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Examination of luminance distributions in the field of vision of drivers in locations with LED billboards

***Abstract**. When in traffic, a driver observes the road and its vicinity. There are objects of various luminance in the driver's field of vision, such as the road, buildings, standard billboards, LED billboards. At night, the road vicinity luminance is much lower than the luminance of the surface of LED billboards. The conducted research allowed to determine typical distributions of luminance in the vicinity of LED billboards located in various places in municipal environment.*

Streszczenie.** W ruchu miejskim kierowca obserwuje drogę oraz otoczenie. W jego polu widzenia znajdują się obiekty o różnej luminancji np. droga, budynki, reklamy tradycyjne, reklamy elektroniczne. W porze nocnej luminancja otoczenia drogi jest znacznie mniejsza od luminancji powierzchni reklam elektronicznych. W wyniku przeprowadzonych badań ustalone zostały typowe rozkłady luminancji w otoczeniu reklam z diodami świecącymi w różnych lokalizacjach w przestrzeni miejskiej. (**Badanie rozkładów luminancji w polu widzenia kierowców w miejscach występowania reklam z diodami świecącymi).

Keywords: luminance distribution, digital billboards, traffic safety.
Słowa kluczowe: rozkład luminancji, reklamy LED, bezpieczeństwo w ruchu drogowym.

Introduction

Outdoor advertising billboards have become inherent elements of many Polish towns and cities. To take advantage of numerous content recipients, such billboards are often located in the vicinity of major motor traffic routes. There are places where many various advertising billboards are located in limited area. Figure 1 shows an example of overcrowding of billboards.

Fig. 1. An example of plenty advertising billboards in a very small area. View during the day

Apart from visual chaos, the billboards also pose a road traffic safety risk. The risk of dangerous situations happening in road traffic increases if the content is presented on LED billboards (billboards with light emitting diodes, electronic billboards). Such billboards are not only large, but also very high brightness - much brighter than traditional billboards. Additionally, the presented content may feature brightness of various levels and dynamically changing images (video, animation). By displaying content that resembles road traffic signs, such billboards often mislead the drivers. They are usually positioned to attract the attention of as many drivers as possible, e.g. in intersections, roundabouts, main traffic routes in towns and cities. It also happens that such billboards are placed directly in the driver's sight line. An example of an electronic billboard in the driver's line of sight is shown in Figure. 2.

At night time and in poor atmospheric conditions during the day (e.g. cloudy sky, fog, rain) such billboards may uncomfortably impair the drivers' vision and hinder their ability to normally drive cars. A great majority of them are a potential source of glare and distraction among the drivers.

Figure 3 shows an example of a billboard with light emitting diodes, whose brightness is very high in comparison to traditional advertising billboards.

Fig. 2. An LED billboard located right in the driver's sight line. View during the day

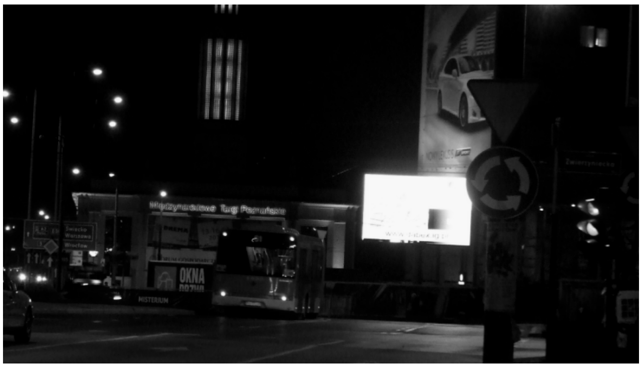

Fig. 3. An example of a billboard of very high brightness at night

The driver's visual task in city traffic is not just limited to observing the road. Visual information from the driver's direct vicinity are also necessary to drive efficiently and safely. Hence, there are objects of various luminance in the driver's field of vision. The brightness of the observed surfaces depends, among others, on adaptation conditions, namely on the distribution of luminance in the vicinity. After nightfall, the luminance of the road and its vicinity is much lower than the luminance of the surface of LED billboards. Being a potential source of glare, such advertisements pose a threat to road traffic safety.

So far, no requirements and recommendations for such billboards have been introduced in Poland [1, 2]. Currently, at the Poznan University of Technology are conducted research for determine requirements for electronic billboards installed in the close vicinity of roads. A laboratory test bed for subjective research is under construction; its purpose is to recreate luminance distributions present in the direct vicinity of roads in various municipal environments.

Examination of the distribution of luminance in the vicinity of roads

In order to determine the distributions of luminance that occur most frequently in the driver's field of vision, the Institute of Electrical Engineering and Electronics of the Poznan University of Technology completed field tests in selected streets in Poznań and Wrocław. The streets were chosen with the possibility of recreation of luminance distributions in the test bed in mind. The streets selected for research were divided into three categories. The first category covered streets with densely developed buildings. The second category - streets, where there was a small number of buildings, usually removed from the side of the road and the third - an important streets for motorized traffic, without buildings.

Figures 4, 5 and 6 show examples of streets selected to examine the luminance distributions.

Ranges of average luminance $\Delta L_{śr}$ of surface surrounding the road were determined on the basis of the measured distributions of luminance. Distributions of luminance were determined on surfaces such as: the roadway, pavements, facades and illuminated windows of buildings, shop windows, lawns, trees (bushes), non-developed vicinity of the road, horizon, traffic signs and information boards.

Fig. 4. A street with prevailing high-density housing

Fig. 5. A street with low-density housing

Luminance distribution was measuring by LMK 98-4 meter with software LMK LabSoft [3].
The results of measurements are presented in Table 1.

Examples of distribution of luminance in the road and in its direct vicinity are presented in Figures 7, 8 and 9.

Fig. 6. A street without housing

Fig. 7. Distribution of luminance in the road with prevailing high-density housing and in its direct vicinity

Fig. 8. Distribution of luminance in the road with single standing buildings and in its direct vicinity

Fig. 9. Distribution of luminance in the road without buildings and in its direct vicinity

Additionally, luminance distribution on advertising carriers located in the vicinity of roads was also measured during field examinations. Due to technical possibilities of completing field examinations of luminance distribution on advertising carriers, the measurements were mainly taken for traditional billboards, where a large banner is illuminated externally or from inside of the advertising carrier.

The measurements served to calculate the average luminance of the examined surfaces. The range of average luminance of the surface of traditional billboards located in the vicinity of roads was determined. The results of measurements are presented in Table 1.

An example of luminance distribution on a traditional billboard surface is presented in Figure 10.

Table 1. List of results of measurements of average luminance $\Delta L_{śr}$ of surfaces surrounding the road

No.	surfaces taken into consideration	street with prevailing high-density housing	street with low-density housing	Street without buildings
		$\Delta L_{śr}$ [cd/m^2]		
1	roadway	1,3 ÷ 3,7	0,9 ÷ 1,9	0,9 ÷ 3,1
2	pavements	1,3 ÷ 3,2	0,9 ÷ 2,4	0,5 ÷2,4
3	facades of buildings	0,7 ÷ 2,6	0,7 ÷ 0,8	-
4	illuminated windows of buildings	5,3 ÷ 27,7	-	-
5	shop windows	2,1 ÷ 40,8	-	-
6	lawns	1,0 ÷ 1,4	0,2 ÷ 0,8	0,2 ÷ 0,8
7	trees (bushes)	0,3 ÷ 0,8	0,3 ÷ 0,6	0,2 ÷ 0,6
8	non-developed vicinity of the road	-	0,1 ÷ 0,5	0,1 ÷ 0,5
9	horizon	0,2 ÷ 0,4	0,2 ÷ 0,3	0,1 ÷ 0,2
10	traffic signs and information boards	1,1 ÷ 4,8	0,5 ÷ 2,6	0,3 ÷2,6
11	traditional billboards (illuminated externally)	7 ÷ 67		
12	traditional billboards (illuminated from inside)	106 ÷ 360		

Fig. 10. An example of luminance distribution on the surface of a traditional billboard

In the case of electronic billboards, the high dynamics of the presented advertising content made it impossible to take luminance measurements in the field. Consequently, the measurements of electronic billboards were taken in laboratory conditions.

Laboratory examination of outdoor LED billboard

The laboratory measurements of photometric parameters were made for a typical LED billboard located in the vicinity of local, Polish roads. Following the manufacturer's declarations, the billboard luminance exceeded 7,500 cd/m^2. An outdoor billboard in *2R1G1B* technology was selected for examination. A single pixel of the displayed image is composed of 4 diodes - 2 red one, a blue one and a green one.

The following is the view of a billboard module, where a single pixel is made of 4 diodes, along with a billboard module with 3 diodes - *1R1G1B.*

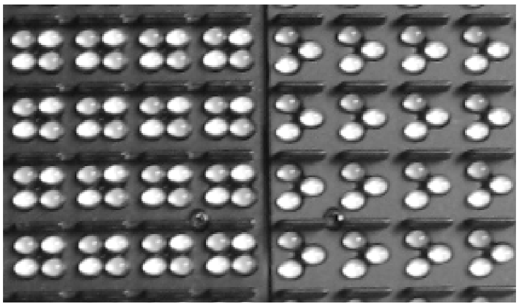

Fig. 11. The construction of a basic billboard module with 4 (left side) and 3 (right side) diodes that create a single pixel of the displayed image

The use of 4 light emitting diodes (including 2 diodes of the same kind) to make a single pixel made it possible to obtain the so-called virtual pixel. Between 2 real pixels, a third one may be actually distinguished, as created by neighbouring diodes. In such a situation, the resolution of the displayed image is two times higher than the billboard's actual resolution. Figure 12 shows how a virtual pixel is created.

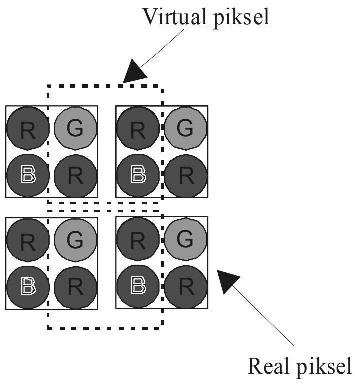

Fig. 12. The principles of creating a virtual pixel in a 4-diode arrangement, the continuous line marks the diodes that make up the real pixel, and the dotted line outlines the virtual pixel

When purchased, the examined billboard featured the highest available resolution, with a functionality of displaying virtual pixels. The spacing between real pixels was 12 mm, and 6 mm between virtual pixels. The billboard was made of 48 modules (8 x 6 arrangement), with each module having a 16 x 16 matrix. The screen's actual resolution was 128 x 96 pixels. The virtual resolution was 256 x 192 pixels.

The completed laboratory examinations encompassed the determination of distribution of luminance in the region of 1, 4 and 9 pixels displaying white colour (maximal pixel luminance) and black colour (diodes switched off) in the real and virtual pixel operation mode. The measurements served to calculate the average and maximal value within the area of a single real pixel.

The results of measurements and calculations are presented in Table 2 and in Figures 13 and 14.

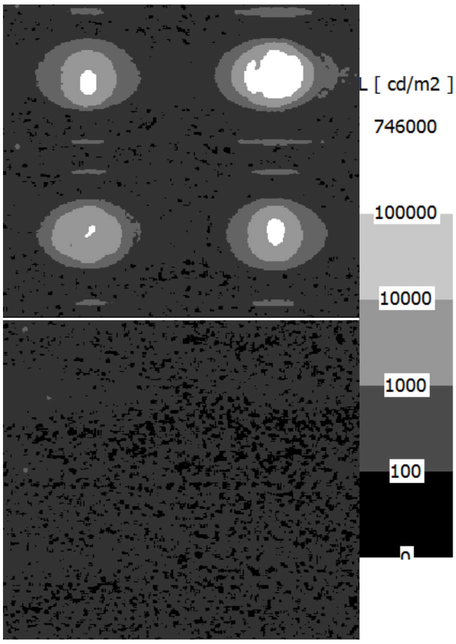

Fig. 13. Luminance distribution for 1 real pixel region, the top section shows a pixel displaying white, and the bottom part shows a switched off pixel

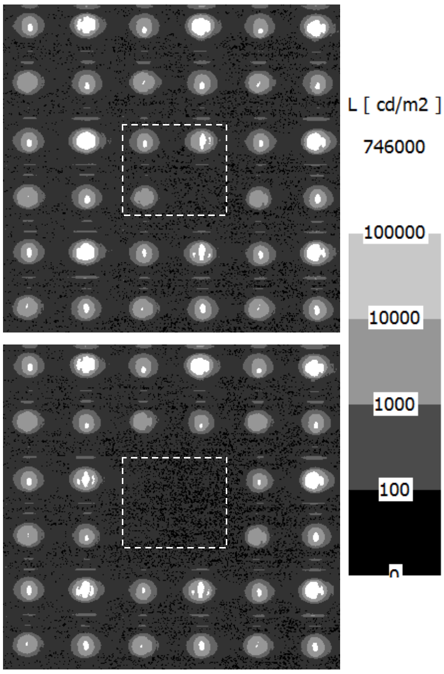

Fig. 14. Luminance distribution for 4 (top) and 9 (bottom) virtual pixels displaying black; the dotted line highlights the analysed pixel

Table 2. Results of measurements of average $L_{śr}$ and maximal L_{max} values of luminance for white and black, in real and virtual pixel mode

No.	Pixel display mode	Region where the colour is displayed	Displayed colour	Luminance calculations for 1 pixel region	
				$L_{śr}$ [cd/m^2]	L_{max} [cd/m^2]
1	real	1 pixel	white	8 352	746 000
2		1 pixel	black	193	1 559
3	virtual	1 pixel	white	8 282	745 800
4		1 pixel	black	6 255	558 300
5		4 pixels	black	3 855	373 300
6		9 pixels	black	167	872

Additionally, luminance distribution on the surface of the billboard for simulated advertising content was measured. Random advertising content, displayed on billboards located in the vicinity of roads, such as business, website and travel agencies advertisements, was selected and displayed on the examined LED billboard.

Figure 15 shows the distribution of luminance for the simulated advertising content.

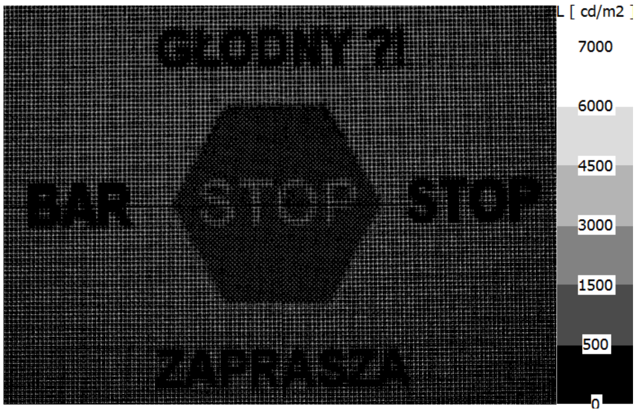

Fig. 15. Luminance distribution on the surface of the billboard examined in laboratory conditions

Summary

The completed field examinations constitute the first stage of examinations into the impact large LED billboards have on drivers' visual performance at night. The conducted examination of luminance distribution in the road and in its closest vicinity permitted to determine ranges of luminance that occur at night in the driver's field of vision. The measurements taken showed that depending on the applied classification of streets, the luminance in the driver's field of vision ranges from 0.1 to about 67 cd/m^2 or about 360 cd/m^2 if there is a traditional illuminated billboard in the road's vicinity. These luminance values are, in most cases, much lower than those of LED billboards. Consequently, given the sight's adaptation to low level luminance, LED billboards are a potential source of glare.

The obtained conclusions will serve to recreate, on a laboratory test bed, distributions of luminance existing in the drivers' field of vision at night; thus, they will make it possible to recreate real road conditions in laboratory environment, as accurately as possible.

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