of authors have proposed an overarching hierarchy of human needs. Most theories derive from Maslow's original work and identify 5 stage hierarchies of human needs.

Fig.3.1: Pyramid of human needs based on Maslow's original idea 1968.

- Physiological Needs (for warmth and comfort)
- Safety and security needs (to feel safe from harm)
- Affiliation needs (to belong – to a community, for example)
- Esteem needs (to feel valued by others); and
- Self-actualisation (for artistic expression and fulfilment)

3.1.1 Public lighting and Maslow's Pyramid of human needs

By drawing from Maslow's Hierarchy of Needs and considering the relationship of these factors with the built environment, it is reasonable to hypothesize that certain aspects of human behaviour are capable of being affected by the presence of the physical and ambient features of public spaces. The physical features of public spaces may include elements such as buildings, streets, landforms and other people, whereas the ambient features may include elements such as illumination, sound, and temperature [1].

In many ways public lighting can also be defined based on the human needs pyramid as proposed by Maslow.

First and foremost public lighting needs to fulfil the physiological needs in an urban space. The basic physiological needs include light required for the elementary visual process – minimum horizontal and vertical illuminance, minimum luminance, contrast, colour rendering etc. The primary importance of light for human beings is that it helps create the vision. Through vision, people perceive and use the space. Perceiving the physical surrounding is also vital for the safety of orientation.

Next we look at the need for safety and security. Light induces psychological effects on people. The amount of information received by people in space increases through light hence fosters the sense of security in people. The way people use and behave in a public space is influenced by the perception of safety in the space. The actual personal safety may differ from the perceived personal safety, but in terms of behaviour constraints, it is perceived danger that influences behaviour. This causes people to avoid places that they associate with personal risk (Keane, 1998; Riger & Gordon, 1981) and to reduce their personal radius [14]. As we observed from the deliverables D.T 1.1.1 - Lighting relates directly to concealment and prospect. Low lighting leads to poor visibility and visibility is an important component of prospect.

Lighting is a powerful deterrent to night-time crime. It significantly reduces the fear of crime and thus encourages more public interactions and natural surveillance, in effect acting as a deterrent to opportunist crime. Both Physiological and Safety needs can be classified under the term "lower order needs". The rest of the needs are classified under "higher order needs".

Hence, the most basic human physiological and safety & security needs or the lower order needs to have to be satisfied by the public lighting before progress can be made to the higher order needs. For example, when we consider the bus-stop case from earlier – the public lighting first and foremost needs to fulfil the basic requirements for visual process. There needs to be a minimum horizontal illuminance to be able to find the way to the bus-stop, a minimum vertical illuminance needs to be provided to be

able to see the bus-schedule, maps etc. A certain contrast level needs to be maintained to allow for facial recognition, threats, approaching traffic etc.

Once these lower order needs are taken care of, the higher order needs start to play a major role. The way people experience public spaces after dark, the way they utilize public spaces, the way in which they interact with others and how it varies from the daytime usage of the spaces, all can be related to the higher order needs as described by Maslow.

Taking the example of the bus-stop from previous chapters, the lighting for the bus-stop can govern how people see and feel about the urban space by controlling the brightness introduced into space. Controlling brightness can direct people's attention and movement through an exterior. The attention and interest of the viewer are drawn to the distant object, given that a softly lit object or area is placed in the front of the viewer and a more brightly lit object or area is placed farther into space. If a person is heading toward an area with higher light level visible to the viewer from the outset, walking through a dimly lit area feels comfortable.

Although there is a hierarchy, the different needs are related in a complex series of inter-linked relationships.

3.2 Demands, Needs, Aspirations, Expectations from Light

"Society and Culture" also influence the choices people make in any given setting and hence have a deep impact on lighting.

Society can be understood as any self-perpetuating human grouping occupying a relatively bounded territory that interacts in a systematic way and possess its own culture and institutions

Culture is best understood in an anthropological sense as a "particular way of life, which expresses a certain meanings and values not only on art and learning, but also in institution and ordinary behaviour (Williams 1961, 28). Hence, the needs form public lighting encompasses not only individualistic but also perceptual and social needs.

In order to understand this better, we have proposed the following "concepts and Notions":

3.2.1 User Demands

A look back at the history of light and its relationship with the physical urban environment and the human being reveals a very unique relationship. Human behaviour, society, functions, activities, customs, culture and traditions all together at first create the need for light, demanding lighting solutions to fulfil the needs of the new lifestyles and the society as a whole.

User demands therefore can be defined as the fundamental needs of an individual or a user group that enable the individual or a user group to carry out the essential functions and at the same time providing a comfortable condition.

User demands can further be understood as multi-dimensional approach involving physiological needs, security needs.

3.2.2 Social Needs

As in the case of higher order needs in Maslow`s pyramid of human needs, as soon as the public lighting fulfils the basic user demands and physiological needs, it opens up a path to further expectations, aspirations, and improvements in the current state of things. This in turn creates a new set of higher order needs from the public lighting.

There is today a deeper inter-connectivity of the urban cityscape to the behaviour and lifestyles of the users that occupy the physical space. The psychological needs, expectations and aspiration for improvements are equally if not more important than meeting the basic user demands.

Social needs hence can be described as the desires, expectations and aspiration for improvement in the urban fabric. These social needs can often encompass psychological and symbolic perception making them very difficult to quantify and describe.

3.2.3 Public lighting Requirements

Through an understanding of "user demands" and "social needs" a set of public lighting requirements can be established. The user demands address the lower order needs like basic physiological and security requirements. The social needs then take care of higher order needs like social sustainability, sense of belonging, aspirations and expectations.

These requirements are often expressed in physical measurable quantities like illuminance, luminance, contrast, glare etc.

Chapter-4: Quality in Public Spaces: The Human dimension

Cities are the places where people meet to exchange ideas, trade, or simply relax and enjoy themselves. A city's public domain – its streets, square, and parks – is the stage and the catalyst for these activities (Richard Rogers, Cities for People- Cities for people).

4.1 Public spaces

Public spaces consist of outdoor environments, sidewalks, streets, parks, city halls, squares, plazas etc. These are the spaces where civic, cultural and social activities occur. Public spaces are a stage for public life, which promotes sense of community, sense of places, pope connection and a sense of belonging.

Public spaces are a mirror of social values, customs and culture. They are the reflection of interactions between physical, social, political and ecomn0omic realities. In public spaces people interact, exchange and communicate (PPS, Carr and Francis 1992).

4.2 Public spaces: Physical and functional qualities

The physical and functional qualities of public spaces are related to the physical amenities, the activities, accessibility, location, surrounding land uses etc. these functional and physical qualities govern the social interactions, comfort, security, attractiveness of the place.

Public lighting at first must be functional to provide a set of physical conditions which encourage participation, public use and activity. Studies have shown that the public spaces that are dynamic and highly visited by people are settings where people are able to engage passively with the environment by looking at others, sit around, easily accessible, contain public art, have natural features like vegetation, water features etc.

In addition, it has also been shown that food, retail and events attract people to urban spaces. The increased visibility in turn promotes the sense of security and hence further increases public footfall (Whyte 1980).

Public lighting therefore requires a clear design based approach.

4.2.1 Urban Design Movements and Evolving nature of Public Spaces

Significant movements have influenced on the shape of the built environment and the form of public spaces since the late nineteenth century. The movements suggest, at the very least, that the practice of urban planning and architecture is continuously motivated by the desire to enhance urban areas and improve quality of life in response to changing circumstances.

1. **City Beautiful Movements**: The City Beautiful Movement was a reform philosophy of North American architecture and urban planning that flourished during the 1890s and 1900s with the intent of introducing beautification and monumental grandeur in cities. The movement emphasized that public spaces should be formed by order, harmony, formality, and symmetry.
2. **The Garden City Movement**: The features advocated by this movement emphasized the form that public spaces should take and where they should be located in relation to the private spaces of neighbourhoods. To signify their importance, the public spaces inspired by this movement were located in the centre of neighbourhoods

3. **Modernism**: The utopia envisioned by Le Corbusier and his followers may have been a popular architectural trend at the time. However it failed to acknowledge the preferences of not only the inhabitants of the buildings but also the impact of those buildings on the public realm and the public users. Little interest was paid to the needs of pedestrians or to how users would interact in that environment. Subsequently, many of these projects failed, were abandoned and eventually demolished because of the social problems that they created.
4. **Behaviourism**: Behaviourist psychology influenced urban planning especially in the 1960s and after, manifesting in such theories as defensible space and crime prevention through environmental design.
5. **New Urbanism**: It is an approach for successfully reducing environmental impacts by altering the built environment to create and preserve smart cities that support sustainable transport. It promotes a sustainable approach towards urban construction that appreciates and develops smart growth, walkability, architectural tradition, and classical design.

4.3 The Social and Movement Space

For the ease of understanding and in terms of public lighting; public spaces can broadly be classified into 2 categories:

- The Social Space – interactions, exchange, socially active
- The Movement Space – movement, socially passive

For decades the social and human dimension has been overlooked and many other issues like rise in vehicular volume have taken centre stage. This is also evident by the fact that most of the public lighting norms are focussed on vehicular movement and put pedestrian and bicycle movement as a secondary consequence.

Major movement spaces like roads, highways etc. provide obstruction to pedestrian movement, creating problems of severance and reducing connectivity. Heavy vehicular traffic frustrates and hampers social use of spaces.

If public lighting is going to be kept designing for vehicular movement alone, the traditional function of city space as a meeting, exchange and social forum will be phased out and will need to negative and unsuccessful public spaces. Therefore a public lighting scheme needs to concentrate more on the human dimension and public needs. The needs of other user groups like pedestrians, shoppers, retailers, tourists etc. need to be taken into account.

4.4 The social dimension: Social sustainability and Placemaking

Understanding the relationship between people (society) and their environment (space) is an essential component of urban design and public lighting strategy. Lighting strategies influence patterns of human activity and thus social life.

In Urban design theory Dear and Wolch (1989) had argued that social relations can be constituted, constrained and mediated by space – these principles can also be applied to public lighting.

- Constituted through light: Lighting characteristics influence social behaviour.
- Constrained through light: Public lighting facilitates or obstructs human activity.
- Mediated by light: "Friction of distance" facilities or inhibits the development of various social practices.

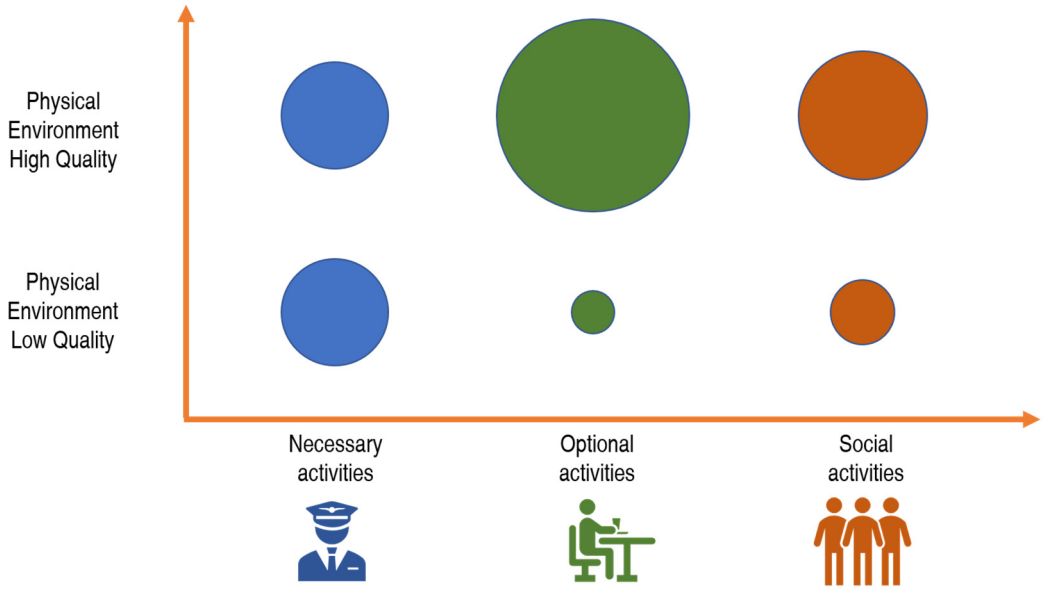


Fig.4.1: The relationship between environmental quality and human activity (source: modified & adapted from Gehl, 2011)

4.4.1 Social sustainability

In contemporary society, the ability of light to generate or reinforce a sense of place has become almost as important as its fundamental role in making objects visible. As an element that is crucial to placemaking- the creation of a unique and recognisable character for a part of the city – lighting is recognised as a powerful tool.

In order to make a place those appeals to residents and visitors alike, it is hugely important that the local community should use and enjoy it.

- Social activities are what make a space attractive. The city at night is often overlooked – and under exploited.
- Lighting must enable a wide range of different uses; encourage social interactions according to the ever-changing requirements of the users.
- The city at night is a different environment from the city in the daytime; a new realm of opportunity is opened for urban and lighting designers in recognising its different roles and meeting its diverse demands.
- If the city at night is to be a real public space, then it must be made accessible to all sectors of the society.

Lighting clearly has a role to play in making socially sustainable places.

4.4.2 The social construction of place

Sense of place is often discussed in terms of the Latin concept of "genius loci" – a notion suggesting people experience something beyond the physical or sensory properties of places and feel an attachment to a spirit of the place.

The sense of belonging along with an individual identity gives rise to a strong sense of place. Lighting design needs to reinforce this concept.

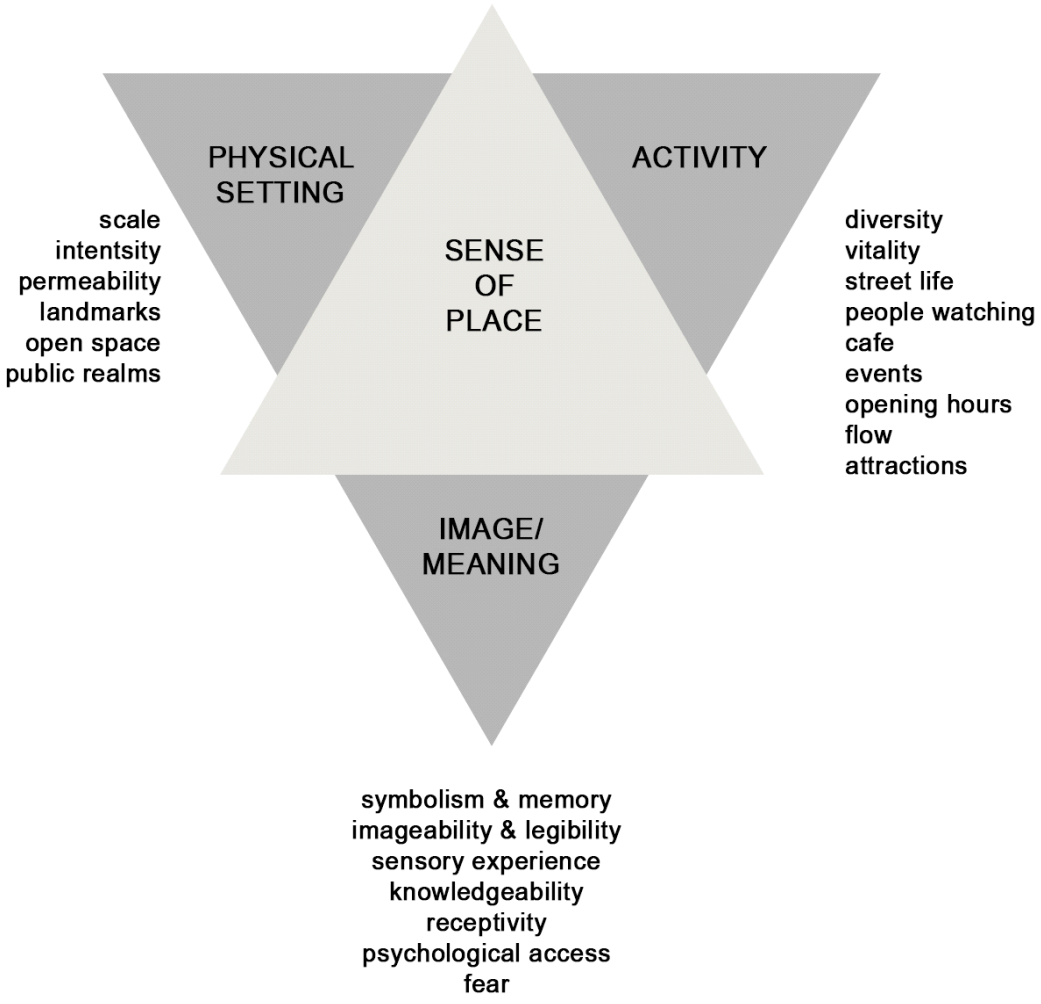


Fig.4.2: What makes a "place". [12]

4.5 Placemaking

Public space is the interface between our homes, our business, our institutions, and the broader world. Public spaces are how we get to work, how we do our errands, and how we get back home. Public space is where nearly half of violent crimes happen, it is where policing ensures safety. Public space is for buying and selling, or for making, playing ad meeting one another. Public space is for conveying our outrage and our highest aspirations, as well as for laying the most mundane utilities and infrastructure.

And when we let it, public space can be a medium for creativity, expression, and experimentation (Placemaking what if.. Pg.1).

With such a varied and important role of public spaces, lighting the public space has never been so critical.

There is an increasing desire to design public spaces as "places".

Placemaking inspires people to collectively reimagine and reinvent public spaces as the heart of every community. Strengthening the connection between people and the places they share, placemaking refers to a collaborative process by which we can shape our public realm in order to maximize shared value. More than just promoting better urban design, placemaking facilitates creative patterns of use, paying particular attention to the physical, cultural, and social identities that define a place and support its ongoing evolution.

Public space is inherently multidimensional. Successful and genuine public spaces are used by many different people for many different purposes at many different times of the day and the year.

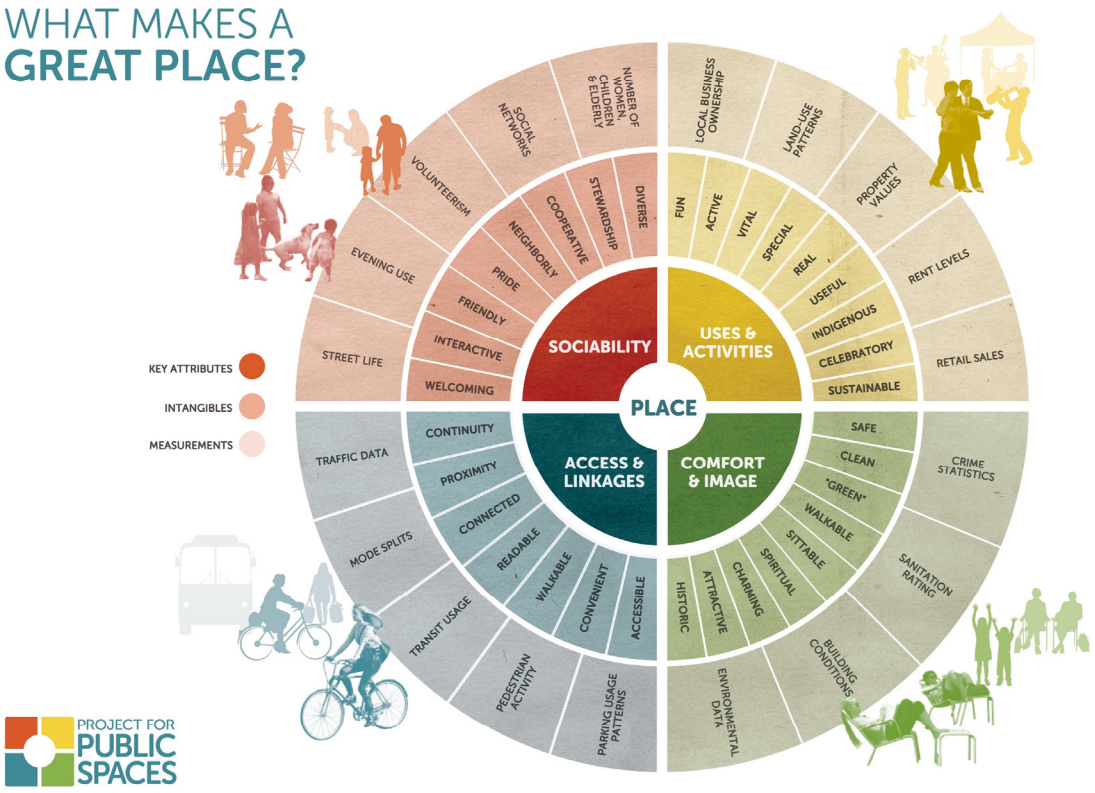


Fig.4.3: What makes a "place". Source: Placemaking what if.. The Place Diagram is one of the tools PPS has developed to help communities evaluate places. The inner ring represents a place's key attributes, the middle ring its intangible qualities, and the outer ring its measurable data.

https://www.pps.org/article/what-is-placemaking

4.6 Light, Social Sustainability and Placemaking

In contemporary lighting design, the ability of light to generate or reinforce a sense of place has become almost as important as its fundamental role in making objects visible. As an element that is crucial to placemaking – the creation of a unique and recognisable character for a part of the city – lighting is recognised as a powerful tool [5].

While placemaking is now an established part of any urban regeneration, and a lighting strategy will usually be submitted at the proposal stage, little real consideration is given to how these areas are used after dark. The city at night is an overlooked – and under-exploited – territory [5].

Public lighting must enable and encourage social interaction according to the ever-changing requirements of the inhabitants. If the city at night is to be a real public space, then it must be made accessible to all sectors of society. Lighting clearly has a role to play in making socially sustainable places.

With dynamic lighting control we can distribute and target light to individuals and groups. Bringing the right light, at the right time for the right user rather than having "one solution fit all situation", customised lighting solutions can be created for different uses, stakeholders and time of use.

Using modern communication tools we can consult, listen and engage with users rather than just inflict lighting schemes on them. By challenging age-old lighting conventions and reassessing user needs, we believe we can work towards lifting local urban communities literally and metaphorically out of the dark.

Chapter-5: Activities in Public spaces-Lighting requirements

Public spaces have been the epicentre of social life by providing people with opportunities to gather and socialize, to celebrate, for children to play in, and for the undertaking of economic, cultural, religious and political activities. As we have seen in the previous chapters a successful public lighting must support and facilitate the activities of people, its design should be informed by an awareness of how people use public space. Various researchers and urban design experts have identified the needs people seek to satisfy in a public spaces- we look at 2 such theories to understand the lighting requirements.

5.1 Activity based

1. Comfort: Comfort is a pre-requisite for successful public spaces. The length of time people stay in a public space is a function and an indicator of its comfort. Sense of comfort includes environmental factors, physical comfort, social and psychological comfort. (pg. 209, chapter 8, the functional dimension)

2. Relaxation: A sense of psychological comfort is essential for relaxation but relaxation is also a more developed state with the body and mind at ease. (Carr et.al 1992:98)

Relaxation often involves respite from, or contrast with, the immediate environment.

3. Passive Engagement: It is the need for an encounter with the space, albeit without becoming actively involved (Carr et.al 1992:103) The primary form of passive engagement is "people-watching". Whyte (1980-13) found that what attracts people is other people, and the life and activity they bring. For example, the mist used sitting places are generally adjacent to pedestrian flow.

4. Active Engagement: It represents a more direct experience with a place and the people (Carr et.al 1992:119). Successful public spaces provide opportunities for varying degrees of engagement, and also the potential to disengage. Lighting can create or inhibit, such opportunities for contact.

5. Discovery and Display: Representing the desire for new experiences, discovery depends on both variety and change. This involves a more deliberate action by the public lighting authority.

5.2 Spaces as Places

1. Access and Linkages: The accessibility of a space can be easily judged by noting its connections to the surroundings including the visual links. A successful public space is easy to get to, easy to enter, and easy to navigate. It is arranged so that you can see most of what is going on there, both from a distance and up close. The edges of a public space also an important role in making it accessible.

A row of shops along a street, for instance, is more interesting and generally safer to walk than a blank wall or an empty space. Accessible spaces can be conveniently reached by foot and ideally, public transit, and they have high footfall.

2. Comfort and Image: A space that is comfortable and looks inviting is likely to be successful. A sense of comfort includes perceptions of safety, cleanliness, and the ability to sit in spaces.

A lack of seating is the surprising downfall of many public spaces, people are drawn to places that give them a choice of places to sit.

3. Uses and Activities: A range of activities are the fundamental building blocks of a great place. Having something to do gives people a reason to come (and return) to a place. A range of activities attract people to a space.

Through the use of dynamic lighting control system, public lighting can for the very first time respond to the above mentioned requirements.

5.3 Effects of light on people and the urban environment

This section reviews the previous studies and research into the effects of light in the urban environment. The reviews have been divided into 3 sections following the 3 goals of the research project as stated earlier in this manual.

5.3.1 Lighting of the Urban Spaces and Emotional Reactions of People

The lighting aspects are grouped into two categories: 'luminous composition' and 'overall composition'. The review also shows that lighting becomes significant in different places of the public space. In this study, the public space is categorized under four urban sections including buildings, roads and pathways, and pedestrian areas and squares. The 'buildings' consists of façade lighting and the immediate surroundings of the buildings that shape the public space. In that sense, buildings are seen as a part of the public space and lighting of this urban section is reviewed to that extent. This section will introduce these lighting aspect groups and will discuss the relationship between these indicators and different urban sections. Nevertheless, this review section will extract the relations between these various aspects of lighting and people's psychological responses to them.

Prior studies stress that light can create shape, emotional response - even a new reality to a familiar space through the use of compositions. The luminous composition consists of the organization of lighting element using one or more design principals. Light can shape how space is seen. Light also adds emotional qualities to the space such as romance, mystery, drama, and excitement. Light creates the focal object by emphasizing specific aspects of the urban environment or altering the daytime appearance. The absence of light as well can create a part of the luminous composition. Three lighting elements can control the effects of the luminous composition: direction, intensity, and colour of light.

The combination of the illuminated elements with each other and with the urban environment creates an overall composition of the urban lighting. This overall composition of lighting creates lighting effects on a larger scale than the luminous composition focuses. This aspect of lighting raises the issues of how the location and different perspectives affect experience of people; how the relation of daytime and night-time appearance affect the perception; and how the appearance and placement of lighting fixtures affect the appearance of the structure; how the level of light affects the light pollution; and how the lighting affects the fear of crime.

Lighting design seeks to establish a priority of importance of the views of an urban scene. The relation between daytime and night-time appearance of the urban elements affects how people experience an urban element or space. Lighting efforts should not create an entirely different image of nocturnal because it can jeopardize people's orientation. The appearance of the lighting fixtures, the luminaires during the daytime is also crucial in the relation of daytime and night-time appearance. Lighting design

of the urban environment should not compromise the daytime appearance. Lighting effect would be preferable and pleasant if the illuminated elements fit in the existing atmosphere by either creating harmony or contrast. Research reveals that fear of crime can exist although the crime rates are low. The knowledge of the spatial environment decreases the fear of crime. The overall lighting composition of an urban section can reduce the fear of crime and, in turn, it can increase the comfort.

Research on earlier papers reveals that there are several perceived attributes of light in the lighting of all four urban sections. The attributes that are brought out in this review for the lighting of buildings are brightness/shadowing, coherence, contrast, distribution of light, legibility, the variety of colour, novelty, and harmony.

The attributes that are brought out for the lighting of roads and pathways are legibility, contrast, brightness/intensity, distribution of light and orientation.

The attributes that are brought out for the lighting of the pedestrian areas and squares are brightness, the sufficiency of light, softness, distribution, and direction of light, color and legibility.

The attributes of the green areas that this review brings out are brightness, shadowing, distribution of light, colour, and legibility. The Research also reveals that people's reaction to the perceived attributes of lighting have commonalities. Emotional appraisals for the perceived attributes of light in the lighting of buildings are stated as- like, dislike, interest, comfort, and discomfort. For roads and pathways, these emotional appraisals are safety, fear, anxiety, confusion, discomfort, and interest. For pedestrian areas and squares these emotional appraisals are safety/security, distraction, discomfort, interest, like, dislike. Moreover, for green areas, these emotional appraisals are comfort, discomfort, interest, dislike, like, fear and security.

Buildings

Buildings are the most significant masses in the built environment. Their appearance during the night dominates the urban nocturnal scene of the cities. They have the significant role in people's perception of the space at night since they create the nocturnal landmarks of the city. Therefore, the lighting of buildings has always been a component of urban lighting. Even before the invention of electrical light sources, buildings were illuminated for functional and aesthetic reasons. The historical illustrations of cities display that buildings were illuminated with candles, torches and gas lamps for special events and festivals in the past.

Roads and Pathways

Roads and pathways provide paths for movement in the urban environment. For the urban environment to be usable at night, these paths need to be illuminated. Until recently urban designers and architects considered road and pathway lighting as an engineering task [17]. A good road and pathway lighting is acquired through utilization of engineering. However, this subject is also the concern of lighting design since road and pathway lighting have a significant effect on how the nocturnal landscape of a city is experienced. The primary role of road lighting is ensuring the safety of movement at night. In addition to ensuring traffic safety, road and pathway lighting has roles in creating secure night environments and improving the aesthetic quality of the urban space. Additionally, it is essential to bear in mind that motorists in the road require different lighting than pedestrians in the pathways.

Pedestrian areas and Squares

Pedestrian areas and public squares are auto-free hardscapes that are structured for the use of citizens for various activities. These areas picture the character of the social structure, and their vibrant character defines the identity of the place. Safe and pleasant use of these areas by people both during day and night has a significant effect on how people experience their urban environment. Lighting plays a vital role in how pedestrian areas and squares are perceived by people at night.

Pedestrian areas and squares of a town are exceptional areas, which should provide a welcoming, warm, and relaxation atmosphere at night. Citizens tend to spend their free time in these spaces and do various activities since the working hours are mostly in the daytime so paying extra attention to their night-time design is crucial. The lighting of the area should provide a sense of welcome, in addition to ensuring safety and security. Lighting for pedestrian areas and town squares must form a balance between good seeing conditions over the entire area and a light pattern that provides an attractive and welcoming visual environment. The lighting of pedestrian areas and squares can create a relationship between the light of the illuminated buildings and objects. Despite all the random factors in the illuminated areas of a city, a composition can be achieved that makes it possible to experience the image of the city at night as a pleasant whole. An overall bland lighting scheme of municipalities derived from tall lighting fixtures, will not entice people to visit and revisit the area unless additional accent lighting is provided. Lighting design of the area should introduce variety aiming at increasing the interest in the place.

5.3.2 Lighting affects positively pedestrian outdoor activity

Research evidence points to the direction that lighting affects people's willingness to use urban spaces after dark [15, 16]. Lighting may also affect the way in which these spaces are used, e.g. route choices [17], and how frequent they are used. Increased amounts of walking and cycling, instead of motorised mobility, has environmental benefits, such as lower levels of fine particles in the air. It also has a positive effect on mental and physiological health [18]. An increased use of outdoor spaces by women, elderly and families also affects the nature of social environment at night.

Besides fear of crime also fear of falling may lead to diminished outdoor activities among elderly. At winter evenings low ambient light levels complicating postural control together with slippery pavements create challenging environment for senior citizens. There is research evidence indicating that lighting system providing horizontal and vertical visual cues affects positively postural control [19-20]. Further research is needed to clarify whether outdoor lighting could also promote the postural control of the elderly through visual cues as LED technology enables incorporation of light sources into street structures. This kind of approach might be more energy efficient than general brightness increase. However, practical applications should carefully study possible eye heights and view angles in order to avoid glare.

5.3.3 Lighting may promote restoration

Restoration is the counterpoint to stress and attentional fatigue. It covers various processes involving renewing or recovering diminished functional resources and capabilities [33-34]. In the restoration research field, two processes have received much attention — one focuses on attention restoration and the other on psychophysiological stress recovery.

While urban planning strategies often refer to the benefits of urban greenery in general terms as promoting the well-being, some cities state more specific benefits and acknowledge the importance of attention restoration. Furthermore, the importance of near home restoration opportunities is increasing due to the aging process facing the world's population. However, the possibility to gain restorative experiences during darker hours is rarely considered although restoration during the evening may be very important, as recreational time is often limited to these hours. The need for restoration may also be considerable in the evening due to the mental effort needed during the workday [35]. Public lighting should promote people's near-home opportunities for restoration, enabling them to distance themselves from their everyday concerns and regain their attentional capabilities. Limited access to restorative environments may have negative consequences on attentional capabilities, health, and well-being [36-39]. Attractive environments may also promote walking and cycling as people may choose their desired footpaths or means of travelling because of the perceived potential for restoration [40-42].

There is preliminary research evidence indicating that focusing light to urban greenery instead of parking lots and roads results in higher perceived restorativeness and preference ratings and lower fear [43-44]. There are also some indications that besides focus of light also other lighting factors e.g. brightness may be connected to restorative potential [45]. Thus lighting provides visual access to restorative environments but the quality of light may also be important for restorative experiences.

However, further research is needed to clarify the preliminary indications.

5.3.4 Lighting affects social behaviour

Several studies within the field of social psychology have indicated that lighting is an environmental factor that may affect social behaviour. Brighter environments have been connected with less selfish behaviour and higher volunteerism, reflective self-regulation and honesty than dimmer environments [46-49]. It has been suggested that darkness may induce a psychological feeling of illusory anonymity that may further disinhibit dishonest and self-interested behaviour [49]. However, also prosocial behaviour in dim environments has been reported [50] thus leading to suggestion that most salient response in any given situation is expressed, regardless of whether it has prosocial or antisocial consequences.

Furthermore, it has to be pointed out that these studies have been conducted in laboratory conditions that differ considerably from public outdoor spaces after dark. It also has to be acknowledged that e.g. bullying may raise status within certain groups and bullying may include recordings of violent acts which are later put into internet. Brighter lighting may thus also contribute violation of the victim. Thus, there is a need for a research studying the possible effects of outdoor lighting on social behaviour. These effects are likely to be context dependent.

5.3.5 Lighting affects positively fear of crime

Street lighting affects positively fear of crime. Fear at night may stem from several reasons. Besides the reasons related to the social environment, or so-called 'social night' [21], and individual factors, such as gender and environmental trust [23], an obstructed field of view has also been connected with feelings of discomfort and fear [24]. The obstruction may be physical, but it may also be caused by insufficient lighting. There is mounting research evidence pointing that lighting positively affects a fear of crime [23, 25-29]. Even still, there are studies showing that lighting only has minor effects [30] or no effects [31] on fear of crime. The factors that might help explain the inconsistency include variations in the

preliminary lighting conditions, the follow-up times, the characteristics of the residents, halo effects and the complex nature of reactions that cannot be reached by practical interventions with only a limited amount of control [32].

5.4 The liveable city, the healthy city and the sustainable city

Given the varied views and theories about urban spaces, public lighting, and quality of light, we have made an attempt at gathering the various theories under 3 main headings. The 3 headings have been borrowed from the concepts developed by Jan Gehl in his book.

We however take these 3 concepts and develop them to create themes which can be easily understood and applied in lighting design strategies.

The 3 over-arching concepts thus are:

1. The liveable city – Quality of light
2. The healthy city – Health, Ecology, Pollution.
3. The Sustainable city – Energy efficiency, social sustainability.

With these 3 general concepts we also combine the 3 main objectives of this research project, namely Quality, Ecology and Energy.

The goal of a better public space puts a distinct and strong demand on the human dimension. There are direct connections between satisfying the user demands and social needs and achieving high quality public spaces.

5.4.1 The Liveable City – Quality of Light

The term liveable city encompasses the concept of "life between buildings" as coined by Jan Gehl 1992. This includes all the very different activities people engage in when they use the public space. These varied activities can include walks from place to place, strolling, promenades, short stops, longer stays, window shopping, actual shopping, conversations and meetings, exercise, dancing running, recreation, street trade, playing, begging and street entertainment.

To further simplify the concept of "liveable city" – A liveable city is-

- A city for walking
- A city for staying
- A city for meeting
- A city for self-expression
- Cities for playing
- Cities for eating
- Cities for safety

A liveable city encourages life in public space, particularly the social and cultural opportunities as well as the attractions of a liveable city. The potential of a liveable city is strengthened when more people are invited to walk, talk, bike, stay, meet, play etc. in a space.

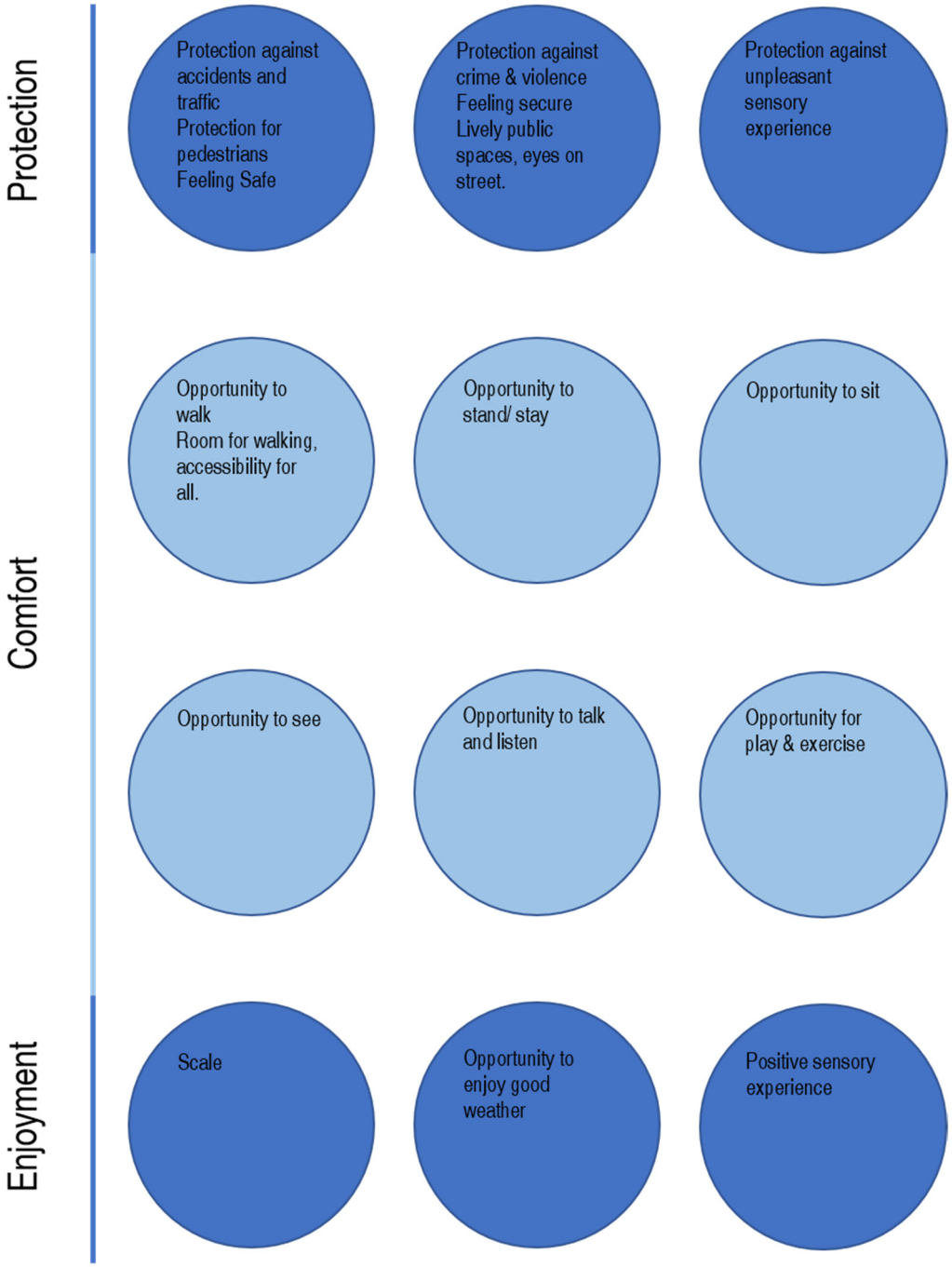


Fig.5.1: The 12 key Quality criteria (source: modified and adapted from Gehl, 2011)

Visual and lighting requirements for Liveable cities

Visual experience and visual comfort are some of the most important aspects of light in public spaces. Many previous researches have concluded that the qualities of artificial lighting in pedestrian areas can have a significant effect on the willingness of people to walk in public areas after sunset [6]. Light levels, uniformity, contrast, distribution, visual size and glare all affect the visual experience and visual comfort.

Visual comfort is most affected by glare, glare can be either Disability glare or discomfort glare. Disability glare is the most critical factor in both pedestrian and motorised movement. Disability glare also adds to the perception of fear at night as the individual is not able to see the complete surrounding views.

Cities for walking

One major step towards developing a liveable, safe, sustainable and healthy city with the ideas of social sustainability along with an open and democratic society is to focus on the human factor, reinforcing the social functions of a space by encouraging a compact city – with development focused around public transport, walking and cycling.

Light plays a crucial role in developing these pedestrian environments. Light is essential for creating a safe, visually comfortable and pleasant pedestrian environment.

Cities for staying

In cities, the stay function is just as important as transport; streets, squares and markets are places to meet and interact. The streetscape is the framework for social activities; it also acts as a stage for performances, everything from the celebration of festivals, national days to a playground for the children.

Light apart from being a potent tool for communication and interaction, it is also a powerful tool in creating certain atmosphere. Light can create specific images and define a sense of place; visual environment is the chief parameter in any given space.

The potential of light to attract our attention and direct our movement makes it an effective tool in creating spaces for staying.

White light has been shown to provide a perception of greater brightness and are perceived as producing more illuminance, as a result lower illuminance levels can be utilised using white light sources as they will be perceived to be as bright as the conventional illuminance levels.

Cities for meeting

The technological revolution has brought about a quantum shift in our lifestyles. We are constantly connected to the entire world through the electronic devices. This has resulted in a shrinking world, where physical distances are no longer significant. Technology has broken the traditional boundaries of time, distance and space.

Dark hours are emerging as the main part of the day, with the concentration of all our activities. People are going out more at night, they are socialising more in public spaces, thus now more than

ever the urban lighting needs to reflect on the relationship between the user and the city. We are restructuring our physiologies, psychologies and values, creating new cultures of public spaces.

Research has shown the importance of facial recognition and colour recognition in increasing the feeling of safety and encouraging more public and social interactions.

Cities for self-expression, play and fun

The creation of a healthy city, healthy not only in terms of health of its citizens but culturally, socially and economically, is dependent on the whether people get the opportunity to express themselves, play, exercise and interact with each other.

The number of festivals, street parties, cultural evenings, sports, exhibitions and performances are a sign of a healthy society. Lighting strategies need to encourage these activities and allow people to play, sing, dance, and perform in public spaces.

In an urban setting the human mind constantly searches for visual cues to have an overall view of the surroundings and create a mental image of the place. The more the space is unfamiliar, the more important it is to have visual orientation to read the space . Light creates focal points, forms perspectives and visual depth assisting the users to locate themselves in the space, and it also positions the user in time, providing an overall sense of historical roots, the present scenarios and the future. Light also allows the user to attach their own meaning to the city and its parts.

Cities for cycling

The creation of a healthy city, healthy not only in terms of health of its citizens but culturally, socially and economically, is dependent on the whether people get the opportunity to express themselves, play, exercise and interact with each other.

The safe city

Feeling of safety is of utmost importance if the people wish to embrace the city space and the importance of this sense of safety in public spaces cannot be overemphasised.

The 2 important fields which influence the sense of safety are safe movement and security.

Cities for safe movement

Safe movement incorporates the safe and smooth flow of all traffic in a city, including vehicular, bicycles and pedestrians. Lighting strategies need to provide for a safe, smooth and efficient movement of the traffic in a city. Special attention needs to be given to pedestrian and cycling traffic which is the most vulnerable from vehicular traffic. Lighting can influence the behaviour of the road or street users. It can clarify land use and create a better interplay between the road/ street and the built area [10]

Traffic Calming: Traffic calming can have the following effects:

1. Reduce the number of traffic accidents and their seriousness
2. Increase safety of pedestrians, cyclists and other slow traffic.
3. Give priority to public transport.
4. Reduce noise and pollution

5. Reduction in the level of conflict between different users.
6. Promote economic development.

Cities and a sense of safety and security

Sense of security simply put is the ability to commute in a city safely without the fear of being robbed, mugged or worse. Light can create a feeling of well-being and positive public space.

Social and cultural infrastructure is essential to foster a sense of identity and belonging. Social interactions enable participants to act together more effectively to pursue shared objective, like lowering crime rate, less filth, better education and better health.

It is thus very important to develop a physical and visual atmosphere that provides the opportunity and the possibilities for healthy social interactions.

Facial recognition is a key element in the feeling of safety at night. People tend to feel safer in cases where they are able to see their surroundings clearly and well in time, they are able to judge a space or situation as safe or unsafe, thereby increasing their feeling of security.

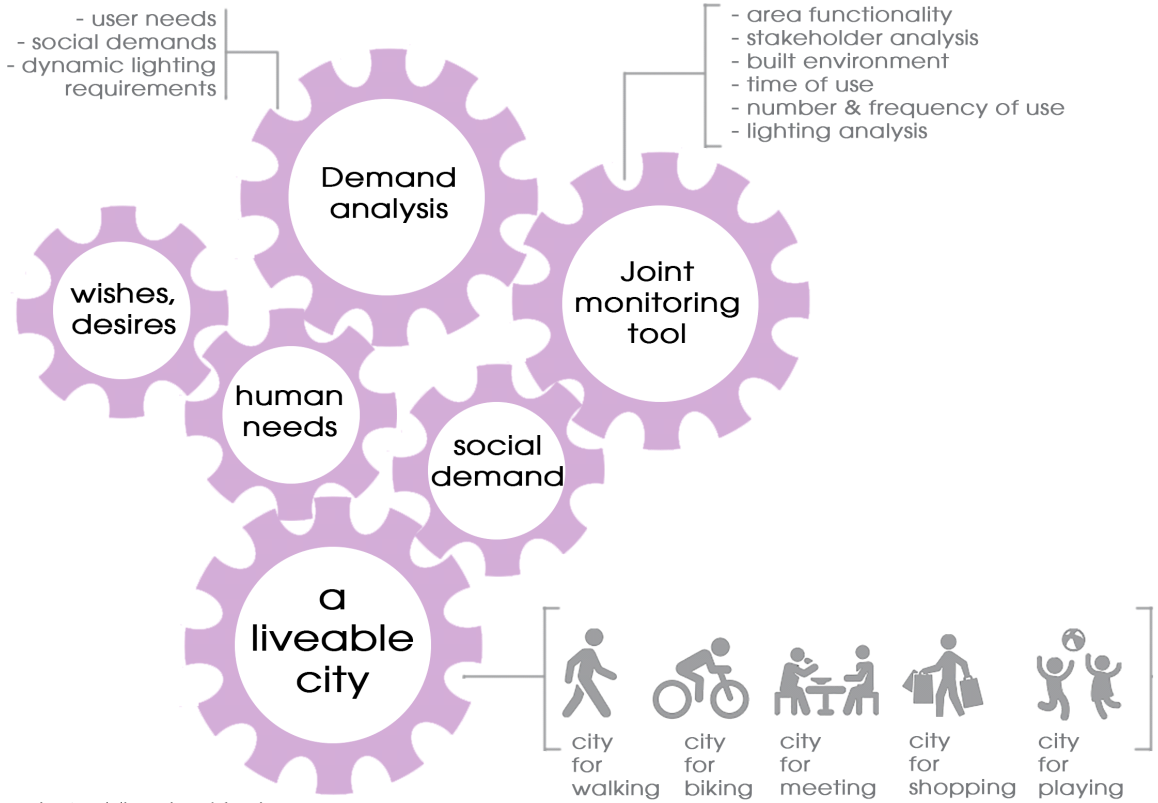


Fig.5.2: The Liveable city

5.4.2 The Healthy City (Ecology, Flora and Fauna)

Health here is not limited to the physical and mental health of humans but envelops health of flora and fauna and health of the environment in general, the underlying principle being the health of the ecology and different eco-systems.

The rapid growth and modernisation has had negative impact not only on the public health but the environment as a whole.

Light pollution and excess lighting is having adverse effect on flora and fauna around the world. Light pollution threatens the entire eco-system, substantially altering the behavioural patterns of the animal population, orientation, foraging, reproduction, migration, communication etc.

The concerns for air, water and land pollution are well known, but light pollution is only now coming into focus. Economic aspects and costs savings have further brought light pollution to the forefront.

Phenomenon like increasing urban sky glow, light trespassing, glare and light clutter are resulting in negative impact on human beings and the environment.

Increasing light at night is also leading to behaviour changes like disorientation, attraction, freezing or freighting in nocturnal organisms. Moreover, evolutionary shifts, imbalance in species are also a side effect of such changes. Furthermore, there have been adverse effects on the nocturnal organisms, for example, birds, fishes, amphibians, insects etc. Quality of night time sky in the meantime has deteriorated to unforeseen levels.

Our contemporary human behaviour and our 24 x 7 lifestyle, days, month and seasonal time cycle are losing their significance. The ever-connected society, late-night shopping, round-the-clock public transportation, shift work and an attractive night-life are liberated us from the day/ night rhythms. As a result, internal clocks, synchronisation between humans and the environment are disturbed.

Light, light rhythms and the cycle of day and night have a significant effect on human beings. Light has a stronger influence on living systems than only transmitting information about the space and the subjects to the eye; its influence is holistic and immediately connected with time and temporal rhythms.

Urban lighting can transform cities at night, it can make it easier for the people to use the city during the night, encouraging not only more use of public and alternative transportation like bicycles, walking etc. but also general social interactions.

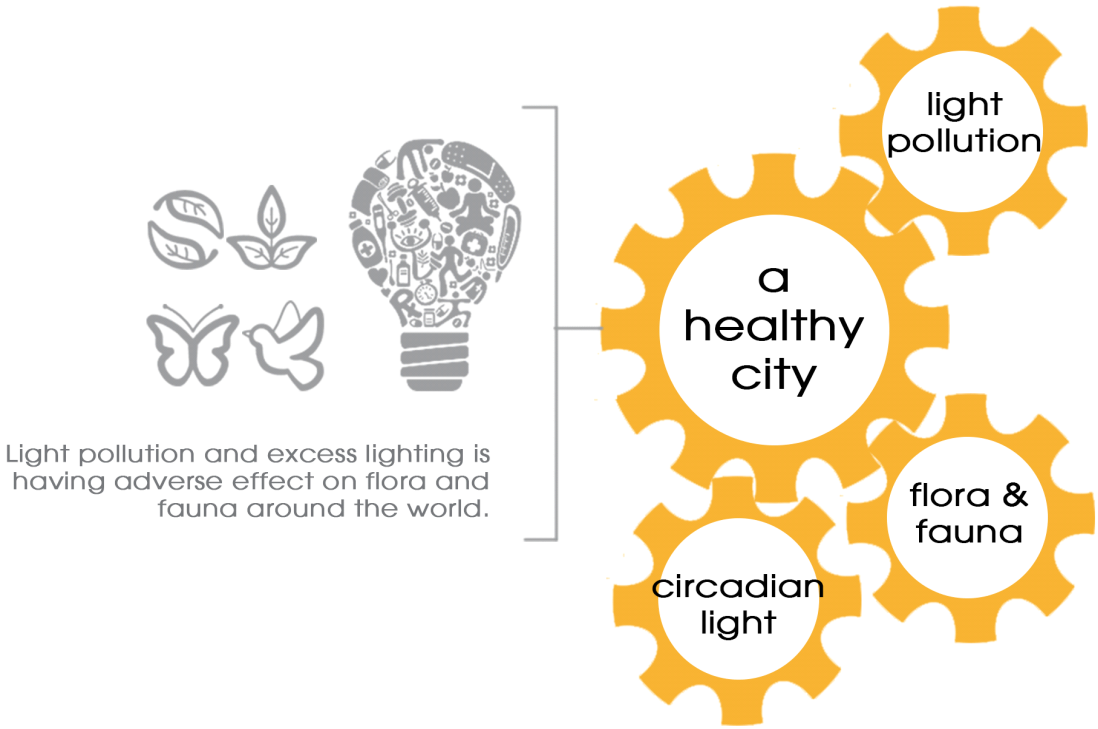


Fig.5.3: The Healthy city

5.4.3 The Sustainable City

Lighting has a vital role to play in building and supporting urban communities that are sustainable – socially, environmentally and economically [5]. Sustainable city results in a marked benefit to the economy and the environment, reduces resource consumption, limits emissions, decreases pollution levels etc. But more importantly a sustainable city also strives towards social sustainability.

The depletion of fossil fuels, escalating pollution, carbon emissions and the resulting threat to the climate are putting increased pressure on developing sustainable urban places. Sustainability is a broad concept encompassing energy consumption, emissions, industrial production, energy supply, resource management and waste management.

Recently the concept of social sustainability has emerged as a critical topic. It focuses on giving various group in the society equal opportunities in the common public space, it emphasises democratic dimensions.

Inclusive Growth: Energy, Economic and Social Sustainability

As cities around the world compete for inward investment from tourism and business, there has been much focus on lighting public spaces, both indoors and out. Much of that investment has gone into illuminating popular tourist areas, heritage buildings and the commercial districts of the city. As a result, urban lighting is unevenly distributed.

While some areas are so brightly lit that the environment suffers from light pollution, many pockets of the city remain underlit at night. This limits local trade and use of public space, undermining economic activity and social cohesion, and leaving local communities literally and metaphorically in the dark.

For economic and social sustainable, lighting design should:

• consider the potential for changes to the lighting conditions and be adaptable to meet different requirements;

• create well lit (but not necessarily bright) spaces to be used by the people who live in the city – rather than spaces designed mainly to be attractive to visitors;

• engage with communities to engender a sense of belonging and civic pride;

• encourage the use of outdoor space at night by local communities;

• challenge lighting codes and guidelines, which can be out-dated and over-specify high levels of light;

• recognise that it is the quality of the lit environment that affects fear of crime, not simply the quantity of lux levels;

• design in shadows as part of the lighting strategy – the intensity and layering of shadow can be just as important in creating a sense of place as the levels of light.

Lighting can be a catalyst for the creation of more accessible, resilient and viable urban areas after dark. By considering the real needs of a community at night, and how light could help strengthen community ties and open fields of possibility to a wider group of residents, public lighting solutions can truly result in "Inclusive Growth".

As advances in lighting continue to focus on reducing costs and saving energy, it is easy to forget the people for whom light is intended. We have come a long way from high voltage, exothermic light sources elevated high above our streets; after more than a century of electric light, recent technological advances have equipped us with technologies capable of genuine human scale and inclusive lighting solutions [5].

Low Carbon Footprint: The sustainable city:

Lighting accounts for nearly 6% of global CO2 greenhouse gas emissions, or 1,900 million tons of CO2 per year that is the equivalent of CO2 emissions from 70% of the world's passenger vehicles. On top of this providing street lighting is one of the most important - and expensive - responsibilities of a city: Lighting can account for 10–38% of the total energy bill in typical cities worldwide (NYCGP 2009).

Furthermore inefficient lighting wastes significant financial resources each year and poor quality lighting creates unsafe conditions that not only result in deterioration of the public space but adds to the financial burden on a city in terms of increased vigilance, policing, surveillance cameras, insurance costs etc. not accounting for the emotional and psychological impacts of crime. All these factors are resulting in the increasing demand of the municipalities for energy efficient lighting solutions but effective lighting strategies.

Unfortunately, in all these discussions of sustainability we tend to concentrate on the reduction in the energy requirements but often forget equally important issues such as quality of light and social sustainability. Lighting strategies can help in achieving environmental, economic and social sustainability.

We have for years implemented urban lighting solutions that have made a lot of compromises in terms of quality of light, colour of light, colour rendition with rigid and inflexible designs, lack of controllability and adaptability etc. all for the sake of efficiency or false efficiency in many cases.

Energy efficiency can also be achieved through changes in life styles, behaviours, attitudes, cultural and social activities such as accepting and adapting to lower light levels, light being available only when it is required and where it is required, dynamic changes in public lighting.

The dynamic lighting solutions make it possible to reduce the energy consumption without reducing the quality of light.

Dynamic and multiple trade offs

The immense range of possibilities offered by the new control systems allows for not one but many trade-offs, in addition these are dynamic trade-offs, implying that trade-offs can be adjusted depending on requirements and needs.

For example there is a need for high colour rendition and warm colour temperatures during certain times of the day, efficiency can be compromised during that time but later when it is not required a lower colour rendition and higher colour temperature could be used to balance the energy consumption. Or in cases where certain areas require higher quality of light at certain times, other areas could have lower quality and quantity of light to again balance the energy requirements.

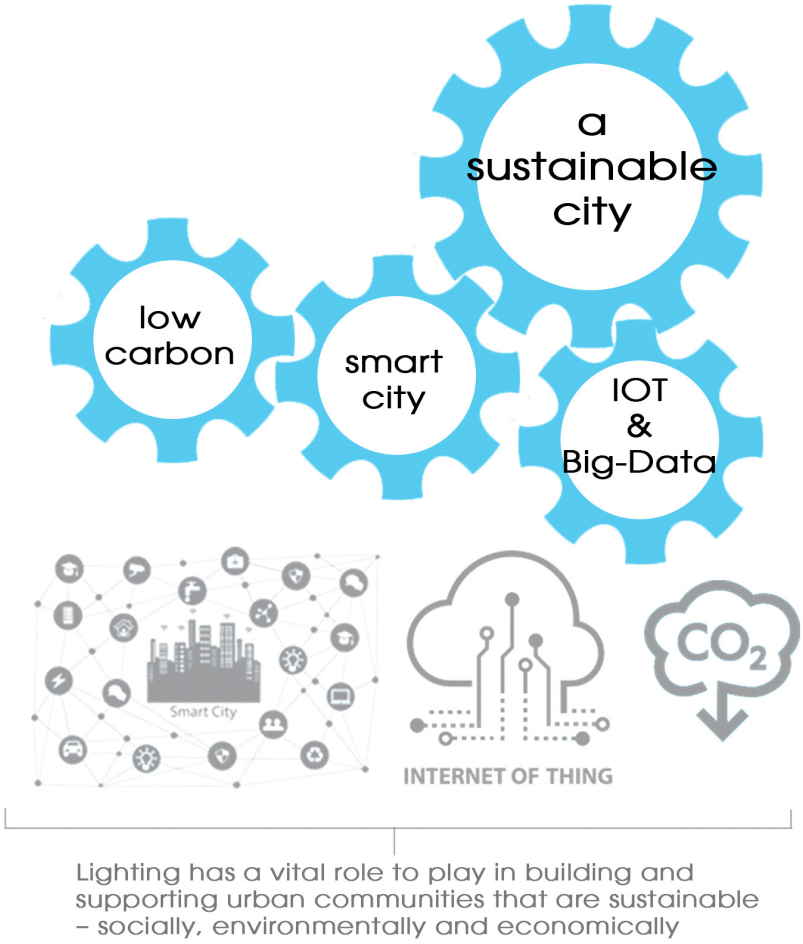


Fig.5.3: The Sustainable city

5.5 Dynamic lighting control and Design possibilities

Dynamic lighting controls make public lighting truly multi-functional, performing different functions at the same time, being able to fulfil different requirements not only in long term but also short term, catering for different users, to name a few. Public lighting for the first time will be able to respond to even hourly changes in uses and not only long term changes. Let us have a look at some of the lighting parameters and how dynamic lighting controls can benefit.

Readability

Light has the capability to create shape, emotional response even on familiar space through the use of compositions and organisation of lighting elements [2].

Reading the surrounding spaces is not only essential in avoiding accidents, but also to get signals from the surroundings as to be how to behave, which routes to choose, where we are, and where we are going.

Through the use of varying light distributions, having light on certain elements and controlling the brightness and direction of light, a visual environment can be created that can help in scanning the surroundings, creating an overall view of the surroundings and provide visual cues.

Readability can involve some features like public buildings, bridges, sculptures, squares etc to act as focal points in order to create a visual map of the space. The interplay of lit and unlit surfaces with varying brightness, colour temperatures, colours and direction can help in creating such readability of the city.

Image of a city

It is the quality of public spaces, the physical and visual environments to evoke a strong sense of representation or remembrance. Light is amongst the best methods of symbolic communication, it works directly with the symbols that make the images of a city and it can very easily alter people's mental image of a place.

Through dynamic lighting controls, light can be very easily modified to suit any environment and situation, this makes it possible for the technology to be simply associated and integrated into a physical environment, visual environment, or any other contexts.

Structuring of a city

Light can be used to define different zones in an urban landscape, structuring the city into private, semi-public or public areas.

Public lighting can be used for the clarification of structure in a city; this clarification can be based on either: a. Functional Hierarchy b. Visual hierarchy.

Functional hierarchy implies structuring space based on: 1. mode of transport 2. Access 3. Stay

Light can be used in identifying and demarcating roads, pavements, and bicycle tracks. Light of certain characteristics can be used in differentiating between various modes of transport. Varying light distributions and directions can be used to highlight important access routes.

Sense of Belonging

Light can be used to develop a physical and visual atmosphere that provides the opportunity and the possibilities for healthy social interactions. LED technology can be used to create a mix of built environment and public spaces with people friendly atmosphere, distinctive features, buffer spaces, sense of safety.

For example, in Koethen a small German town a decision was made to demolish 17 houses in a local street, constituting one-third of the street structure. After previous initiatives had failed to raise awareness, a 30-minute blackout was followed by a spotlight on the 17 houses. This prompted the local population to take action and in the following months the house owners, local community member and local building company discussed ways to minimise the impact of the demolition [9]. This example illustrates that light can stimulate awareness for urban environments and participative processes. [10]

Visual Orientation

For any urban lighting scenario it is as important to know where you are and to be able to see in which direction you need to go. One of the major positive influences of being able to control and modify the vertical and semi cylindrical component lies in the fact that we perceive a surrounding or situation brighter when we have certain vertical illuminance

Dynamic lighting controls offer the possibility to separate vertical and semi cylindrical illuminance from horizontal illuminance. This can help in creating sharp contrasts between surfaces and creating clear distinctions between surfaces and spaces. This can further be developed to define the various zones in an urban landscape distinguishing between intimate, personal, social and public space.

In city centres, nodes and recreational centres, where people are less familiar with the surroundings it becomes necessary to have vertical orientation, providing surfaces, elements that can serve as orientation points. Thus vertical illumination can be used as a specific design tool to identify the different zones and create clear distinctions between them.

Human Scale and Visual experiences

The variability available in the light distribution through dynamic lighting controls, offers the possibility to create spatial and visual experiences that reflect the character of the space.

Article "Close encounters with buildings" [11] talks about dynamics of pedestrian scale façade lighting. According to this article, at 3 feet distance from the building, pedestrians can see less than 10 feet height of the building.

By adjusting the light distribution / directions of light specific sections of the façade can be illuminated instead of the entire façade as per the view available from the street. This will create new interesting visual fields as well as maintaining the sense of orientation.

Colour Temperature

It is possible to vary the colour temperature of the LEDs. This is a very unique and useful tool to alter or change the perception of a particular urban spaces depending on the use, time of day, celebrations etc. For example a busy lively market square can have neutral white light as the evening sets in attracting more customers and shoppers; as the evening progresses the colour temperature can be changed to more warm white for a relaxing and calm atmosphere encouraging dining and other activities and with closing hours a cold white light can be used to indicated the end of business hours.

The use of different colour temperature is also very useful in identifying and organising the various zones in an urban landscape.

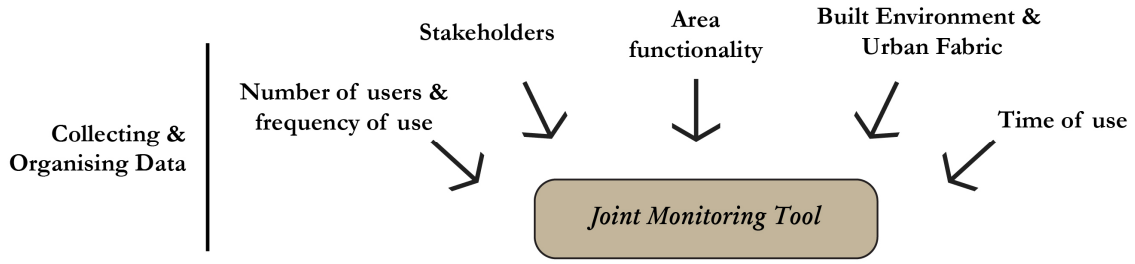
Chapter-6: Tools for assessing User demands, Social needs

As observed in the previous chapters the complex inter-linked relationship between the needs, demands and society can be very difficult to measure, quantify and describe.

To help create a set of requirements that can be easily understood and interpreted by the various stakeholders, we developed a set of tools to help in this process.

6.1 Joint Monitoring tool

The joint monitoring tool is envisaged as an instrument through which the user's demand for dynamic lighting according to their social needs can be established. The monitoring tool consists of the following components. Using these components the important parameters can be established and investigated in detail to develop the dynamic lighting requirements.



6.1.1 Area functionality

An urban space can be used for different activities like walking, staying, meeting, shopping, fun, working and so on. Each of these activities in turn has its own particular lighting requirement and demand. Walking requires good orientation and way finding, while on the other hand shopping and meeting needs good colour rendering, inviting atmosphere amongst other requirements.

Furthermore, different areas in the urban space are used/ suitable for different activities, some areas are mostly for walking while other can be used for meeting and shopping. Developing a zoning plan and understanding the area functionality can help in defining the predominant lighting requirements in that area and can combined with other areas with similar requirements. This will lead to the development of a dynamic lighting plan for the urban area.

6.1.2 Stakeholder analysis

Different stakeholders have different needs and expectations from the public lighting, resulting in different lighting requirements for different stakeholders.

A simple public park can also have a number of extremely varied stakeholders, ranging from the elderly people who use it for walking, children for playing, adults for sport or jogging to the municipal authority keen on energy saving, police and insurance agencies keen on reducing acts of vandalism and damage to health and property.

Every stakeholder in the above example has a specific lighting requirement and more importantly an expectation from lighting. Elderly would require higher illumination levels to see properly, children and

their parents will demand not only uniform lighting but good colour rendering and facial recognition to identify strangers. Similarly, municipality, police and insurance agencies will demand higher light levels and lower contrasts at certain time of the night.

Such varied demands can only be fulfilled by dynamic lighting and a detailed analysis of the stakeholders and their demands can help develop dynamic lighting scenarios tailor-made for each stakeholder and sensitive to their behaviour.

6.1.3 Built Environment/ Urban Fabric, Access and circulation

Light is reflected by the architecture and the built environment. Light makes the urban fabric, open spaces, walkways, squares etc. visible. The need for orientation, for solving the tasks, for having the appropriate atmosphere influences the needs for a good lighting. There is a need to explore the spatial, social, functional and historical context of urban spaces to identify the need for dynamic light.

Light reveals the architecture, spaces and the urban fabric and also influences the use and type of users in a built space.

An urban space will be used by a variety of users for different uses at varying points in time and each user and activity will have its own lighting requirements.

A historical city centre will by frequented by tourists requiring good orientation and way finding, this city centre will also be a shopping area and late in the evening serve as an area for eating and drinking. Hence, a dynamic lighting strategy can be developed after a clear understanding of not only the activities but also where these activities take place and by whom.

6.1.4 Time of Use

The biggest potential for dynamic light is to understand that during the dark hours of a day the function of the space and the stakeholders are very different.

Change is the only constant and it is most visible in any exterior space. The activities, users and frequency of use are all dependent on time. A park will be used early in the morning by joggers, and as evening approaches children and young adults will be the dominant users. As the night progresses depending on the time of the week, adults or students will use it for meeting up and hanging out. On top of this, this particular pattern of use will depend on weather, season, time of the year, holiday season to name a few.

The lighting requirements at every point of time will vary and this is where the potential of dynamic lighting can be fully realised.

A detailed analysis of the activities, users and spaces as a function of time will enable the development of a dynamic lighting strategy that can serve all the users, all the activities and all spaces, at all times.

6.1.5 Number of users and frequency of use

The number of users and frequency of use also changes as per the changing activities, uses and time in an urban space. The number of users along with the time of use can determine the lighting requirements.

All the people do not use all the public spaces all the time, hence a strategy can be developed by observing the number of users along with the frequent of use as a function of time.

A city street will be used for walking by office workers in the evening, perhaps followed by smaller number of shoppers going home and then a large number of young adults to go to bars or clubs. The activity of "walking" is the same but number of users and type of users are changing.

Understanding such number of users and frequency of use will help in creating dynamic lighting solutions that can serve the changing requirements.

6.1.6 Lighting analysis and conditions survey

Last but not the least it is very important to understand the existing lighting conditions so that a comprehensive dynamic lighting strategy can be developed. It is very important in the planning of dynamic lighting to understand the different layers of light sources, from street lighting to ambient light sources like advertisement.

In order to fully understand the impact of dynamic lighting strategies, it is important to understand the lighting situations before the design intervention.

Such analysis also helps in investigating the acceptance of new dynamic lighting and understanding the problems and complaints of the users. Plus, it can be a good basis to compare certain features like energy consumption, carbon foot print etc.

6.2 Demand Analysis

The aim is to develop a comprehensive demand analysis which will identify the dynamic lighting requirements of a particular site.

1. Area Functionality: The acquired understanding of the different activities and uses in a space combined with the zoning and grouping of these activities will help in establishing:

1.a Differentiated lighting requirements for various "activity zones" in an urban space.

1.b Grouping of "activity zones" with similar requirements for dynamic lighting.

1.c Developing dynamic "lighting zones" in accordance to the different "activity zones"

1.d Identifying the dynamic lighting potential/ appropriateness in "activity zones"

1.e Establishing lighting scenarios for the dynamic use of light in the "activity zones"

2. Stakeholder Analysis: The clear understanding of the different users and their varying demands and expectation will help in the following:

2.a Tailor-made lighting requirements for different user groups to suit their specific needs.

2.b Clear understanding of the expectations and demands from lighting according to the different user groups.

2.c Establishing the dynamic lighting requirements in response to the interactions and overlapping of different stakeholder demands and expectation.

2.c Developing dynamic lighting requirements to meet these demands and expectations.

2.d Possible combination of lighting requirements for user groups with similar needs.

2.e Dynamic lighting scenarios which respond to similar stakeholder needs as a function of time.

3. Built Environment/ Urban Fabric, Access and circulation: Lighting situation in the built environment and urban fabric governs where the users perform particular activities. This analysis can be used for the following:

3.a Clear understanding of the changing lighting requirements in a space, to develop dynamic lighting strategies in response.

3.b Dynamic lighting strategies to tackle the varying users and expectations from a space.

3.c Understanding prominent landmarks, features or spaces to develop an appropriate dynamic lighting strategy as a response.

4. Time of use: A distinct knowledge of the time of use or an activity and of which users use a space at what time will help in the following manner:

4.a A distinct awareness of the changing lighting requirements in a space.

4.b Suitable dynamic lighting strategies in response to the changing requirements.

4.c Use of presence/ absence sensors, time switches, CCTV, weather data for dynamic lighting control.

4.d Encouraging or discouraging certain social behaviour through dynamic lighting control. Like encouraging pedestrian/ cycling, traffic calming, social interactions etc.

5. Number of users and frequency of use: The exact number of users at what times and frequency of use can help in the following:

5.a Studying the changing lighting requirements with changing number of users.

5.b Developing a suitable dynamic lighting strategies to tackle these changes in requirements.

5.c Use of presence/ absence sensors, time switches, CCTV for dynamic lighting control.

5.d Encouraging or discouraging certain social behaviour through dynamic lighting control. Like encouraging pedestrian/ cycling, traffic calming, social interactions etc.

6. Lighting analysis and conditions survey: The study of the existing lighting conditions can help in the following:

6.a Comparing the before and after situations.

6.b Studying the impact of dynamic lighting strategies.

6.c Investigating the acceptance of dynamic lighting strategies.

6.d Monitoring the impacts of dynamic lighting strategies.

6.3 User Participation as a Design Tool

When implementing projects within a certain area, such projects should be accepted by the local population. Furthermore, any one project is more likely to be accepted when people's opinions and visions are included before, during and after its implementation. In addition, when co-operating with local inhabitants, projects are better linked to the social environment where they are implemented. The user participation is defined as "the various design related behaviours and activities that the target users or their representatives perform in the systems development process" [3].

The goal of public-centric design process is the early focus on the end-users needs and it is generally agreed that better optimizations and usability is achieved with the participation of the potential users in the different system design stages. Since participants vary on the scope, participation can happen during different stages of the problem solving or system optimization processes - identification of the problem, evaluation of the problem, possible solution generation process, selection of one (best) solution and implementation.

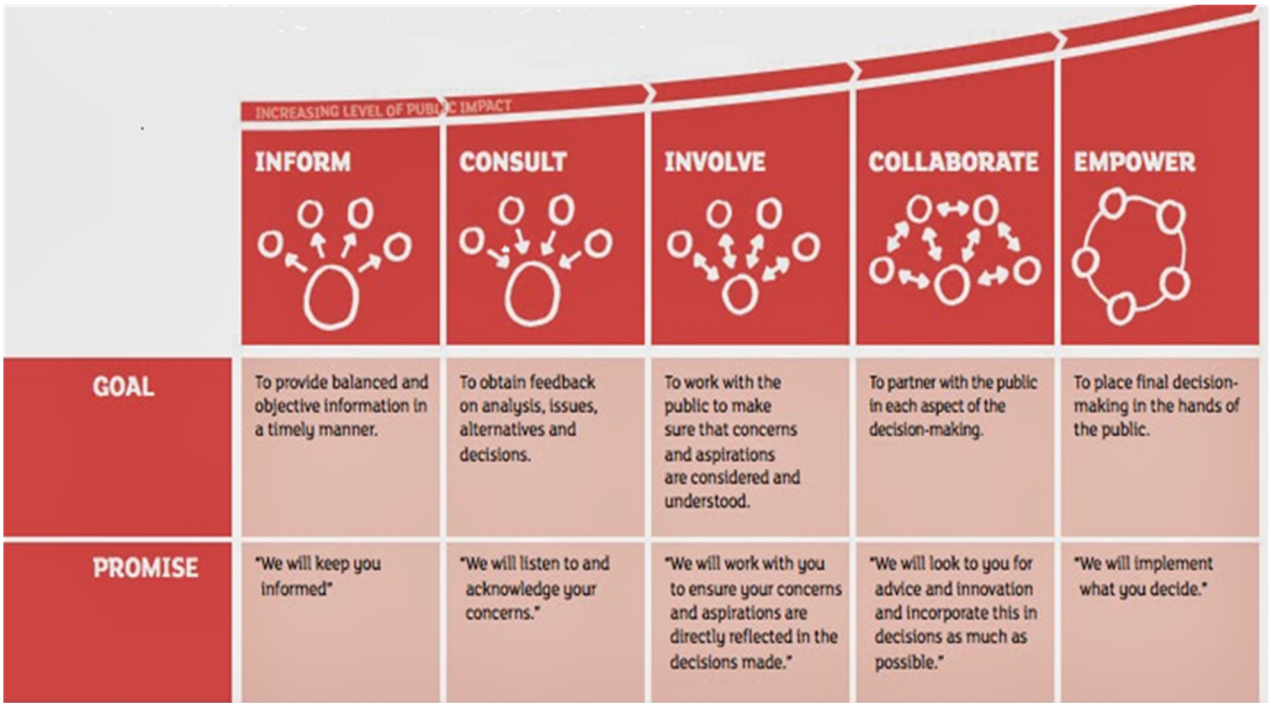


Fig.6.1: Different spectrums of user participations [13]

6.4 Social Research in Public lighting [Source: Urban Lightscapes/Social Nightscapes by the Configuring Light Programme, Project coordinators: Joanne Entwistle, Don Slater, Mona Sloane]

1. Understanding the social is a fundamental and distinctive way of knowing a design site:

Social understanding is of key importance: to find out how diverse users of a space understand and use it, to get at the complexity of the social life of a space engaging with people through conversations, observations, discussions, is to be integrated into spatial analysis, which, alone, can be dramatically misleading.

2. Social research needs to be integral part of lighting design

Collecting the stories of residents on how they use and understand the space is of key importance and should be integral part to lighting design, instead of taking the abstract form of background statistics, surveys or public consultation. Taking stock of what we think we know is not just a way of improving social knowledge or our social evidence base. It should also be central to generating design ideas and probing avenues of design strategy (including generating doubts about particular ideas and avenues). For example, questioning assumptions about who uses this space and how may focus attention on different stakeholders or practices than the original brief, opening up new lines of design thinking.

3. The dialogue between social research and design needs to be creative and responsive

4. Lighting demonstrations are key for good lighting design

People lack a language of light and find it very difficult to talk about and imagine possibilities of lighting. Integrating lighting demonstrations into the social research and lighting design process can generate more sophisticated data and lead to more site-specific designs.

5. Social research in design and consultations are different but complementary processes: Knowing what to ask, in what way and to whom requires a social knowledge base; and this can also help contextualise and interpret what comes up in consultations.

6.5 Tools for assessing social parameters for Dynamic public Lighting

1. Preparation of questions for interview, discussion and observation

Formulating research questions:

Starting from the assumption "what do we need to know"; a clear research question is also a good way of thinking about what questions can and can't be answered;

1. Choosing appropriate methods

Choosing appropriate methods for the specific situation is of key importance: interviews; observation; demonstrations and interactions; mapping/reading/decoding; big data/social analytics; published data/demographics/statistics.

2. Doing and recording fieldwork

Recording is crucial for social research in lighting design. Viable strategies are:

• digitally recording conversations (with permission), and transcribe them, or not, afterwards;

• photography or record walks or observations;

• taking detailed field notes, whether observations are words or sketches.

The main thing is to think in advance about how you are going to record and remember what you encounter, and do so in a way that is sensible and appropriate for your situation (for example, ask yourself 'How much detail do you need? What means of recording might disrupt the situation you are trying to understand?').

3.Risks and ethics

All social researchers have a responsibility to ensure that the physical, social and psychological well-being of research participants is not adversely affected by the research. As far as possible participation in sociological research should be based on the freely given informed consent of those studied.

4. Analysing material

A. Step-by-step: guide to doing social research in lighting design

PREPARATION: DESIGNING RESEARCH

• Agree a research question

• Choosing research methods

FIELDWORK

ANALYSING YOUR MATERIALS

• Explore your material – together – by looking for themes and devising codes or labels

• Reflection

B. Articulating lighting

The task for social research in lighting design is to help people reflect on more aspects of lighting. it is usually not easy to get people to talk about lighting directly. As mentioned above, light tends to be in the background, taken for granted. Light is 'infrastructural' in the sense that it is the enabler of activities and thus tends to be "invisible".

In fact, much social research for lighting design is not directly about light and lighting at all, but about things like pathways, atmosphere and anticipated uses of spaces.

It is possible to intervene on different "parameters" of light: the different features that designers can change, and which people notice and can discuss, are:

• Luminosity/brightness

• Contrast, relative brightness and distribution

• Luminaires, mountings and other fixtures

• Lighting heights, positions, lighting directionality, and vertical versus horizontal planes

• Shadows, spillage and casual lighting such car traffic and lights in windows

• Colour temperature, colour rendering, etc.

6.6 Lighting Masterplans involving user contribution

A recent example of positive and successful implementation of a lighting masterplan along with a redevelopment scheme has been the Liverpool One Development. The project aimed at integrating urban renewal and public realm design, with a focus on community participation and crime prevention. The lighting masterplan had been closely developed and coordinated with the overall urban master plan. The master plan provided a link between the city centre and the waterfront, allowing for a mix of cultures and uses to interact and celebrate Liverpool's past connection with water.

The lighting master plan aimed "to encourage human reaction and movement, encouraging the flow of pedestrian traffic towards areas of special interests" Varying colour temperatures have been used to differentiate and locate users, visual cues are provided by highlighting key architectural elements.

The overall success of Liverpool One as a safe combination of lighting and development was primarily achieved through involving users in the design process from the beginning. Some of the main features that have led to the success of the development include:

a. Involvement of the local police department, to determine crime patterns and vulnerable areas

b. The involvement of the local council, to ensure that designs can be sustained and maintained

c. The involvement of local people and their opinions and concerns about the designs

d. The inclusion of specific cultural and historical elements related to the locations involved.

Ensuring that the lighting masterplan was integrated into the overall masterplan from the early stages has helped in the overall effectiveness of the scheme [7].

Chapter 7 – Lighting Toolbox for Dynamic lighting

Lighting design has long been defined by strict codes and light level recommendations, our view is that lighting in the public realm is too diverse and complex to be successfully categorised empirically.

A row of flickering gas lights under a moonless midnight sky in a Park can seem as bright to the adaptable human eye as a garish LED screen in an over-lit shopping street; apparent quality and quantity of light entirely depends on the context [5].

7.1 Adaptive Lighting Standards

Standards are slowly being introduced and developed for adaptive/ dynamic lighting. In the standards however, the standards refer to adaptive lighting and not as dynamic lighting. Here is a brief overview of the various standards.

7.1.1 CIE Standard

In CIE 115:2010 recommendations are provided for adaptive public lighting. The goal of these recommendations is to rationalise the use of public lighting and reduce energy consumption. The main idea behind the standard is to reduce the luminaire output in off-peak traffic hour in a pre-determined pattern.

Parameter	Options	Weighting Value V_w	Selected V_w				
			Δt_1	Δt_2	Δt_3	Δt_4	Δt_5
Speed	Low	1					
	Walking speed	0					
Traffic volume	Very high	1					
	High	0.5					
	Moderate	0					
	Low	-0.5					
	Very low	-1					
Traffic composition	Pedestrians, cyclists &motorised traffic	2					
	Pedestrian & motorised traffic	1					
	Pedestrian & cyclists only	1					
	Pedestrians only	0					
	Cyclists	0					
Parked vehicles	Present	0.5					
	Not present	0					
Ambient luminance	High	1					
	Moderate	0					
	Low	-1					
Facial recognition	necessary	Additional requirements					
	Not necessary	No additional requirements					

Fig.7.1: Adaptive lighting weightage calculation process from the CIE 115: 2010 [1]

Adaptive strategies are determined based on traffic volume and composition, time interval, parking vehicles (obstacles) and environmental conditions, such as ambient luminance for facial recognition. The adaptation is done by reducing the average illuminance or luminance levels of the lighting class in such a way that the other quality criteria remain unaffected. Table 1 describes how to calculate the correct weighting for each time interval.

Using the table the adequate "p" lighting class for a specific time interval Δt can be determined. The process is based on street parameters, traffic volume and composition, parking vehicles (obstacles), ambient luminance and facial recognition. For example, Δt_4 is adequate for lighting class P3, this information can then be combined with information from "P class condition" (table 2) to calculate within which interval the illuminance levels should be adapted.

Lighting class	Avg horizontal illuminance $E_{h.av}$	Min. horizontal illuminance $E_{h.min}$	Additional requirement if facial recognition is necessary	
			Min vertical illuminance $E_{v,min}$	Min semi-cylindrical illuminance $E_{sc,min}$
P1	15	3.0	5.0	3.0
P2	10	2.0	3.0	2.0
P3	7.5	1.5	2.5	1.5
P4	5.0	1.0	1.5	1.0
P5	3.0	0.6	1.0	0.6
P6	2.0	0.4	0.6	0.4

Fig.7.2: Lighting parameters adapted from CIE 115: 2010 [1]

The table above shows the average/ minimum horizontal, vertical and semi-cylindrical illuminance for lighting class P- pedestrian and low-speed traffic areas – normal conditions (no adaptive lighting)

To ensure uniformity, the actual value of the maintained average illuminance should not exceed 1.5 times the value indicated for the class. Furthermore, a higher colour rendering contributes to a better facial recognition.

In practice this implies that the reduction of the recommended average illuminance of a specific lighting class should be proportional and equally distributed for all the involved luminaires. For example, switching off every other luminaire would produce contrast level above 1.5 times, which is higher than the recommended levels (CIE 2010). The uniformity of light levels is important because of vision adaptation in relation to contrast ratio.

7.1.2 IES (IESNA) Standard

IES (formerly IESNA) brought out the updated RP-08-05 including adaptive lighting. This update varies from the CIE 115:2010 recommendations on the process of how it determines the adapted levels, but is similar in objectives like illuminance levels and adaptation premise. It also establishes that it is only possible to modify recommended average luminance (illuminance in the case of CIE 115:2010).

IES use pedestrian conflict situations as the basis for adaptive lighting. Three levels of conflict: high, medium and low are defined along with the respective average luminance. The conflict level is also time dependent allowing for a transition from high to low conflict and vice versa. Table below indicates the adaptive criteria and the recommended levels of luminance for the normal and adaptive state for different type of street and conflict classification.

Selected Street Classification	Selected Pedestrian Classification	Average Luminance (cd/m^2)	Adapted Luminance (cd/m^2) 50% Reduction
Major	High	1.2	0.6
	Medium	0.9	0.45
	Low	0.6	0.3
Collector	High	0.8	0.4
	Medium	0.6	0.3
	Low	0.4	0.2
Minor	High	0.6	0.3
	Medium	0.5	0.25
	Low	0.3	0.15

Fig.7.3: Recommended average and adapted luminance as per IES RP-08-05 [2]

7.1.3 San Jose, California: Public Streetlight Design Guide

As part of the "Green Vision" adapted in 2008, the city of San Jose developed a custom made adaptive lighting strategy based on both CIE 115:2010 and IES RP-08-05.

The highlight of this strategy is the use of "speed of dimming" as an important criterion along with the usual illuminance levels and uniformity control.

There is no recommended process, calculation method or reference values for the speed of dimming transition, there is an agreement on slow dimming speeds. These are generally based on their experience and argue that although a 50% difference in lighting is not easily perceived, a sudden change in the light levels on the other hand is easily perceivable.

In a test conducted by Virginia Tech Transportation Insititute, Continuum Industries and Clanton & Associates showed that a dimming of 50%, the difference in visibility was hardly noticeable. Only below 50% and in particularly around 25% significant differences were being perceived [3].

Figure 7.4 shows the relationship between perceived luminance and measured illuminance. The relationship is non-linear implying that perceived luminance is different from the measured illuminance [4]. This allows for having a dimming strategy based on the natural adaptation of the visual system.

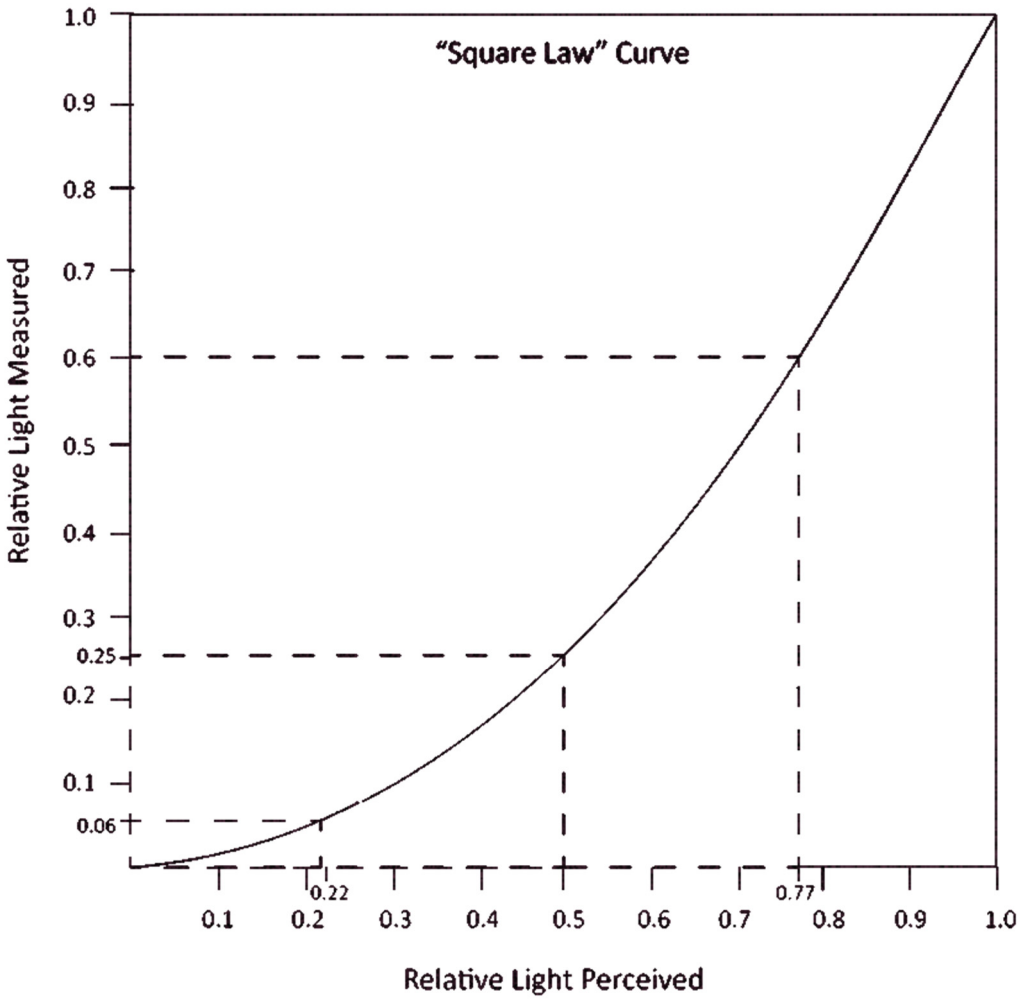


Fig.7.4: Non-linear relation between perceived luminance and measured illuminance. [4]

Chapter 8 – Changing City: Future Developments

8.1 Evolving urban spaces

As our built environment and architecture becomes increasingly ephemeral, the same is being experienced in the public spaces. Urban spaces are increasingly experienced as a relative rather than an absolute value.

Further there is a trend towards the shrinking sense of Public spaces. The city is evolving into increasingly private clusters of loosely connected "islands" or zones. A recent survey revealed that people in the age group of 18-35 years are purchasing goods within a 5 minute walking radius from either the place they live or work. This implies people are spending more and more time in a relatively small area of the city and also there no time bound journey as large distances are not covered.

Added to these changes shopping blocks, entertainment centres, business parks are also changing the scale of the city. Such developments are also usually focused inwards, instead of communicating with the public street, activities pouring out onto the open spaces, merchandise and messages to interact with the public space- the trend is more to focus onward towards a privately controlled space hidden from the public city.

These developments are giving rise to the need for flexible and adaptive systems of lighting. Lighting systems that need to respond to the new and unique demands created by such urban changes. Need for light is becoming more individualistic, not bound by time or space.

Such changes in the need for lighting, will eventually lead to re-thinking in the approach of public lighting. Public lighting need not be bound by a specific time or to a specific place. Good quality light cannot be restricted anymore to important city centres.

8.2 Evolving urban Lifestyles

The technological revolution has brought about a quantum shift in our lifestyles. We are constantly connected to the entire world through the electronic devices. This has resulted in a shrinking world, where physical distances are no longer significant. Technology has broken the traditional boundaries of time, distance and space.

We are having flexible working times, choosing the time to work or even working all the time, technology has made it possible to work from anywhere and everywhere.

There are no time bound journeys, for example, people no longer need to travel at a specific time in the day to reach their place of work or home. The journeys today are no longer purely for functional purposes alone, there are no specific destinations, time schedules or routes.

The very purpose for public lighting is being transformed because of these changes, the need for functional lighting to get from point A to point B, will be replaced by the need to have right quality of light for social interaction, entertainment, exchange and also awareness.

Technology today has created a networked society, where, as mentioned before function of time is losing its importance. Thus there will be greater need to reinforce the notion of time of day, weeks, months and seasons. There will be a greater need to have time and seasonal orientation.

Dark hours are emerging as the main part of the day, with the concentration of all our activities. People are going out more at night, they are socialising more in public spaces, thus now more than ever the urban lighting needs to reflect on the relationship between the user and the city. We are restructuring our physiologies, psychologies and values, creating new cultures of public spaces. Lighting needs to be based on multi-dimensional approach involving people's aspirations, demands, fears and interactions in the public spaces.

8.3 Social Media

"The democratization of tools such as smartphones and tablets, and the digital media streams they produce, has accelerated the production of an "augmented urbanity". It has been over a decade since scholars and architects have really started to leverage digital technology and social media in their urban research, but this is still a developing field. Lev Manovitch, through his Big Data Lab, hails the promising insights that the analysis of these massive, ready-made data streams can provide when approaching human behaviour and urban systems. Today, there exists a fuzzy, dense and interactive virtual space running parallel to physical cities that harbours perhaps infinite insight potential for researchers." [5]

Social media platforms like Instagram, Facebook, Snapchat etc. are providing innovative methods for designers and urban planners to better understand a city, its functions and the user's behaviour.

Many social media platforms allow posting and uploading of status, location and most importantly photographs. Such information which is freely and openly available on the internet can be used as a powerful tool for urban design analysis, tourist and public movement, time and duration of stay, complaints and problems to name a few.

8.4 Internet of Things and Big Data

The concept of IoT is simple, everyday objects will have network connectivity, allowing them to send and receive data across a network, whether that's wired or wireless.

Sensors can detect motion, direction, footfall, ambient light levels, temperature, light output, colour temperature, quality and operating temperatures. On-board processors can locally analyse the data they receive or upload it to the central management system. The cloud platform is the brain of the networks (ecosystem). The cloud platform can be designed to manage the high-velocity/high-volume transaction data from the on-premise environment and provide an extensible platform to develop applications and data visualizations. Some of the possibilities are:

- Energy management
- Lighting analytics
- Enterprise control
- Predictive maintenance

8.5 Self learning and correcting systems

Through Dynamic lighting controls, an intelligent self-learning system can be envisaged, that can learn by itself and implement changes and modifications as required.

The vast array of sensors, control systems and data processing applications offer the singular opportunity to study and learn from various parameters, variables and conditions. Such solutions can analyse the various parameters and variables affecting public lighting in a situation and through possibilities offered by Big-Data and data processing can easily learn and predict the lighting requirements in the future.

The various new technologies that we have surrounded ourselves with also offers the possibility to predict trends, possibilities and define various permutations and combinations of our needs, demands, aspirations and behavioural patterns. Every phone is in a way a GPRS device, pin pointing ones location, and when combined with sensors and cameras, a system can be easily developed that anticipates our requirements.

There will not be one constant system to follow for 10 years but a system that can be tested, changed and modified according to the changing needs, requirements or scenarios.

8.6 SMART Indicators for a "Smart City"

The traditional SMART indicators are defined as:

- specific,
- measurable,
- achievable,
- relevant and
- time-bounded

The SMART indicators are a tool that allows each set of stakeholders to measure progress in their own sector as well as indicators that function as checks and balances on the progress of other sectors. These set of indicators can easily be adapted to public lighting, allowing for the assessment of the broad and inclusive vision of a desired future for a place, but also to include the detailed measures of success that indicate positive progress towards that vision.

The indicators include such things as walkability, employment levels and average economic output; targets set in legislation (such as carbon reduction and air quality targets); guiding principles/factors of success (such as well designed, well connected and sustainable); and characteristics of indicators (such as pragmatic, few in number, easy to measure and flexible, and with a commitment to continued measurement and reporting).

The following list of SMART indicators can be further developed for Public lighting:

Social indicators

- number of users and quality of movement – walking, running, cycling
- happiness
- the number of families taking their children to nursery schools (as a measure of integration into society)
- the lollipop indicator (measures if parents are willing to send their children to buy a lollipop, incorporating issues of community cohesion, feelings of safety and walkability)

- levels of unrest
- how successful people think the city is as a place
- how connected people feel to the city

Environmental indicators (including the city's physical environment)

- the quality of the physical environment
- light pollution reduction
- carbon footprint reduction

Economic indicators

- energy saving
- real estate prices/rent
- the number of city-projects/pilot projects that receive funding

Synergistic Benefits

Synergy is the combined power of a group of things when they are working together which is greater than the total power achieved by each working separately. The goal of having a zero carbon city can only be achieved when the different infrastructural, social and public services work in complete harmony and coordination.

When this concept is applied to services like traffic regulation, with the use of frequency and intensity sensors, street and public lighting can be dimmed to minimum levels during periods of decreased or low traffic movements, saving on energy demands. Similarly, in cases of medical or police emergencies, lighting levels, colour rendering qualities could be increased to assist quick action and response.

Essential social services like important announcements and information can be transmitted through the public lighting system. CCTV cameras and emergency services can be easily integrated and the public lighting can be programmed to respond to such situations.

Public lighting can form an important link between the various other services and infrastructural activities in a city.

Chapter 9 – Dynamic lighting toolbox for Public lighting

This section proposes an initial a set of tools for dynamic lighting that can be used to bring about a positive impact on public lighting. These are the first steps towards creating a larger design tools and strategies for dynamic lighting and are aimed at achieving the 3 principles described in the beginning of this manual – Quality, Ecology and Environment.

9.1 Preliminary Toolbox

The manual outlines various urban design theories, public spaces definition, user needs and demands. There are also different tools proposed to define the user needs and develop dynamic lighting requirements. This toolbox will aim to synthesis all this information and aim to provide a set of tools for designers to be able to develop dynamic lighting strategies. This toolbox will be further developed in the later deliverables.

Taking the "typological" approach, the public space can be defined into certain typological definitions – landscape, squares and plaza, built spaces, architecture, circulation etc. Each typology can further be associated with certain basic lighting parameters that can influence the particular typology.

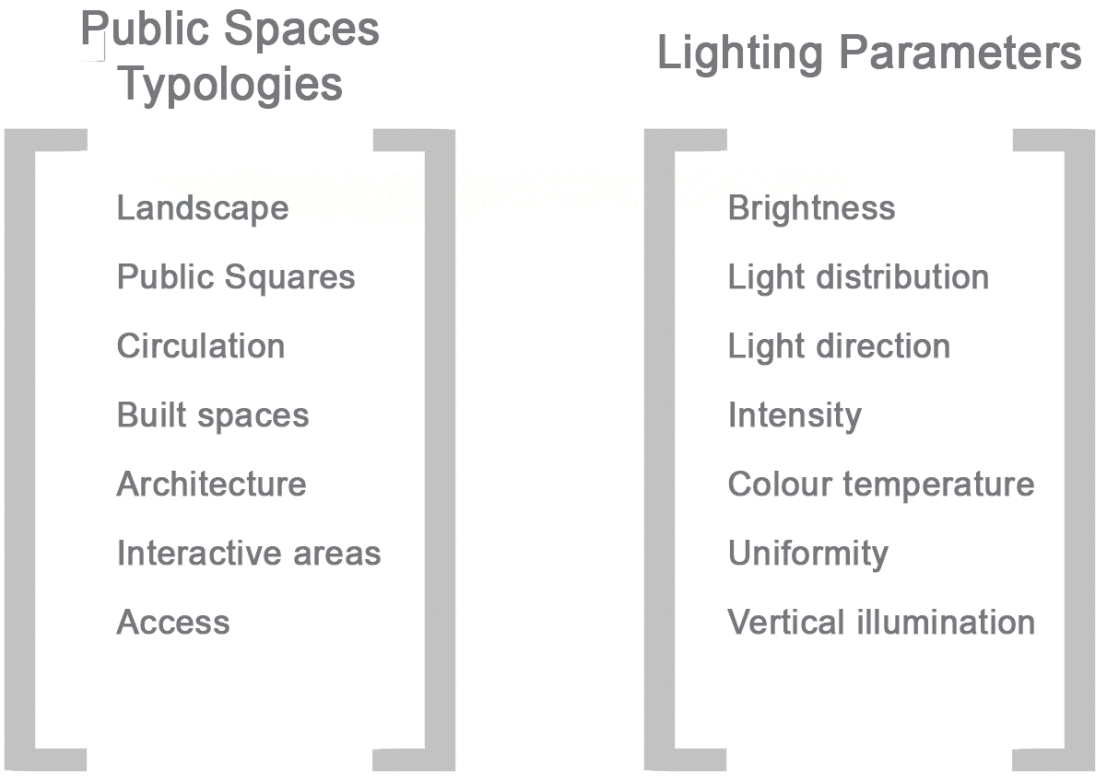


Fig.9.1: Preliminary Toolbox: Public space typologies and lighting parameters

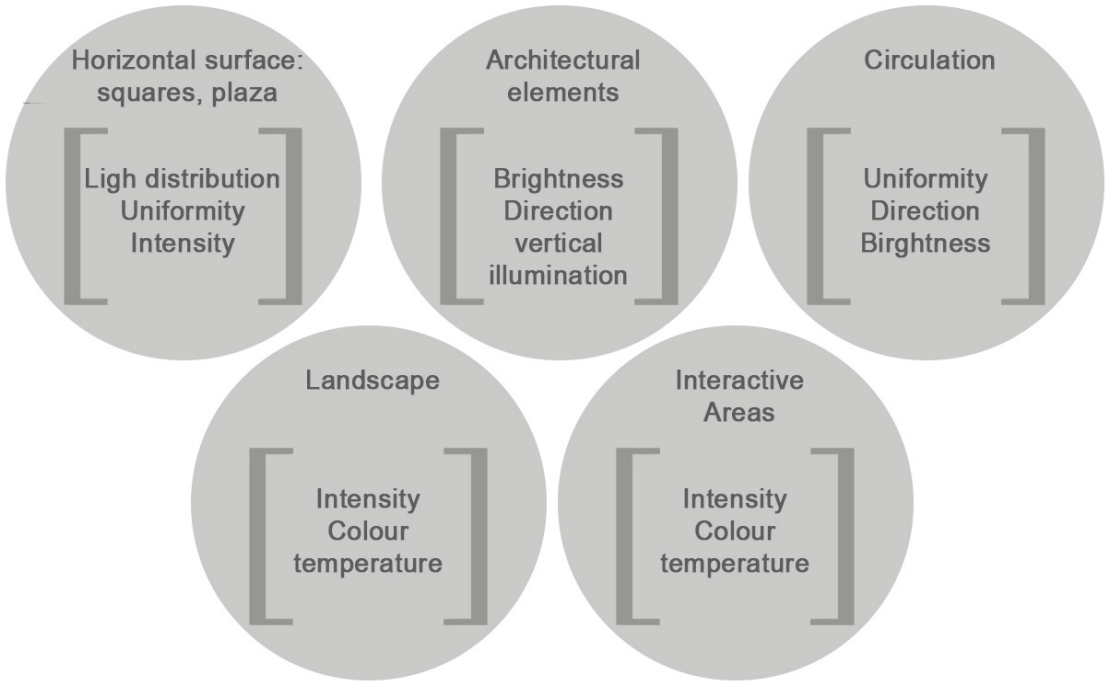


Fig.9.2: Preliminary Toolbox: Use of lighting design parameters to influence the Public space typologies.

Example: Horizontal surfaces: Squares and Plazas

The horizontal surface plays an important role in the definition of a square and a plaza; this is due to the fact that it usually occupies the largest surface area. Together with the architectural elements it creates the central field of view.

Brightness: The level of brightness and contrast can ensure safe circulation, pools of light can signal a cosy comfortable space, and different intensity of light can create hierarchy. Light distribution can be adjusted to select what is illuminated, which areas receive reflected light. Similarly, colour temperature can be used to signal time of night, season or weather or even the end of shopping time.

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