

IMPACT OF ILLUMINATED ADVERTISING DEVICES ON ROAD TRAFFIC SAFETY

LUBOŠ NOUZOVSKÝ*, ZDENĚK SVATÝ, KAREL KOCIÁN, JONÁŠ MALEČEK

Czech Technical University in Prague, Faculty of Transportation Sciences, Department of Forensic Experts in Transportation, Konviktská 20, 110 00 Prague, Czech Republic

* corresponding author: nouzovsky@fd.cvut.cz

ABSTRACT. This article examines the impact of illuminated advertising devices on road safety in urban environments. By measuring the light parameters of advertising displays and comparing them to public lighting, the study analyzes how the brightness and dynamic elements of these devices affect driver attention, reaction times, and overall ability to perceive traffic situations. The findings indicate that high-brightness, dynamic advertising displays can significantly increase the risk of traffic accidents, especially during nighttime driving. The study also highlights the insufficiency of current legislative regulations, which primarily focus on public lighting systems, and suggests that more comprehensive guidelines should be established to address the specific characteristics of illuminated advertising devices. Two measurement methods were employed: horizontal illumination of roadways and a gradient luminance analysis, both of which provided insights into the disruptive influence of these devices on road safety. The article concludes by recommending specific legislative changes, improved regulation of advertising installations, and the development of further research to better understand the long-term effects of these devices on accident rates. By addressing these challenges, this research aims to contribute to safer road environments and minimize the negative impact of illuminated advertisements on traffic flow and driver behavior.

KEYWORDS: Advertising devices, road safety, lighting.

1. INTRODUCTION

The impact of advertising devices on road safety is still the subject of many new studies and publications in the international scientific research community [1]. The solution to this problem is undoubtedly complex and involves not only the examination of the technical characteristics of the advertising devices, such as their dimensions, positioning in relation to the road, lighting intensity or the use of dynamic elements, but also the content of the messages presented. The combination of these aspects can lead to the driver's attention being diverted from the situation on the road to the advertising devices, which increases the risk of road accidents and has a negative impact on road safety. This may result not only in disruption of traffic flow but also in damage to property or serious health risks to road users [2]. For these reasons, a growing number of expert studies and researches are focusing on analysing this issue, trying to clarify the influence of individual factors and proposing possible measures to regulate them, including adjustments to legislative standards.

In the urban environment, advertising has long been an integral part of the public realm. Illuminated advertising, especially at night, attracts the attention of drivers and distracts them from the traffic situation. This phenomenon can reduce or interfere with drivers' attention, increase their reaction time and impair their ability to recognise obstacles or traffic signs in time [3]. Studies show that the brightness and

contrast of illuminated advertising compared to road lighting can significantly affect visual field perception and contribute to the risk of road accidents [4]. Given these risks, it is necessary to further investigate the lighting parameters of these devices, such as their intensity, dynamics and positioning, and to find ways to regulate their impact on road safety [5, 6]. This paper focuses on this issue and presents two types of measurements that can be used to assess the impact of illuminated or light-emitting advertising devices.

2. LIGHTING PARAMETERS OF ADVERTISING DEVICES AND THEIR EVALUATION

Driver's thinking and perception is a complex and intricate system influenced by a number of internal and external inputs. The interaction of a person with a vehicle in relation to a specific traffic situation is primarily determined by the driver's sensory perception, which enables a person to orient themselves in a given situation. Visual perception is therefore essential, as it mediates up to 90% of the perception of the environment. It is all the more important to ensure that this perception is correct, even in low light conditions, when illuminated signs objectively stand out more than other objects [6].

The Czech Act No. 13/1997 Coll. on Roads states that it is possible to place and operate advertising devices that "do not dazzle the users of the respective

road or otherwise interfere with road traffic” [7]. However, the general nature of these restrictions makes them difficult to enforce in some cases. This may be because there are currently no regulations governing the lighting parameters of advertising devices. The closest thing to this are the technical standards CSN EN 13201-1 to 5 [8], which define measurement methods, evaluation and glare classes, but apply to public lighting.

For the purpose of the measurements processed and evaluated in cooperation with the company SATHEA VISION s.r.o., advertising devices were included in the public lighting system mainly for the following reasons:

- Advertising devices are usually placed in a similar position to the road as the standard public lighting system.
- The light sources used for advertising devices are similar to those used for public lighting systems.
- A lighting design methodology has been developed to minimise the negative impact on a driver, which is also applicable to advertisements.
- Current Czech legislation and technical standards, other than those for public lighting, only marginally address the issue of active advertisements.
- The impact of illuminated advertisements on the road can be measured using methods designed to measure the quality of public lighting systems.

Two different approaches were used to assess the effect of the luminance of the selected advertisements, namely horizontal road illuminance measurements and gradient luminance analysis.

2.1. ROAD HORIZONTAL ILLUMINANCE MEASUREMENT

2.1.1. MEASUREMENT PROCEDURE

Measurements are taken by an automated data collection platform (Figure 1). The platform uses calibrated sensors to measure traffic on three parallel levels in the carriageway. The entire system uses advanced compensation for adverse effects and interference. The sampling and processing speed allows measurements to be made in real-time traffic, and the measured data is interpolated to produce a matrix of equidistant points in accordance with the ČSN EN 13201 lighting evaluation standard. The measurement is also dependent on road conditions and vehicle manoeuvrability. A Class B hand-held luxmeter was used to verify the measurements (Figure 2).

2.1.2. LOCATIONS

Measurements were carried out at eight locations (i.e. D1 to D8), which are shown in the following maps and visual overview (Figures 3–5). All sites are located on two streets in Prague, namely Rozvadovská spojka and 5. května. The advertising devices have been selected according to their luminosity and variability



FIGURE 1. SATHEA traffic horizontal illuminance measurement vehicle.

SONEL S.A. Test and Calibration Laboratory Wokulskiego 11 Str. 58-102 SWIDNICA tel. 74 8583880, 861, 882, 883			
CALIBRATION CERTIFICATE			
Date of issue:	19 August 2015	Certificate No:	145376/15 Page 1/2
OBJECT OF CALIBRATION	Light meter type: LXP-10B, serial No of sensor: BY0351, manufacturer: Sonel		
APPLICANT	Sonel S.A. ul. Wokulskiego 11, 58-100 Swidnica		
CALIBRATION METHOD	According to IW05 – Instrukcja wzorcowania luksomierzy.		
ENVIRONMENTAL CONDITIONS	Ambient temperature: +(22 – 22)°C±2°C Air humidity: (53 – 54)%±15%		
DATE OF CALIBRATION	19 August 2015		
TRACEABILITY	Calibration results were referred to national measurement standard of luminous intensity maintained in GUM with the application of standard light meter L-100 Serial No. 393/2009.		
CALIBRATION RESULTS	The results have been presented on page 2/2 of this certificate including uncertainty of measurement.		
UNCERTAINTY OF MEASUREMENT	Uncertainty of measurement has been evaluated in compliance with EA-4/02 M:2013. The expanded uncertainty assigned corresponds to a coverage probability of 95 % and the coverage factor k=2.		
Approved SONEL S.A. Inženýrský oddělení Dušan Štefánek			
This certificate may be presented or copied as a whole document only.			

Zřizovatel: dle / Annex to FPO2/19/05/14

Wydání / Edition 1, 28.02.2014



FIGURE 2. Calibration certificate and SONEL luxmeter.

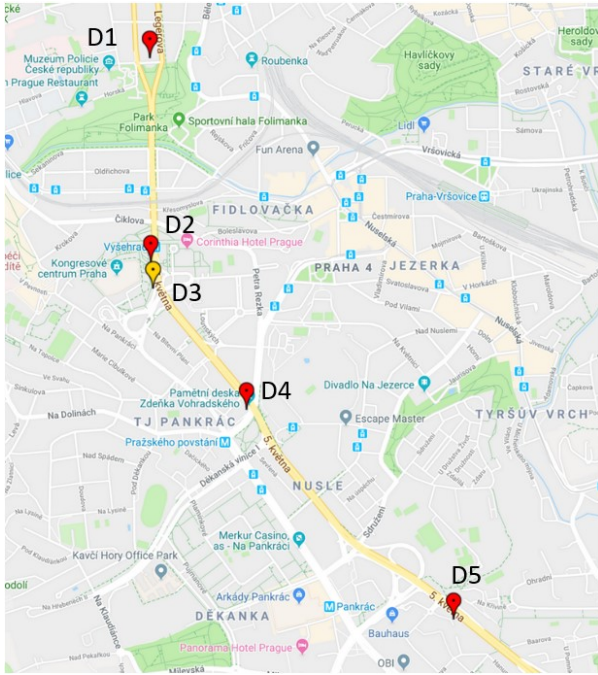


FIGURE 3. Location of 5. května street with marked advertising devices [9].

(i.e. dynamics), whereby the advertising media at locations D1 to D6 have dynamically variable content, while the advertisements at locations D7 and D8 are static.

2.1.3. PROCESSING AND EVALUATION

Measured data was first interpolated and filtered to give the most accurate picture of illuminance along the road. Data in the direction of one lane were then selected, and was further filtered using a moving average filter with a window of 7 forward and 7 backward samples (the smoothed data is shown in the graphs below). In each graph, the location of the respective advertising device is always marked with a red bar to assess whether the road illuminance is affected at that location. The following figures show locations D8 and D1 as an example see in Figures 6 and 7.

The advertisement at the D8 location was the only one found to have a significant effect on the longitudinal uniformity of the lighting due to its position directly above the carriageway. All other advertisements close to the road were found to have a negligible effect on the longitudinal uniformity of the lighting.

Measured data, including the effect of the advertising device on the illuminance, can also be displayed in a heatmap or greyscale spectrum for better illustration, as shown in Figure 8.

2.1.4. SUMMARY OF HORIZONTAL ILLUMINANCE MEASUREMENTS

The data show that the influence of advertising devices in question on the illuminance of the measured sections is minimal and at the level of measurement error. This conclusion was confirmed by manual measurement

with a luxmeter, where the change caused by the light emitted by the advertising device was about 10% of the illuminance on the roadway compared to the state when the advertising was switched off. This is probably due to the orientation of the advertisement, where its normal is approximately parallel to the road. The light rays hit the road at a high angle to the normal of the impact area. Illuminance is a function of the angle of incidence, so the effect is negligible. It should be noted, however, that a light source which does not contribute to the illumination of the road and its surroundings can only be considered as a source of glare with a negative effect on the visual performance of the driver.

2.2. GRADIENT LUMINANCE ANALYSIS

The purpose of the measurement is to evaluate the brightness of the light sources in the captured scene. For this measurement, the images were converted to grey scale and then rendered in false colours for subjective evaluation. No further adjustments were necessary when the photos were evaluated numerically.

2.2.1. MEASUREMENT PROCEDURE

The measurements were carried out at selected locations in the streets 5. května and Rozvadovská spojka. The optical sensor system was placed according to the requirements of ČSN EN 13201 on a standard observer (i.e. at a height of 1.5 m, at a distance of 60 m from the advertising device and with an inclination of the observation plane of 1°). The composition of the scene was such that the advertising device, roads and public lighting fixtures were recorded at a distance of at least 150 m from the advertising device.

The images were taken using a Sony ILCE-5000 camera with a 19mm fixed focal length lens. All shooting parameters except the shutter speed were kept constant. The sensitivity (ISO) was set at 100 and the aperture at f14, and the shutter speed was varied from 1/4000 s to 1 s for each scene to find the point at which the sensor operates in the linear range. The three best images were then selected for further processing – the first for subjective evaluation and the other two for objective (numerical) evaluation.

The specifics and limitations of the specific measurements reported in real-time traffic included the following:

- High dynamic scene contrast.
 - ▷ High brightness of an advertising device and luminaires.
 - ▷ Luminous flux from an advertising device directed at the driver at a more direct angle than public lighting.
 - ▷ Restrictive sensor angles against interfering light.
- Sites do not allow fully static measurements.
 - ▷ Dynamic advertisements are switched off at 22:00, a time when there is still a lot of traffic at these locations.

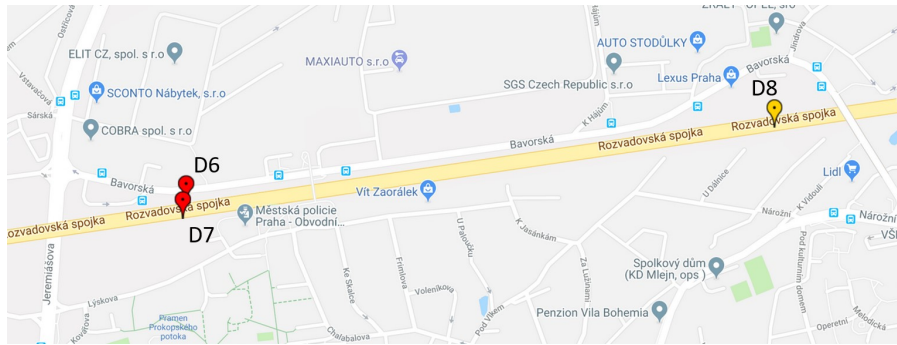


FIGURE 4. Location of Rozvadovská spojka street with marked advertising devices [9].

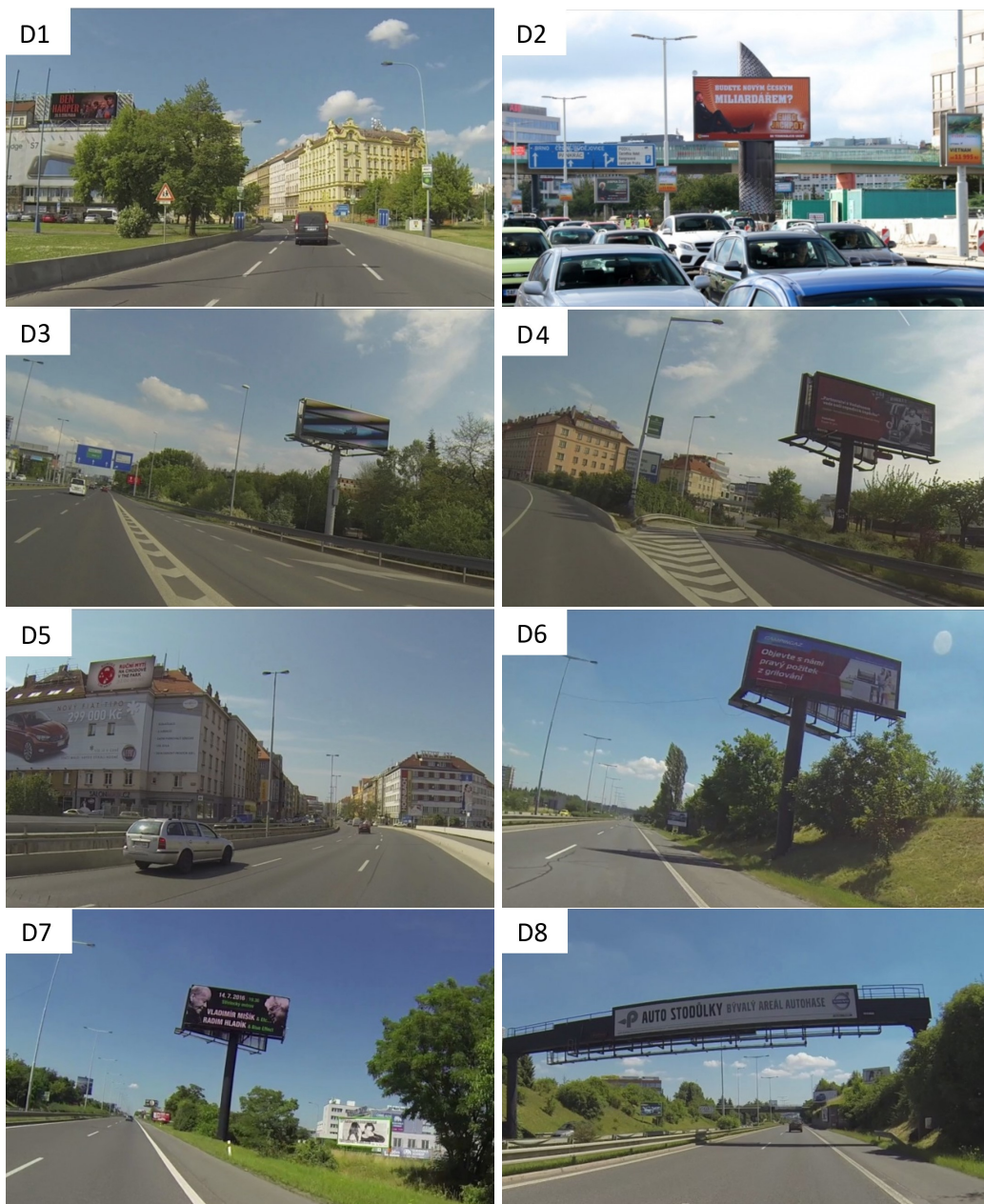


FIGURE 5. Locations D1 to D8.

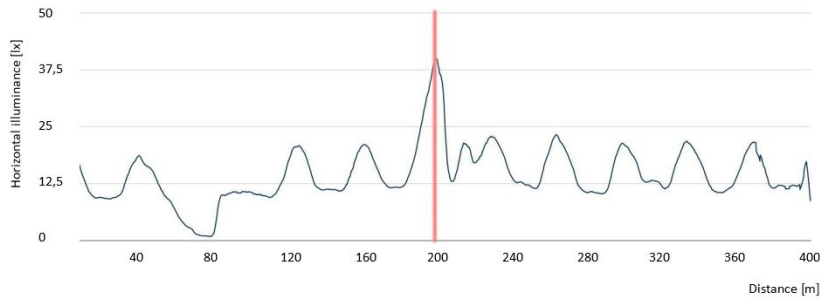


FIGURE 6. Graph of the horizontal illuminance at the D8 location, showing the influence of the advertising device.

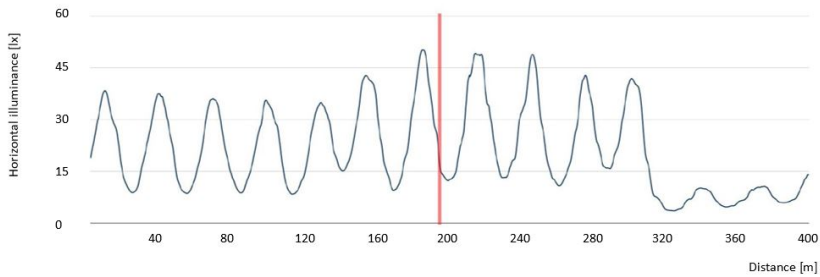


FIGURE 7. Graph of the horizontal illuminance at the D2 location, showing the influence of the advertising device.

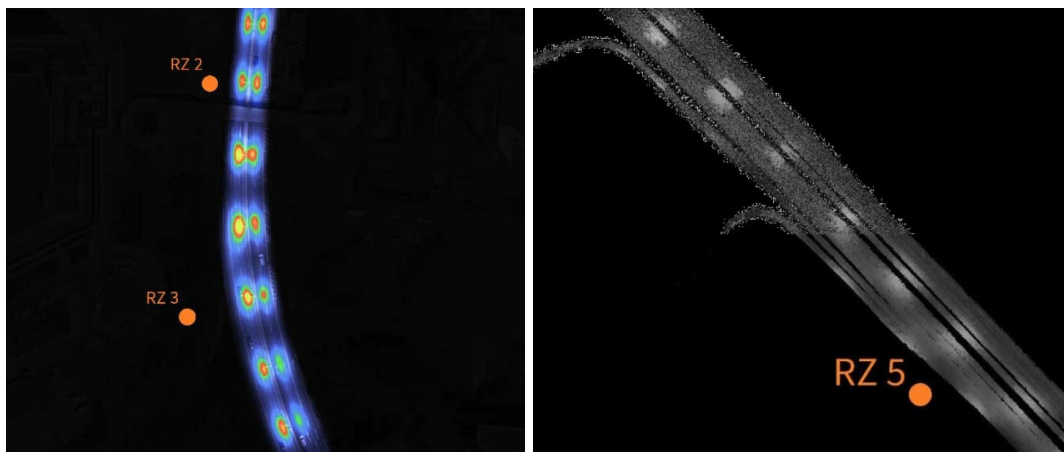


FIGURE 8. Heatmap (left) and grey scale (right) data display.

- ▷ It is not possible to regulate traffic on roads for fully static measurements.

2.2.2. LOCATIONS

The locations selected for the gradient luminance analysis are identical to those for the horizontal road illuminance measurements. Due to the financial, organisational and data requirements of such measurements, the measurements were carried out at locations D1 and D4 to D7. A subjective expert assessment of illuminance and the effect of illuminated advertising on drivers was also carried out for the selected locations.

2.2.3. PROCESSING AND EVALUATION

Objective assessment The only applicable parameter for assessing glare on roads is the threshold increment (TI), which is a measure of the reduction in visibility caused by the restrictive glare of the luminaires in the road lighting system [4]. However, due

to the relatively heavy traffic and the time-varying content of the advertisements, it could not be reliably determined. Therefore, the ratio of the equivalent veiled luminance of the public lighting and the signage was used as a proxy for the assessment. Curtain luminance is defined as:

$$L_v = 10 \frac{E_{rk}}{\vartheta^2} \quad [\text{cd} \cdot \text{m}^{-2}] \quad (1)$$

where

- E_{rk} – illuminance at the point of the observer’s eye in a plane perpendicular to the line of sight and inclined by 2° from the horizontal,
- ϑ – is the angle formed by the line of sight and the line connecting the observer’s eye and the source of glare.

The most significant fixed source of glare on roads is public lighting. The equivalent veil luminance of the

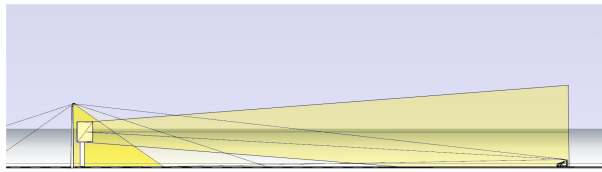


FIGURE 9. Angle comparison between an advertising device and a public lighting luminaire.

public lighting system was therefore used as a reference illustrated in Figure 9. If the equivalent luminance did not exceed the reference luminance, the advertisement was considered to be an insignificant source of glare in relation to the public lighting sources already installed and meeting the requirements of ČSN EN 13201.

Luminaires between 30 and 300 metres from the monitoring site were included in the assessment. The luminaires are marked L1P (nearest luminaire to the right of the road), L1L (nearest luminaire to the left of the road), L2P (second nearest luminaire to the right of the road), etc. The marking of an advertising device corresponds to the marking of the same advertising device on the map. Two locations have been used as examples, namely D5 and D6, whose values are given in detail (see Table 1 and 2).

The second column indicates the angle in degrees between the plane of observation and the junction of the light source and the camera lens. The solid angle indicates how much of the total field of view is occupied by a given light source. The average illuminance of an object is the calculated value of the luminous intensity of each pixel of the image that falls within the space of a given light source. The relative horizontal illuminance produced by a given source corresponds to the average brightness of the object, angle and solid angle according to the relationship:

$$\bar{E} = \frac{\bar{L}}{\cos \vartheta} \tau \quad [\text{lx}] \quad (2)$$

where

- \bar{L} – average brightness of the object – the value of the luminous intensity of each pixel of the image belonging to the area of the light source,
- ϑ – is the angle formed by the plane of observation and the junction of the light source and the camera lens,
- τ – solid angle – the size of the object in the field of view.

Table 3 shows the resulting luminance analysis values. The veiling luminance of public lighting is the sum of all individual luminances. The veiling luminance of an advertisement is, as the name suggests, the veiling luminance induced by the advertisement. The main indicator of glare is the ratio of the veiling luminance of the advertisement to the sum of the veiling luminances induced by the public lighting luminaires. The higher the value, the more significant

the glare caused by the advertising device compared to the glare caused by the public lighting system.

The results show that one of the advertising devices significantly exceeds the luminance values of the public lighting system. However, such a result does not justify the claim that the advertisements do not comply with the current standard for street lighting. However, it can be stated that the technology used is capable of exceeding the permitted values for public lighting by several times in terms of radiated brightness.

Subjective assessment This assessment considers the overall situation at the selected locations and the impact of the advertisements on drivers in relation to other objects and the overall road environment. The aim is to provide a comprehensive picture of the situation at the measured locations in terms of visual presentation. As a result, the sites were classified into three levels according to their impact on drivers, as shown in the situations below:

Advertisement with a minimal subjective impact on the observer

The advertisements at D1 and D4 locations are so unobtrusive within the overall brightness of the scene that their impact on the driver is minimal. Subjectively, there is little or no glare to the driver.

Advertisement with an average subjective impact on the observer

For D6 and D7 advertising devices, the effect on the driver depends mainly on the content displayed in terms of the colours used and the intensity of the brightness.

Advertisement with a high subjective impact on the observer The advertisement at D5 location is a high-brightness device. Within the overall brightness of the scene, it stands out significantly above the brightness of other light sources and the brightness of the road. In this comparison, it is clear that the ambient scene values around the billboard, in particular the road surface, are close to zero. Such an effect is undesirable because the driver, whose vision is adapted to the high brightness of the billboard, does not have sufficient reserve to distinguish less bright details on the road. This increases the likelihood of missing an obstacle, confusing information from vertical road markings and similar undesirable features. Situations are shown in Figure 10.

2.2.4. SUMMARY OF BRIGHTNESS ANALYSIS RESULTS

The advertisements and locations that were most suitable for evaluation in terms of road geometry, luminaires and mast heights were selected to determine the impact of illuminated advertising on drivers. The measurements show that individual advertisements vary in both brightness and position in the field of view. The equivalent veiled luminance of D1 and D4 is less than the equivalent veiled luminance of the public lighting, whereas for D6 and D7 it is close to this value. In the case of sign D5, the measured

Light Source	Angle ϑ	Solid Angle τ	Average Brightness of the Object \bar{L}	Relative Horiz. Illuminance \bar{E}	Relative Veil Brightness L_v
	[°]				
Luminaire L1P	16,328	0,000036	4655,62	0,16301	0,00611
Luminaire L1L	14,261	0,000027	4873,28	0,12627	0,00621
Luminaire L2P	9,412	0,000011	3286,72	0,03586	0,00405
Luminaire L2L	8,944	0,000006	1680,84	0,00992	0,00124
Luminaire L3P	6,487	0,000002	719,62	0,00154	0,00037
Luminaire L3L	6,708	0,000004	2286,08	0,00976	0,00217
Luminaire L4P	5,278	0,000003	2334,78	0,00658	0,00236
Luminaire L4L	5,421	0,000002	1486,98	0,00365	0,00124
Luminaire L5P	4,615	0,000002	1293,12	0,00297	0,00140
Luminaire L5L	4,628	0,000003	839,88	0,00250	0,00117
Advertisement D 5	5,850	0,002111	545,22	1,14520	0,33463

TABLE 1. Brightness analysis readings for D5 location.

Light Source	Angle ϑ	Solid Angle τ	Average Brightness of the Object \bar{L}	Relative Horiz. Illuminance \bar{E}	Relative Veil Brightness L_v
	[°]				
Luminaire L1P	23,179	0,000025	6662,016	0,15570	0,00290
Luminaire L1L	22,815	0,000027	1546,912	0,03857	0,00074
Luminaire L2P	10,79	0,000005	5611,392	0,02601	0,00223
Luminaire L2L	10,647	0,000018	1968,32	0,03417	0,00301
Luminaire L3P	6,994	0,000005	3054,56	0,01399	0,00286
Luminaire L3L	6,903	0,000004	713,792	0,00267	0,00056
Luminaire L4P	5,135	0,000003	1131,392	0,00349	0,00132
Luminaire L4L	5,018	0,000002	282,176	0,00065	0,00026
Luminaire L5P	4,056	0,000002	1788,352	0,00411	0,00250
Luminaire L5L	4,004	0,000001	269,344	0,00034	0,00021
Luminaire L6P	3,315	0,000001	537,344	0,00067	0,00061
Luminaire L6L	3,25	0,000002	776,256	0,00126	0,00119
Luminaire L7P	2,769	0,000001	328,544	0,00026	0,00034
Luminaire L7L	2,704	0,000001	465,792	0,00044	0,00060
Luminaire L8P	2,314	0,000001	432	0,00041	0,00076
Luminaire L8L	2,288	0,000001	588,448	0,00055	0,00106
Advertisement D6	4,251	0,001126	25,831	0,02901	0,01606

TABLE 2. Brightness analysis readings for D6 location.

Location	Veiled Luminance of Public Lighting	Veiled Luminance of Advertisement	Ratio of Veil Luminance (Ad./PL)
Location D1	0,039	0,012	0,307
Location D4	0,029	0,018	0,620
Location D5	0,026	0,335	12,717
Location D6	0,021	0,016	0,759
Location D7	0,031	0,029	0,935

TABLE 3. Results of the brightness analysis of D1, D4, D5, D6 and D7 locations.

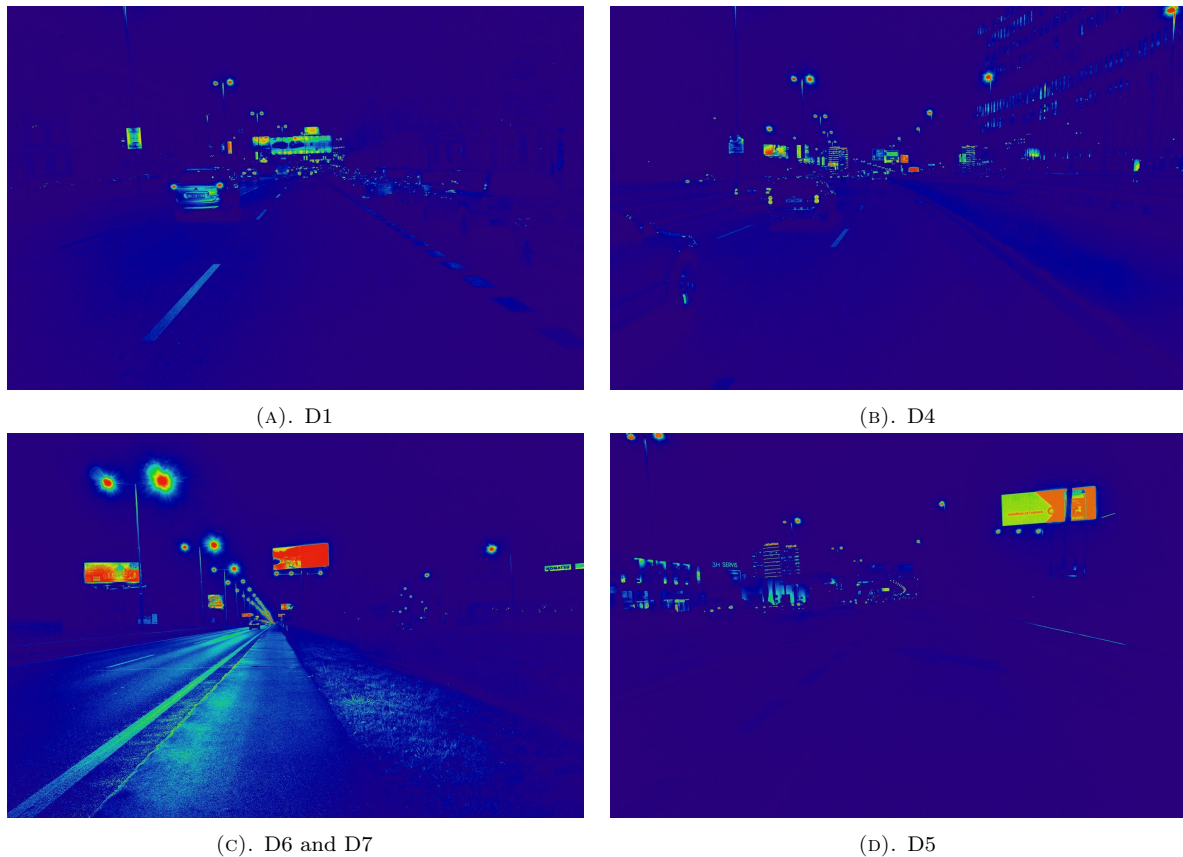


FIGURE 10. Brightness analysis in false colour.

values were significantly higher than the public lighting illuminance. On the basis of these measurements, with such a result, it cannot be said that some advertisements violate the current standard for street lighting ČSN EN 13 201. However, it can be stated that, thanks to the progress made in the development of LEDs, advertisements can achieve luminance values that are not negligible at night, but on the contrary can exceed the luminance of the permitted fixed light sources (i.e. public lighting) many times over.

The luminous intensity of some advertisements is significantly higher than that of other light sources. This increases the adaptive brightness of the scene for the driver. Compared to the brightness of the road, which is several orders of magnitude lower, this increases the risk of missing an obstacle, reduces the driver's visual performance and increases reaction time.

A particular phenomenon that occurs in the case of an active advertising device with variable content (i.e. a dynamic advertising device) is the change in panel brightness over time. Currently, all legislation relating to street lighting only deals with fixed, constant luminous sources. No methodology has been developed to assess lighting systems with time-varying parameters. However, it should be noted that, from a physiological point of view, two undesirable phenomena occur. The first is a sudden change in the brightness of the screen, which can cause blinding glare or at least a significant

reduction in visual performance for a short period of time. The second is a reflex associated with peripheral vision. When there is a sudden change in peripheral brightness, a reflexive withdrawal of attention from the stimulus occurs (i.e. the hazard response). These phenomena can pose a greater hazard than glare from fixed sources of constant luminous flux [10].

3. CONCLUSIONS

The results of the measurements confirm that advertisements, especially those with high brightness and dynamic content, can have a negative impact on road safety. However, this was not clearly demonstrated for all the selected samples. The brightness and contrast of advertisements distract drivers from the traffic situation, which can lead to longer reaction times and an increased risk of accidents. Based on the results of this study, it can be concluded that the current legislation in the Czech Republic, which focuses on roads, traffic or the lighting system, does not sufficiently cover the specifics of illuminated and light-emitting advertising devices. Therefore, it would be more than appropriate to adopt more specific legislative measures that take into account not only static but also dynamic advertising devices and set limits on their brightness, dynamics and positioning.

Advertising can be identified as a source of discomforting glare. No positive effects of advertising devices on road safety or visual comfort of drivers have been

identified as part of the classification of advertising devices as part of the public lighting system. The purpose for which such light sources are installed differs from that of public lighting systems.

The light sources of the advertising devices measured are not optically modified in any way to improve the visual comfort of the driver (shading, direction of light flow, etc.). However, public lighting luminaires must be adapted in this way. In particular, the absolute value of the luminance of the advertisement and the subsequent calculation of the threshold increment is a parameter that would allow the advertisement to be classified as technically unsatisfactory in the light of current legislation.

REFERENCES

- [1] J. Hinton, O. Oviedo-Trespalacios, B. Watson, N. Haworth. Beyond the billboard: A review of other external sources of driver distraction. *Accident Analysis & Prevention* **208**:107771, 2024. <https://doi.org/10.1016/j.aap.2024.107771>
- [2] Czech Republic. Ministry of Transport. BESIP Strategy 2021–2030, 2020. [2024-08-11]. <https://besip.cz/Besip/media/Besip/data/web/Strategie-BESIP-2021-2030.pdf>
- [3] K. Bucsuházy, M. Semela, M. Belák, et al. Analysis of selected off-road glances during driving in real road traffic. *Transportation Research Procedia* **45**:580–586, 2020. Transport Infrastructure and systems in a changing world. Towards a more sustainable, reliable and smarter mobility. TIS Roma 2019 Conference Proceedings. <https://doi.org/10.1016/j.trpro.2020.03.054>
- [4] T. A. Dingus, F. Guo, S. Lee, et al. Driver crash risk factors and prevalence evaluation using naturalistic driving data. *Proceedings of the National Academy of Sciences* **113**(10):2636–2641, 2016. <https://doi.org/10.1073/pnas.1513271113>
- [5] T. Blodek, P. Vrtal, T. Kohout, et al. Verification of night road safety inspection by luminance analysis. In *2024 24th International Scientific Conference on Electric Power Engineering (EPE)*, pp. 1–5. 2024. <https://doi.org/10.1109/EPE61521.2024.10559538>
- [6] R. Brome, M. Awad, N. M. Moacdieh. Roadside digital billboard advertisements: Effects of static, transitioning, and animated designs on drivers' performance and attention. *Transportation Research Part F: Traffic Psychology and Behaviour* **83**:226–237, 2021. <https://doi.org/10.1016/j.trf.2021.10.013>
- [7] Parliament of the Czech Republic. Act No. 13/1997 Coll. 1997.
- [8] ČSN 13 201-1,2,3,4,5 (1.10.2024), Osvětlování pozemních komunikací [In Czech; Street lighting]. ČNI Praha.
- [9] Google. Maps. [2024-08-11]. <https://www.google.com/maps>
- [10] L. Nouzovský, P. Vrtal, T. Kohout, Z. Svatý. Using the eye tracking method to determine the risk of advertising devices on drivers' cognitive perception. *Applied Sciences* **12**(13):6795, 2022. <https://doi.org/10.3390/app12136795>