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Magazine for professional lighting design

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PRACTICAL ISSUES

LED outdoor advertising in the urban context

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Light+Building 2016

LED outdoor advertising in the urban context



Photo: J. Hartmann, July 2015.

Case study of "Walk": a video installation integrated into the façade of a store in Zürich/CH.

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With the rapid development of solid state lighting technology and the availability of LED light sources, coupled with the benefits they offer such as energy efficiency, long lifespan and the fact that they can be controlled and programmed, we are now finding LEDs being more widely used for animated advertising. In spite of the pace at which SSL is developing, or perhaps because of this, there is a distinct lack of evaluation guidelines or recommendations for professional designers. It is therefore essential that more research is carried out on this issue on an international scale, and that experts in the field get their heads together in order to formulate some basic guidelines that can be applied in practice.

Since the beginning of the 20th century the night-time image of our towns and cities has slowly but surely been shaped by luminous advertising^[1]. The technological changes luminous advertising has undergone, together with the increased application of animated displays in the urban realm, have proven to be highly influential when it comes to developing new business opportunities – in the leisure and retail industries – in the hours after darkness. In Berlin/D alone, the turnover for digital outdoor advertising rose by 307 per cent between 2007 and 2011^[2]. This trend is in evidence all over the world. It has become clear that lighting design and luminous advertising linked to retail outlets and events in the public realm, which in turn enhance the (window) shopping experience and the use of urban spaces after dark, render our towns and cities even more popular and attractive for an extended period of time every day. City dwellers, people in town on business, and visitors or tourists enjoy the atmosphere generated after dark, which is an added commercial benefit for shop and business owners^[3]. On the other hand, the fact that the new technology is becoming more affordable has led to a new 21st century night-time experience, a bright, transformed image of the city by night, guaranteeing enhanced media exposure, but to a certain extent with no relevance to the architecture it uses or to the urban areas in which it is applied^[4].

In spite of the comprehensive use of the new medium there are no clear rules or regulations to date that

address the requirements which need to be met in order to apply LED technology as a means for advertising in a creative and acceptable fashion. This lack of guidance makes it extremely difficult for local authorities to make educated decisions when it comes to dealing with applications for building permits of this kind. The problem right now lies in the fact that specifications do not define content adequately, the products applied are not suitable, or the choice of location for the displays is inappropriate. The need for the integration of control technology in order to be able to programme and change the displays is frequently overlooked or simply forgotten. Since SSL technology has developed so fast more research needs to be done in this field and steps taken to ensure the relevant decision-makers are adequately informed. Only then can the technical potential of SSL be meaningfully applied in the urban context. International and national professional associations and bodies have produced a significant amount of literature on "outdoor lighting"^[5-14], but the existing recommendations and regulations in Europe have not been adjusted to address the requirements pertaining to digital advertising. Nor have the numerous legal stipulations laid down for advertising in the public realm been appropriately updated^[15-22]. A process for measuring the luminance of systems comprising of changing light levels, such as LED video installations, also does not exist at present^[23].

There is therefore a need for a firm foundation on which adequate

guidelines can be based. Before recommendations and guidelines can be defined, however, we first need to establish a precise and universally valid definition of LED outdoor advertising.

Proposal from the authors: A digital advertising platform is a means of advertising or marketing just about anything in a public or privately owned space. At the same time, it can also be used commercially for marketing purposes (light art installations). The systems are sources with light-emitting diodes (LEDs) and feature different resolutions, colours, luminous intensities and lighting controls. They can be installed on a temporary or permanent basis, and content can be dynamic or static, in low or high resolution, and in the form of text, images or video sequences. Thanks to technological advancements in the development of the brightness of LEDs, such display systems can also be used outdoors during daylight hours. There are different types of digital advertising platforms: signs, logos, lettering, shop windows, screens or media facades.

Overview of the issues involved

The design and planning of LED outdoor advertising that is to be integrated into the architectural context should always be verified in correlation with the following aspects:

- ⇒ impact on critical traffic zones where increased attention is required (increased number of pedestrians, cyclists, car and tram drivers on the streets)
- ⇒ impact on human health (mind and body) and well-being (especially

in residential areas and in close proximity to hospitals and sanatoriums) ⇒ impact on the environment (light pollution, inability to view the sky at night, flora and fauna which become disoriented in relation to time and place).

Impact on traffic situations

LED technologies for outdoor advertising are relatively new. That said, performance with regard to brightness, resolution, animation, quality, colour, and so on, continues to develop at a very fast pace. The influence and impact on road traffic and road users have not been sufficiently investigated to date, however. Studies carried out over the last ten years focussing on the correlation between the recurrence of traffic accidents and the presence of electronic signage and advertising should be consulted^[24]. Furthermore, it is already a well-known fact that a driver's foveal and peripheral vision must not be restricted. Road and traffic safety can otherwise not be guaranteed^[25-29].

Since state-of-the-art LED technology enables full-motion, real-time videos, graphics and even audio, it is becoming increasingly possible to realise interaction solutions involving cars, trams, cyclists and pedestrians. Whatever technical potential there is available, road traffic safety must never be subjected to risk. The light emitted by a digital luminous advertising display should not compete with street lighting systems or traffic lights, or undermine the effect or perception of the same. Bright light and visually perceptible changes in the environment, especially after



Fig. 1: The LED video installation integrated into the facade of PKZ Women in Zürich/CH faces a town square. The building itself borders on a pedestrian zone with tram lines running along it and is positioned diagonally to the exit to the underground car park of a shopping centre. Source: Google Earth.



Fig. 2: The LED display extends across the entire height of the ground floor and first floor of the building and has an enormous visual impact on the street situation, above all thanks to the dynamic content, the high luminance levels and the cool white colour temperature, which stands in stark contrast to its surroundings after dark. Photo: J. Hartmann, July 2015.

Fig. 3 and 4: The images show to what extent and in what intensity the light emitted by the installation radiates into the surrounding urban space. **Left:** installation switched on; **right:** installation switched off. **Photos:** J. Hartmann, July 2015.



dark, are known to attract the human eye. Which is exactly what advertising is all about, of course. The eye focuses on the brightest point within the field of vision (phototaxis)^[30]. A driver or cyclist distracted by unexpected or fascinating lighting effects or animations is not likely to be able to respond adequately in an emergency. Accidents and collisions are thus more likely to occur – especially at or near intersections and traffic junctions. LED outdoor advertising should therefore be prohibited in the immediate vicinity of intersections and traffic junctions. LED advertising should also not be installed near to pedestrian crossings so as not to distract people crossing the road quickly and safely. Extreme differences in brightness occurring in road traffic are not only disturbing for drivers and cyclists. Psychological glare also affects pedestrians, and older persons in particular, who are consequently unable to judge situations correctly.

Given that the perceived brightness must always be considered in the context of the brightness of the luminous advertising display within its immediate surroundings, it is not possible to identify or quote a standard luminance level as an adequate basis for evaluation. The proposal is therefore to divide buildings and their surroundings into four different environmental categories (see points

3.3 in table 1), in which the permissible luminance in accordance with CIE/ILP guidelines for spill light is defined along with restrictions regarding outdoor lighting schemes^[31, 32].

Impact on health and well-being

Research findings in the fields of medicine and neuroscience have demonstrated that there is a direct link between human health and well-being and spectral composition and luminous intensity.

Outside medical circles little is known about the non-visual effects of light. In 2000, scientists discovered a new type of photoreceptor in the eye: intrinsically photosensitive Retinal Ganglion Cells (ipRGC)^[33, 34]. Today we know that this group of cells is responsible for capturing and processing information about the light around us to regulate our circadian clock. The cells are sensitive to the blue range of the spectrum between 460 and 500 nm^[35]. Artificial light at night, especially in the blue range, can have a profound stimulating effect on our biological clock^[36].

Outdoor luminous advertising can play a role in the suppression of the secretion of melatonin. This, in turn, undermines the human immune system and triggers certain biochemical processes. The production of melatonin has a significant influence on the regulation on anti-

cancer (NK cells) and anti-germ cells (B cells)^[37]. All living creatures need a well-functioning circadian rhythm based on a balanced melatonin level to enable the body to renew cells overnight. Even brief exposure to artificial light with the wrong spectral composition during the night can negatively affect melatonin secretion. For years studies have confirmed that people working shifts at night under fluorescent or LED light sources run a higher risk of contracting cancer – breast cancer in women and prostate cancer in men – as well as developing a tendency towards obesity and sleep disorders^[38-40]. Artificial Light At Night (ALAN) is on the increase worldwide^[41]. Changes in our natural day-night rhythm due to artificial light is closely related to the most common health problems in society today. It is therefore crucial that an effort is made to reduce and purposefully avoid light trespass in the urban realm.

Impact on the natural environment

Light pollution is the term used to describe unnecessary, inappropriately focussed or disturbingly conspicuous artificial light – a side effect of modern civilisation. It is in evidence in large cities around the world and recent photographs published by NASA indicate that the use of LEDs

for road lighting actually add to the problem. Researchers have defined three main causes of light pollution – the phenomenon of light emitted into the earth's atmosphere: sky glow, light trespass, and discomfort glare^[42, 43]. The illumination of the night sky in urban areas is the result of light being directly and indirectly reflected by molecules and particles in the atmosphere. Light trespass into buildings is a common phenomenon in towns, and describes the influx of unwanted light into inhabited buildings after dark. Discomfort glare arises from light sources the eye cannot readily adapt to. It leads to feelings of unease, undermines vision, and can cause eye irritation. Poorly designed LED outdoor advertising displays can give rise to discomfort glare for pedestrians, cause light trespass, and contribute towards sky glow.

Studies in the field of biodiversity have verified a number of cases where the negative impact of artificial lighting on the environment is clearly evident^[44]. Uncontrolled lighting at night impacts the behaviour of birds^[45], fish^[46], turtles, bats^[47] and insects^[48] who by nature rely on darkness to survive. Observations have shown that an excess of artificial light, and coloured light in particular, can have a huge impact on nocturnal species^[49]. The consequence: a mal-



function of the circadian rhythm. Changes in the amount of ambient light late in the evening or at night can lead to reproduction problems, displacement from a species' natural habitat, and fluctuations in seasonal migratory routes – with the result that certain species run the risk of dying out^[50-52].

The time during which trees and plants are subjected to light stimuli on a daily basis, the photoperiod or diurnal rhythm of the plants, can have an effect on the growth and shape of the leaves, their inherent pigments, the dormancy period before the tree or plant buds, and root growth. Artificial lighting can cause

shifts in the natural photoperiod and related periods of growth^[53]. Extending the day in this artificial manner also leads to changes in the blossoms. Growth under continuous lighting prevents the plants and trees becoming dormant, which is necessary to enable them to survive adverse conditions during the winter months, for example.

Case study of "Walk"

One real-life example of how a lack of regulatory know-how led to the unsatisfactory implementation of the luminance ratio and choice of colour for an LED outdoor advertising display in the urban context is the

permanent video installation entitled "Walk" designed by British artist Julian Opie. It was realised in March 2014.

The installation is integrated into the shop window of PKZ Women, which is in the main shopping street in the centre of Zürich/CH (Fig. 1).

The shop owner expressly wanted a digital artwork incorporated into his building as an integral part of the shop window to ensure that the façade would be seen from a distance and attract the attention of passers-by (Fig. 2). The innovative LED display has indeed rendered the shop window a true highlight. When it comes to LED outdoor advertising,

this installation can certainly be classified as a pioneer project in the City of Zürich, and was officially approved in this prestigious location by the urban planning office^[54-55]. Based on this information, the authors set about carrying out a critical analysis of the situation in order to determine what recommendations are necessary to enable future projects to be qualified and evaluated.

The location in itself is critical. The façade faces a local town square with a statue of Heinrich Pestalozzi surrounded by grassed areas and trees. During early evening and at night the statue and the building

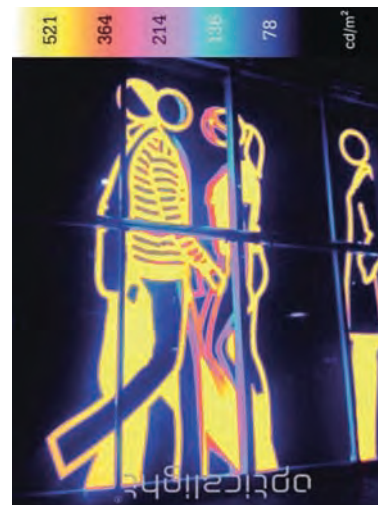


Fig. 5a: Photo of the video installation using a calibrated app from Opticalight.
Fig. 5b: False colour rendering with a cd/m^2 calibrated colour spectrum. April 2016.

Fig. 6: Close-up view of the low resolution pixel pitch. Photo: J. Hartmann.

facade behind it receive additional light emitted by the video installation. The exit to the underground car park that belongs to the shopping centre on the other side of the road faces the installation and immediately attracts the attention of car drivers leaving the car park.

The LED screen is installed on the right-hand side of the front facade of the building and spans a total area of around 50 square metres (720 x 720 centimetres), extending over two storeys.

In order to remain visible during the daytime, especially on sunny days, the luminance level of the LED screen is visually very striking. What is more important is that the brightness is not controlled to align with the daytime and night-time conditions in the given environment (Fig. 3 and 4).

Given the fact that the content of the art installation is animated and continually in motion, it is extremely difficult to measure actual luminance levels and compare them with the ambient brightness. In general one can say that the installation is clearly not adequately aligned to the ambient brightness and is thus disturbing, since the contrast to the urban surroundings after dark is too strong.

To support the analysis study, sample measurements were taken of the installation. Luminance measurements were taken after dark on a cloudless night. Viewed from the point of emission, the measuring cell was parallel to the reference surface when the measurements were taken. The luminance was measured using a newly developed candela-meter app for iOS devices from Opticalight/CH.

The PKZ advertising display was recorded as having a luminance of up to 687cd/m^2 , taken at a distance of six metres to the facade. According to CIE/ILP guidelines the recommended luminance value for buildings in inner-city areas is 25cd/m^2 . The values for the PKZ installation were therefore 27 times higher than those quoted in the standard. (Fig. 5b)

In parallel, tests were undertaken to measure the luminance of the display using a Technoteam LMK mobile air portable camera photometer and a Konica Minolta LS-110. Neither of these works when it

comes to measuring the luminance of moving images, since it is difficult to specify exposure times and the point measurements are not possible because of the changing frame rate (interference with the sampling rate of the sensors). The grid structure of the LED screens/pixel boards and the pulsing light give rise to extreme differences in luminance levels, which makes it practically impossible

The app is a valuable analysis tool for the lighting designer. It is sufficiently accurate for the lighting designer to be able to judge whether there is a problem with the proportion of vertical luminance to ambient light levels.

Measuring luminance is a very complex procedure, because the positioning of the measuring device to the surface to be evaluated must



Fig. 7: Glare caused to pedestrians. Photo: J. Hartmann, July 2015.



Fig. 8: Tram drivers suffer from the glare caused by the LED installation. Photo: J. Hartmann, July 2015.

to determine average or minimum and maximum luminances.

Right now, the latest version of the candela app from Opticalight is the only tool available for evaluating moving installations adequately and for determining the proportionality of the existing luminance. (To perform measurements using the Opticalight app correctly the device must be calibrated and all older versions of the app deleted.)

be coordinated precisely and the results of measurements taken depend on the spectral evaluation options the measuring device offers.

If exact measurements are required, then the designer must resort to the method hitherto applied for static, non-moving luminance areas (for example, using an LMK camera or a Minolta LS-110), and the moving images must be stopped in order for the measure-

ments to take place (cf. measuring frame rate).

The LED advertising display comprises LED panels with a low resolution pixel pitch of approximately three by three centimetres (Fig. 6). The resolution of the content is therefore very coarse (pixelated graphics). It is generally important to consider content and lighting control and incorporate this into the planning and implementation. There are a number of systems that focus on so-called "Digital Signage and Content Management"^[56].

Even if the artist opted to avoid colour change and only use one luminous colour – cool white – the outcome remains critical given the context and taking into consideration the effect of the colour temperature described above. The test measurements indicate the level of contrast between the colour temperature measured at the entrance area to the store and in front of the video installation at eye level (1.65 metres): entrance area without the LED screen 3441K (warm white), and LED screen 6666K (cool white). The choice of colour temperature should always be defined within the urban context and aligned to the time of day in order to avoid any negative impact on the surroundings. What can work perfectly well during the daytime may be totally unsuitable in the evening or at night.

The oversized stick men are in constant vertical movement and "run" faster than the average pedestrian, which also generates a certain restlessness in the public space. Given that the brightness of the LEDs is not aligned to the ambient brightness, the display gives rise to glare and is visually uncomfortable for pedestrians and passers-by (Fig. 7). This situation is particularly disturbing for tram drivers using the road after dark (Fig. 8).

"Walk" is in operation from 6 am to midnight every day. With respect to this installation, the following technical and design aspects need to be considered, complemented and elaborated upon:

⇒ According to the DIN EN 12464-2 German standard, luminance distribution in the field of vision has a crucial bearing on how effectively the human eye adapts to its surroundings. This in turn affects visual

comfort and the person's ability to master the visual task. Sudden changes in luminance levels should therefore be avoided^[57].

⇒ In their guidelines for evaluating of luminous advertising the Schweizer Licht Gesellschaft (Swiss Lighting Society) stipulate (SLG 401: 1997d): "The impact of the luminous advertising must be contained and controlled so that it has no negative effect on road users. For reasons of safety, it is especially important to take the needs of drivers into consideration"^[58]. This guideline requires further review in order to address issues concerning digital advertising systems, in particular with regard to the impact such systems may have on junctions or intersections where accidents can occur involving trams, cars and pedestrians.

⇒ The luminance of the video installation in the evening and at night should be reduced so that the degree of brightness can be defined and adjusted automatically via sensor technology to align with the ambient brightness of roads, buildings and squares in the near vicinity.

⇒ The moving images/scene changes should be slowed down to one change every 30 seconds to one minute to avoid creating the impression of hectic movement or causing irritation^[59]. ⇒ The installation should be switched off at 10 pm at the latest in the winter, and at midnight in the summer, to minimize any potentially negative effects on flora and fauna in the neighbouring park and reduce light trespass in the living spaces in surrounding buildings.

⇒ After sunset, the colour temperature should be adapted to align with the luminous colours used in shops in the vicinity (warm white) and with the atmosphere in the shopping street. The blue end of the spectrum (460 to 500nm) should definitely be avoided.

Conclusion

This article addresses core issues concerning the use of LED outdoor advertising on buildings in the urban context. Given that this topic is so new and complex, we need a realistic basis for evaluation in order to be able to design and realise such systems based on specific know-

1 Defining the location

1.1 Location/environmental zone*

Environmental zone	Ambient brightness	Examples
E0 protected areas	dark	UNESCO Starlight Reserves (DA Dark Sky Parks)
E1 naturally dark landscapes	predominantly dark	national parks, areas of outstanding beauty
E2 rural	low district brightness	small villages or relatively dark urban areas
E3 suburban	medium district brightness	small urban centres and urban areas
E4 urban	high district brightness	town and city centres with high levels of activity at night

1.2 Basis for planning

layout / site plan with position of LED advertising marked in sectional drawing facade view with LED advertising system drawn in to scale recent colour images of surroundings with photogrammetry/3D rendering

1.3 Position/perimeters

Zone 1: display/shop window set back Zone 2: facade other

Zone 1: display/shop window set forward Zone 3: crest/roof other

1.4 Distances / spacing

max. projection over border of the property _____ cm

min. height from pavement _____ cm

min. distance to edge of road _____ cm

distance to facades/buildings opposite _____ cm

1.5 Position in relation to road junctions / roads with heavy traffic:

junctions triangular parallel

other

2 Type of advertising platform

2.1 Type of advertising

sign lettering/signage screen

contour lighting display/shop window media facade

logo other

2.2 Degree of lighting

one-sided emission two-sided emission

2.3 Dimensions (m²)

< 0.5 1.5 - > 5

0.5 - 1.5 > 5

2.4 Content

static text animated text < 20 images/sec.

static image animated image (video) > 20 images/sec.

other

2.5 Duration of installation

permanent temporary period of time: from _____ to _____

2.6 Luminous colours applied

monochromatic (one colour / hue) RGB RGBW colour-changing

3 Technical parameters

3.1 Lighting data

Energy consumption [W/m²] _____

Ambient luminance [cd/m²]* _____

Luminance of advertisement [cd/m²]* _____

Luminous flux [ANSI lumens] [lm] _____

Spectral composition [nm] _____

Colour temperature [K] _____

Colour rendering index [CRI] [Ra] _____

3.2 Control/hours of operation/optical light

Hours of operation 0 (0) - 20 (0) 20 (0) - 22 (0) 22 (0) - 06 (0)

as required other

GPS sensor for automatic location detection yes no

Timer clock planned yes no

Twilight sensor planned yes no

Adjustment colour temperature day/night spectral information intensity adjustment

3.3 Obtrusive light limitations**

In areas with residential housing in the immediate vicinity the spectral composition must exclude any blue content (460 - 500nm) after 10 pm

	Maximum upward light ratio (Sky glow) ULH [Max. %]**	Light intrusion through windows Ev [lx]	
		Pre-curtain****	Post-curtain
E0	0	0	0
E1	0	2	0
E2	2.5	5	1
E3	5	10	2
E4	15	25	5

	Maximum Luminance luminous intensity [cd]		Building Luminance pre-curtain Average L [cd/m ²]
	Pre-curtain	Post-curtain	
E0	0	0	0
E1	2.500	0	0
E2	7.500	500	5
E3	10.000	1.000	10
E4	25.000	2.500	25

* Based on Lighting recommendations for avoiding obtrusive light (Institute of Lighting Professionals, 2011)

** In order to avoid daylight undermining measured values as far as possible, the luminance level should be measured one hour after sunset and one hour before sunrise. Measurements should be taken during dry weather; avoid taking measurements when it is foggy, raining or snowing

*** Based on Lighting recommendations for avoiding obtrusive light (Institute of Lighting Professionals, 2011)

**** ULH - Upward Light Ratio of the installation is the maximum permitted percentage of luminance flux that goes directly into the sky

***** Curtain - the time after which stricter requirements (for the control of obtrusive light) apply

Tab.1: Features of and evaluation criteria for LED outdoor advertising.

how and skills. A first step would be to draw up immission control regulations in order to protect human beings, flora and fauna and the atmosphere from hazardous effects caused by lighting and to prevent any harmful effects arising^[60]. As professional lighting designers, it is our responsibility to be involved in compiling such regulations and laws.

The necessary development and compilation of guidelines for animated LED outdoor advertising should be part of this process. If this process is developed and disseminated in a constructive, open fashion, it could prove to be an extremely useful tool for local authorities and designers. Table 1 compiled by the authors and entitled "Features of and evaluation criteria for LED outdoor advertising" is designed as an aid for facilitating application procedures, and can be used when submitting written applications to gain permission to install an LED outdoor advertising system.

References

- [1] Frecot, J., & Sembach, K. J. (2002). *Berlin im Licht: Photographien der nächtlichen Stadt*. Berlin: Nicolaische Verlagsbuchhandlung.
- [2] Reich-Schilcher, C. (Hg.) (2014). *Stadt- und Stadtbild Berlin Werbekonzept Handbuch*. Berlin: Senatsverwaltung für Stadtentwicklung und Umweltkommunikation, 20.
- [3] Jon Dawson Associates. (2008). *Feature Lighting in Liverpool: An Impact Assessment of the City's Lighting Programme, a report for Liverpool Vision and Liverpool City Council*.
- [4] Zielinska-Dabkowska, K. M. (2014). Critical Perspectives On Media Architecture: Is It Still Possible To Design Projects Without Negatively Affecting Urban Nighttime Environments And Will The Future Remain Dynamic, Bright And Multi-Colored?. *MAB14 conference*, 101–108. New York: ACM.
- [5] Society of Light and Lighting (SLL). (1992). *Lighting Guide LG06: The outdoor environment*. Lavenham: Lavenham Press.
- [6] DIN (2007): DIN EN 12464-2 *Licht und Beleuchtung – Beleuchtung von Arbeitsstätten – Teil 2: Arbeitsplätze im Freien*.
- [7] Commission Internationale de l'Éclairage (CIE). (2003). *Guide on the Limitation of the Effects of Obtrusive Light from Outdoor Lighting Installations*. CIE Publication 150. Vienna: CIE.
- [8] Commission Internationale de l'Éclairage (CIE). (1997). *Guidelines for minimizing skyglow*. CIE Publication 126. Vienna: CIE.
- [9] Deutsche Lichttechnische Gesellschaft (LiTG). (2011). *Empfehlungen für die Messung, Beurteilung und Minderung von Lichtimmissionen künstlicher Lichtquellen*. 12.3. Berlin: LiTG.
- [10] The Institution of Lighting Engineers. (2012). *ILE Guidance Note for the Reduction of Light Pollution*. Rugby: ILE (now Institution of Lighting Professionals).
- [11] Institution of Lighting Professionals (ILP). (2011). *GN01: 2011 Guidance Notes for the Reduction of Obtrusive Light* (Rugby: ILP).
- [12] Klaus, G., Kägi, B., Kobler, R. L., Maus, K., & Righetti, A. (2005). *Empfehlungen zur Vermeidung von Lichtemissionen. Vollzug Umwelt*. Bern: Bundesamt für Umwelt, Wald und Landschaft. <http://www.bafu.admin.ch/publikationen/publikation/00847/index.html?lang=de> [5.6.2015].
- [13] Schweizerischer Ingenieur- und Architektenverein (SIA). (2013). SIA 491:2013 *Vermeidung unnötiger Lichtemissionen im Aussenraum*. Zürich: SIA.
- [14] Schweizerische Licht Gesellschaft (SLG). (1997). SLG 402:1997 *Lichttechnische Bewertung der Wirkung von Beleuchtungsanlagen, insbesondere Flutlichtanlagen, auf den Verkehr*. Bern: SLG.
- [15] Schweizerische Licht Gesellschaft (SLG). (1997). SLG 401:1997 *Lichttechnische Bewertung von Lichtreklamen*. Bern: SLG.
- [16] Reich-Schilcher, C. (Hg.) (2014). *Stadt- und Stadtbild Berlin Werbekonzept Handbuch*. Berlin: Senatsverwaltung für Stadtentwicklung und Umweltkommunikation.
- [17] Department for Communities and Local Government. (2007). *Town and Country Planning (Control of Advertisement). Planning Policy Guidance (PPG) Note 19, Outdoor Advertisement Control*. Communities and Local Government Circular 03/2007. Norwich: The Stationery Office (TSO).
- [18] *Large digital screens in public spaces*. (2009). Joint guidance from English Heritage and Commission for Architecture and the Built Environment (CABE). London: CABE.
- [19] Department for Communities and Local Government. (2007). *Outdoor advertisements and signs: a guide for advertisers*. Wetherby: Communities and Local Government Publications.
- [20] Institution of Lighting Engineers (ILE). (2001). *Technical Report 5: Brightness of Illuminated Advertisements*. Rugby: ILE (now Institution of Lighting Professionals).
- [21] *Konzept Reklameanlagen. Beurteilungskriterien und Vorgaben*. (2006). 3. revidierte Fassung März 2013. Zürich: Stadt Zürich, Amt für Städtebau.
- [22] *Gesamtkonzept Aussenwerbung. Richtlinien für Reklameanlagen, Megaposter und Plakatierung*. (2006). Zürich: Stadt Zürich, Amt für Städtebau.
- [23] Bund/Länder-Arbeitsgemeinschaft für Immission Schutz (LAI). (2012). *LAI Hinweise zur Messung, Beurteilung und Minderung von Lichtimmissionen*, 6.
- [24] Wachtel, J. (2009). *Safety Impacts of the Emerging Digital Display Technology for Outdoor Advertising Signs*. Final Report. Berkeley: The Veridian Group, Inc.
- [25] Rea, M. (2001, Jan./Feb.). The Road Not Taken. *The Lighting Journal*, 18-25.
- [26] Lewin, I. (2000, Jan./Feb.). Visibility Factors in Outdoor Lighting Design (Part 2). *The Lighting Journal*, 34-39.
- [27] Rea, M., & Boyce, P. Different Sources for Different Courses under Mesopic Lighting Levels. *Proceedings of the 4th International Lighting Research Symposium*, Orlando, Florida. Lighting Research Office of the Electric Power Research Institute. May 1998.
- [28] Rumer, K. (1990). The Basic Driving Error: Late Detection. *Ergonomics*, 33, 1281-1290.
- [29] Berthelot, C., & Maestre, D. (1993). Curvilinear Approach to an Intersection and Visual Detection of Collisions. *Human Factor*, 35, 521-534.
- [30] Martin, E. A. (Hg.). (1983). *Macmillan Dictionary of Life Sciences* (2. Aufl.) London: Macmillan Press, 362.
- [31] The Institution of Lighting Engineers. (2012). *ILE Guidance Note for the Reduction of Light Pollution*. Rugby: ILE (now Institution of Lighting Professionals).
- [32] von Bommel, W. (2015). *Road Lighting. Fundamentals, Technology and Application*. Cham: Springer International Publishing, 253-254.
- [33] Provencio, I., Rodrigues, I.R., Jiang, G., Hayes, W.P., Moreira, E.F., Rollag, M. D. (2000). A Novel Human Opsin in the Inner Retina. *J. Neurosci.* 20 (2), 600–605.
- [34] Brainard, G. C., et al. (2001). Action spectrum for melatonin regulation in humans: evidence for a novel circadian photoreceptor. *Journal of Neuroscience* 21 (16), 6405–6412.
- [35] Gaddy, J. R., Rollag, M.D., & Brainard, G.C. (1993). Pupil size regulation of threshold of light-induced melatonin suppression. *J Clin Endocrine Metab* 77, 1398-1401.
- [36] Haim, A., & Portnov, B. A. (2013). *Light Pollution as a New Risk Factor for Human Breast and Prostate Cancers*. Dordrecht: Springer Verlag.
- [37] Roberts, J. E. (2012). Lighting and Human Health. Light Symposium Wismar/ D. <http://lightsymposium.de/documents/Roberts,%20Joan%2015.pdf> [20.6.2015].
- [38] Schernhammer, E. S., & Thompson, C. A. (2011). Light at night and health: the perils of rotating shift work. *Occupational and Environmental Medicine* 68, 310–311.
- [39] Straif, K., Baan, R., & Grosse, Y., et al. (2007). Carcinogenicity of shift-work, painting, and fire-fighting. *Lancet Oncol.* 8, 1065–1066.
- [40] Stevens, R. G., Blask, D. E., Brainard, G. C., Hansen, J., Lockley, S., Provencio, I., Rea, M. S., & Reinlib, L. (2007). Meeting Report: The role of environmental lighting and circadian disruption in cancer and other diseases. *Environ Health Perspect.* 115, 1357-1362.
- [41] Gaston, K. J., Visser, M. E., Hölker, F., (16 March 2015). The biological impacts of artificial light at night: the research challenge. *Phil. Trans. R. Soc. B370*. London: The Royal Society Publishing: [doi: 10.1098/rstb.2014.0133](https://doi.org/10.1098/rstb.2014.0133)
- [42] Society of Light and Lighting (SLL). (2012). Guide to limiting obtrusive light. Lavenham: Lavenham Press.
- [43] von Bommel, W., *Road Lighting. Fundamentals, Technology and Application*. (2015). Cham: Springer International Publishing, 253-254.
- [44] Böttcher, M. (Bearb.). (2001). *Auswirkungen von Fremdlicht auf die Fauna im Rahmen von Eingriffen in Natur und Landschaft. Schriftenreihe für Landschaftspflege und Naturschutz*. Bonn-Bad Godesberg: Bundesamt für Naturschutz (BfN).
- [45] Ballasus, H., Hill, & K., Hüppop, O. (2009). *Gefahren künstlicher Beleuchtung für ziehende Vögel und Fledermäuse. Berichte zum Vogelschutz* 46, 127-157.
- [46] Moore, M. V., Kohler, S. J., & Cheers, M. S. (2006). Artificial light at night in freshwater habitats and its potential ecological effects. In: Rich, C., Longcore, T. (Hg.). *Ecological Consequences of Artificial Night Lighting*. Washington, Covelo, London: Island Press, 365-384.
- [47] Boldogh, S., Dobrosi, D., & Samu, P. (2007). The effects of the illumination of buildings on house-dwelling bats and its conservation consequences. *Acta Chiropterologica*, 9, 527-534.
- [48] Eisenbeis, G., & Eick, K. (2011). Studie zur Anziehung nachtaktiver Insekten an die Strassenbeleuchtung unter Einbezug von LEDs. *Natur und Landschaft. Zeitschrift fuer Naturschutz und Landschaftspflege* 86 (7), 298-301.
- [49] Zielinska-Dabkowska, K. M. (2013). To light or not to light. Exterior illumination of tall buildings and bridges and its negative impact on the life of birds and fish – what professional lighting designers need to know, *Professional Lighting Design*, 91, 38-43.
- [50] Outen, A. R. (1998). *The possible ecological implications of artificial lighting*. Hertfordshire: Biological Records Centre.
- [51] Dominoni, D.M., et al. (2013). Urban-like night illumination reduces melatonin release in European blackbirds (*Turdus merula*): implications of city life for biological time-keeping of songbirds. *Frontiers in Zoology*, 10:60, [doi:10.1186/1742-9994-10-60](https://doi.org/10.1186/1742-9994-10-60).
- [52] Kempnaers, B., Borgström, P., Loës, P., Schlicht, E., & Valcu, M. (2010). Artificial night lighting affects dawn song, extra-pair siring success, and lay date in songbirds. *Current Biology* 20 (19), 1735-9. [doi: 10.1016/j.cub.2010.08.028](https://doi.org/10.1016/j.cub.2010.08.028).
- [53] Briggs, W. R. (2006). Physiology of plant responses to artificial lighting. In: Rich, C., Longcore, T. (Hg.). *Ecological Consequences of Artificial Night Lighting*. Washington, Covelo, London: Island Press, 389-411.
- [54] Fassbind, T. (5.3.2014). *Die Lichtflut, die alles überblendet*. Tages-Anzeiger, Zürich. <http://www.tagesanzeiger.ch/zueroch/stadt/Die-Lichtflut-die-alles-ueberblendet/31622342/print.html> [20.6.2015].
- [55] Schoop, F. (6.3.2014). *Kunst wirbt für Kleiderkauf*. Neue Zürcher Zeitung, Zürich <http://www.nzz.ch/zueroch/kunst-wirbt-fuer-kleiderkauf-1.18256970> [20.6.2015].
- [56] https://en.wikipedia.org/wiki/Digital_signage [20.6.2015].
- [57] DIN (2007): DIN EN 12464-2 *Licht und Beleuchtung – Beleuchtung von Arbeitsstätten – Teil 2: Arbeitsplätze im Freien*, 8.
- [58] Schweizerische Licht Gesellschaft (SLG). (1997). SLG 401:1997 *Lichttechnische Bewertung von Lichtreklamen*. Bern: SLG.
- [59] Reich-Schilcher, C. (Hg.) (2014). *Stadt- und Stadtbild Berlin Werbekonzept Handbuch*. Berlin: Senatsverwaltung für Stadtentwicklung und Umweltkommunikation, 19.
- [60] Bundesministerium der Justiz und für Verbraucherschutz. (2013). *Gesetz zum Schutz vor schädlichen Umwelteinwirkungen durch Luftverunreinigungen, Geräusche, Erschütterungen und ähnlichen Vorgänge*. (Bundes-Immissionsschutzgesetz – BImSchG), <http://www.gesetze-im-internet.de/bimSchG/index.html> [20.6.2015].