Street Lighting Design and Analysis with Particular Reference to Abu Dhabi

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This paper briefly describes street lighting design and the standard requirements of lighting design in particular reference to UAE. The photometric parameters for different types of roads in Abu Dhabi is analysed and simulated using DIALux. The results are in agreement with the standard requirements. A realtime scenario has been done using cross section developer tool for different streets in Abu Dhabi. Simulation results have been compared with CIE and IESNA standards. In the analysis phase, photometric behaviours including chromaticity coordinates, S/P ratio, CRI, CCT values of different luminaires were compared. Higher CCT accounts for increased alertness in sleep. The proposed methodology shall motivate lighting design aspirants to balance efficient design along with sustainability.

Keywords: Street light design, luminance, illuminance

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1 Introduction

The objective of the lighting of traffic routes is to make other vehicles on the road viewable. It is done by producing a comparison between the luminance of the vehicle and the luminance of its immediate background, which is the road surface. This difference is obtained by increasing the luminance of the road surface above that of the vehicle so that it is seen in silhouette against the road surface.

According 2018 statistics of International Energy Agency (IEA), 3.2 % of the world electricity consumption is by streetlighting [1] as shown Fig. 1. Street lighting has always been a major task in energy efficiency because it represents 10 to 20% of the Electricity used in most cities and sometimes even more in developing countries.[12] The Abu Dhabi Municipality working with The Department of Municipal Affairs Abu Dhabi launched the Abu Dhabi sustainable lighting Strategy in 2010 to ensure the quality of vision as well as sustainable lighting would be the core of future development [2]. Proper street lighting design comes at this point where the photometric behavior of luminaire influences quality of vision as well as sustainability.

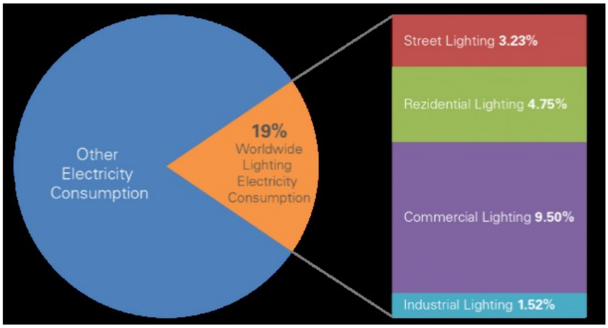


Fig. 1: Consumption of world electricity – Year 2018 (Source: International Energy Agency)

This paper endeavors the use of computer-based simulation software DIALux for streetlighting design. The photometric behaviour like Illuminance, Luminance, CCT measurement through simulation helps to evaluate efficiency, safety, health [3] and economic issues related to urban environment. The physical measurements using ordinary lux/candela meters are practically difficult and not design friendly. DIALux 4 is a user-friendly tool that improves its own performance consistently. The Department of Municipalities and Transport, Abu Dhabi prefers DIALux as lighting calculations software. Further lighting measurement field tests must be carried out after energizing the luminaires and before road opening in order to confirm actual lighting levels against the lighting calculations submitted to the authority [4].

Lighting parameters of the road luminance in practical case can be done by a Reflex-viewing automatic manual luminance meter. The density of the lighting system (PDI)Dp and the annual energy consumption indicator (AECI) as per EN 13201:2016[5] International Standards in Street Lighting includes guidelines issued by IESNA (Illuminating Energy Society of North America) viz ANSI/IESNA RP-8-00 and CIE 140/EN 13201[6].

Regarding LED/Solid State Lighting a list of items that still need research include metrics for assessing the effectiveness of roadway lighting, with and without headlights to achieve maximum contrast., metrics for assessing light depreciation and means of determining the end of useful life,

metrics to characterize environmental and health effects of roadway light spectrum[10-11]. The AMA (American Medical Associations) makes guidelines for outdoor lighting at night, particularly street lighting, which must include a color temperature of no greater than 3000K[16].The questions still arising while designing using LED luminaires include, Will the higher color temperature of LED luminaries result in the need for less overall illumination? Will LED luminaires last as long in the field as predicted by manufacturers? Does the higher color temperature of LED luminaires create any health concerns related to the effect of melatonin levels on sleep and alertness? Does the higher color temperature of LED luminaires create any environmental concerns?
In this work we simulated standard expressway, city boulevard, city avenue, city street, and access lane in Abu Dhabi using DIALux 4.13 with CIE as well as IESNA standards and also analysed the photometric behaviour of different LED luminaires. The proposed design strategy balances to choose luminaires having higher quality of illumination and which are environment friendly.

2 Lighting Standards in UAE – Literature Review

An optical technique to calculate problem of illuminance distribution of LED street lighting luminaires is to calculate the luminous flux of LEDs in street lighting applications. This technique selects the LED, lenses, and the driver, for a full luminaire design [7].Regarding dimming systems in street LEDs,Hussain .A.Attia proposed a decentralized street LED dimming system that is installed on each pole and whose dimming action is controlled by the dimming circuit of the pole itself[14].

Bassam Hesham J in Bahrain illustrated an intelligent system to simulate a real – life scenario. As far as now most of the street lighting systems in Bahrain use non-dimmable High-Pressure Sodium Lamps (HPS) with on/off control system. The present day system is costlier, may cause irrelevant energy use in many regions, and reduces the life span of lamps. While comparing High-Pressure Sodium and LED was, it is clear that Power consumption cost of LED is less than the power consumption cost of High Sodium Lamps [8]
In another case study in Qatar, ME2 represents urban areas lighting class with 30 miles per hour as speed limits and have high end pedestrian activity including zebra crossings.ME3a represents 40 mph or less speed limit, parking is restricted at peak times and there are positive measures for pedestrian safety reasons. The case study in this paper was conducted for 6 km road project using Dialux 4.9 software [9,15].An important aspect of road surface lighting is how much it can improve pedestrianvisibility[13].

2.1 Streetlighting Standards in Abu Dhabi

The roads in Abu Dhabi are classified as Freeways/Expressways, Boulevard, Avenue, Street, Access Lane according to the average daily traffic flow (ADT), the speed of vehicles, the type of vehicles in the traffic and the frequency of conflict areas and pedestrians.

Road lighting is generally divided into different classes; for motorized traffic where the needs of the driver are important, subsidiary roads where the lighting is primarily intended for the pedestrian and cyclist, and for urban centers where public safety and security are priority.

2.1.1 Design Criteria

The main design criteria are Minimum Average Design Level viz the Luminance (Lav), illuminance (Eav), as well as overall uniformity (U0), threshold increment (Tl), Surround Ratio (SR) of the road surface.

2.1.2 Lighting Classes for Traffic Routes

Lighting classes as per DMA (Department of Municipal Affairs Abu Dhabi) In Roadway and Public Realm Lighting specification and Roadway Compliance Check List Table are shown in the graph (Fig.2).

Lighting Class M2 is to be adopted as per DMA Lighting Specifications either a luminance of 1.3 cd/m² or 1.5 cd/m², which means approximately 20 lux or 25 lux of illuminance. Lighting Class M4 is to be adopted as 1.0 cd/m², this means approximately 15 lux. Comparison of luminance for different lighting class are shown in Fig. 2. The schedule of Lighting Levels as per PR-402 ADM Lighting Manual version 3.0: July 2021are shown in the Table 1.

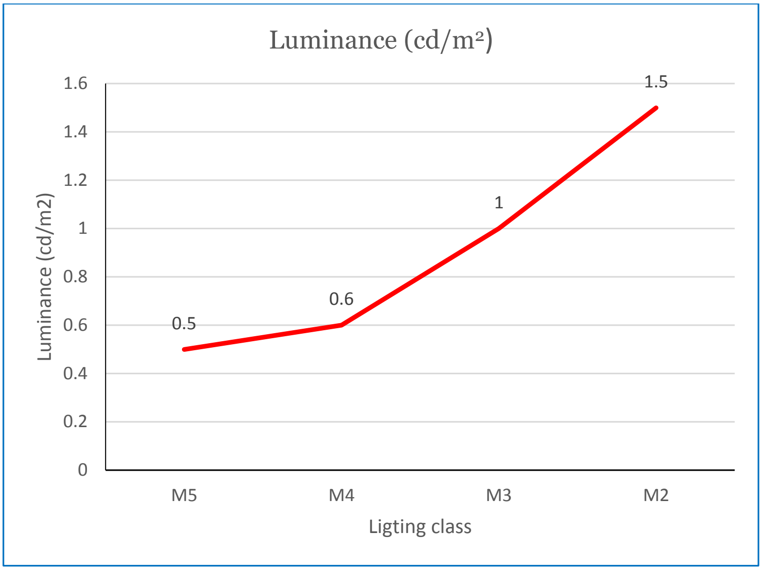


Fig. 2: Comparison of Illuminance

Table 1. Lighting Classes recommendation for Traffic Routes at Abu Dhabi

Area/Road way Type/ Lighting Class	Minimum Average Design Level: Luminance(L)=cd/m² Illumination (Em)=lux	Uniformity Ratio (Minimum to Average)	Longitudinal Uniformity (Minimum to Maximum)	Emin /E max	TI	SR (EIR)	Pole Heights, Spacing & Priority Arrangements
Highways/ Freeways (100Kph or higher)	1.0 cd/m² (Conflict Areas 30lux)	Uo≥0.4	Ul ≥ 0.7	≥0.2	≤10 %	≥0.5 (≥0.35)	20m Pole Height 80-95m Spacing Median Arrangement
Major Arterials (80Kph)	1.0 cd/m² (Conflict Areas & Crosswalks 30 lux)	Uo≥0.4	Ul ≥ 0.7	≥0.2	≤10 %	≥0.5 (≥0.35)	20m Pole Height 80-95m Spacing Median Arrangement

Arterials (60Kph) (USDM: Boulevards)	1.2 cd/m² (Conflict Areas & Crosswalks 30lux)	Uo≥0.4	Ul ≥ 0.7	≥0.2	≤10 %	≥0.5 (≥0.35)	14m Pole Height 55-69m Spacing Median Arrangement
Secondary Arterial (USDM: Avenues)	0.8 cd/m² (Conflict Areas & Crosswalks 20 lux)	Uo≥0.4	Ul ≥ 0.7	≥0.2	≤15 %	≥0.5 (≥0.35)	14m Pole Height 55-69m Spacing Median Arrangement
Sector Internal Roads (USDM: Streets)	8-10 lux (Conflict Areas & Crosswalks 15lux)	Uo≥0.4	N/A	≥0.2	≤15 %	N/A	8-10m Pole Height 40-45m Spacing Single-Sided
Access Lanes (USDM)	5-7.5 lux (Conflict Areas & Crosswalks 15lux)	Uo≥0.4	N/A	≥0.2	≤15 %	N/A	8-10m Pole Height 40-45m Spacing Single-Sided

Higher values of threshold increment account for greater disability glare. A 5% of minimum threshold increment is permitted where low luminance light sources are used. In certain conditions, it is difficult to compute the maximum threshold increment. Another method to reduce disability glare is to choose a luminaire as per the classes in Table 2. Various classes are denoted by the luminous intensity of the luminaire, in candelas/1000 lumens of bare light source output, at 70, 80, and 90 degrees from the downward vertical, in any direction, and the luminous intensity above 95 degrees, in any direction. Class G3 represents a cut-off luminaire. Class G6 represents to a full-cutoff luminaire. The higher the class the better.

Table 2. Luminaire classes for the control of disability glare

Lighting Class	Maximum Luminous intensity /1000 lumens at 70 (cd/1000 lm)	Maximum Luminous Intensity /1000 lumens at 80 (cd/1000 lm)	Maximum Luminous Intensity /1000 lumens at 80 (cd/1000 lm)	Luminous Intensity above 95 (cd)
G1	-	200	50	-
G2	-	150	30	-
G3	-	100	20	-
G4	500	100	10	0
G5	350	100	10	0
G6	350	100	0	0

The general requirements of LED include

- Test reports regards to LED chips, fitting type, and driver current
- High-power white LEDs with a minimum efficacy of 125LPW for 4000K shall be used
- Drivers RoHS compliance, IP 66 for whole fitting
- Drivers shall be IP66 encapsulated type, driver current maximum of 750m A, and shall work at 80°C ambient temperature, driver, THD shall be less than 20%
- CRI minimum 70, refractor shall be tempered glass with minimum IK08
- Housing shall be high pressure die cast aluminum with low copper content designed to manage heat generation

As per CIE 115:2010[18] the lighting classes for motorized traffic is shown in Table 3 and lighting classes for Pedestrian and low speed traffic is shown in Table 4. M&C Lighting classes for different values of Road Surfaces q0 are shown in Table 5.

Table 3. Light classes for Motorised Traffic from CIE 115:2010

Lighting Class	Road Surface				Threshold Increment	Surround Ratio
	Dry			Wet		
	Lav in cd·m-2	U_o	U_l	U_o	*f*TI in %	*R*s
M1	2.0	0.40	0.70	0.15	10	0.50
M2	1.5	0.40	0.70	0.15	10	0.50
M3	1.0	0.40	0.60	0.15	15	0.50
M4	0.75	0.40	0.60	0.15	15	0.50
M5	0.50	0.35	0.40	0.15	15	0.50
M6	0.30	0.35	0.40	0.15	20	0.50

Table 4. Light classes for Pedestrain and low speed traffic areas from CIE 115:2010

Lighting Class	Average horizontal illuminance Eh, av in lx	Minimum horizontal illuminance Eh, min in lx	Additional requirement if facial recognition is necessary	
			Minimum vertical Illuminance Ev, min in lx	Minimum semicylindrical Illuminance Esc, min in lx
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

Table 5. M and C Light classes of Comparable lighting levels for different values for q0 from CIE 115:2010

Lighting class M			M1	M2	M3	M4	M5	M6
Average luminance *L* in cd/m²			2.0	1.5	1.0	0.75	0.50	0.30
Lighting class C if $q0$ = 0.05 cd/m²			C0	C1	C2	C3	C4	C5
Average illuminance *E* in lx			50	30	20	15	10	7.5
Lighting class C if $q0$ = 0.07 cd/m²		C0	C1	C2	C3	C4	C5	
Average illuminance *E* in lx		50	30	20	15	10	7.5	
Lighting class C if $q0$ = 0.05 cd/m²	C0	C1	C2	C3	C4	C5		
Average illuminance *E* in lx	50	30	20	15	10	7.5		

IESNA classifies [17]roads as freeway A, freeway B, expressway, major, collector, local. Recommended values as per luminance method of IESNA are given in Table 6.

Table 6. Luminance Method – Recommended Values

Road and Pedestrian Conflict Area		Average Luminance L_{avg} (cd/m²)	Uniformity Ratio L_{avg}/L_{min} (Maximum allowed)	Average Luminance L_{max}/L_{min} (Maximum allowed)	Average Luminance L_{Vmax}/L_{avg} (Maximum allowed)
Road	Pedestrian Conflict Area				
Freeway Class A		0.6	3.5	6.0	0.3
Freeway Class B		0.4	3.5	6.0	0.3
Expressway	High	1.0	3.0	5.0	0.3
	Medium	0.8	3.0	5.0	0.3
	Low	0.6	3.5	6.0	0.3
Major	High	1.2	3.0	5.0	0.3
	Medium	0.9	3.0	5.0	0.3
	Low	0.6	3.5	6.0	0.3
Collector	High	0.8	3.0	5.0	0.4
	Medium	0.6	3.5	6.0	0.4
	Low	0.4	4.0	8.0	0.4
Local	High	0.6	6.0	10.0	0.4
	Medium	0.5	6.0	10.0	0.4
	Low	0.3	6.0	10.0	0.4

3. Research Methodology

Prior to the simulation design, the following information is required for street lighting calculation.

- Mounting height

- Luminaire type and optic setting
- Lamp type
- Initial luminous flux of the lamp
- IP rating of the luminaire
- Leaning interval planned for the luminaire
- Pollution category for location
- Luminaire maintenance factor
- Lamp replacement interval
- Lighting class
- Luminaire tilt
- Width of carriageway
- Width of driving lane
- Width of adjacent areas
- Luminaire arrangement

The evaluation is done using simulation in DIALux 4.13. DIALux is a digital lighting software-based mode and tool concept. Street lighting simulation steps in DIALux are described below.

1. Input the road geometrical information like the number of lanes, details of sidewalks, details of medians, lay by, grass strip etc. with their geometric dimensions in SI Units.

2. For the luminaire design select the luminaries either from catalogs or from lumsearch or from the IES files for the luminaires already available and then arrange the luminaries from the provided luminaire arrangements.
3. Start calculations once the luminaire is selected. After that change the luminaires if it does not satisfy the recommended lux levels or change the luminaire arrangements.
4. Repeat the above steps until recommended lux levels are satisfied.
5. Documentation task bar will have all the documents including the product data sheet.

Typical standard expressway, city boulevard, city avenue, city street, and access lane from Abu Dhabi Road Cross-sections Developer Tool has been simulated using DIALux 4.13 for both CIE as well as IESNA standards. There is a difference between IESNA and CIE standards at the arrangement of luminaire during photometric measurement. The American standard works with an alignment of C0 plane perpendicular to the kerb while the European Standard works with alignment of C0 plane parallel to the kerb.

3 Simulation Results and Analysis

3.1 Typical Expressway

Typical expressway in Abu Dhabi consists of five or six lanes each of width 3m and ADT (Average Daily Traffic) greater than 40000, vehicle speed 100kmph or higher is considered and is created. Maintenance factor of 0.80 is used in all areas of the project. IESNA RP-8-00 as well as CIE is chosen with Tarmac R3 for road surface. Lighting construction uses PHILIPS BGP627 T25 DX70 /740 405W LED with luminous flux of 66000lm, CCT 3000K. Height of the pole selected as 20.00m and the distance between poles is 80m. Average luminance of 1.3cd/m^2 has been observed. The overall uniformity is 0.43. Photometric results for expressways as per IESNA and CIE methods are shown in Fig. 3 and Fig.4 respectively. As per Abu Dhabi Streetlighting Standards Simulation results are satisfactory.

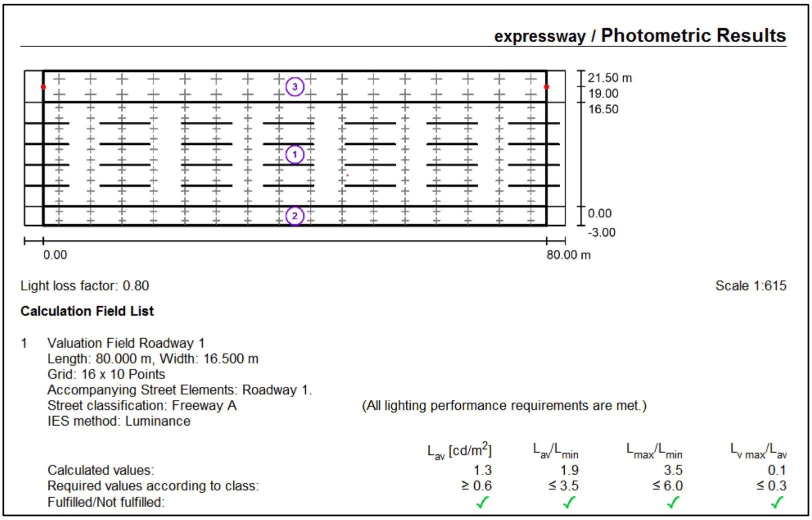


Fig. 3: IESNA Photometric Results for Expressways

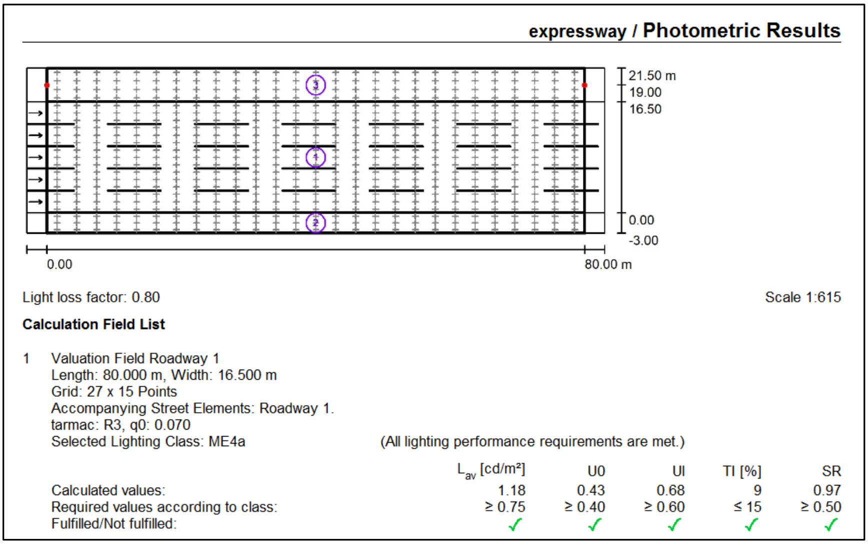


Fig. 4: CIE Photometric Results for Expressways

3.2 Typical City Boulevard

Typical city Boulevard consists of two lanes of 3.3m and one outer lane of 3.5m on each side separated by 6m median.it has a frontage lane of 3m width connecting to the main lanes with a lay by of 2.5m. Typical boulevards usually have ADT is around 15000and vehicle speed 60kph.

Luminaire used is PHILIPS BGP627 T25 DX70 /740 405W. Height of the pole was 14.00m and the distance between poles is 56m in the study. Cross section details are shown in Fig. 5 and IESNA and CIE photometric results are shown in Fig. 6 and Fig.7. Average luminance is 1.3 cd/m² for IESNA and 1.27 cd/m² for CIE results. Uniformity values for CIE is not satisfied with the same arrangements.

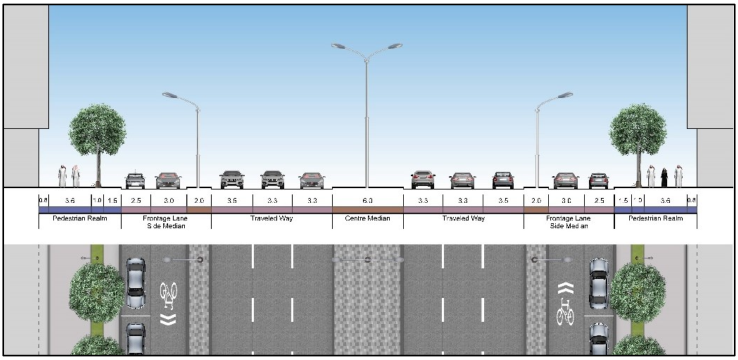


Fig. 5: Cross Section of Typical City Boulevard at Abu Dhabi

Light loss factor: 0.80 — Scale 1:444

Calculation Field List

1 Valuation Field Roadway 1
Length: 56.000 m, Width: 10.100 m
Grid: 12 x 6 Points
Accompanying Street Elements: Roadway 1.
Street classification: Freeway A
IES method: Luminance

(All lighting performance requirements are met.)

	L_{av} [cd/m²]	L_{av}/L_{min}	L_{max}/L_{min}	$L_{v\,max}/L_{av}$
Calculated values:	1.3	2.2	4.2	0.1
Required values according to class:	≥ 0.6	≤ 3.5	≤ 6.0	≤ 0.3
Fulfilled/Not fulfilled:	✓	✓	✓	✓

Fig. 6: IESNA Photometric Results for Typical City Boulevard at Abu Dhabi

Light loss factor: 0.80 — Scale 1:444

Calculation Field List

1 Valuation Field Roadway 1
Length: 56.000 m, Width: 10.100 m
Grid: 19 x 9 Points
Accompanying Street Elements: Roadway 1.
tarmac: R3, q0: 0.070
Selected Lighting Class: ME4a

(Not all lighting performance requirements are met.)

	L_{av} [cd/m²]	U0	Ul	TI [%]	SR
Calculated values:	1.27	0.38	0.43	10	1.00
Required values according to class:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15	≥ 0.50
Fulfilled/Not fulfilled:	✓	✗	✗	✓	✓

Fig. 7: CIE Photometric Results for Typical City Boulevard at Abu Dhabi

3.2 Typical Avenue

Typical Avenue has two 3.3m inner lane and two outer lane of 3.5m lane separated by 6m median and two lay by on both sides of 2.5m. scheduled lighting levels are 0.8cd/m2.PHILIPS BGP 627 T 25 DX70 having 405W has been used in the 6m median with pole height of 14 m and spacing of 55m. In the Pedestrian Realm PHILIPS Luma 2 BGP625 225W DW10 is used with a pole height of 10m and spacing of 40m having luminous flux of 31923 lm. All design parameters of the three lanes are satisfactory with IESNA standards . Cross section details of City Avenue are shown in Fig. 8. IESNA and CIE photometric results are shown in Fig. 9 and Fig.10 respectively.

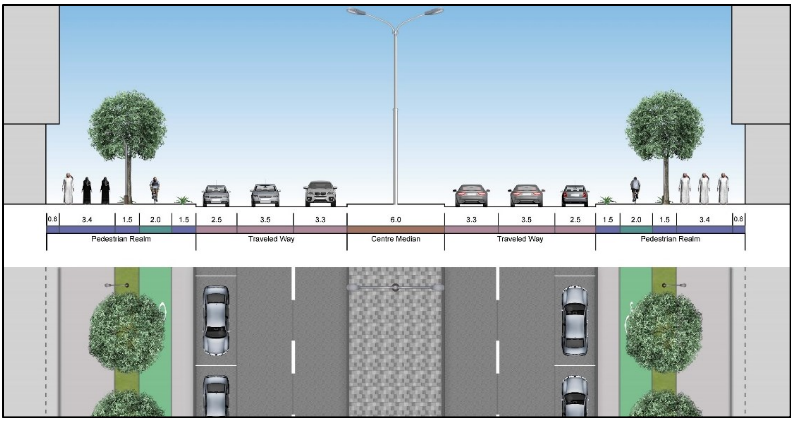


Fig. 8: Cross section of Typical city Avenue at Abu Dhabi

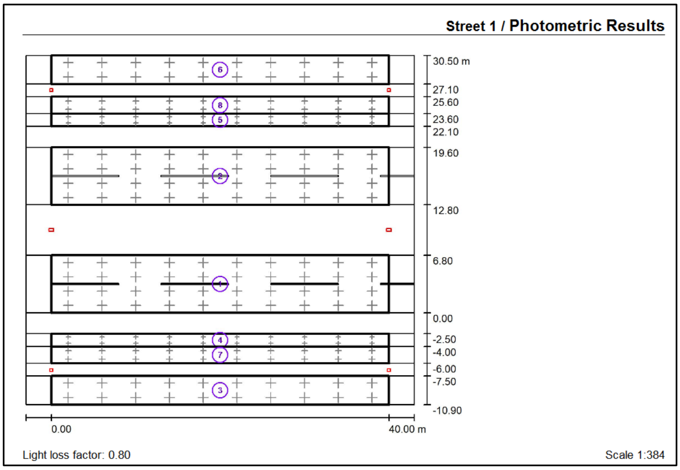


Fig. 9: Photometric Results

Light loss factor: 0.80 Scale 1:384

Calculation Field List

1 Valuation Field Roadway 1
Length: 40.000 m, Width: 6.800 m
Grid: 10 x 4 Points
Accompanying Street Elements: Roadway 1.
Street classification: Freeway A
IES method: Luminance

(All lighting performance requirements are met.)

	L_{av} [cd/m^2]	L_{av}/L_{min}	L_{max}/L_{min}	$L_{v\,max}/L_{av}$
Calculated values:	2.8	1.8	2.8	0.1
Required values according to class:	≥ 0.6	≤ 3.5	≤ 6.0	≤ 0.3
Fulfilled/Not fulfilled:	✓	✓	✓	✓

Fig. 10:IESNA Photometric Results for Typical Avenue at Abu Dhabi

Light loss factor: 0.80 Scale 1:384

Calculation Field List

1 Valuation Field Roadway 1
Length: 40.000 m, Width: 6.800 m
Grid: 14 x 6 Points
Accompanying Street Elements: Roadway 1.
tarmac: R3, q0: 0.070
Selected Lighting Class: ME4a

(Not all lighting performance requirements are met.)

	L_{av} [cd/m²]	U0	Ul	TI [%]	SR
Calculated values:	2.69	0.49	0.47	6	1.01
Required values according to class:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15	≥ 0.50
Fulfilled/Not fulfilled:	✓	✓	✗	✓	✓

Fig. 11: CIE Photometric Results for Typical Avenue at Abu Dhabi

3.3 Typical City Street

Typical City Street has two 3.0m lanes and lay by on both sides of 2.5m. scheduled lighting levels are 8 to 10 lux. PHILIPS MVP 506 1X CDM- having 341W has been used with pole height of 10 m and spacing of 40m. All design parameters of the three lanes are satisfactory. Cross sectional details of City Street are shown in Fig. 11. IESNA and CIE Photometric Results for Typical City Street are shown in Fig.12 and Fig.13 respectively.

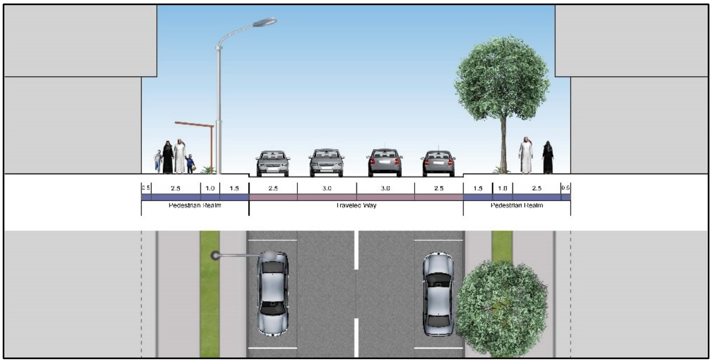


Fig. 12: Cross section of Typical city Avenue at Abu Dhabi

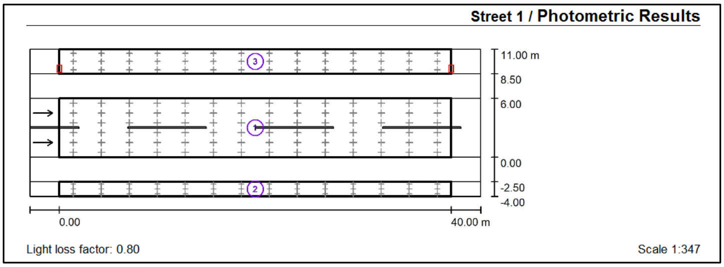


Fig. 13: Photometric Results

Light loss factor: 0.80 Scale 1:347

Calculation Field List

1 Valuation Field Roadway 1
Length: 40.000 m, Width: 6.000 m
Grid: 10 x 4 Points
Accompanying Street Elements: Roadway 1.
Street classification: Freeway A
IES method: Luminance

(All lighting performance requirements are met.)

	L_{av} [cd/m²]	L_{av}/L_{min}	L_{max}/L_{min}	$L_{v\,max}/L_{av}$
Calculated values:	1.6	1.5	2.3	0.2
Required values according to class:	≥ 0.6	≤ 3.5	≤ 6.0	≤ 0.3
Fulfilled/Not fulfilled:	✓	✓	✓	✓

Fig. 14: IESNA Photometric Results for Typical City Street at Abu Dhabi

Light loss factor: 0.80 Scale 1:347

Calculation Field List

1 Valuation Field Roadway 1
Length: 40.000 m, Width: 6.000 m
Grid: 14 x 6 Points
Accompanying Street Elements: Roadway 1.
tarmac: R3, q0: 0.070
Selected Lighting Class: ME4a

(Not all lighting performance requirements are met.)

	L_{av} [cd/m²]	U0	Ul	TI [%]	SR
Calculated values:	1.50	0.58	0.46	7	0.67
Required values according to class:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15	≥ 0.50
Fulfilled/Not fulfilled:	✓	✓	✗	✓	✓

Fig. 15: CIE Photometric Results for Typical City Street at Abu Dhabi

3.4 Typical City Access Lane

Typical City Access Lane has two 3.0m lanes. scheduled lighting levels are 5 to 7 lux. PHILIPS BGP621 T25 DN08/740,75 W LED has been used with pole height of 8 m and spacing of 40m. As per IESNA standards all design parameters of the three lanes are satisfactory. Cross section details of City Access Lane are shown in Fig. 14. IESNA and CIE Photometric Results Typical City Access Lane are shown in Fig. 15 and Fig.16 respectively.

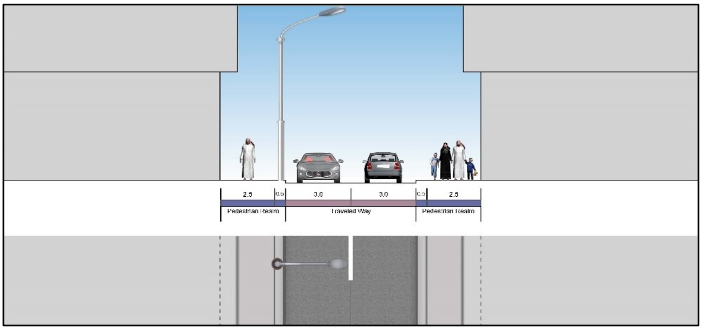


Fig. 16: Cross Section of Typical City Access Lane at Abu Dhabi

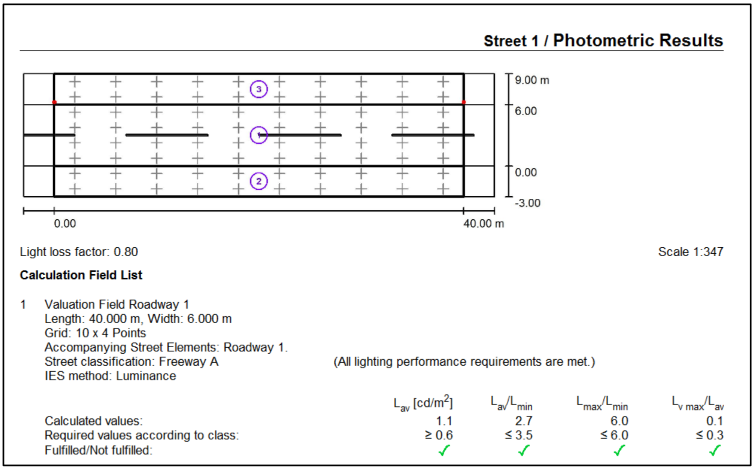
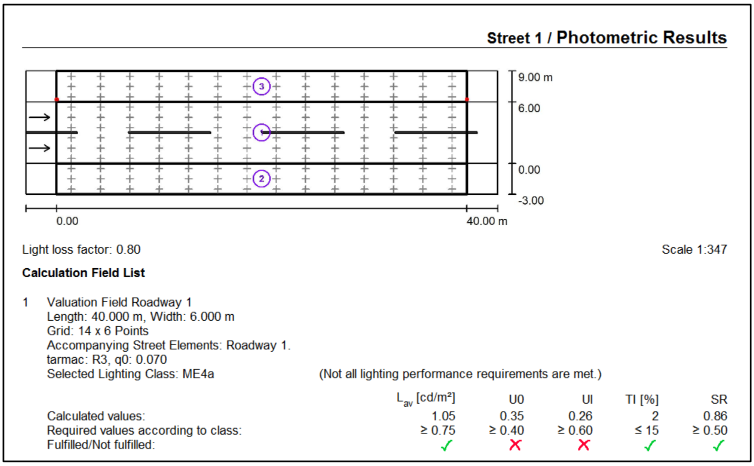


Fig. 17: IESNA Photometric Results for Typical City Access Lane at Abu Dhabi



Street 1 / Photometric Results

Light loss factor: 0.80 Scale 1:347

Calculation Field List

1 Valuation Field Roadway 1
Length: 40.000 m, Width: 6.000 m
Grid: 14 x 6 Points
Accompanying Street Elements: Roadway 1.
tarmac: R3, q0: 0.070
Selected Lighting Class: ME4a (Not all lighting performance requirements are met.)

	L_{av} [cd/m²]	U0	Ul	TI [%]	SR
Calculated values:	1.05	0.35	0.26	2	0.86
Required values according to class:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15	≥ 0.50
Fulfilled/Not fulfilled:	✓	✗	✗	✓	✓

Fig. 18: CIE Photometric Results for Typical City Access Lane at Abu Dhabi

Analysis of different Luminaire Types for Sustainability

The Lighting construction includes exporting Luminaire files from different catalogs other than the built in DIALux luminaire Catalog. Philips luminaires having CCT of 3,000K and 4,000K have been used for the different types of streets. Philips LEDs with lower CCT produces lesser white light in comparison with other luminaires and found to be more efficient when considering sustainability and visual comfort.

4 Conclusions

DIALux is a user-friendly tool which improves its own performances consistently. Literature survey for Streetlighting design of Abu Dhabi has been done. Simulations has been carried out using DIALux software for the Typical Expressways, Boulevard, Avenue, city street and access lane in the Emirate of Abu Dhabi. Simulation results shows the satisfactory results with IESNA standards on all type of roads. Uniformity values of CIE standards are not satisfied for similar road projects.

In this paper, we simulated road lighting design with particular reference to Abu Dhabi and compared CIE and IESNA standards. Also analyzed and compared photometric behaviour of different luminaires. Philips LEDs having CCT of 3000K is found to be rendering lesser white light levels than those having 4000K.

The proposed methodology shall motivate the lighting design aspirants to consider the colour calibration reports to calculate colour values and CCT recommended by CIE and recommends to balance visual comforts along with efficient designs.

References

1. International Energy Agency (2018)” IEA 2018 Report”

2. AbuDhabi City Municipality (2014)”Abu Dhabi Public Realm and Street Lighting Handbook”pg-9

3. Yao.Q, Zhang.w, Zhang.L,Bian.Y (2020)“Establishing functional Model of Photometric Performance of Trichromatic Light Sources in Chromaticity Diagrams” vol 28 no 4/17IEEE photonics.

4. Government of AbuDhabi(2021) “PR-402 ADM Lighting manual’’,third edition pg23

5. Hristian panchev,university of varna,Bulgaria(2021)”Research and analysis of lighting and energy performance of the street lighting segment of the highway” IEEE

6. Road lighting-part1,2,3,4,5-European Lighting Standard EN13201-2015

7. Vitor.C. Bender,(2013)” Design methodology for street lighting luminaires based on a photometrical analysis”IEEE

8. Bassam Hesham J, Nour-Eddine Mansour, university of Bahrain,(2019)” Bahrain intelligent street lighting -A study to Retrofit Bahrain street lighting” IEEE

9. Shereen Farhana, Mazen Elsaadany(2019),” An optimal stand-alone solar streetlight system design and cost estimation”2021 IEEE,6th international conference on renewable energy: generation and applications

10. American Association of State Highways And Transportation Officials-(2018) “AASHTO Roadway Lighting Design Guide”pg 11

11. Colorado Department of Transportation (2019)“Lighting Design Guidelines”

12. Tiago. F. Vieira, Davi B Brito,(2019) “An IoT based smart utility pole and street lighting system” IEEE

13. Donghee han,Hyo Bin choi and Yong sin kim,(2018)”Design of Road Surface Lighting system for rear lamp using automotive ultrasonic sensor” IEEE

14. Hussain.a.attia ,Amjad omer,Maen Takruri,(2016)”Design of decentralized street LED Light Dimming System”IEEE

15. Safaa Alzubaidi,and Prashant kumar soori,(2012)”study on energy efficient street lighting system design” IEEE

16. US Department of Transportation Federal Highway Administration (2012)“Lighting Handbook”

17. Illuminating Engineering Society of North America(2000) “American National Standard Practice for Roadway Lighting ANSI/IESNA RP-8”

18. International Commision on Illumination(2010)”Lighting of Roads for Motor and Pedestrian Traffic,”CIE 115:2010