Energy Efficient Outdoor Lighting System Design: Case Study of IT Campus

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Abstract. Outdoor lighting solutions are a key to safe urbanization. It is important that assessment of lighting is done at the design stage keeping in mind the crucial parameters like environment friendly design, light pollution, and energy efficiency. These crucial parameters are met by meticulously using lighting standards at each and every stage of lighting design. This process further naturally inclines in realizing sustainable lighting solutions for the future generations. In this paper, a case study of an Information Technology (IT) campus which requires suitable outdoor lighting system is considered. Outdoor lighting is very essential from the security perspective and also for the people and vehicle movement during night time. Hence it is necessary to design and implement an effective lighting scheme. To achieve this it is necessary to perform extensive lighting calculations and simulations in DIALUX software platform.

Keywords—Outdoor lighting design, LUX levels, Illuminance, Uniformity Factor

ABBREVIATIONS:

| Abbreviation | Description       |
|--------------|-------------------|
| Eav          | Average lux level |
| Emin         | Minimum lux level |
| Emax         | Maximum lux level |
| u0           | Utilization factor |
| IT           | Information Technology |

1. Introduction

Lighting has high impact on outdoor activities of people and is a key parameter that contributes to social well-being as well. [1-5] examines how urban morphological characteristics contribute to the outdoor lighting system. In developed countries, outdoor activities are on a rise for urban residents which demands suitable lighting system [6-9]. This had tremendously increased the necessity for
urban planning and design. Daylight harvesting is rapidly spreading hand in hand with urbanization [10–17]. Smart city is the next generation city that is much looked up at and that targets at creating a different dynamic of urban cities which takes into account the safety, comfort of people with energy efficient techniques [18-22]. More and more research is focusing on how to build energy efficient lighting systems as well [23-27]. It is important to engineers to keep the associated standards or technical reports in mind while handling different lighting applications and solutions [28–31].

In this paper, a case study of an Information Technology (IT) campus which requires suitable outdoor lighting system is considered. Section II discusses the methodology to be incorporated to provide the outdoor lighting system for IT campus is explained. Section III is the results and discussion explains how extensive lighting calculations and simulations are carried out in DIALUX software platform. Sections IV discusses the conclusion and future scope of the proposed work.

2. Methodology

As a general thumb rule, while lighting the roads of different width, the following steps are incorporated:

2.1. Planning data

The detail of the perimeter or road for which lighting design is to be done is initially captured. Few key details include length and width of road, light loss factor and upward light ratio.

2.2. Luminaire parts list

Based on the planning data, the count of luminaries part required is computed. Also the Luminous flux (Luminaire), Luminous flux (Lamps), Luminaire Wattage, Luminaire classification according to CIE and CIE flux code is arrived at for the collective luminaries parts. Also a user defined Correction Factor is decided at this stage.

2.3. Luminaires (layout plan)

Based on the luminaries part list, the next step is to place the luminaries at exact locations on the road. This will be treated as the final lighting layout plan of the road.

2.4. Luminaires (coordinates list)

Based on the luminaries layout plan, the coordinates list if generated. The coordinates list includes:

- Position X in meters
- Position Y in meters
- Position Z in meters
- Rotation X in °
- Rotation Y in °
- Rotation Z in °

2.5. Calculation surfaces (results overview)

Based on the coordinates list, the roads are initially designated based on location and a type is allotted to them. The calculation surfaces computes for all roads:

- Grid specifications
- Average lux level
- Minimum lux level
- Maximum lux level
- Utilization factor
3. Results and Discussion

A case study of an IT campus is considered. It is necessary to design and implement an effective lighting scheme. To achieve this it is necessary to perform extensive lighting calculations and simulations in DIALUX software platform. Requires lighting calculations using DIALUX software.

The model is created considering road level as 1.5mtr from 0 plane. Hence heights shall be read - 1.5mtr from indicated levels.

3.1. Classification of area based on lighting requirements

The total area is segregated into three based on lighting requirements:

3.1.1 Perimeter Lighting:

The IT perimeter single arm lighting planning data for Fig. 1 is as follows:

- Light loss factor: 0.75,
- Upward Light Ratio (ULR): 0.5%
- Scale 1:1184

Luminaire Parts List is as given in Table I.

![Fig. 1. Perimeter Lighting Single Arm.](image)

| No. | Pieces | Designation (Correction Factor) | Ø (Luminaire) [lm] | Ø (Lamps) [lm] | P [W] |
|-----|--------|---------------------------------|---------------------|---------------|-------|
| 1   | 6      | ENXT P 36L WH CR PC SD (1.000)  | 3681                | 3681          | 30.2  |
| Total |       |                                 | 22085              | 22085         | 181.2 |

The IT perimeter lighting single arm layout plan based on luminaries is given in Fig. 2. The luminaries part list comprised of 6 numbers of ENXT P 36L WH CR PC SD with values 3681 lm, 30.2 W, 1 x 1 x User defined (Correction Factor 1.000). The arrangement of parts is also shown in Fig. 3, for which the luminaries’ coordinates list is computed as shown in Table II.

| No. | Position [m] | Rotation [°] |
|-----|--------------|--------------|
|     | X  | Y  | Z  | X  | Y  | Z  |
| 1.  | 1.834 | 1.292 | 6.350 | 0.0 | 0.0 | 0.0 |
| 2.  | 1.834 | 26.292 | 6.350 | 0.0 | 0.0 | 0.0 |
| 3.  | 1.834 | 51.292 | 6.350 | 0.0 | 0.0 | 0.0 |
| 4.  | 1.834 | 76.292 | 6.350 | 0.0 | 0.0 | 0.0 |
| 5.  | 1.834 | 101.292 | 6.350 | 0.0 | 0.0 | 0.0 |
The IT perimeter lighting single arm calculation surfaces is given for Fig. 4 as in Table III. The calculation surfaces are performed for two items with perpendicular type:
- Item 1: Service Road
- Item 2: Vertical Illumination of Fence Wall. The scale is 1:1452. The summary of results is as shown in Table IV. It indicates the number of light fixtures required, average LUX level achieved and uniformity factor.

|   |   |   |   |   |   |
|---|---|---|---|---|---|
|6. | 1.834 | 261.292 | 6.350 | 0.0 | 0.0 |

Fig. 2. Luminaries Layout Plan.

Fig. 3. Luminaries Coordinates List.

Fig. 4. Calculation Surfaces.
TABLE III. CALCULATION SURFACE LIST

| Designation | Grid | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | $u_0$ | $E_{min}/E_{max}$ |
|-------------|------|---------------|---------------|---------------|------|------------------|
| Item 1      | 4 x 50 | 13            | 6.68          | 22            | 0.525 | 0.308            |
| Item 2      | 2 x 17 | 4.17          | 1.45          | 11            | 0.346 | 0.127            |

TABLE IV. SUMMARY OF LUX LEVELS

| Type         | Quantity | Average [lx] | Min [lx] | Max [lx] | $u_0$ | $E_{min}/E_{max}$ |
|--------------|----------|--------------|----------|----------|------|------------------|
| Perpendicular| 2        | 9.98         | 1.45     | 22       | 0.14 | 0.07             |

The IT perimeter lighting single arm 3D rendering is shown in Fig. 5.

3.1.2 Service Road Value Chart ($E_{Perpendicular}$:

Item 1 which is the service road is analyzed. The value chart ($E_{perpendicular}$) is arrived at as shown in Fig. 6 where values are indicated in lux and the scale considered is 1:391. Table V are the lux value indicators arrived for Service Road.

TABLE V. SERVICE ROAD: LUX INDICATORS

| $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | $u_0$ | $E_{min}/E_{max}$ |
|---------------|---------------|---------------|------|------------------|
| 13            | 6.68          | 22            | 0.525 | 0.308            |

Fig. 6. Service Road: Value Chart.
3.1.3  **Vertical Illuminance of Fence Wall Value Chart (E,Perpendicular:)**

Item 2 which is the vertical illuminance of fence wall is analyzed. The value chart (E,perpendicular) is arrived at as shown in Fig. 7 where values are indicated in lux and the scale considered is 1:358. Table VI show the lux value indicators arrived for vertical illuminance of fence wall.

![Fig. 7. Vertical Illuminance of Fence Wall: Value Chart.](image)

| $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | $u_E$ | $E_{min}/E_{max}$ |
|----------------|----------------|----------------|-------|------------------|
| 4.17           | 1.45           | 11             | 0.346 | 0.127            |

3.2. **Classification of lighting based on width of road**

Within the three areas discussed, there maybe different widths of roads that maybe employed. In this paper, we have analyzed for:

3.2.1  **10m wide road:**

The lighting planning data for Fig. 8 is as follows:

- Light loss factor: 0.75, ULR (Upward Light Ratio): 0.5%
- Scale: 1:1183
The Luminaires Parts List is as given in Table VII. The layout plan based on luminaries is given in Fig. 9. The luminaries part list comprises of ENXT P 54L WH CR PC with Luminaires classification according to CIE: 100; CIE flux code; 30 66 95 100 100; Fitting: 1 x User defined (Correction Factor 1.000). The arrangement of parts is also shown in Fig. 10, for which the luminaries’ coordinates list is computed as shown in Table VIII.

| No. | Pieces | Designation (Correction Factor) | Φ (Luminaires) [lm] | Φ (Lamps) [lm] | P [W] |
|-----|--------|---------------------------------|-------------------|---------------|------|
| 1   | 11     | ENXT P 54L WH CR PC SD (1.000)  | 5429              | 5429          | 45.1 |
| Total |       |                                  | 59721             | 59721         | 49.63|

The 10m wide calculation surfaces are given for Fig. 11 as in Table IX. The calculation surfaces are performed for two items with perpendicular type:
Item 1: Service Road and

| No. | Position [m] | Rotation [°] |
|-----|--------------|--------------|
| X   | Y    | Z   | X   | Y    | Z   |
| 1.  | 16.365 | 13.706 | 6.00 | 0.0  | -10.0 | 180.0 |
| 2.  | 16.365 | 25.706 | 6.00 | 0.0  | -10.0 | 180.0 |
| 3.  | 16.365 | 37.706 | 6.00 | 0.0  | -10.0 | 180.0 |
| 4.  | 16.365 | 49.706 | 6.00 | 0.0  | -10.0 | 180.0 |
| 5.  | 16.365 | 61.706 | 6.00 | 0.0  | -10.0 | 180.0 |
| 6.  | 16.365 | 73.706 | 6.00 | 0.0  | -10.0 | 180.0 |
| 7.  | 16.365 | 85.706 | 6.00 | 0.0  | -10.0 | 180.0 |
| 8.  | 16.365 | 97.706 | 6.00 | 0.0  | -10.0 | 180.0 |
| 9.  | 16.365 | 109.706 | 6.00 | 0.0  | -10.0 | 180.0 |
| 10  | 16.365 | 121.706 | 6.00 | 0.0  | -10.0 | 180.0 |
| 11  | 16.365 | 1.706  | 6.00 | 0.0  | -10.0 | 180.0 |
Item 2: Vertical Illumination of Fence Wall. The scale is 1:1451. The summary of results is as shown in Table X.

Fig. 10. Luminaries Coordinates List.

Fig. 11. Calculation Surfaces.

**TABLE IX. Calculation Surface List**

| Designation | Grid | \(E_{av}\)[lx] | \(E_{min}\)[lx] | \(E_{max}\)[lx] | \(u_0\) | \(E_{min}/E_{max}\) |
|-------------|------|----------------|----------------|----------------|-------|------------------|
| Item 1      | 3 x 10 | 22             | 14             | 30             | 0.611 | 0.458            |
| Item 2      | 2 x 10 | 5.40           | 3.77           | 7.45           | 0.698 | 0.508            |

**TABLE X. SUMMARY OF LUX LEVELS**

| Type         | Quantity | Average [lx] | Min [lx] | Max [lx] | \(u_0\) | \(E_{min}/E_{max}\) |
|--------------|----------|--------------|----------|----------|--------|------------------|
| Perpendicular | 2        | 19           | 3.77     | 30       | 0.20   | 0.13             |

3.2.2 Service Road Value Chart (E, Perpendicular)

The value chart \((E,\text{perpendicular})\) is arrived with 10m road width specification as shown in Fig. 12 where values are indicated in lux and the scale considered is 1:391. Table XI are the lux value indicators arrived for Service Road.

**TABLE XI. SERVICE ROAD: LUX INDICATORS**

| \(E_{av}\)[lx] | \(E_{min}\)[lx] | \(E_{max}\)[lx] | \(u_0\) | \(E_{min}/E_{max}\) |
|----------------|----------------|----------------|--------|------------------|
| 22             | 14             | 30             | 0.611  | 0.458            |

3.2.3 Vertical Illuminance of Fence Wall Value Chart (E, Perpendicular)
Item 2 which is the vertical illuminance of fence wall with 10m width is analyzed. The value chart (E, perpendicular) is arrived at as shown in Fig. 13 where values are indicated in lux and the scale considered is 1:358. Table XII show the lux value indicators arrived for vertical illuminance of fence wall.

**TABLE XII. FENCE WALL: LUX INDICATORS**

| $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | $u_0$ | $E_{min}/E_{max}$ |
|---------------|----------------|----------------|-------|-------------------|
| 5.40          | 3.77           | 7.45           | 0.698 | 0.506             |

4. Conclusion

To achieve safe urbanization, it is important to provide suitable outdoor lighting solutions. The lighting design assessment is done at the initial stage of design. It is necessary that crucial parameters like environment friendly design, minimum light pollution, and high energy efficiency are key constraints while providing effective lighting solutions. As a lighting design engineer, it is important to follow lighting standards at each and every stage of the design. This process contributes to the trajectory growth in sustainable lighting solutions for the future generations. In this paper, a case study of an IT campus which requires a suitable outdoor lighting system is considered. The outdoor lighting is very essential from the security perspective and also for the people and vehicle movement during night time. Hence it is necessary to design and implement an effective lighting scheme. To achieve this it is necessary to perform extensive lighting calculations and simulations in DIALUX software platform. The proposed lighting design calculations maybe extended to commercial buildings,
offices, residential complex and other urban environments. This in turn aids in realizing sustainable smart cities.

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