Introduction

Street lighting in most of the towns and cities in India are poor maintained and energy inefficient. There is tremendous potential for the improvement in maintenance practices and for the energy conservation with improved O & M practices and with energy efficient retrofits.

India, generates about 1,00,000 MW as per the present statistics. About 17-20% of which was used for the lighting systems, which operate at 220V ac at 50 Hz. Power quality is rather poor in India. Interruptions both planned and unplanned are common. Line voltage variation of 30% or higher is common, as are spikes and surges. All these problems are contributing for the reduced lamp life and lead to frequent lamp replacements and hence higher O & M costs. This is over burden to the most of the sick municipalities in the country. In addition to the power quality problems, poor and inefficient design of the lighting systems also causing pain to the municipalities in the country.

A well designed street lighting or public lighting or outdoor lighting should permit users of road at night to move about with the greatest possible safety and comfort so that the traffic capacity of the road at night is as much equal as possible that planned for the daytime. Efficiently designed street lighting enables the driver to see distinctly without the use of dipped or driving headlights and helps to locate any traffic signs and possible obstacles on the road with out much difficulty. It also helps pedestrian to see distinctly the edges of the footways, vehicles and obstacles.

Presently there are very few municipalities in the country with metering facilities for street lighting consumption. Most of the municipalities pay the bill to respective SEBs based on the number of fittings in the municipal area. This practice not only creates revenue loss to the SEB but also increases O & M for the municipalities. The street lighting load will be estimated based on the lamp wattage and the number of fittings. This does not account the losses in the chokes and the losses in the distribution lines and transformers. Most of the places, supply to the street lights is given from the distribution transformers.

The main reason for the poor and inefficient design of the street lighting system in any municipalities are

- Selection of energy inefficient equipment,
- Poor designing practice of street lights,
- Poor power quality,
- Higher O & M costs, and
- Lack of skilled labour.

Technological advancements in lighting technology has developed lot of energy efficient lighting equipment like

- Low loss chokes,
- High lumen tubes,
- Low wattage lamps for the same lux levels, and
- Energy efficient luminaries.

Incorporation of these at the planning and designing stage itself reduces the higher operating cost of the street lighting on municipalities. In lieu of poor power quality conditions in the country, selection of lamps which operate over wide range of power parameters, would reduce the O & M cost of the lamps significantly.

Methodology

The methodology for the analysis of any street lighting system is as follows:

Data Collection

This includes details like

- Type and number of lamps and fittings in the city/town,
- No. of distribution transformers connected with lighting.

- Connected load details for each distribution transformer,
- Lighting tariff details,
- Details of various streets in the city (Main roads, Secondary roads, residential roads, etc.), and
- O & M practices.

Selection of Streets

Based on the data collected on number and type of streets in the city, one street each should be selected for each category. The categories of streets should be considered based on various national and international standards.
IS 1944 (Part I and II) – 1970 categories the streets as follows:

Group A – For main roads. This is sub-divided in to two categories:

Group 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 the drivers

Group A2 – For other main roads with considerable mixed traffic like main city streets, arterial roads and thoroughfares

Group B – For secondary roads which do not require lighting up to Group A standard. This is also sub divided in to two categories:

Group B1 – For secondary roads with considerable traffic, such as principal local traffic routes, shopping streets etc.

Group B2 – For secondary roads with light traffic

Group C – Lighting for residential and unclassified roads not included in the previous groups

Group D – Lighting for bridges and flyovers

Group E – Lighting for town and city centres

Group F – Lighting for roads with special requirements, such as roads near airfields, railways and docks.

Based on the type of the roads, illumination levels required for each type of street should be collected from the standards. Table I gives the classification of lighting installation and level of illumination required.

Table I

Classification	Avg illumination, lux	Ratio minimum /Avg. illumination	Type of Luminaire	
			Preferred	Permitted
Group A1: Important traffic routes	30	0.4	Cut-off	Semi-cut-off
GroupA2: Main roads carrying mixed traffic like main city roads, arterial roads etc.	15	0.4	Cut-off	Semi-cut-off
GroupB1: Principal local traffic routes, shopping streets etc	8	0.3	Cut-off or semi-cut-off	not-cut-off
GroupB2: Secondary roads with light traffic	4	.03	Cut-off or semi-cut-off	not-cut-off

Measurement of Lighting Load and Light levels

After selecting the streets, lighting load and lux level measurements should be carried out for each street. Apart from these, the following measurements should be taken

- Type of lamps installed in the street,

- Pole to pole distance,
- Road width,
- Mounting height, and
- Angle of tilt.

Approach for Analysis

The data collected and measurements taken should be used for the analysis. The performance parameters required for the street lighting analysis are based upon the appearance of the road from the vehicle driver's point of view. It was established that most night

Table II			
Factor	**Fluorescent**	**High-Pressure Sodium**	**High Pressure Mercury**
Wattage	40	250	125
Output (lumens)	2700	27000	7500
Efficiency (lumens/watt)	55	87	35
Lamp Life (hours)	10000-20000	18000-24000	12000-24000+
Energy use	Medium	Low	High
Color Rendition	Good	moderate	Good

Driving was characterised by the ability to see objects on the road surface be silhouette.

The basis for the analysis depend upon the following data:

- Roadway Geometry and Road Classification: Analyse based on the IS:1944 – 1970 data.
- Light output data: Collect from the manufacturer (see Tale II)
- Road Surface reflection data
- Required performance parameters for the design: As per IS: 1944 – 1970

Lamp Output Data

Generally, three types of lamps are used for the street light which are High Pressure Sodium Vapour Lamps (HPSV – 250W), High Pressure Mercury Vapour Lamps (HPMV – 125W) and fluorescent Lamps (FTL – 40W). Performance data of these lamps is collected from the manufacturer and are given in Table II.

Apart from Table II, other rating HPSV and HPMV lamps are also in use at Junctions and important places. Halogen lamps of 500 W and 1000 W are also in use for high bay masts in big cities at main junctions.

Roadway Geometry and Luminaire Selection

As the basic geometry and lighting scheme of the section of the road will be the same on average throughout its length, only specified length (about 0.5 to 1 km) of the road can be studied for the analysis. The parameters that are to be recorded are as follows.

- Width of streets,
- Number of streets, and
- Number and width of driving lanes

The following should also be recorded on lighting scheme

- Type of luminaire,
- Luminaire spacing,
- Luminaire mounting height,
- Angle of tilt,
- Overhang and outereach of luminaire,

- ➢ Arrangement – single sided, staggered or opoosite, axial, and
- ➢ Any non-standard orientation of luminaries.

Standard luminaire spacing for different curb-to curb width of roads is given in Table III.

Table III			
Curb-to-curb width	**Luminaire**	**Spacing**	**Mounting Height**
60-90 feet	400-W Cobra	120-150 feet	38 feet
40-75 feet	250-W Cobra	150-175 feet	32 feet
36-44 feet	250-W Cobra	150-175 feet	32 feet
38-44 feet	70-W Acorn	160-200 feet	15 feet
28-34 feet	70-W Acorn	160-200 feet	15 feet

Typical layout of the luminaries on a road is shown diagrammatically in Fig. 1.

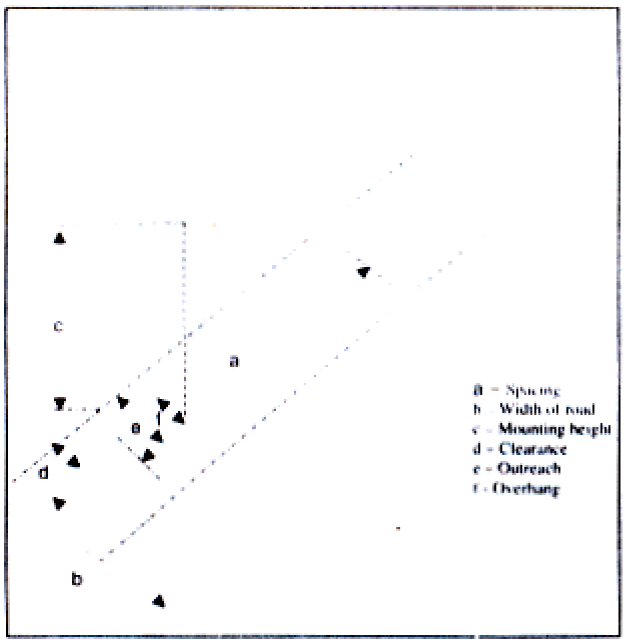

Fig 1

Arrangement of luminaries along with the road mainly depends on the road width. All luminaries on one side of the road is recommended only when the width of the carriageway is equal or less the mounting height. Staggered arrangement is recommended when the width of the road is greater than the value recommended for single side lighting but not exceed 1.5 times the mounting height. Luminaires on either side of the road is advisable when the width of the road is more than 1.5 times the mounting height. Axial mounting, in which the luminaries are placed along the axis of the road, is recommended for narrow roads where the width of which does not exceed the mounting height. This is more acceptable for tree-lined roads.

Luminaire spacing between two poles is measured and compared with the standard data available. The standard data for luminaire spacing to height ration is Table IV.

Table IV	
Type of Luminaire	**Maximum spacing/ height Ratio**
Cut-off / Full Cut-off	3
Semi-cut-off	3.5
Non-cut-off	4

Cut off Luminaire: A light distribution where a negligible amount of light is permitted at a horizontal plane located at the bottom of a luminaire.

Semi-cut-off Luminaire: A light distribution where slightly more light is permitted at a horizontal plane located at the bottom of a luminaire than the cut-off distribution.

Non-cut-off Luminnaire: A light distribution that can produce considerable light above the horizontal plane located at the bottom of a luminaire.

Mounting Height

The mounting height should be greater as the road way is wider to obtain adequate transverse uniformly. As a general rule heights of 9 to 10 meters are suitable for Group A roads and 7.5 to 9 metres for Group B roads. Heights of less than 7.5 metres are undesirable except in certain special cases, such as the lighting of residential roads or roads bordered by trees.

Outreach and Overhang

The outreach is usually determined by architectural or aesthetic considerations. The overhang should not in general exceed one-fourth of the mounting height; excessive overhang leads to reduce visibility of obstacles and footways.

All the above recorded parameters should be analysed with reference to the data available in various standards to meet the requirements.

Siting of Luminaires at Various Locations

Curves: Curves of larger radium of the order of 1000 m can be treated as straight. For curves of similar radius, a study of the respective shows that it is mainly luminaries which are placed at the outside of a bend which contribute to the brightness of the carriageway, and that in order to bring about the same degree of juxtaposition of the patches the spacing should be progressively reduced as the bend is more pronounced. For similar reasons the overhang should not be excessive.

Single side arrangement is obviously recommended because it gives in addition effective beaconing of the curve. Staggered arrangement is to be avoided as far as possible, because not only does the beaconing effect usually disappear, but the driver may even be deceived in to thinking that there is a side road.

At curves on roads where the width exceeds 1.5 times the mounting height additional luminaries should be mounted on the inside of the curve.

Crossroads and Pedestrian Crossings: The basic principle of the arrangement of luminaries at crossroads can be illustrated by the mode by which a pedestrian traversing a pedestrian crossing is seen. Lighting by a single luminaire whose position has been chosen so that the bright patch which it produces covers the greater part of the pedestrian crossing, nevertheless leaves a dark background against which the pedestrian is difficult to see. It is desirable, therefore, to provide a supplementary luminaire placed further away than the first and on the other side of the road.

Table V	
Area of Application	**Practices for Good Lighting Design**
Curved Roads	Spacing recommended between poles is 0.75 times the normal spacing recommended for that road
T Junctions	Recommended to have a luminaire located at a point half the spacing from the joining end of the perpendicular part of the T-junction. An additional lumanaire is required directly opposite to the same road.
Cross junction	Additional luminaires are located on the traffic islands of the junction to provide clear visibility and indication of the junction.
High-mast lighting	Suitable locations should be chosen around the area and floodlights with appropriate beam spreads to achieve the desired lighting criteria.

If this reasoning is applied to traffic in both directions, it indicates that the crossing should always occur midway between two consecutive luminaires situated on either side of the carriageway. Moreover, to draw attention to the discontinuity of the carriageway without altering the continuity of the lighting, it is recommended that the spacing of these situations should be reduced so as to increase the level of illumination, and to use materials, for marking the crossing on the carriageway, which will provide and maintain good contrast under the conditions of illumination and view which will occur. Luminaires should never be sited just before the crossing and on the near side.

Lighting Application for Various Tasks

Table V furnishes the information on streetlight application for the areas like flyover and junction, curves, T-junction and cross-junction, etc.

Energy Conservation Opportunities

It is generally observed the following parameters contribute to low lighting levels on the street

- Improper pole to pole spacing,
- Inadequate or higher mounting height,
- Improper angel of title,
- Interruptions due to road side trees,
- Improper selection of lamps and fittings, and
- Poor maintenance of the lamps (continuous dust accumulation, change in orientation, non replacement of burn out lamps, etc.).

In addition to the avoiding improper design practices mentioned above, the energy efficiency of the street lighting systems can be achieved by

- Selection of energy efficient lamps (replacing 40 W with 36 W slim tube, selection of high lumen lamps, using HPSV lamps in place of HPMV lamps, etc).
- Selection of low loss chokes in place of conventional chokes.
- Maintaining reduced and constant voltage to the lighting fittings through lighting voltage controllers.
- Incorporation of timer controllers in the lighting circuits to switch ON and switch OFF automatically.
- Energy metering and monitoring to assess the exact lighting consumption and to take corrective actions accordingly.
- Replacing traffic signal lights with LED lamps.

Energy Metering and Monitoring

Metering is the basis through which energy savings can be measured and hence, energy end-use metering became a requirement for most of the facilities who really want to control their energy usage for all type of end use applications. In many cases, energy metering itself can and should realistically be viewed as a valid energy conservation measure. Energy metering and sub-metering is, however, inherently different than most other energy conservation measures. Energy metering, by itself, saves no energy. Only when data supplied by an energy metering system are converted into information, and ultimately intelligence, can energy savings be achieved. Savings are achieved as a result of management acting on energy metering information, not by the metering itself. Thus metering must be accompanied by specialized engineering services that add value to the metering system.

It is roughly estimated that exact monitoring of the street lighting consumption would increase the financial burden on municipalities as the operating load will be higher than the connected load in lieu of the accounting of choke consumption and system losses. Though the per kW cost would reduce after the metering, due to additional choke consumption and system losses, the annual operating cost of the street lighting system is likely to go up. Unless, energy conservation measures are taken up and implemented, it is likely that the operating cost of street light is going to increases and put additional financial load on municipalities.

Installation of energy meters would help municipalities in terms of

- Monitoring the exact consumption of the street lighting,
- Controlling the burning hours of lamps per day,
- Monitoring the area wise street lighting consumption, and
- Finding out the hidden energy saving potential with intelligent data analysis from the energy meters.

Installation of energy meters would help electricity board in terms of

- Monitoring the exact consumption of the street lighting,
- Improvement in revenue collection, and
- Actual operating load on each transformer centre.

In general, however, energy savings estimates from the implementation of metering systems with proper monitoring and analysing the data seem to range from 1-5%. Because this is an estimate made before the system is installed, it is also common to offer a range of potential savings.

Projects like these (metering street lighting installations) should provide the basis for developing a generalized model for implementing metering as an energy conservation measure. Municipalities should not get an impression that installing energy meters means it is going to increase the financial burden. This could be avoided to maximum extent by calculating the connected load including the consumption of the chokes. Electricity Board also should fix the tariff based on the consumption of both the lamp and the choke consumption. Also, it is very essential to bring awareness among the users on energy metering system and should educate the users about the benefits of the energy metering system. Municipalities should also realise the importance of the implementation of the energy conservation measures and subsequent achievable benefits through energy metering system.

Hence, the following suggestions are made for municipalities in order to control their operating cost of the street lighting.

- Implement all the energy conservation measures with improved O & M practices.
- Turn the data from an energy metering system into valuable information and intelligence through engineering applications.
- Optimize existing energy consumption through the identification of O & M and process modifications.
- Implement capital measures that appear to be cost-effective for the optimized system.

Overall, this process of metering and monitoring should help municipalities for more efficient utilization of scarce capital.

Checklist for O & M

This aim of public lighting should permit users of the road to move about with greatest possible safety and comfort so that the traffic capacity of the road at night is as much equal to that planned for the daytime as possible.

It is essential to the proper functioning of a public lighting installation that it should be properly maintained. Certain maintenance activities, aimed at keeping the effectiveness of the installation at the highest possible level are economically justified, so that

- The heavy investment in public lighting installation should continue to provide a good return.
- Because in a poorly maintained installation the power consumption is to a large extant wasted.

Maintenance of a lighting installation should embrace

- Replacement of defective and missing lamps and accessories.
- Systematic replacement of lamps having a reduced efficiency, that is, those lamps that have come to the end of their useful service life.
- Cleaning of luminaries and lamps. The soiling of the luminaries depends very much on local conditions, the presence of industries in the area and the prevailing direction of the winds, etc.
- Maintenance of cables and columns.
- Inspection of main earthling arrangements, gaskets, the tracing of defects and broken lamps, and control of switching equipments.
- Mounting height and angle of tilt should be maintained for desired light levels.
- Proper clearance should be maintained between carriageway and the light pole to avoid accidents and for safety.
- Set guidelines while allowing permission to set up brightly hoardings on roadways to avoid any accidents due to glare due to hoardings.
- Proper and sufficient lighting should be provided for pedestrian crossing area.
- The traffic signals which are installed with the conventional incandescent lamps should be replaced with LED type bulbs.
- Care should be taken so that fuse carriers are provided in proper enclosures. Similarly fuses of appropriate rating should be used so that uninterrupted lighting is available during night time to ensure safety and security.
- Trimming of trees can be taken up to ensure good lighting is available, if trees are obstructing the light levels on the street.

Conclusion

Interest and awareness in measuring and ultimately optimizing energy consumption and cost are growing. And implementing a street lighting monitoring system is a critical component of energy optimization for municipal corporations. The trend to municipal corporations recognizing that they simply can't afford not to adopt energy management to reduce their operating cost on street lighting and not to utilise the metering systems seems likely to emerge.

Reference book:
IEEMA Journal
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