

The comparison of vehicle headlamps

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Abstract. The aim of this article is the comparison of vehicle headlamps in terms of pedestrians' visibility at nighttime conditions. The study was designed to gain results, which could serve as a basis for the pedestrian-vehicle accident analysis in terms of visibility during night drive. For this study were used comparable vehicles (same vehicle type and model year) with different headlamps type. Three different headlamps (halogen, xenon and LED headlamps) were used for the analysis. Experiments were carried out under similar conditions (straight road, nighttime, no disturbing factors). During a series of static tests, the vehicle approached at predefined distances to the figurant - pedestrian standing on the right side of the roadway. For the luminance analysis were used Luminance Distribution Analyser LumiDISP - software for analysing the luminance conditions based on evaluation of image data from digital photos.

1. Introduction

The vehicle-pedestrian crashes often lead to severe injuries especially due to pedestrian vulnerability. The probability of a crash with a pedestrian is increased especially in reduced visibility condition especially at nighttime. To significantly increase pedestrian safety, pedestrians must become aware of the driver's limitation and become more visible. Drivers often do not recognize their visual limitations and are not prepared to react to unexpected risk such as pedestrians or obstacles [1].

Drivers abilities to recognize pedestrians on the open road were measured in several studies [1-3]. The driver perception of the pedestrian is influenced by several factors, among other pedestrian clothing, location and driver age. Pedestrian perception distance decrease when the situation is unexpected, pedestrian wear dark clothes on a dark road and is located on the left side of the approaching vehicle, vehicle lights are set to low-beam mode, the driver is older or impaired in some way, glare is present, a pedestrian is not moving and/or visibility is limited [4-6]. Green also stated only a few studies analysed beam setting and glare. Borzedndowski et al. concluded that drivers may not accurately judge the effects of headlamp glare on their vision [7]. The headlamps need to be correctly adjusted to not cause glare to oncoming traffic. The amount of glare depends on beam aim, intensity, spread and wavelength [4].

For the determination of visibility distance is necessary to analyse where pedestrian contrast reaches the detection threshold. Luminance and related contrast are influenced by headlamp types and by the type of lighting as well. Types of vehicle headlamps and their advantages summarized [8]. The most spread type are halogen headlamps which firstly appeared in 1962. Xenon headlamps have bright white natural light produced by the eponymous ionized inert that is placed inside the bulb of the gas-discharge xenon headlamp. LED headlamps use very bright white light-emitting diodes, their advantages are the efficiency, reliability, durability, compactness, insensitivity to vibrations and higher power compared to



conventional light headlamps. The data from the Czech in-depth accident study (CzIDAS) confirmed halogen headlamps as the most spread type of headlamps. From the dataset of personal vehicle accidents with a pedestrian at night time condition in 2011 – 2020 were 80% of vehicles equipped with halogen headlamps, 8% with xenon headlamps and 2% with LED headlamps [9].

The visibility of pedestrians according to the headlamp type was analysed e.g. Bradáč [10] compared halogen and xenon headlamps in terms of different visibility of three different pedestrian clothing – white, leisure and dark. Baleja [11] analysed halogen, xenon and LED vehicle headlamps. Two different model situations were analysed – vehicle headlamp in a low-beam mode, vehicle headlamp in a low-beam mode together with public lighting. The aim of this article is the comparison of vehicle headlamps in terms of pedestrians visibility at night time conditions in both lighting modes – low-beam and high-beam. Three different headlamps (halogen, xenon and LED headlamps) were used for the analysis.

2. Measurement

The main purpose of static measurement was to identify the illumination parameters of selected headlamp types. During a series of static tests, the vehicle approached at predefined distances to the figurant - pedestrian standing on the right side of the roadway oriented frontally towards the vehicle. The analysis of luminance was realized in the following distances between vehicle and pedestrian - 30 m, 40 m, 50 m, 60 m, 70 m, 80 m, 100 m, 120 m, 140 m, 160 m, 180 m, 200 m, 220 m, 240 m a 260 m. For every distance were analysed both types of lighting – high-beam and low-beam. Two differently dressed (leisure-type of clothing and dark clothing) figurants participated the experiment (Figure 1).



Figure 1. Pedestrian clothing

For this study were used comparable vehicles (same vehicle type and model year) with different headlamps type, namely three vehicles Skoda Octavia of the third generation – Skoda Octavia III. generation (facelift) with halogen headlamps, Skoda Octavia III. generation with bi-xenon headlamps and adaptive function AFL, Skoda Octavia III. generation RS230 (facelift) with full-LED headlamps with an adaptive lighting function.

Experiments were carried out under similar conditions (straight road, without disturbing factors). The location for the experiment was chosen mainly concerning its character, absence of public lighting and other light smog. The test track was a straight, dry, two-lane directionally undivided road with horizontal road marking and an asphalt surface without defects and with negligible directional and height differences (Figure 2). There has been dense forest in the road surroundings. The static measurement

was carried at nighttime condition (January 2019, since 18:30 until 23:50 – night phase), the visibility was not impaired by fog or rain.



Figure 2. Test track [12]

For the luminance analysis were used Luminance Distribution Analyser LumiDISP - software for analysing the luminance conditions based on evaluation of image data from digital photos. The analyser was placed inside the vehicle at the high level and longitudinal position of the driver's eyes. The luminance of the pedestrian and close environment was analysed. The determined values were used for the calculation of contrast using equation (1). C is contrast, L_a is object luminance and L_b is the background luminance. If the object is brighter than the background, the contrast is positive. If the object is darker than the background, the contrast is negative.

$$K = \frac{L_a - L_b}{L_b} \quad (1)$$

For the calculation were used the average values of luminance in a predetermined area (Figure 4 and 5). The analysed area of the pedestrian was low limb area (Figure 3) in the case of low-beam lighting and whole-body (without head) area in case of high-beam lighting.

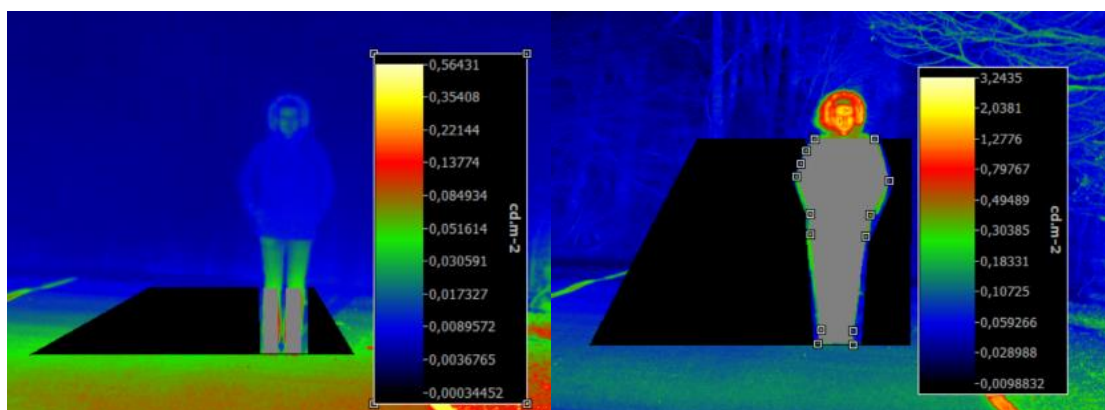


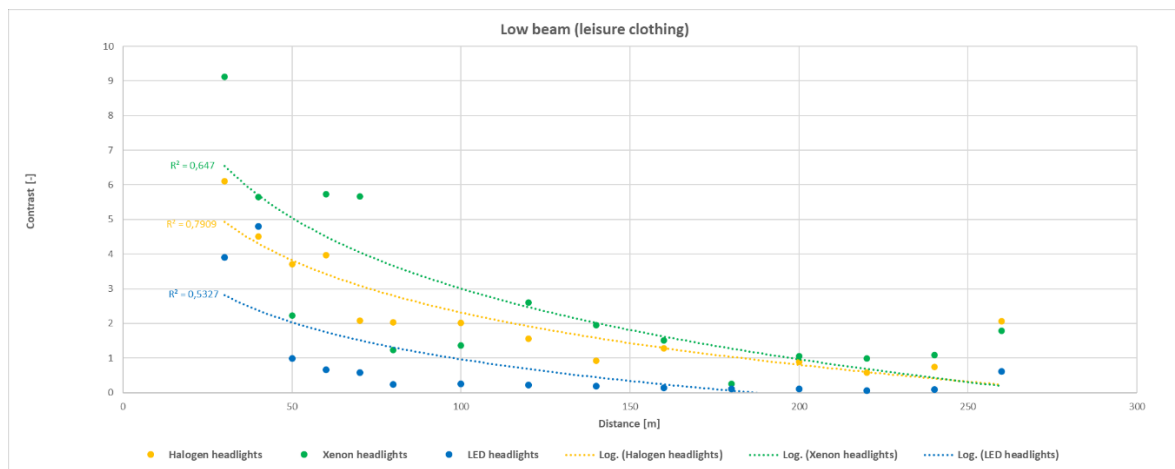
Figure 3. Areas for luminance analysis for low-beam (left) and high-beam (right)

3. Results

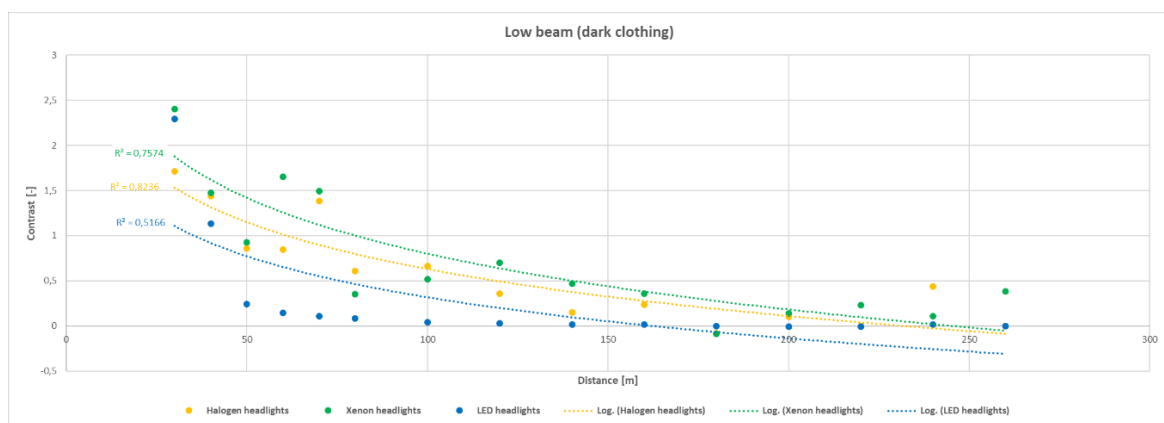
3.1. Low-beam headlamps

The analysis of all measurements allows to identify the relationship between the contrast created by pedestrian illumination by the vehicle and the vehicle distance from the pedestrian. The contrast values for low-beam headlamps are illustrated by the following graphs for both types of pedestrian clothing. In the case of dark clothing are contrasted values approximately one-third of contrast values for leisure clothing pedestrian. The highest contrast values are reached by xenon headlamps with minor exceptions

in the whole measured distance range. The lowest contrast values are achieved by LED headlamps. LED headlamps have the highest luminous flux, but a very sharp transition edge between lighting and not-lighting area.

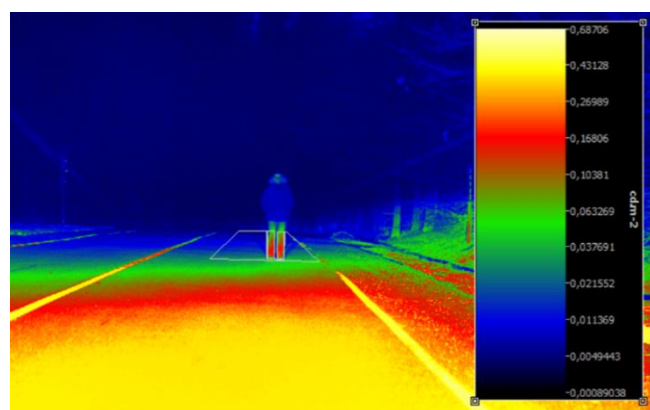


Graph 1. Contrast of leisure clothing when illuminated by low-beam headlamps



Graph 2. Contrast of a dark pedestrian when illuminated by low-beam headlamps

The luminance distribution of all three types of analysed headlamps is illustrated by the following figure. In the case of halogen headlamps could be seen light dispersion and related gradual transition between illuminated and non-illuminated part of the road and pedestrian. The light dispersion positively affects headlamps afterglow. Among all tested headlamps, LED headlamps have the sharpest edge of the illuminated area.



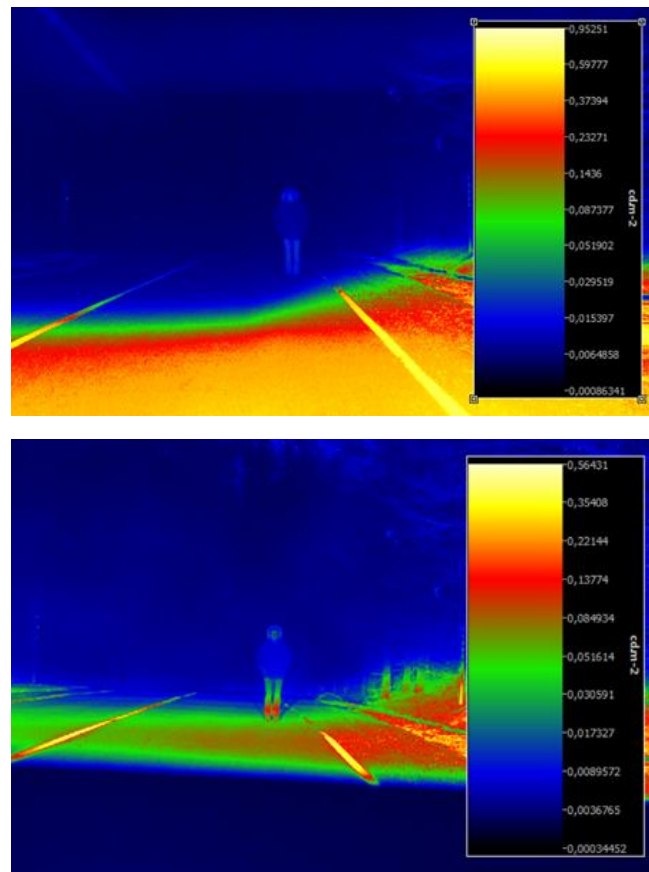
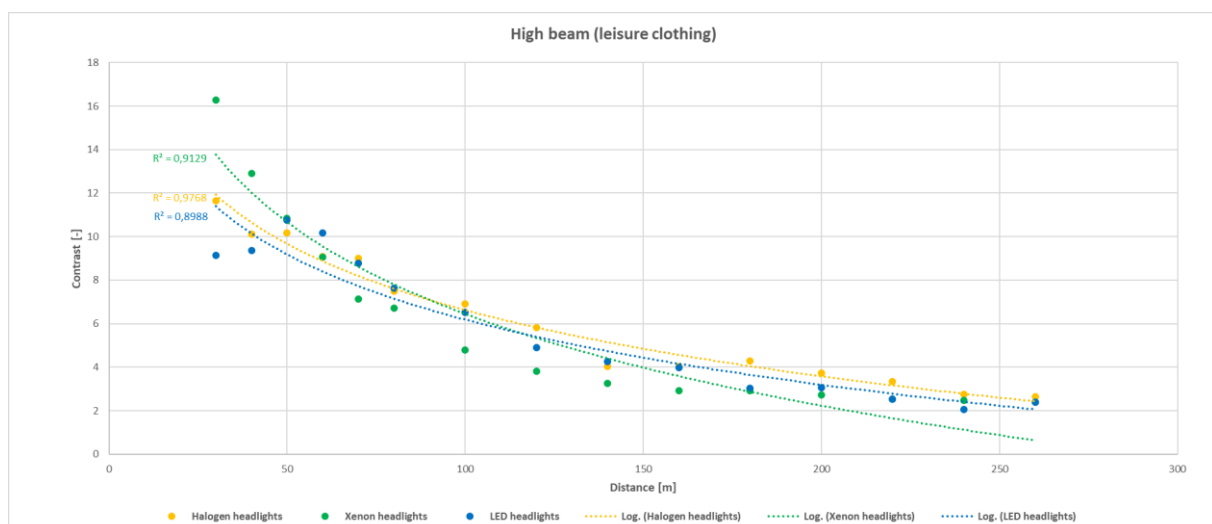


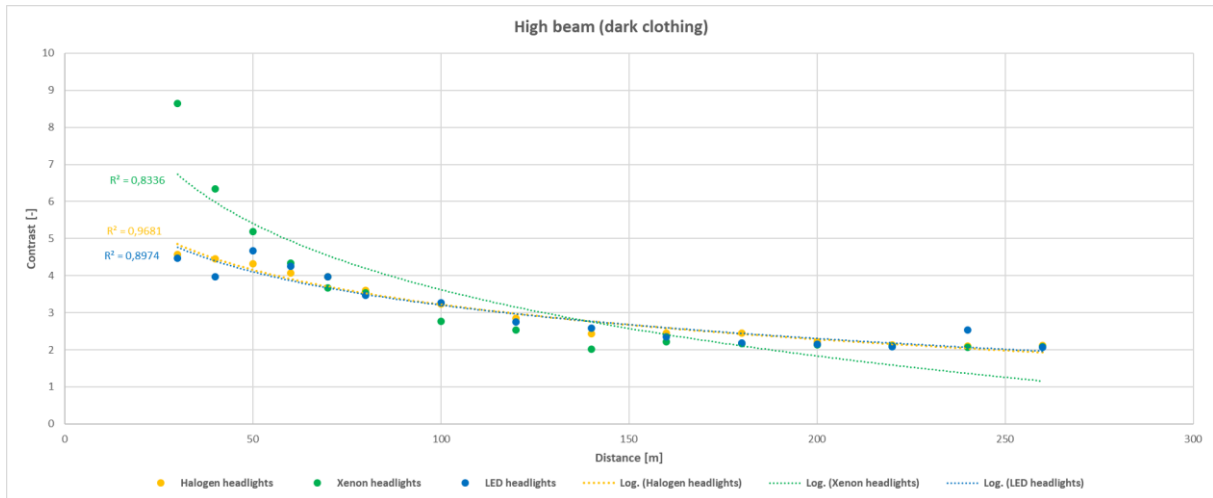
Figure 4. Luminance distribution, low-beam, 50 m (halogen headlamps, LED headlamps, xenon headlamps)

3.2. High beam headlamps

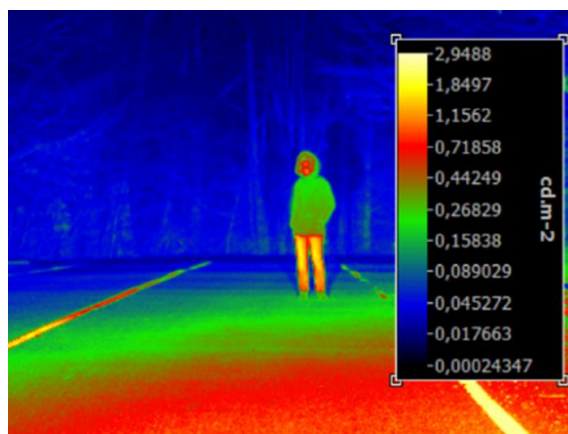
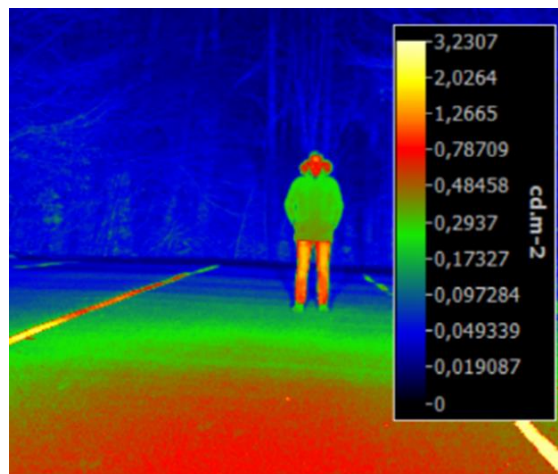
The contrast values for high-beam headlamps are illustrated by the following graphs for both types of pedestrian clothing. Approximately up to 60 meters achieves the highest contrast values xenon headlamps. For higher distances the contrast level decreases below the contrast level of the LED and halogen high-beam headlamps. The trend of contrast for LED and halogen headlamps is similar while the halogen headlamps contrast values are slightly higher. The luminance distribution of all three types of analysed headlamps is illustrated by the following figure.



Graph 3. Contrast of leisure clothes when illuminated by high-beam headlamps



Graph 4. Contrast of a dark clothes when illuminated by high-beam headlamps



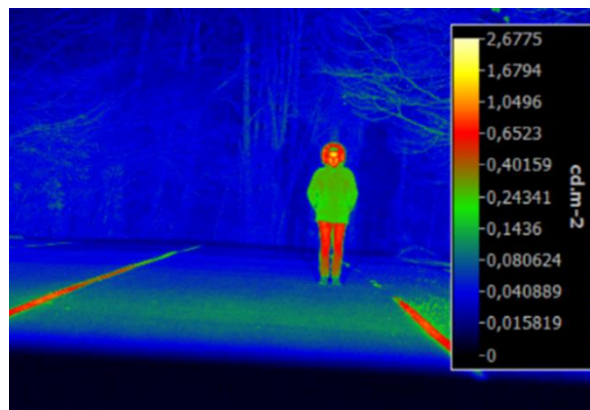


Figure 5. Luminance distribution - high beam, 60 m (halogen headlamps, LED headlamps, xenon headlamps)

4. Conclusion

The aim of the article was analysis and comparison of the relation between the contrast created by pedestrian illumination by the vehicle and the vehicle distance from a pedestrian in terms of three types of headlamps – LED, halogen, xenon. The contrast values are influenced not only by the type of headlamps but also by the mode of lighting settings (low-beam, high beam), the mutual distance between pedestrian and vehicle, clothing colour or environment. Vehicle dynamic movements (especially during driving on the uneven roadway) also influenced the illumination and related driver perception of the pedestrian.

The comparison of headlamps shows the highest contrast values reached by xenon headlamps, especially while using low-beam headlamps. High-beam headlamps analysis shows the highest contrast values of xenon headlamps in a mutual distance range between vehicle and pedestrian in the range from 0 – 60 meters. Similarly in previous experiments Bradáč et al. [10] focused on halogen and xenon headlamps comparison on vehicle Skoda Yeti. The xenon headlamps have a higher value of luminous flux in comparison with halogen headlamps and higher thermal chromaticity. The light colour is closer to daylight in comparison with halogen headlamps.

Analysis of contrast shows the lowest values achieved by LED headlamps. LED headlamps contain shorter wavelength light and the highest luminous flux, but a very sharp transition edge between lighted and not-lighted area. The main advantage is the minimal glare of drivers of oncoming vehicles, the enlightenment operation area is smaller. In comparison, halogen headlamps have the lowest luminous flux, but due to the relatively great light dispersion of halogen headlamps is the pedestrian illuminated earlier.

Based on the above measurements, it can be stated that the most ideal combination of the headlamps of a passenger car is a combination of a xenon headlamp as low-beam headlamps and LED or halogen high beam headlamps. While the halogen headlamps achieved better results at distances above 100 m, especially for leisure clothing pedestrian, all three types of light sources achieved similar results with the dark pedestrian, with a slight predominance of the LED headlamps.

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References

- [1] J. W. Muttart, Effects of Retroreflective Material Upon Pedestrian Identification at Night. *Accident Reconstruction Journal*, 1, 2000.
- [2] R. Kledus, M. Semela, and A. Bradáč, Comparative Perception of Objects by Drivers from Stationary and Moving Vehicles in Regular Road Traffic. In 19th EVU Congress Prague 2010

- Proceedings. Brno: Tribun EU s.r.o., s. 9-28. ISBN: 978-80-7399-136- 4, 2010.
- [3] S. A. Balk, R. A. Tyrrell, J. O. Brooks, and T. L. Carpenter, Highlighting human form and motion information enhances the conspicuity of pedestrians at night. *Perception*, 37(8), 1276-1284, 2008.
- [4] M. A. Green, Roadway human factors: From science to application. Lawyers & Judges Publishing Company, Incorporated, 2018.
- [5] J. M. Wood, R. A. Tyrrell, and T. P. Carberry. Pedestrian visibility at night: Effects of pedestrian clothing, driver age, and headlamp beam setting. In TRB 2003 Annual Meeting, January 2003.
- [6] B.C. Benea, D.D. Trusca, G.R. Toganel, and A.I. Radu, Pedestrian visibility at night: the influence of the pedestrian clothing and the defective headlamp of the car. In IOP Conference Series: Materials Science and Engineering (Vol. 568, No. 1, p. 012003). IOP Publishing, August 2019.
- [7] S. A. W. Borzendowski, A. A. S. Sewall, P. J. Rosopa, & R. A. Tyrrell, Drivers' judgments of the effect of headlamp glare on their ability to see pedestrians at night. *Journal of safety research*, 53, 31-37, 2015.
- [8] E. M. Portniagin, A. A. Ivasinkova, O. A. Svirbutovich, A. V. Gorban, and N. A. Gorban. Analysis of the headlamps checking parameters. In IOP Conference Series: Materials Science and Engineering (Vol. 632, No. 1, p. 012031). IOP Publishing, October 2019.
- [9] Czech in-depth accident study (CzIDAS), Transport Research Centre, Czech Republic, [Online] 2021. Available at: www.vyzkumnehod.cz.
- [10] A. Bradáč, M. Semela, J. Škoda, S. Sumec, R. Kledus, and M. Bilík. Comparison of Halogen and Xenon Headlamps in Terms of Pedestrians' Visibility. Proceedings of the 21st International Conference LIGHT SVĚTLO 2015. p. 133-137. ISBN: 978-80-214-5244-2, 2015.
- [11] J. Baleja, O. Dolejší, P. Běčák, K. Skokanský, and T. Novák, The visibility of pedestrians in the traffic area, using different light source technologies of car headlamps, Proceedings Of The 10th International Scientific Symposium On Electrical Power Engineering (Elektroenergetika 2019), Slovakia, 2019.
- [12] Google maps, Test track [Online] 2021. Available at: www.google.cz/maps.