International Commission on Illumination
Commission Internationale de l'Eclairage
Internationale Beleuchtungskommission

OP10

NEW WAYS TO ACHIEVE CLIMATE AIM IN ROADWAY LIGHTING

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DOI 10.25039/x46.2019.OP10

from

CIE x046:2019

Proceedings
of the
29th CIE SESSION
Washington D.C., USA, June 14 – 22, 2019

(DOI 10.25039/x46.2019)

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NEW WAYS TO ACHIEVE CLIMATE AIM IN ROADWAY LIGHTING

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DOI 10.25039/x46.2019.OP10

1 Motivation

In many industrial countries, traditional luminaires with gas discharge technology are replaced with LED luminaires. Replacement to LEDs provides nearly 50% energy savings, as demonstrated by various studies. In parallel, as noted by Gibbons and Fotios [1] in 2018, the illuminance level has been increasing continuously over the last 50 years.

If 30-year old luminaires are replaced today with LEDs, the luminance level according the standard for the new installation is much higher, see Figure 1.

Figure 1 – Replacement of luminaires (left picture: view after right: post installation; right picture: view after left after installation)

Therefore, this situation raises the following two questions: Is the energy saving based on new LED luminaires offset by the higher light levels generated? Do we, as lighting engineers and designers, are at the end with our knowledge regarding energy savings?

2 How can we save energy?

The solid state lighting has significantly more potential than only the high luminance efficacy. The following 7 approaches should be discussed:

1. Using adaptive concepts
2. More precise light distribution
3. Use of the Utilization factor
4. Car2X - Communication
5. Reducing glare sources
6. Using VL-concepts
7. Marking light

In the following paper, points 1, 2, 4 and 7 will be addressed. The others points will be discussed in the presentation.

3 Adaptive illumination concepts

The idea of adaptive illumination concepts is not new. Light should be switched off when it isn't needed. Road lighting is an exception. Currently, thousands of kilometres of roads are illuminated although no users are present on these roads during the entire night. The energy was cheap, the illumination was used as a ground ballast for the power station during the night, the gas discharge technology used was not developed for short switch on and off times, and residents and road users complain when the road lighting was switched off.

In the meantime, the price of energy is increasing, (where some local authorities pay the half of their budget on the energy costs of road lighting), the technology of power station used is changing, it is no longer necessary to use road lighting as a ground ballast, the Solid-State-Lighting supply the technical conditions to use adaptive concepts and a ‘Green policy’ will be more and more acceptable.

Recent projects have shown (for instance Interreg [2]), that a reduction of energy demand of 50 % related to the currently standard technology used is possible. Before a wider roll out commences, cheap and reliable sensor and network technology are necessary.

The broad understanding about adaptive light is to dim the light when is not needed. But adaptive lighting means much more, particularly as the roadway is not the only relevant area for lighting. Different zones with different demands exist. While the light levels for roads are well defined, the criteria for cyclists and pedestrians are much more uncertain and criteria for facades are very rudimentary. First if we have specific criteria for different relevant areas, luminaires can be designed as address the lighting needs which match the necessary demands. The new concept of road lighting is now described as ‘**Zonal Adaptive Lighting (ZAL)**, what means: Only so much light - on *specific areas* (road, parking zone, cycle and pedestrian path and facades) at a *specific time* – as is needed (project Steffi).

4 Precise light distribution

The aim of this study (project Steffi) was to reveal how much energy, in percentage terms can be saved, if a precisely controlled light distribution is used compared to the best available standard light distribution. A simulation tool was developed at the TU Berlin (project UNILED), to determine optimal luminance intensity body for different criteria given. Such criteria are

- maximal homogeneous illuminance distribution for a road class by limited glare values (TI) and minimal luminance flux
- maximal homogenous luminance distribution for a road class including dry or wet road by limited glare values (TI) and minimal luminance flux and
- best visibility conditions (described by VL, STVL, Revealing power, Probability of hidden zones) for a road class including dry or wet road by limited glare values (TI) and minimal luminance flux.

The comparison was calculated for a range of lighting situations. The following illustrates the simulation steps:

- Task: Find an optimized luminance intensity body for the following road (ME3 class; width: 9 m + footpath) with a standard evaluation field (from 60 m to 100 m)
- Pole parameter: height (h) = 12 m, 1 m overhang; pole spacing: 60 m

Figure 2 shows the result of the simulation:

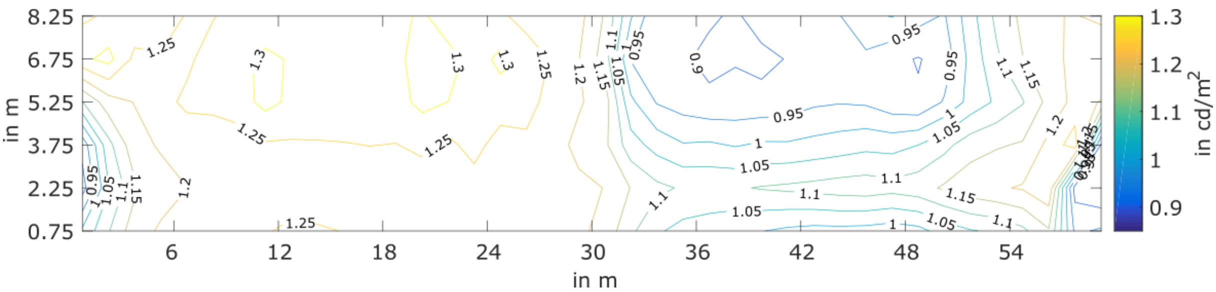

Figure 2 – Luminance distribution for the observer in 60 m distance from the point 0 m for an optimized LIC

The following numbers are be achieved: L_{min}=0.85 cd/m^2, L_{max}=1.32 cd/m^2, L_{ave}=1.14 cd/m^2, U_0=0.75, TI = 11, Φ = 8,000 lm.

The next step was to find the lens, which can create this lighting distribution, even though this lens may not be normally available. The best fit of the searched LIC can be achieved through combination of 2 to 3 different lighting distributions, see Figure 3. In the example presented, the match of the lighting distributions was 83% for the measuring field.

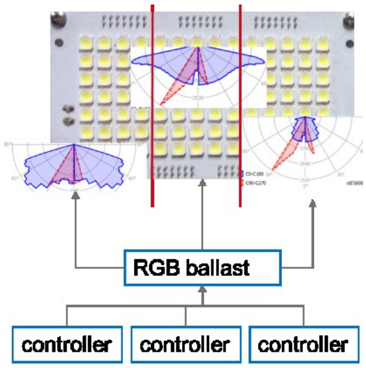

Figure 3 – Creation of the optimized LIC through combination of different lighting distributions

Table 1 demonstrates the potential energy saving for different calculation methods and LICs. The second column shows necessary luminance flux for a luminaire chosen by the corresponding CE3 class. If this method (CE 3 class) would be used in a design process, this road would not fulfil the necessary luminances for a ME3 class. If the correct design process is used, then a luminaire with 13,781 lm would be necessary to guarantee the ME3 class requirements (Column 3).

Additionally, we analysed an asymmetrical LIC in the study.

Table 1 – Compare of demand energy for the best standard LIC, what we found, the optimal symmetric LIC and an optimal asymmetrical LIC

	luminous flux for CE3	Standard LIC	Optimal sym-metrical LIC	Optimal asym-metrical LIC
Luminous flux in lm	9720	13781 lm	8000 lm	6200 lm
Energy saving compare to standard LIC	-	-	42 %	55 %

According to Table 1 the application of an optimal symmetric LIC would save 42% of energy for the same light quality. Additionally, savings of energy are possible if other light concepts like an asymmetrical LIC would be used, illustrated in Figure 4.

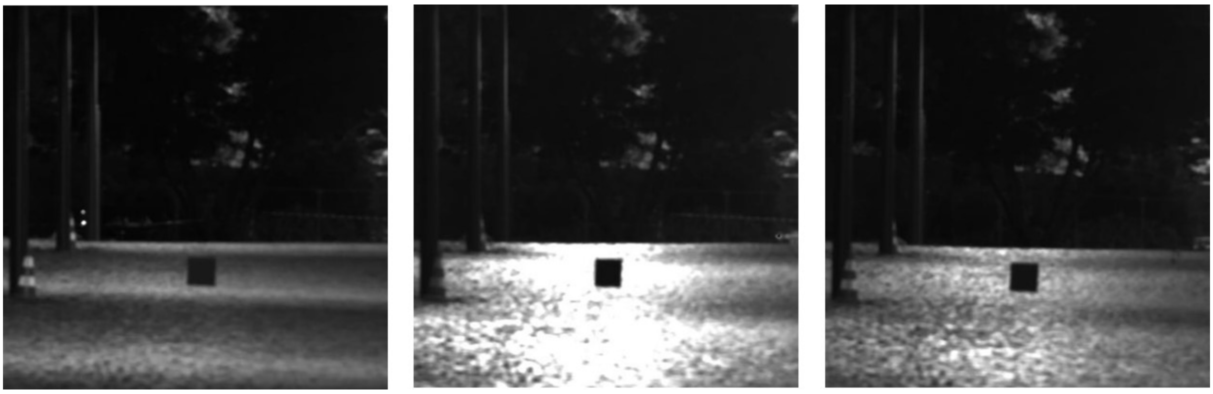

Figure 4 – left: forward beam, middle: counter beam, right symmetric beam (current standard)

5 Car2x Communication

The following question is a current point of discussion in Germany: Can we switch off the road illumination for motorways in large cities (like Hamburg or Berlin)? According the climate aims, this is the wrong question. Car lighting is designed to light a road without road lighting, to support drivers visibility. Because of glare, car drivers use low beam in 95% of driving in Europe. Figure 5 illustrates the light distribution of a low beam headlight. More than 90% of the light is used for directly lighting the road. Only 5% of the light is situated above the cut of line, what is necessary for visibility. That means if the road is already illuminated by streetlights, then only 5% of light of the headlamp is necessary for a drivers visibility.

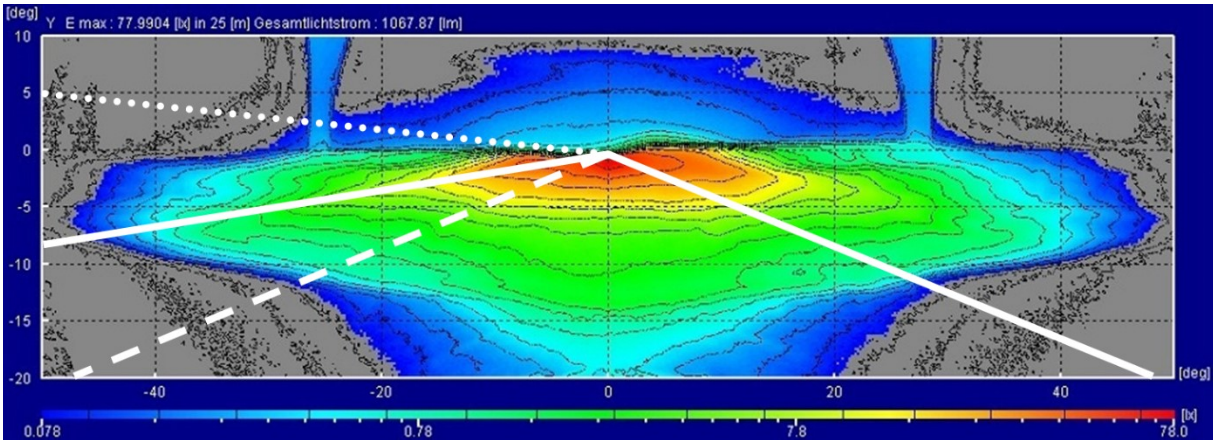

Figure 5 – Distribution of low beam headlight on a 10 m measuring screen; the dotted line represents the eye movement of an oncoming driver, the dashed the centre of the road and the solid line the right and left edges of road

In a small study, data was analysed, if a dimmed day time running light are used instead of low beam headlights. Table 2 shows the results.

Table 2 – Energy saving potential by an integration of car and road lighting

	Energy demand for 1 km street	Energy demand for headlights (1 car)	2,000 Cars/h	5,000 cars/h
With Luminaires (M3 class)	1 kWh	0.1 kWh	200 kWh	500 kWh

The illumination of 1 km road demands energy power of 1 KWh. If one car uses this road (1 km) in one hour, it uses 0.1 kWh (each headlamp 55 W for H4 or H7 lamp minus 10 W for a dimmed day time running light). If 2000 cars use the same road (1 km) in one hour, 200 kWh is consumed by lighting of the street. 5000 cars need 500 kWh. If a car could detect that it is in a well-lit zone and changes its light from low beam to dimmed day time running light – the energy saving potential is enormous. A necessary assumption in this scenario is car2X Communication.

Such testing platforms has been built between two locations in Berlin ‘Brandenburger Tor’ and ‘Ernst-Reuter-Platz’ in the project (diginet PS) to investigate such possibilities [3].

6 Marking light

Marking light is an interesting new road lighting concept for wet roads. Normally, the light of street luminaires is reflected by the road and consequently the road looks black. More light brings more glare but does not increase visibility. Based on the light of the marking light directly aimed at the object of interest, the contrast can be increased very effectively. Pedestrians are visible within a range of 100 m as compared to 10 to 20 m without marking light, as demonstrated in Figure 6. The shown demonstrator has been built in another project (BENE) defining all necessary photometric and geometric parameters for a marking light depending the surrounding conditions.

Figure 6 – Marking light as an additional function to improve the traffic safety

Of cause, the technological effort for these systems is relatively high, but if road lighting is a part of a smart city, the concept of marking light becomes a powerful application. Because marking light works most effectively in dark surroundings, it is possible to use it in conjunction with reducing the lighting class. In this case, marking light can contribute to achieve a very low energy consumption.

7 Conclusions

It can be shown that energy saving and light quality (traffic safety) mustn’t be a contradiction! If more than traffic safety is the focus of lighting design, zonal adaptive lighting (ZAL) will help to address the different demands for all road users in a much better way, than current lighting solutions. The light on facades can be reduced, when it isn’t needed. This provides additional benefits, such as improved sleeping quality of neighbouring residents **and** reduces the light po**llution and sky glow effects**. Ultimately, the absence of light provides enormous benefits, but we have to discover new strategies to achieve this, without impacting on traffic safety. As such, strategies that provide better and more precise light distribution.

In sum, lighting engineers and lighting designer have multiple options to reduce the energy demand to help in fulfilling our climate aims. Like the three presented examples discussed, the potential is enormous! Some further solutions will be presented during the conference.

The following solutions should been taken into account:

- Using adaptive concepts
- More precise light distribution
- Use of the Utilization factor
- Car to X - Communication
- Reducing glare sources
- Using VL-concepts
- Marking light

Of course, a higher education for engineers, public and policy people and a higher investment into these new technologies are necessary! But for our climate it is worth to do it.

Acknowledgements

The presented work is partly funded by the Federal Ministry for Economic Affairs and Energy (BMWi) within the research project "Steffi (03ET1339A), by the Federal Ministry for Education and Research (BMBF) within the framework of the research project UNILED (13N13650), by the Federal Ministry for Transport and Digital Infrastructure within the framework of the research project Diginet PS (16AVF1021A) and by EU/SenStadt Berlin project EFRE within the research project "BENE" : (EU/SenUVK 1053-B5-O).

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[1] Fotios, S.; Gibbons, R. (2018): Road lighting research for drivers and pedestrians: The basis of luminance and illuminance recommendations. In: *Lighting Research & Technology* 50 (1), S. 154–186.

[2] Interreg Project: https://www.interreg-central.eu/Content.Node/Dynamic-Light.html

[3] Diginet PS Projekt: http://diginet-ps.de/