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ROAD CLASSIFICATION BASED ENERGY EFFICIENT DESIGN AND ITS VALIDATION FOR INDIAN ROADS

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ABSTRACT

Road lighting consumes a significant portion of global electricity. A good road lighting design ensures the fulfilment of visual requirements with optimized design. The initial step for a good road lighting design is to identify the exact lighting class of the concerned road. The existing Indian Road lighting Standard IS: 1944, 1970 is not so well defined with respect to the modern Indian roads. It demands a specific model for classifying any Indian road. This paper focuses towards the validation of a proposed model, which is a modified mathematical model as recommended by CIE: 115, 2010 for classifying the exact lighting category of the Indian roads. This paper also highlights the scope of energy saving by changing the design according to the changed lighting class during different traffic hours in night. Some innovative design is also proposed for a new road based on the proposed classification methodology.

1. INTRODUCTION

A road can be defined as a business connector, used by individuals to accomplish their business purpose. The lighting in the road guides the individuals through their journey to the place of affair inducing a strong influence on their mood and motivation. Thus, convenient road lighting is very necessary. Road lighting is a very special form of lighting design. The other necessities of road lighting are to allow all road users to proceed safely, to allow pedestrians to see hazards, recognize other pedestrians, and give them a sense of security, also to improve the night time appearance of the environment. To fulfil the requirements of road lighting, a proper road lighting design is required. Road lighting class is the most influencing parameter of a road lighting design. It demands the maximum attention as it defines all the photometric requirements in order to provide safety and security to road users, also to minimize the electricity consumption [1,2].

The two existing International Standards for road lighting are: CIE115, 2010 (Technical Report for Lighting of Roads for Motor and Pedestrian Traffic) and IESNA RP-8–00 (Roadway Lighting). CIE115, 2010 has proposed a model for the selection of appropriate lighting class based on luminance concept, taking into account the different parameters relevant for the given visual task [3].

In India, the road lighting standard is not well defined. It demands more specific consideration towards the optimized solution for the mixed traffic scenario in Indian roads. According to IS:1944, 1970 the roads are classified in six different groups- A, B, C, D, E, F. Group A and B are further classified into two sub-groups A1, A2 and B1, B2. In the standard, Group A1 refers to ‘very important road with rapid and dense traffic’ and Group A2 is for ‘other type of main roads with considerable mixed traffic’. Group B is for ‘secondary roads which do not require up to Group A’. Considering Group A, the term 'important' is a relative term which depends on users. The Indian Road Lighting Standard IS:1944, 1970 is based on illuminance but global standard says that instead of illuminance, luminance concept should be considered when selecting quality criteria for lighting roads. The normal direction of view of motorists is toward the road. The road surface forms the background to the objects present on the road. The surface is visible by virtue of light being reflected from it and entering the eye of the observer; thus the greater the amount of reflected light, the stronger will be the visual sensation which is measured by luminance. Illuminance is the amount of light falling on the surface; it is incapable of making any visual sensation; so luminance is considered as the photometric parameter for road lighting.

Hence a proper guideline is required for road lighting in Indian context. The recommendations in CIE: 115, 2010 are structured with such an intension that it is easily adaptable to the need of individual countries and it also serves for developing national standards for lighting [5]. Hence the ongoing development process of Indian road lighting standard proposed a new model following current CIE technical report on road lighting.

The aim of this paper is to validate the proposed new classification system for Indian roads and to demonstrate few case studies based on the proposed classification model [6].

2. DESCRIPTION OF THE MATHEMATICAL MODEL CONSIDERED FOR VALIDATION

The current CIE Technical Report CIE:115, 2010 for 'Lighting of Roads for Motor and Pedestrian Traffic' is the first step in making a new mathematical model based upon few traffic related parameters, ambiance related parameters considered with their corresponding weighting values [3]. This new mathematical model is a modification of the existing CIE: 115, 2010 model. As in India a mixed traffic scenario persists, the CIE: 115, 2010 model is modified, taking into consideration the critical aspects of Indian roads. The lighting classes for motorized road are classified into 6 different M lighting classes, from M1 to M6 and it also recommends the lighting criteria like, average luminance, overall uniformity, longitudinal uniformity, threshold increment, surrounding ratio for the corresponding class of road. The appropriate lighting class has to be selected according to traffic volume, traffic speed, traffic class, existence of medians and cross roads, surrounding brightness, existence of parked vehicles as well as visual guidance.

In the new model limits/ranges of the different parameters (traffic volume, traffic speed and ambient luminance) are set to classify the different motorized roads of India into M1, M2…M6 classes. Example the values for the three different categories of speed is provided for very high speed > (60 km/h), for high speed (40–60 km/h) and for moderate speed < (40km/h), with weights 1, 0.5 and 0 respectively. Similarly, the traffic density is categorized into very high> (60 traffic volume in number per min), high (50–60 traffic volume in number per min), moderate (30–50 traffic volume in number per min), low (10–30 traffic volume in number per min) and very low< (10 traffic volume in number per min) with weights 1, 0.5, 0, –0.5 and –1 respectively. In India a mixed traffic scenario persists in majority of the places, therefore to determine the type of traffic density or speed of vehicle by follow-

Fig. 1. Location of VIP Road

Table 1. Classification of Different Roads with Respect to New Model as per Indian Context

Sl No.	Road name	Traffic volume in № / min					Traffic speed, km/h			Traffic class			Median		Cross road		Surrounding brightness			Parked vehicle		Visual guidance		Sum of weights (V_{WS})	Class of road (6-V_{ws})	Class as rounded up
		60 and above, very high	50–60, high	30–50, moderate	10–30, low	<10, very low	>60 Very High	40–60, High	<40, moderate	Mixed with High % of non-motorized	Mixed	Motorized only	No	Yes	High (above 3 nos. \Km)	Moderate (below 3 nos.\ Km)	High	Moderate	Low	Present	Not Present	Poor	Moderate or Good			
		Weights					weights			weights			Weights		Weights		weights			Weights		Weights				
		1	**0.5**	0	-0.5	-1	1	0.5	0	0	1	2	1	0	1	0	**1**	**0**	**-1**	**0.5**	**0**	**0.5**	**0**			
1	G.T. ROAD	1					1			2			0		1		0			0		0.5		5.5	0.5	1
2	VIP ROAD	0					1			2			1		1		0			0		0		5	1	1
3	APC ROAD	0.5					0.5			2			1		0		0			0		0		4	2	2
4	BIDHAN SARANI	0					0			2			1		0		0			0		0		3	3	3
5	BALLYGUNGE CIRCULAR ROAD	0					0			2			1		0		0			0		0		3	3	3

6	S. C. MALLIK ROAD(BAGHA-JATIN)	0	0	1	0	1	0	0.5	0	2.5	3.5	3
7	PURNO DAS ROAD	0	0	2	1	0	0	0	0	3	3	3
8	MAYFAIR ROAD	-0.5	0	1	1	0	0	0.5	0	2	4	4
9	DOVER LANE	-1	0	0	1	0	0	0.5	0.5	1	5	5
10	NKDA 160	-1	0	1	1	0	-1	0	0.5	0.5	5.5	5
11	JATINDRA MO-HAN SARANI	-1	0	1	1	0	-1	0.5	0.5	1	5	5

ing the guideline a minute observation is very much essential. In CIE: 115, 2010, the lighting class is determined by the formula,

$$M = 6 – V_{ws}, \text{ where}$$

V_{ws} denotes the sum of all the weighing values. If M is not an integer, it is advised to adopt the first lower integer. This formula only holds for V_{ws} having values less or equal to 5. In Indian context, analysis shows that there are situations where weighing value greater than 5 may be obtained. Thus, to overcome this limitation in selection of the lighting class the existing formula is amended as per convenience. The revised formula to determine the lighting class is

$$M = 6- V_{ws}, V_{ws} <=5,$$
$$M=1, V_{ws} >5,$$

where V_{ws} denotes the sum of all the weighing values. If M is not an integer, it is advised to adopt the first lower integer.

3. VALIDATION OF THE MATHEMATICAL MODEL FOR ROAD LIGHTING IN INDIAN SCENARIO

Validation is the process of ensuring that a model is sufficiently accurate for the required purpose; in other words, building the right model for a particular purpose. No model is ever fully accurate; indeed, there are justifiable reasons for not having completely accurate models. Further, the accuracy of any model is determined with reference to the purpose for which the model is to be used. In this paper the sole aim is to ensure that the model, which is a modified version of CIE: 115, 2010, is sufficiently accurate in determining the lighting class of the Indian roads, Table 1.

For validating the model, few motorized roads of Kolkata are considered. Uniqueness of Kolkata lies in the fact that it is one of the most populous metropolitan cities of India having a typical mixed traffic scenario. The motorized roads under consideration are surveyed and their distinct features are identified. Considering these distinct features of individual road, they are classified into different lighting classes. Table 1 exhibits the classification of few roads of Kolkata with respect to the modified CIE model. An extremely busy road with rapid traffic should obviously fall under a higher street lighting class than a comparatively less important road. But if a reverse situation happens, then the model used to determine the lighting class of the road is questionable.

As per Table 1, Grand Trunk Road (G.T. Road), the summation of V_{WS} is coming as 5.5. This is a very important and main road, hence, the exact class for this road is coming M1.Ballygunge Circular Road has a higher lighting class than Mayfair Road. By analyzing the practical scenario, the class of Mayfair Road should be lower than Ballygunge Circular Road as the traffic density of the latter one is much higher that the former one. Again considering Dover Lane, a very lonely road, has a lighting class lower than Mayfair Road, which is also justifiable. Thus, analysis says that the proposed classification system for Indian roads is valid, as it holds a sufficient accuracy in determining the road lighting class.

4. DEMONSTRATION OF FEW CASE STUDIES OF ROAD LIGHTING DESIGN BASED ON THE PROPOSED CLASSIFICATION MODEL

Few roads of Kolkata are classified considering the new model, and case study of these roads is done. In the case study, retrofit designing is carried out for each road.

– Vip Road lighting design condition and its existing traffic data is officially known as Kazi Nazrul Islam Sarani is a major thoroughfare connecting the city Kolkata with the Netaji Subhas Chandra Bose International Airport. It's located in the north-east outskirts of the city having an average width of 15 meters. There is also a median of 1 meter present throughout the roadway. Fig.1 shows the location of VIP Road. Fig. 2 shows the real time picture of this road.

Only motorized traffic is present with a very high average speed of more than 60 kmph. As the road leads towards the sole airport of the city, the traffic density is also very high; almost 50–60 vehicles flow per min. The visual guidance of the road is quite good because it's one of the most important roads of Kolkata.

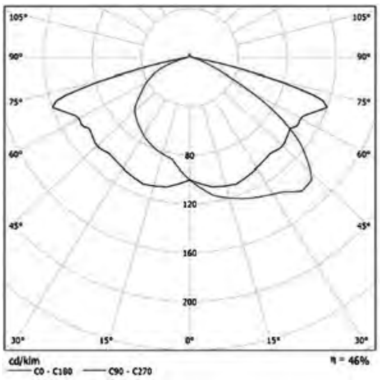
Thus analyzing the existing condition, the road class is found out to be M1. 400W High Pressure Sodium Vapor (HPS) luminaire (Fig. 3) is present with median arrangement, having mounting height 8 meter and span 18 meter.

– Redesigning of the lighting condition of the road – the controlling criteria of lighting of roads for motorized traffic are average luminance (L_{av}), overall uniformity (U_0), longitudinal uniformity (U_1), and surrounding ratio (SR). The recommended values of these parameters for different types of motorized roads are provided in CIE: 115, 2010. For every road, depending on its type of lighting class these criteria should be satisfied. But for VIP road it's seen that the criteria are not being satisfied as per its existing condition (details are provided in Table 2), thus retrofit designing is done for this road.

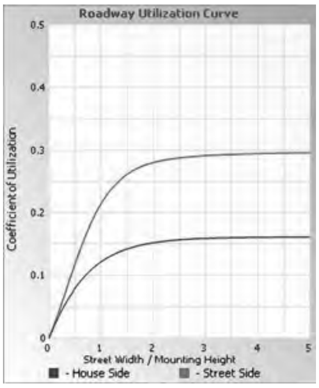
The luminaire used is changed and the height of the pole is also changed to fulfill the required value. Designing is done with 250W LED luminaire (Fig. 4) with median arrangement, having mounting height 10 meter and span 18 meter.

In Table 2 the comparison between the required value, the existing value and the achieved value is shown. The retrofit design does not satisfy the required value, but the achieved value by the retrofit

Fig. 2. Real time picture of VIP Road

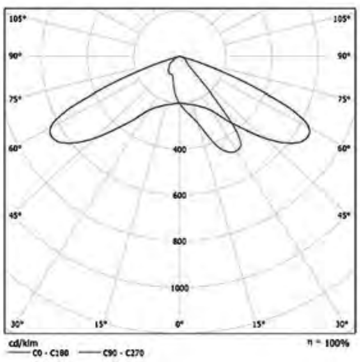


Polar curve of 400W HPS luminaire

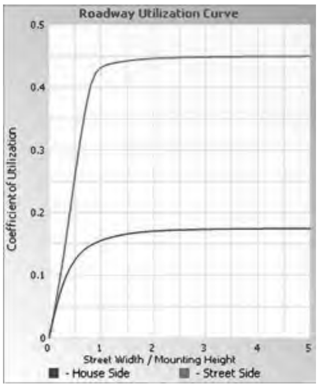


Coefficient of utilization (COU) of 400W HPS luminaire

Fig. 3 Polar Curve & COU diagram of 400W HPS luminaire



Polar curve of 250W LED luminaire



Coefficient of utilization (COU) of 250W LED luminaire

Fig. 4 Polar Curve & COU diagram of 250W LED luminaire

design is better than the value achieved by the existing design. The wattage of the luminaire used for retrofit design is much lower than the existent luminaire, which results in a huge energy saving.

– Energy saving calculation for existing design 400 W HPS is used, having an18-meter span and pole on median arrangement. Number of 400W lamp based luminaires required for the 1 km length equal to 110. Power consumption for a single 400W lamp and ballast system installed at existing pole is (400+58) W = 458 W. The total daily energy consumption of 400 W lamps for 12 h is (458×110×12) Wh = 604 kWh. For new design 250 W LED is used, having an 18-meter span and pole on median arrangement. Number of 250W LED based luminaires required for the 1 km length is equal to 110. Power consumption for a single 250W lamp and driver system installed at existing pole is equal to (250+12) W = 262 W. The total daily energy consumption of 250 W lamp for 12h is (262×110×12) Wh = 346 kWh. Hence, total daily energy saving from 400W HPS lamp to 250W LED for 1km length span of road is equal to (604–346) kWh = 258 kWh.

– When the road is classifying with respect to time, another vital issue of the time dependent lighting requirements changes is appearing. Generally, to classify any road, the weighting values of different traffic parameters are taken for evening peak hours. The recommended values of different lighting parameters are set considering the scenario of peak traffic hours. But a road that falls under a specific lighting class at evening peak hours may not fall under same lighting class at night time. The number of moving vehicles and their speed in a particular road changes with time. Changes may also occur for surrounding luminance. These changes results in the change of the lighting class of the road. For VIP Road a survey was done from 6.00pm to 12pm and from 00.01am to 6.00am. The traffic volume differs for these two separate time span. VIP Road having M1 class, changes to M2 class for the night time, i.e. off peak hours. The use of LED based luminaire not only provides the electrical energy savings, through the reduced installed power, it can also be dimmed as required. A 250 W LED luminaire is used for evening peak hours, which is dimmed to 172 W after midnight. Table 3 shows the

Table 2. Comparison of the Recommended Values of Photometric Parameters, Between the Existing Design and Retrofit Design Value

Class- M1	Recommended values of road lighting design parameter for motorized traffic mentioned in CIE115, 2010	Existing lighting design of VIP Road using 400W HPS luminaire	Retrofit design of VIP Road using 250WLEDluminaire
L_{av}	2.0	2.14	2.32
U_0	0.4	0.36	0.5
U_1	0.7	0.35	0.47
S.R	0.5	0.92	0.96

Table 3. Values of the Photometric Parameter Using a Dimmed LED Luminaire

Class- M2	Recommended values of road lighting design parameter for motorized traffic mentioned in CIE115, 2010	Retrofit design of VIP Road using 250 W LED in dimmed condition i.e. at 172W
L_{av}	1.5	1.49
U_0	0.4	0.5
U_1	0.7	0.47
SR	0.5	0.96

values of the photometric parameters achieved after dimming.

The similar studies have been carried out in few different categories roads of Kolkata. The results have been tabulated in Tables 4,5,6,7.

5. DEMONSTRATION OF A NEW ROAD DESIGN

A new road of width 15 meter is considered, which needs to be designed. The road has motorized traffic condition with vehicles moving at a very high speed and no parked vehicles present. The road lighting design of this street needs to be accomplished. The first step towards road lighting design is to find out the lighting class of the road which needs to be designed. Therefore, the lighting class of the considered road needs to be determined.

While analyzing the present scenario of the considered road it's seen that the road falls under M1 type of lighting class. Succeeding the class determination, proper designing needs to be carried out. To procure an appropriate design, the recommended values of M1 class for average luminance, overall and longitudinal uniformity, threshold increment and surrounding ratio need to be satisfied. Three types of light sources are considered:

– High pressure sodium vapour (HPS),
– Metal Halide (MH),
– LED.

Designing is done by these light sources. Table 8 shows the comparison of the obtained values by the three different luminaires. ***Therefore it is preferable to use 240W LED.***

Another vital issue is the time dependent changes of the lighting requirements. With time the number of moving vehicles in a particular road changes. Surrounding brightness may also vary with time. These changes result in the change of lighting class. For the above considered road the traffic volume is high from 6pm-11pm, almost 50–60 number of vehicles/minute are present; with the growing hours of night the traffic volume decreases gradually, it comes down to 30–50 number of vehicle/ min from 11pm to 2am, further it decreases to 10–30 vehicle number/min from 2am to 6am.There is a change noticed in the surrounding brightness also, after midnight it decreases to a lower level. Consequently, M1 type of road converts to M2 or M3 type of road. For M2 or M3 type of road the value of required luminance is less than that for M1 type of road.

Thus, when the luminance requirement is less, a lower wattage luminaire is required, but it's not possible to use two different wattage luminaire (at different time span) for the same road. LED, having a dimmable functionality, is preferred be

Table 4. Comparison of their Commended Values of Photometric Parameters, Between the Existing Design and Retrofit Design Value

Class- M2	Recommended values of road lighting design parameter for motorized traffic mentioned in CIE115, 2010	Existing lighting design of APC Road using 400W HPS luminaire	Retrofit design of APC Road using 250W MH luminaire
L_{av}	1.5	0.86	1.6
U_0	0.4	0.61	0.71
U_1	0.7	0.55	0.71
SR	0.5	0.98	0.95

Table 5. Comparison of Recommended Value of Photometric Parameters Between the Existing and Retrofit Design Value

Class- M3	Recommended values of road lighting design parameter for Motorized traffic mentioned in CIE115, 2010	Existing lighting design of Purno Das Road using 400 W HPS Luminaire	Retrofit design of Purno das Road using the under mention Luminaire 135 W LED Luminaire
L_{av}	1.0	0.9	1.4
U_0	0.4	0.71	0.67
U_1	0.6	0.53	0.57
SR	0.5	0.93	0.89

Table 6. Value of the Photometric Parameter Using Dimmed LED Luminaire

Class- M4	Recommended values of road lighting design parameter for Motorized traffic mentioned in CIE115, 2010	Retrofit design of Purno Das Road using 135W LED in dimmed condition i.e. at 90W
L_{av}	0.5	0.82
U_0	0.4	0.73
U_1	0.6	0.73
SR	0.5	0.9

used in these cases. Hence, for the considered road design with 240W LED is recommended, which can be dimmed as required. The change in the class of road with the changing hours of the day is shown in the Table 9.

With change of lighting class the requirement of luminance changes. Designing is done with dimming the 240W LED luminaire to 210W for M2 and 125W for M3 class, which is shown in Table10. It's seen that the desired level of photometric values is achieved by dimming the LED luminaire. Energy required for this condition is calculated below.

240 Watt LED is used, having a 16 meter span and double row opposing arrangement. Number of 240W LED based luminaires required for the 1 km length is 126. Power consumption for a single 240W lamp and driver system installed at existing pole is (240+10) W. The energy consumption from 6pm to 11pm of 240 W lamp for 5 h is (250×126×5) Wh= 157.5 kWh. Power consumption for a single 210W lamp and driver system installed at existing pole is (210+10) W. The energy consumption from 11pm to 2 am of 210 W lamp for 3 h is (220×126×3) Wh = 83.2 kWh. Power consumption for a single 125W lamp and driver system installed at existing pole is (125+10) W. The energy consumption from 2 am to 6am of 125 W lamp for 4h is (135×126×4) Wh = 68 kWh. The total daily energy consumption of 240 W lamp with dimming condition for 12 h is (157.5+83.2+68) Wh =308.7 kWh. Therefore, if dimming is done then energy consumed can be further reduced to 308.7 kWh from 378 kWh. Al-

Table 7. Comparison of Recommended Value of Photometric Parameters Between the Existing and Retrofit Design Value

Class-M5	Recommended values of road lighting design parameter for Motorized traffic mentioned in CIE115, 2010	Existing lighting design of Dover Lane using 135W LED luminaire	Retrofit Design of Dover Lane using 90W LED luminaire
L_{av}	0.5	1.01	0.53
U_0	0.35	0.3	0.59
U_1	0.4	0.62	0.57
SR	0.5	0.9	0.86

Table 8. Comparison of Recommended Value of Photometric Parameters Between the Existing and Retrofit Design Value

Class-M1	Recommended Values of Road Lighting Design Parameter for Motorized traffic Mentioned in CIE115, 2010	Lighting Design of New Road using 250W HPS Luminaire	Lighting Design of New Road using 250 W MH Luminaire	Lighting Design of New Road using 240W LED Luminaire
L_{av}	2	2.08	3.03	2.16
U_0	0.4	0.69	0.3	0.8
U_1	0.7	0.72	0.85	0.74
SR	0.5	0.97	0.49	0.5

most 70 kWh can be saved daily by just dimming the LED light.

Thus, for this 15-meter road designing by 240 W LED luminaire is recommended, keeping the arrangement double row opposing with a span of 16m and height of pole 9 m. For the peak hours (6–11) pm no dimming is required, from 11pm to 2am the LED luminaire should be dimmed down to 210W and further it should be dimmed down to 125W from 2am to 6 am to obtain the most optimum energy efficient design.

6. DISCUSSION

The entire paper depicts the enormous possibilities of changes to be inducted in road lighting design in Indian scenario. The example of VIP Road as has been given here clearly reveals that possibilities of up gradation of road lighting design. VIP Road is a very important road with just motorized traffic. The mathematical model as modified over existing CIE suggests that the lighting class of VIP road will be M1. The existing lighting design of VIP road is made with 400 W HPS luminaire, with 10 meter mounting height, and 18 meter spacing. The measured results are appreciably less than the recommended value. If the same is redesigned with LED maintaining the exact light level and uniformities as recommended for the specific lighting class, enormous energy will be saved as well as photometric and visual criteria are perfectly satisfying. Similarly, for Purno das Road (mixed traffic mainly motorized) the existing lighting design is made with 400 W HPS luminaire, with 9 meter mounting height and 20-meter spacing. The measured results of the existing setup are appreciably less than the recommended value. Hence, determination of exact lighting class and their energy efficient design based upon that will be the most optimized road lighting design in all the possible way.

7. CONCLUSION

A complete optimized road design encompasses all the possible aspects of photometric requirements as well as visual requirements with energy saving dimensioning. The optimization term will be justified in the context of energy saving as well

Table 9. Classification of the New Road for Different Time Span With Respect to New Model as per Indian Context

Sl No.	Road name	Traffic volume in № ./ min					Traffic speed km/h			Traffic class			Median		Cross road		Surrounding brightness			Parked vehicle		Visual guidance		Sum of weights (Vws)	Class of road (6-Vws)	Class as rounded up
		60 and above, very high	50–60, high	30–50, moderate	10–30, low	<10, very low	>60 Very High	40–60, High	<40, moderate	Mixed with High% of non-motorized	Mixed	Motorized only	No	Yes	High (above 3 nos. \Km)	Moderate (below 3 nos.\Km)	High	Moderate	Low	Present	Not Present	Poor	Moderate or Good			
		Weights					weights			weights			weights		weights		weights			Weights		weights				
		1	0.5	0	-0.5	-1	1	0.5	0	0	1	2	1	0	1	0	1	0	-1	0.5	0	0.5	0			
a)	NEW ROAD (6pm-11pm)	0.5					1			2			0		1		0			0		0		4.5	1.5	1
b)	NEW ROAD (11pm-2am)	0					1			2			0		1		0			0		0		4	2	2
c)	NEW ROAD (2am-5am)	-0.5					1			2			0		1		-1			0		0		2.5	3.5	3

Table 10. Comparison of Recommended Value of Photometric Parameters With the Achieved Values for New Road for Different Time Span

NEW ROAD	Class- M1(6pm-11pm)		Class- M2(11pm-2am)		Class- M3(2am-6am)	
	Recommended values of road lighting design parameter for Motorized traffic mentioned in CIE115, 2010	Lighting design of new road using 240W LED luminaire	Recommended values of road lighting design parameter for Motorized traffic mentioned in CIE115, 2010	Lighting design of new road using dimmed 240W LED luminaire (210W)	Recommended values of road lighting design parameter for Motorized traffic mentioned in CIE115, 2010	Lighting design of new road using dimmed 240W LED luminaire (125W)
L_{av}	2	2.16	1.5	1.66	1.0	1.12
U_0	0.4	0.8	0.4	0.8	0.4	0.8
U_1	0.7	0.74	0.7	0.74	0.6	0.74
SR	0.5	0.5	0.5	0.5	0.5	0.5

as requirements of road lighting. The different international and national standards say about the necessity of lighting classification of road. The classification methodology can help categorization of different roads from the traffic importance. This paper depicts that necessity of lighting classification of road in Indian context. Moreover, it also proposes a specific methodology to classify the Indian road from their traffic requirement. Indian road is typically mixed in nature. Hence, this specific classification methodology is suitable for lighting classification of road. The validation of the model has been executed with different roads of a metro city like Kolkata, as this city roads are more complex in nature. Moreover, the novelty of the paper is that, this paper depicts, how the requirement of lighting design parameters changed, even in the low traffic hours. This categorization method, suggests a specific shifting of the lighting class of a same road in different traffic hours at night time. Hence, lighting design of the roads should be done with luminaires having pre-programmed multi stage dimming facilities to achieve the desired lighting parameters during different traffic hours in night time. This can lead to a huge energy saving.

The other aspect, with which the paper has been dealt with, is how this classification system can be used for sake of optimized road lighting design. The evolved lighting class of the road will ensure the exact requirement of the photometric parameters for the concerned road. Hence, a step towards over designing will not at all be that frequent. The selections of luminaires as well as installation characteristics are the most vital criteria for quality road lighting design. This paper clearly reveals that aspect too. The selection of luminaire for a specific road lighting application is the most important step. The positioning of the luminaires, mounting height etc. are the installation characteristics which may change an entire design in a broader dimension. Though, the spectrum of the light sources plays a significant role in road lighting design, but that aspect has not elaborated in this paper.

This paper may finally be considered as a comprehensive guideline for optimized road lighting design. As the different countries have their different requirements based upon their nature of traffic, the proposed classification metric is also a pioneering step in Indian road lighting design.

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