Jadavpur University

Smart Street Lighting

by

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A thesis submitted in partial fulfillment for the degree of Master of Technology

in the

Partha Sarathi Satvaya — Palash Kundu

School of Illumination Science, Engineering & Design

July 2020

Declaration of Authorship

I, Subhajit Sarkar, declare that this thesis titled, 'Smart Street Lighting' and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University.
- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- I have acknowledged all main sources of help.
- Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

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Timing and Will;
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Jadavpur University

Abstract

Partha Sarathi Satvaya — Palash Kundu
School of Illumination Science, Engineering & Design

Master of Technology

by Subhajit Sarkar

The Thesis Abstract is written here (and usually kept to just this page). The page is kept centered vertically so can expand into the blank space above the title too. . .

Acknowledgements

A lot of inputs from various sources have gone into the making of this report and the analysis that has been carried out. I take this opportunity to express my deep sense of gratitude and indebtedness to my university guide Parthasarathi Satvaya of School of Illumination Science, Technology and Design, Jadavpur University, for being thoughtful and understanding institutional guide for project and her constant guidance and supervision.

I am also highly indebted to Dr. Kamalika Ghosh, Director, School of Illumination Science, Engineering & Design, Jadavpur University, for her guidance and enormous support to fulfil this project work. Besides I am very thankful to her for providing me her precious time, invaluable suggestions and above all - huge support.

I would like to acknowledge my sincere thanks to Prof. (Dr.) Saswati Mazumdar, Prof. (Dr.) Biswanath Roy, Asst. Prof. Mr. Suddhasatwa Chakraborty from Department of Electrical Engineering, Jadavpur University for providing me the valuable suggestion and encouragement in carrying out this project work.

I am very much thankful to Pradip Pal and and Mrs. Champa Mukherjee of School of Illumination Science, Engineering and Design, Jadavpur University, for their indispensable co-operation during my project work especially in measurement and instrument handling.

Last but not the least, my special thanks to all my friends who help me directly in completing my thesis successfully. . . .

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Abbreviations

kWh	Kilowatt-hour
Lm	Lumen output
Lm/W	Lumen per watt

Physical Constants

Speed of Light $c = 2.997\ 924\ 58 \times 10^{8}\ \mathrm{ms}^{-\mathrm{S}}$ (exact)

Symbols

a	distance	m
P	power	W (Js^{-1})
ω	angular frequency	$rads^{-1}$

For/Dedicated to/To my Parents...

Chapter 1

Introduction

The thought of outlining a new framework for the street lights that don't devour immense measure of power and light up a vast zone with high intensity. Smart Street lights framework is an essential piece of the smart city which represents 10-40% of aggregate power utilizations which is a discriminating attentiveness toward general society powers. So vital and productive vitality advancements are to be executed for monetary and social security.

1.1 Background of Study

The present framework is similar to, the road lights will be exchanged on in the night prior to the sun sets and they are exchanged off the following day morning after there are adequate lights on the streets. The hindrance of the framework is that we require manual operation of the road light which needs labor.In sunny and rainy days, ON and OFF time differ discernibly which is one of the significant hindrances of the present street lights systems.Conventional street lighting systems are online most of the day without purpose. The consequence is that a large amount of power is wasted meaninglessly.

1.2 Implications & solutions

To confront the different issues referenced above in the conventional lighting framework we require a lighting framework that is well furnished with ongoing innovations in Lighting. As it is known to everybody that conventional sources to produce power is limited, and we are exhausting it at a fast pace.

1.2.0.1 Demerits of Classical Street Light

- Street lights stay on when there is natural light.
- These road lights need a manual intervention for switching.
- It additionally needs labor to control.
- These road lights are lighted at its full intensity without any activity on the road.
- Higher power utilization and waste of power.
- Less dependable.
- Manual activity required due to changes in season.

So in the event that we can utilize smart systems in this specific case with the goal that all the road lights can be switched on and off accordingly when it is required. Furthermore, in the event that we can utilize controller circuits to execute a model so all the road lights can possibly be lit with its full intensity when there is action in its area else it should be lit at a given intensity. With the goal that we can save a large quantity of energy.

With the developments of light emitting diodes which have much lower energy consumption along with high efficacy; we should utilize light emitting diodes rather than all conventional light sources. With the assistance of all these sensors accessible in the market; we ought to have full control over the road lights for the well-being and security of lives in the avenues, alongside an adaptable transportation framework.

With the wide accessibility of adaptable lighting innovation like light transmitting diode (LED) lights and all over accessible remote web association, quick responding, dependable working, and power moderating street lighting frameworks get to be reality. The reason for this work is to portray the Smart Street Lighting framework, a first way to deal with performing the interest for adaptable smart lighting frameworks. The goal of this undertaking is to plan an automated lighting framework which focuses on the saving of power; to construct a vitally energy efficient smart lighting framework with integrated sensors and controllers; to outline a smart lighting framework with particular methodology plan, which makes the framework adaptability and expandability and configuration a smart lighting framework which similarity and versatility with other commercial products and mechanized automated system, which may incorporate more than lighting frameworks.

1.2.1 conclusion

Street lights are doing more than ever in today's smart cities. With digital networks and embedded sensors, they collect and transmit information that help cities monitor and respond to any circumstance, from traffic and air quality to crowds and noise. They can detect traffic congestion and track available parking spaces. Those very same networks can remotely control LED lights to turn on and off, flash, dim and more, offering cities a chance to maximize low-energy lighting benefits while also improving pedestrian and bicyclist safety. With street lights creating a network canopy, those networks of data can be used by more than just lighting departments, empowering even schools and businesses via a lighting infrastructure that brightens the future of the digital city.

Smart lighting helps cities save energy, lower costs, reduce maintenance—all while better serving citizens and reducing energy use and CO2 emissions. Automation and networked control can further increase your energy savings and reduce maintenance spending. Networked street lighting built on a scalable platform can reduce crime up to 10% and make roadways safer through improved visibility. Leveraging intelligent control systems can rapidly increase lighting efficiencies and traffic management.

Chapter 2

Public Street and Road Lighting

Street lighting design is the design of street lighting such that people can safely continue their travels on the road. Street lighting schemes never brings the same appearance of daylight, but provide sufficient light for people to see important objects required for traversing the road. Street lighting plays an important role in:

- Reducing the risk of night-time accidents
- Assisting in the protection of buildings/property (discouraging vandalism)
- Discouraging crime
- Creating a secure environment for habitation

2.1 Basic Features of Street Light Luminaires

The basic features of a street lighting luminaires are:

- Roadway luminaires are mounted horizontally and thus have fixed vertical aiming.
- Roadway lighting luminaires have particular intensity distributions which are desired to light long narrow horizontal stripes on one side of the luminaire, while minimizing the intensities on the other side of the luminaire.

- The intensity distributions up and down the narrow strip are generally the same.
- Any fixed aimed luminaire which does not have this type of intensity distribution is called an area luminaire.

2.2 Main Objectives of Street Lighting Design Scheme

The main objectives of street lighting design scheme are given below:

1. Perfect visual sensation for safety
2. Illuminated environment for quick movement of the vehicles
3. Clear view of objects for comfortable movement of the road users.

2.3 Main Factors in the Street Lighting Design Scheme

Main Factors affecting the Street Lighting Design Scheme are:

- Luminance Level Should be Proper:Luminance always influences the contrast sensitivity of the obstructions with respect to the background. If the street is brighter, then darker surroundings makes the car driver adapted,unless the driver will be unable to perceive the objects in the surroundings. As per CIE,5m away from the road on both sides will be lit by Illuminance level at least 50% of that on the road.
- Luminance Uniformity must be Achieved To provide visual comfort to the viewer's eyes, enough luminous uniformity is needed. Luminous uniformity means the ratio between minimum luminance level to average luminance level, i.e. It is termed as longitudinal uniformity ratio as it is measured along the line passing through the viewers position in the middle of the traffic facing the traffic flow.

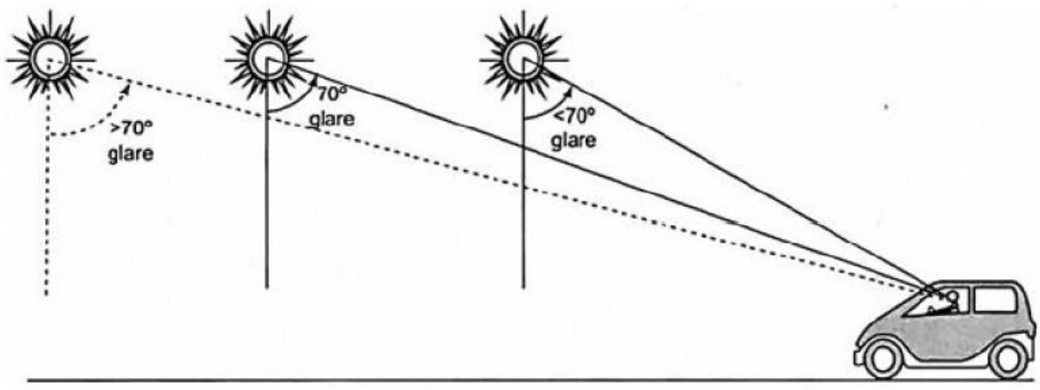

FIGURE 2.1: Glare from diffrent angles

- Degree of Glare Limitation is always taken into design Scheme Glare means visual discomfort due to high luminance [Figure 2.1]. There are two types of glare created by the street light luminaires,
  - Disability glare
  - Discomfort glare

  Disability glare with regard to highway/street lighting, glare may be distinguished as that which produces disability and that which causes discomfort.Glare causes a significant reduction in the observer's capacity to see or discern a potential hazard, which is important for safe night driving. Discomfort glare , on the other hand, is that which causes distraction, annoyance, and fatigue in the extreme.
  Discomfort glare is a common factor due to unplanned street lighting scheme.One way to avoid glare is to increase the height of the luminaire mountings; another way is to locate the luminaires in such a manner that they are not in the driver's normal line of the sight.It is generally observed that light emitted at angles less than 70° from the downward vertical cannot fall on the driver's eye,because the roof of the vehicle acts a shield and thus avoids glare. Figure 2.1 shows effects of glare at diffrent angles.

- Lamp Spectra for Visual Sharpness depends on the Proper Luminaries.It is very much essential to make an object as per its size and dimension.

- Effectiveness of Visual Guidance is also an important factor.It helps a viewer to guess how far another object is from his position.

2.4 Classification of Roads

Roads are classified in five ways:

A1 For very important routes with rapid and dense traffic where the only considerations are the safety and speed of the traffic and the comfort of drivers.

A2 For main roads with considerable mixed traffic like main city streets, arterial roads, and thoroughfares.

B1 For secondary roads with considerable traffic such as local traffic routes, and shopping streets.

B2 For secondary roads with light traffic

C For residential and unclassified roads not included in the previous groups.

D For bridges and flyovers.

E For towns and city centers.

F For roads with special requirements such as roads near airports, and railways.

2.5 Types of Distribution of Light in Roadway Lighting

2.5.1 The following are the types of vertical distribution of light

2.5.1.1 Cut-off

In the cut-off system, the light is reduced as completely as possible above a 70° angle with the downward vertical, the main beam being at this angle. Practically no light is emitted above 80°. This system eliminates glare and performs very well with matt surface. The tail of the bright patch is negligible and the head is relied upon, making it more suitable for central mounting. Luminaire spacing should be smaller.

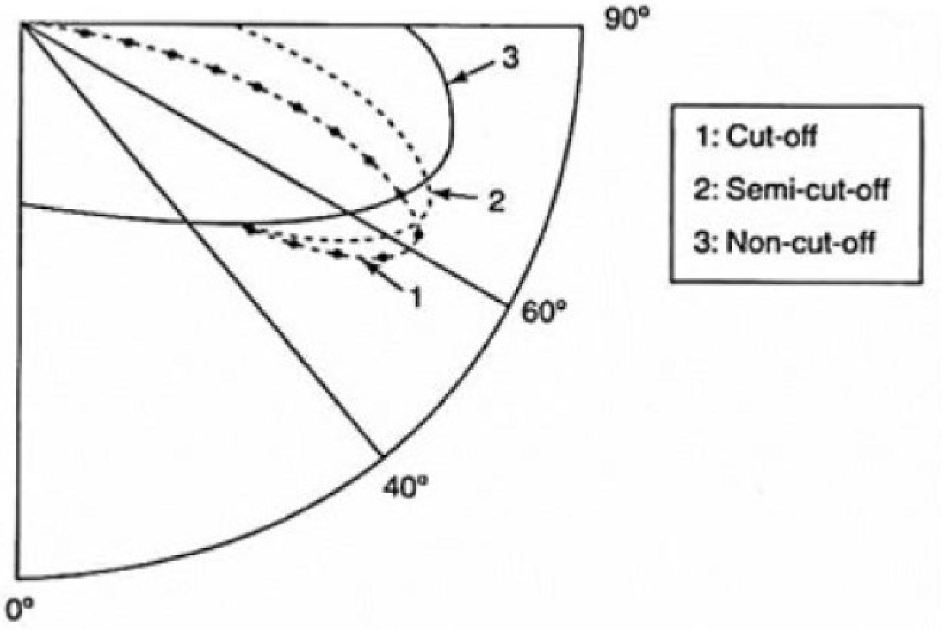

FIGURE 2.2: Types of vertical distribution of light

2.5.1.2 Non-cut-off medium angle beam

In the non-cut-off system, the peak intensity is at about 80°; a certain amount of glare is inevitable; this system is not generally adopted these days.

2.5.1.3 Semi-cut-off (non-cut-off high angle beam)

The semi-cut-off system is in between these two, with the peak intensity at about 75°. This, of course, results in a certain amount of glare. Luminaire spacing can be more than in the cutoff system. This system is not suitable for a central arrangement of luminaires.Distribution of light in the horizontal direction is also important.Footpaths and kerbs also need lighting.

2.5.2 The types of horizont al distribution of light are

2.5.2.1 Symmetrical distribution

Symmetrical distribution is useful in pedestrian sidewalks and at the end of a cul-de-sac.

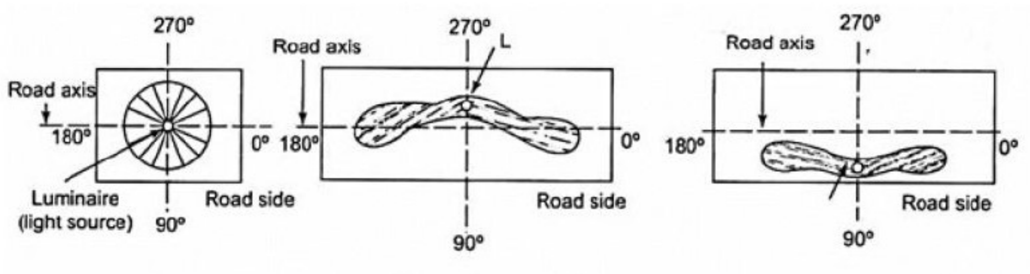

FIGURE 2.3: types of horizontal distribution of light

2.5.2.2 Axial distribution

Axial distribution is suitable for the central arrangement of luminaires.

2.5.2.3 Non-axial distribution

Non-axial distribution is preferred when most of the light has to be beam onto the carriageway; in this case, the luminaires are mounted on the far side of road kerbs. The axial and non-axial distributions throw two main beams – one upward and the other downward onto the road.

2.5.3 Mounting Height

A high mounting of light makes the luminance more uniform and reduces glare while low mounting hampers discernment by silhouette by increasing the illumination of the objects.The general heights are 7.5 to 12 m for high-traffic roads and 3 to 8m for other minor roads.[Figure 2.4]

2.5.4 Spacing

This controls the minimum illumination on the pavement. Preferably, it can be 35 to 45 m on important routes, roughly 3 to 5 times the mounting height.[Figure 2.4]

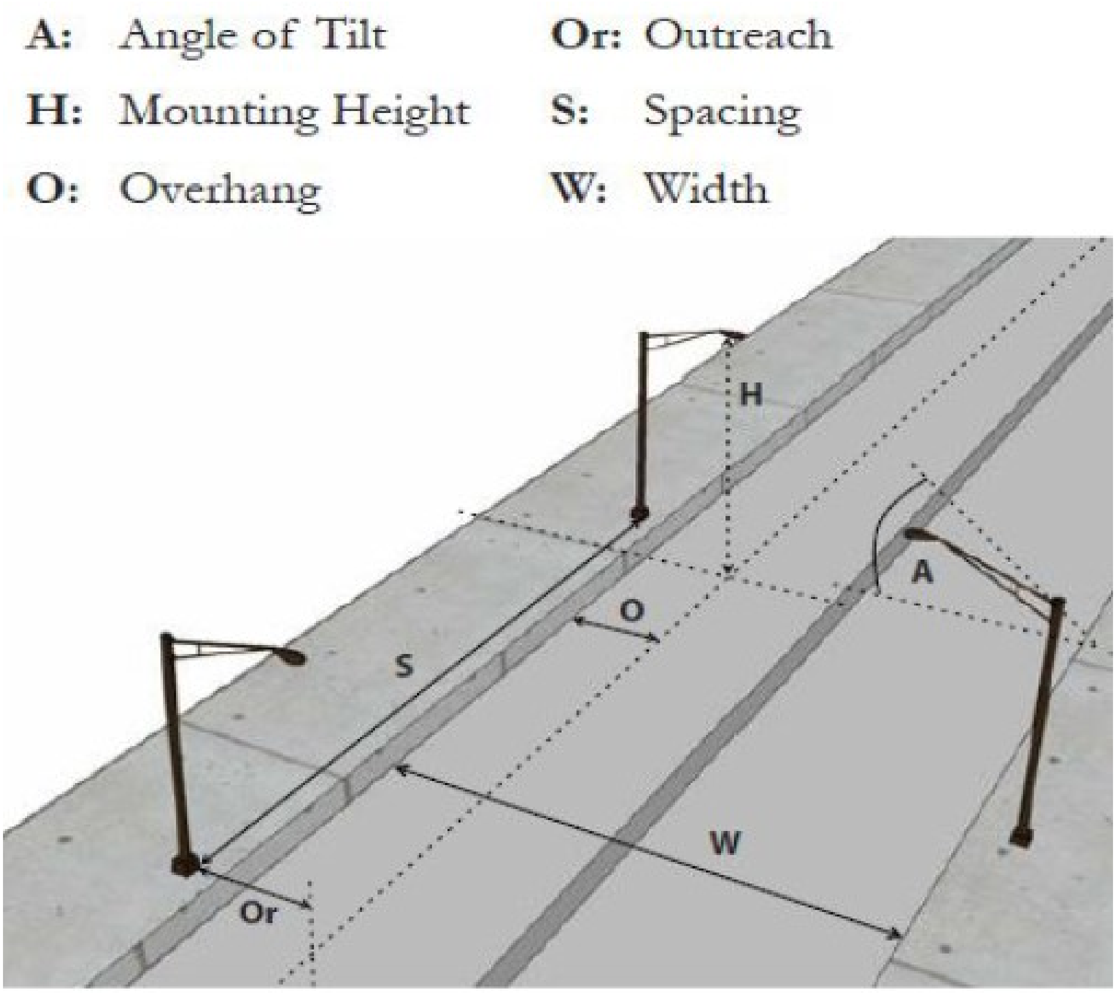

FIGURE 2.4: street lighting features

2.5.5 Outreach

Outreach [Figure 2.4] is the horizontal distance between the center of the column and the center of the luminaire and is usually determined for architectural aesthetic considerations.

2.5.6 Overhang

Overhang [Figure 2.4] is the horizontal distance between the center of a luminaire mounted on a bracket and the adjacent edge of a carriage way. In general, overhang should not exceed one-fourth of the mounting height to avoid reduced visibility of curbs, obstacles, and footpaths.

2.6 Spread and Throw Angle of Street Light Luminaire

The two main terms related to the street light luminaire are:

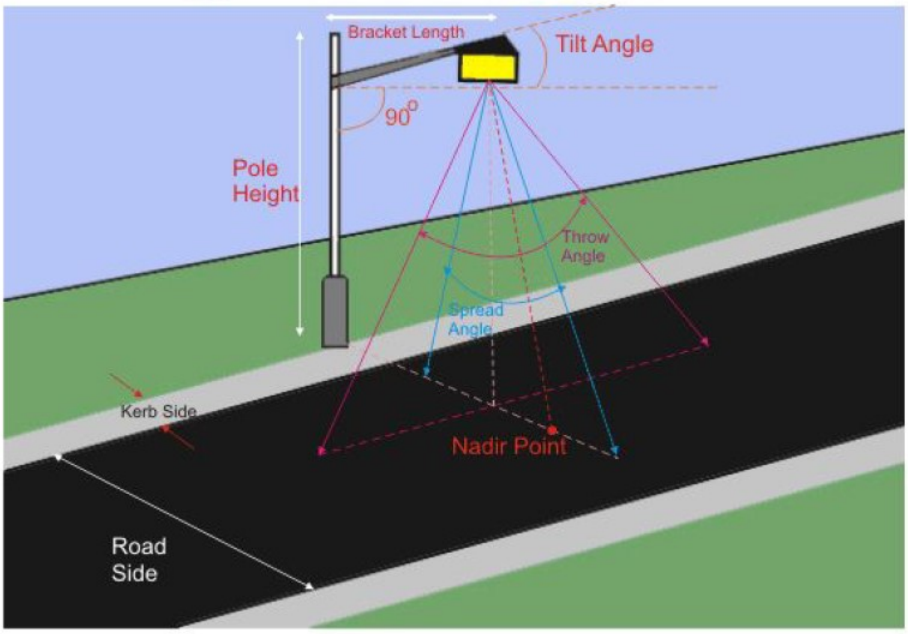

FIGURE 2.5: Throw and spread angle

2.6.1 Spread angle

It is the angle of the luminaire to direct the luminous flux across the road.

2.6.2 Throw angle

It is the angle of the luminaire to direct the luminous flux along the road.
It is denoted by: α**T**

$$\alpha_{max} = \frac{\alpha_1 + \alpha_2}{2}$$

when $\alpha_{max} < 60°$ -short throw angle.
when $\alpha_{max} > 70°$ -long throw angle.
when $60° > \alpha_{max} < 70°$ -intermidiate throw angle.

2.7 Pole Arrangement Schemes in Street Lighting Design

Four fundamental types of siting arrangements are recognized in street lighting . They are:

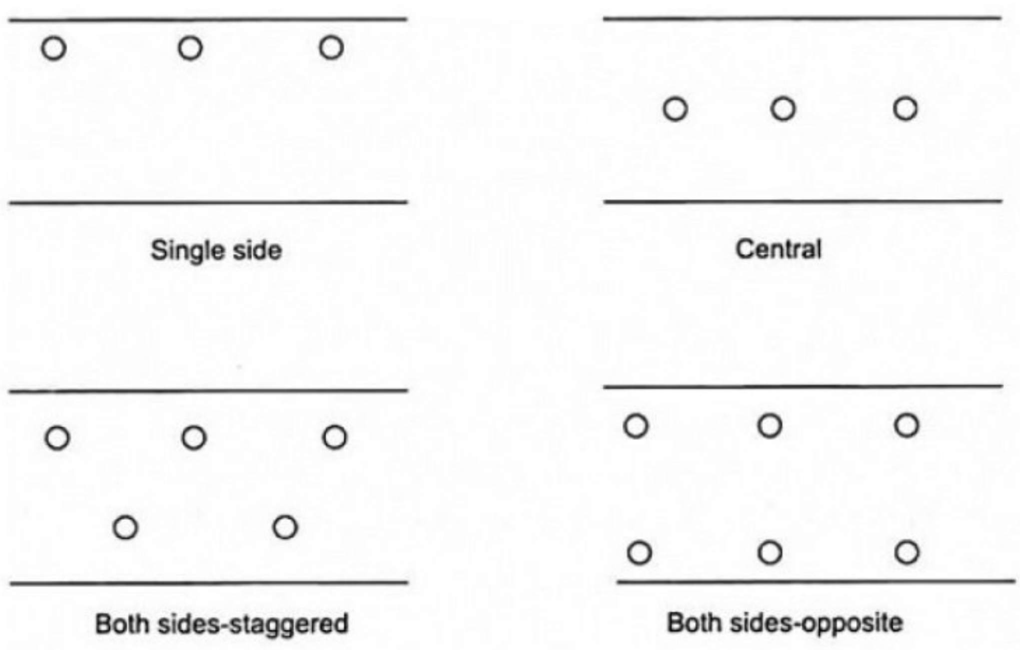

FIGURE 2.6: Pole Arrangement Schemes in Street Lighting Design

2.7.1 Single side arrangement

Single side arrangement,where all the luminaires are on one side of the road. This is recommended only when the width of the road is equal to or less than the mounting height.[Figure 2.6]

2.7.2 Staggered arrangement

Staggered arrangement where the luminaires are placed on either side of the road in a zigzag formation. This is recommended when the road width is 1 to 1.5 times that of the mounting height.[Figure 2.6]

2.7.3 Opposite mounting

Opposite mounting where the luminaires are situated on either side of the road opposite to one another. This is advisable for road widths more than 1.5 times that of the mounting height.[Figure 2.6]

2.7.4 Axial mounting

Axial mounting where the luminaires are placed along the axis of the road. This is recommended for narrow roads the width of which does not exceed the mounting height.[Figure 2.6]

2.8 Recommended Levels of Illumination

Type of Road	Road Characteristics	Average Level of Illumination on Road Surface in Lux	Ratio of Minimum/ Average Illumination	Type of Luminaire Preferred
A-1	Important traffic routes carrying fast traffic	30	0.4	Cutoff
A-2	Main roads carrying mixed traffic like city main roads/streets, arterial roads, throughways	15	0.4	Cutoff
B-1	Secondary roads with considerable traffic like local traffic routes, shopping streets	8	0.3	Cutoff or semi-cutoff
B-2	Secondary roads with light traffic	4	0.3	Cutoff or semi-cutoff

FIGURE 2.7: Recommended Levels of Illumination

2.9 Illumination of Traffics Rotaries

The central island is well lit by luminaires set on top of columns at its edge; further, lights are provided at the kerbs of the four arms.

2.10 Illumination on Curves

The outside of the curves are provided with luminaires when staggered arrangement is used on the straights. Cut-off and semi cut-off systems of vertical distribution are preferred to yield uniform standard of road brightness.If the width of road is large in relation to the mounting height of theluminaires, the inside of the curve also may have to be providedwith lights. The spacing of the luminaires is governed by the mounting height as well as by the radius of the curve, which may range from 20 to 50 m.[Figure 2.8]

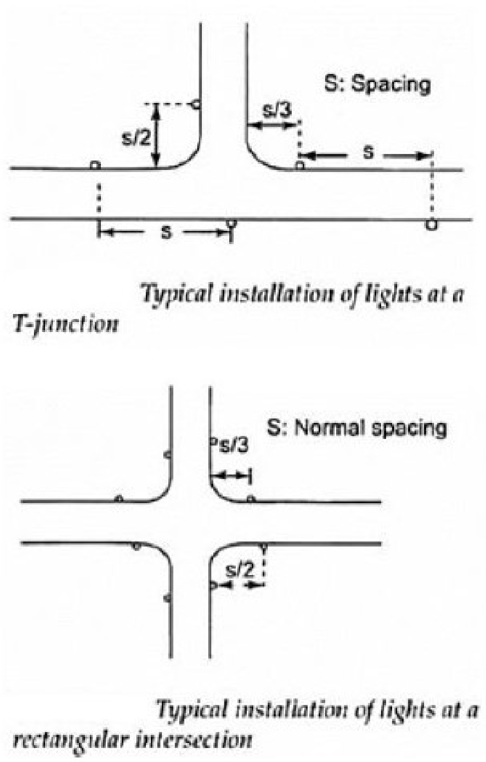

FIGURE 2.8: Illumination on Curves and intersections

2.11 Illumination of Intersections

Typical installations of lights at a T-junction and at a rectangular intersection are shown above fig [Figure 2.8]

2.12 Illumination of Bridges

Standard mounting of 9 m height cannot be provided on bridges.Generally, luminaires are mounted on parapets at a height of 3 to 5m. Avoiding glare poses a problem, and usually cut-off arrangements help to overcome this.

2.13 High-Mast Lighting

This is advantageous in locations such as grade separations, car parks and toll plazas. The number of lighting poles can be minimal.The height of the system may range from 15 to 45 m.

2.14 Types of Lights

The choice of lights is governed by life, wattage, brightness, efficiency, colour given in table 2.1:

Type of Lamp	**Luminous Efficacy** (lm/W)	**Color Rendering Properties**	**Lamp life** Hours	**Remarks**
High Pressure Mercury Vapor (MV)	35-65	Fair	10,000-15,000	High energy use, poor lamp life
Metal Halide (MH)	70-130	Excellent	8,000-12,000	High luminous efficacy, poor lamp life
High Pressure Sodium Vapor (HPSV)	50-150	Fair	15,000- 24,000	Energy-efficient, poor color rendering
Low Pressure Sodium Vapor	100-190	Very Poor	18,000-24,000	Energy-efficient, very poor color rendering
Low Pressure Mercury Fluorescent Tubular Lamp (T12 & T8)	30-90	Good	5,000-10,000	Poor lamp life, medium energy use, only available in low wattages
Energy-efficient Fluorescent Tubular Lamp (T5)	100-120	Very Good	15,000-20,000	Energy-efficient, long lamp life, only available in low wattages
Light Emitting Diode (LED)	70-160	Good	40,000- 90,000	High energy savings, low maintenance, long life, no mercury. High investment cost, nascent technology

TABLE 2.1: Types of Lights

Appendix A

An Appendix

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