Acta Polytechnica CTU Proceedings **41**:58–65, 2023
https://doi.org/10.14311/APP.2023.41.0058

THE INFLUENCE OF MODERN HEADLAMPS ON THE RECOGNITION OF PORTABLE TRAFFIC SIGNS AND WARNING TRIANGLES

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Abstract. This article focuses on the issue of portable traffic signs and their visibility using different light sources such as halogen, Xenon, or LED. The measured values of luminance and retroreflection for each object are used to distinguish the individual results. The results show the differences between the various light sources on the visibility of the measured objects. Furthermore, from these results it is possible to evaluate portable traffic signs regarding degradation due to mechanical wear or aging.

Keywords: Retroreflection, portable traffic signs, light sources, luminance, mechanical wear.

1. Introduction

This paper expands on the authors' previous publication presented at the JuFoS conference and uses parts of the text from it [1]. Portable traffic signs have a significant impact on road safety in non-standard situations such as road repairs, detours, or traffic accidents. According to accident statistics, approximately 350 accidents in the Czech Republic are related to traffic signs every year. For this study, the term 'portable traffic signs' includes traffic devices and warning triangles since these are used in similar non-standard situations. One of the motives of this study was the existence of several variations of light sources in modern vehicles such as halogen, Xenon, LED, or Laser diode, which are mentioned by [2–4]. The goal was to determine the visibility of portable traffic signs regarding different light sources from different distances, considering factors such as proper placement of the sign or its degradation due to mechanical wear or aging. To achieve this, retroreflection and luminance measurements were carried out on selected samples of portable traffic signs, particularly 20 pairs of portable traffic signs and 5 different types of warning triangles. This project did not address the effects of adaptive technologies of modern headlamps, such as AFL or ADB, whose effects on visibility have been addressed by [5]. Based on the results and experience with the first static measurement, a second static measurement was carried out. The second static measurement compared halogen reflector headlamps and halogen projector headlamps. To reduce measurement inaccuracies, only new traffic signs and devices that are expected to meet the legislative requirements were used and new bulbs were fitted to both types of headlamps. The measurement procedures and evaluation methodologies were identical to the first static measurement.

1.1. Current state

There is a methodology for the placement of traffic signs in the Czech Republic set by technical standards [6, 7]. Based on these standards, we recognize the following portable traffic signs and traffic devices. Portable traffic sign is vertical traffic sign placed on a red and white striped column and active surface of the sign must be retroreflective according to EN 12899-1. Traffic devices are mainly devices for traffic management. These include traffic cones, direction signs, or guide signs. Retroreflective materials should be used for sign faces according to EN 12899-1. The white stripes of traffic cones should be retroreflective according to EN 13422 [8, 9]. Retroreflection is a feature that allows the light cast by a vehicle's headlights to be reflected back to the driver. This feature allows the driver to see the traffic sign in time and react to it during the day and in the dark [10]. There are three classes of retro-reflectivity – RA1, RA2, and RA3. The higher the class of the sheeting, the better the visibility of the sign or device at night. The methodology of measuring retroreflection, according to the mentioned standards, consists only the laboratory measurement and does not consider the actual visibility by the driver in the real world.

2. Method

2.1. Methodology for measuring retroreflection

Retroreflection values were measured on the entire set of portable traffic signs, traffic devices and warning triangles. For this purpose, signs and devices that were commonly used on roads were selected. The aim of the measurement was to verify whether the selected sings and devices meet the requirements of EN 12899-1 and EN 13422 in the case of traffic cones and ECE 27-04

Figure 1. Retroreflection measuring using Zehntner ZRS 6060 EN [1].

Figure 2. Placement of measuring device LumiDISP in front of the vehicle [1].

in case of the warning triangles [8, 9, 11]. A Zehntner ZRS 6060.EN retroreflectometer was used for the measurements (see Figure 1 for example of measuring process). This is a device designed to measure the retroreflection coefficient RA of vertical traffic signs or other similar materials. This device is intended for measuring the retroreflection coefficient in the field. Before the actual measurement, it was necessary to clean each sign and to let the measuring device stabilize outside of the transport package for at least 5 minutes before the actual measurement. The measurement of vertical traffic signs (including traffic devices) is carried out at three randomly selected measuring points of the same-colored area. The device itself then averages these values and displays the resulting values of the retroreflection coefficient. These values can be compared with the values specified in the relevant standards EN 12899-1 and EN 13422.

2.2. Methodology for measuring luminance

Luminance was measured using the LumiDISP. This device is luminance distribution analyzer that uses the analysis of luminance ratios with the help of digital photography to photometrically measure luminance and its distribution. The output of this device are luminance maps from which it is possible to determine the luminance value of individual traffic signs at any point in the captured digital image. Both portable traffic sign measurements were taken at a location where there was minimal light pollution. The first static measurement took place when the moon was new, and it was clear to partly cloudy. Three types of headlights were used for this measurement – halogen reflector, Bixenon and LED, all on Škoda vehicles. The second static measurement took place when the moon was nearly full, and the sky was clear. For this measurement, Škoda vehicles equipped with halogen reflector headlamps and halogen projector headlamps were used. The device was placed in front of the vehicle to avoid any disturbance of the windscreens of each vehicle, as shown in Figure 2. For each type of headlamp, measurements were collected for low beam and high beam settings. All the measurements were at an airstrip with a tarmac surface and a minimum gradient. The measured objects were each positioned 0.5 m from the right side of the road and the centerline of the vehicle with the respective headlamps was 1.75 m from the right side of the road. The first distance measured was 80 m, which is approximately the distance needed for the vehicle to stop from a speed of $9\,\mathrm{km\,h^{-1}}$ including the driver's reaction time of 1.0 s and applying the minimum required braking deceleration of $5.8\,\mathrm{m\,s^{-2}}$ for passenger vehicles. The second distance was 350 m, which was the maximum possible distance that could be achieved on the site. Averages of the luminance values of individual pixels for the marker area were used to evaluate and quantify the marker luminance. Therefore, comparisons can also be made between various traffic signs in different sizes. For the evaluation of the brightness of the triangles, a similar method as for the traffic signs was used. In the case of triangles, only the values of the physical parts of the triangles without background were used. The average luminance of each triangle included the internal non-reflective parts if the triangle had them.

2.3. Test measurements

To determine the influence of the environment, tilt, or change of position of the measured sign, a test measurement was performed. The test measurement showed that the error of the measured values due to the influence of weather conditions was below 10 %. A change of position (up to 10 cm) and a rotation of the sign (up to 5°) did not have any significant effect and were insignificant compared to the influence of the environment.

2.4. Headlamp adjustment and intensity measurement

Prior to the second static measurement, both types of halogen headlamps were adjusted, including replacement of halogen bulbs and adjustment. H4 and H7 halogen bulbs were used in the measurements for halogen reflector and projector headlamps respectively. The headlamps were then adjusted, and the illuminance measured. These operations were carried out using a Tecnolux 12799/LX2/P regloscope. This is a diagnostic device designed to check and adjust all types of headlamps. 'It is an optical-mechanical device working on the principle of direct projection of the image of the light emitted by the headlamp and enabling the inspection and adjustment of headlamps of motor vehicles whose height above the ground is at least 200–1300 mm [12].

2.5. Traffic signs selection

For the retroreflection measurements, both new signs and pairs of signs that were already in use were measured. The measured values were compared with the respective norms to determine the state of degradation of the signs. The measurements indicated that the retroreflection values can be used to determine to a certain extent the wear of the signs that cannot be determined otherwise (e.g., the absence of a manufacturing label or details of eventual refurbishment).

In the case of the second static measurement, only new traffic signs and devices were selected.

3. Results

3.1. The first static measurement

For the first static measurement, similar Škoda vehicles equipped with different types of headlights were chosen. Specifically, the vehicles were a Škoda Octavia III (2018) with halogen reflector headlamps, a Škoda Superb III (2015) with Bixenon projector headlamps and a Škoda Superb III fl. (2022) with full LED Matrix headlamps.

3.1.1. Distance 80 m

Low-beam mode

Measurements with the LumiDISP device at 80 m in low beam mode resulted in the highest values for Halogen headlights for all measured objects. For the remaining types of headlamps, the following patterns were apparent (see Figure 3):

- Objects that were mostly below 150 cm height from the road surface displayed higher luminance values for full LED headlamps in comparison to Bixenon headlamps,
- the remaining objects, which had the bottom edge at a height of 150 cm, displayed higher values for Bixenon headlamps in comparison to full LED headlamps.

High-beam mode

At 80 m in high beam mode, the highest luminance values were achieved when using the full LED headlamps. In all cases, the Halogen headlamps performed better than the Bixenon headlamps. Curiously, for the warning triangles, Halogen headlamps came out better in high beam mode, although full LED headlamps were better for the cones and other signs. The full LED headlamps performed the best with the signs with a border that used the RA3 sheeting, as expected. For the Halogen and Bixenon headlights, these signs showed similar values to the white signs using RA2 sheeting.

Figure 4 provides a representation of the average luminance values measured for each portable traffic sign. Differences due to degradation can be seen for each pair. Figure 5 shows a series of LumiDISP outputs in the form of luminance maps demonstrating the differences between the headlamps for the same traffic sign.

3.1.2. Distance 350 m

Low-beam mode

For the measurements at 350 m, five pairs of traffic signs were selected, which were similar in size and at the same time featured identical colors on different backgrounds, and one warning triangle. Again, in the low beam setting, the Halogen headlamps gave the best values for all measured objects, while the Bixenon headlamps performed the worst. The results for the warning triangle were in the same manner.

High-beam mode

For measurements at 350 m in high beam setting, the full LED headlamps performed best, and the Bixenon headlamps again performed worst. As was the case at 80 m, the Halogen headlamps performed best in the high beam setting. Figure 6 shows comparison of different types of headlamps and beam modes.

3.2. The second static measurement

For the second static measurement, two similar Škoda vehicles equipped with halogen headlamps were chosen. Specifically, the vehicles were a Škoda Fabia II (2004) with halogen reflector headlamps and a Škoda Roomster (2007) with halogen projector headlamps. Only new traffic signs were used for this measurement and new halogen bulbs were fitted in the vehicles to avoid any possible interference with the measurement. When measuring the illuminance, even when new bulbs were used, the projector headlamps of the Škoda Roomster were found to have a low intensity value, where the right headlamp did not meet the minimum intensity value required for vehicle operation. In order to be able to compare the results, this fact was considered by recalculating the measured luminance ratios using the measured intensity values of the individual headlamps. For the second static measurement at 80 m, the position of the sign above the road level was changed. According to TP 65 it is recommended to place the lower edge at a height of at least 60 cm above the road level [6]. In the case of this static measurement, the bottom edge of the sign was placed at a height of 105 cm and 150 cm on the post. The measurements also used traffic devices

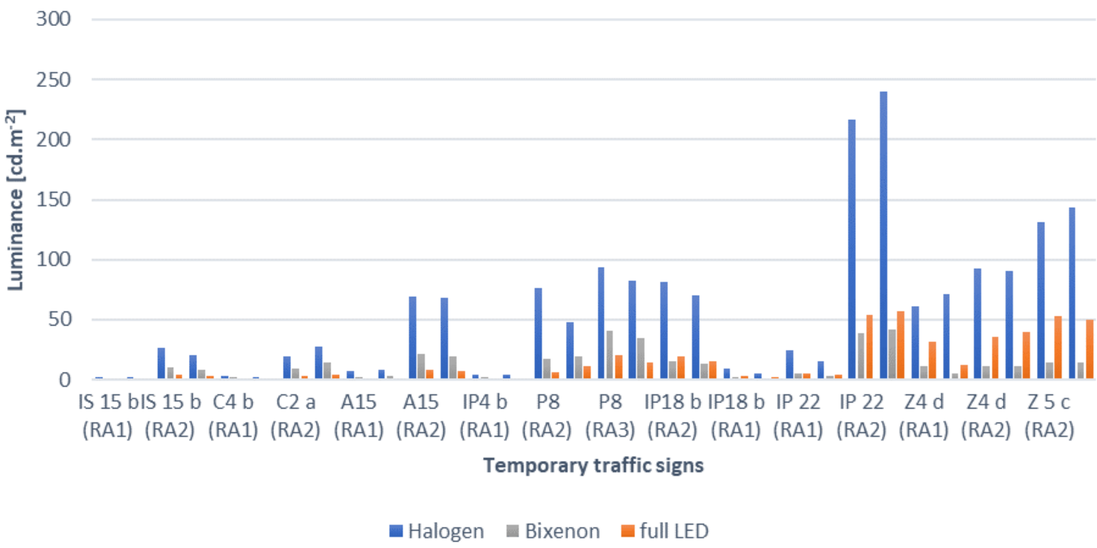

Figure 3. Luminance values (cd m^{-2}) at 80 m using a low beam headlamp setting [1].

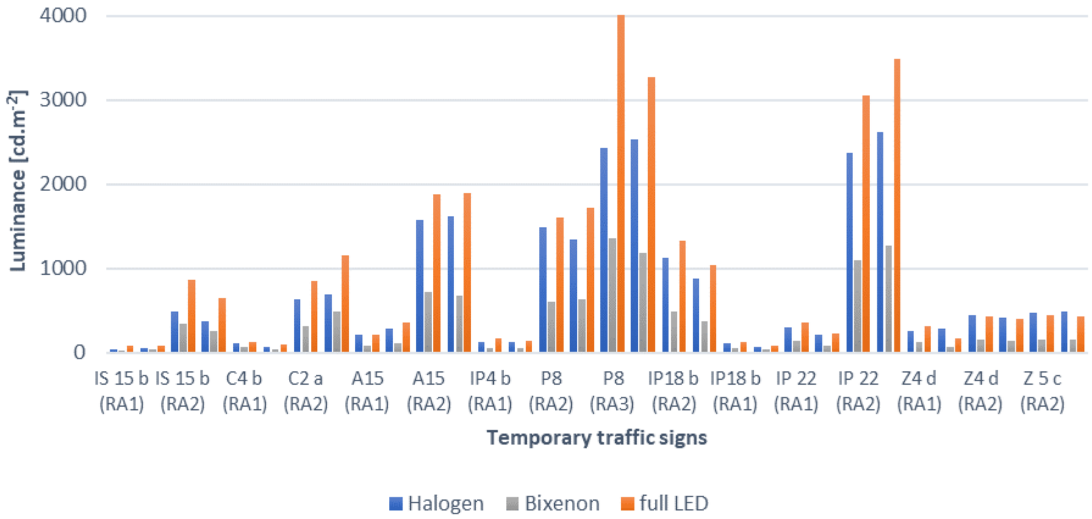

Figure 4. Luminance values (cd m^{-2}) at 80 m using a high beam headlamp setting [1].

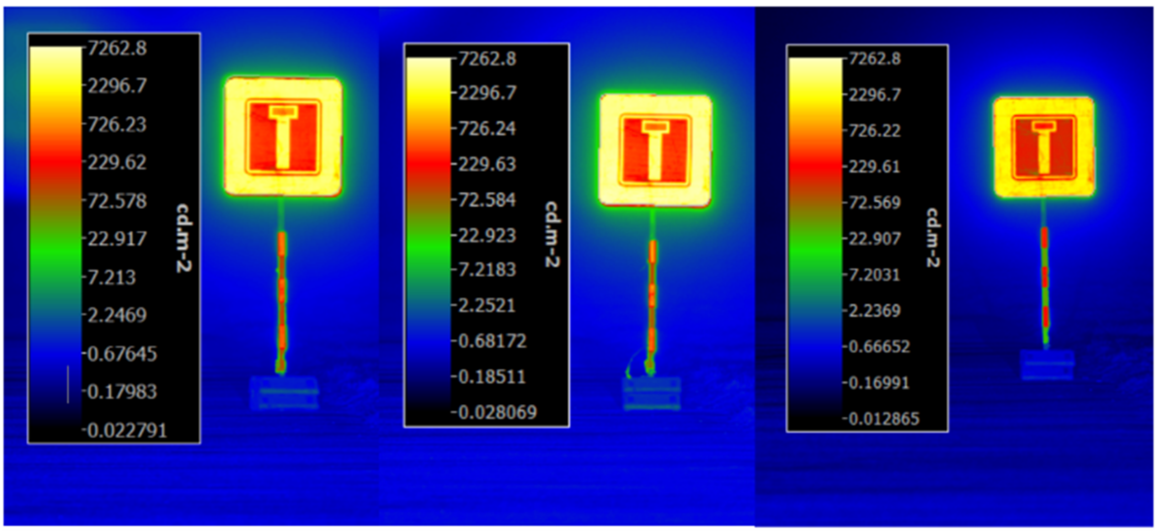

Figure 5. Comparison of traffic signs in terms of luminance, from left in order Halogen, full LED, Bixenon [1].

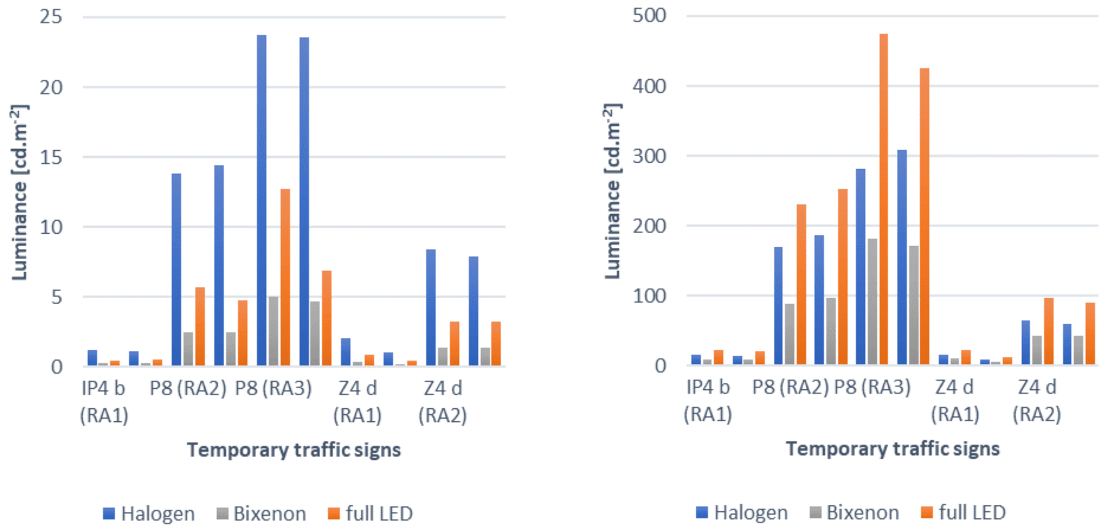

Figure 6. Comparison of luminance values at 350 m using a headlamp setting (Low-beam on the left, high-beam on the right) [1].

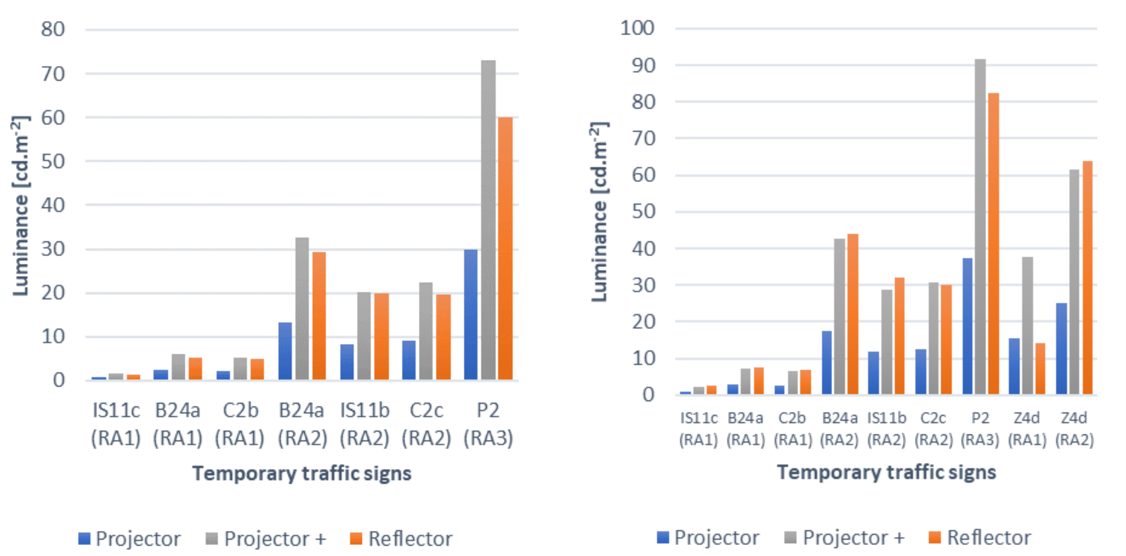

Figure 7. Comparison of luminance values at 80 m using a Low-beam headlamp setting (height 150 cm on the left, height 105 cm on the right).

whose design does not allow them to be placed at different heights. For this reason, they were placed at only one height as specified by the design.

3.2.1. Distance 80 m

Low-beam mode

Measurements with the LumiDISP at 80 m in low-beam mode showed the highest values for the halogen reflector headlamps for all measured objects. After correcting the results in relation to the intensity of the headlamps used ("Projector +" in Figure 7), the halogen headlamps with projectors showed better results in all cases. In the case of a lowering the height of the traffic sign from 150 cm to 105 cm, there was a slight increase in the brightness values for both the halogen reflector headlamps and halogen projector headlamps. As expected, for both headlamps, all the RA1 class signs came out worst. The signs with the larger white and red areas showed the best average luminance values.

High-beam mode

Measurements at the 80 m distance in high-beam mode were also made for two different traffic sign heights. The results show that the halogen projector headlamp performed better for the signs placed with the lower edge at a height of 150 cm, even before recalculation to compare the light intensities. This is due to the alignment of the headlamps, where the main beam halogen projector was aligned higher than the main beam halogen reflector. Both headlamps were adjusted to the correct tolerance. For markers at 105 cm lower edge height, the halogen headlamp

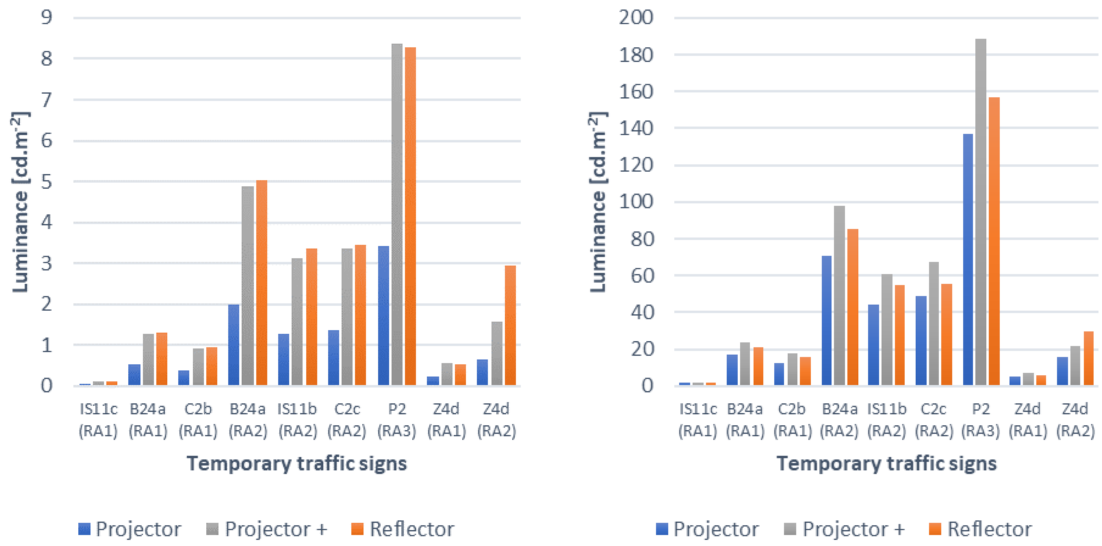

Figure 8. Comparison of luminance values at 350 m using a different headlamp setting (Low-beam on the left, High-beam on the right).

reflector came out better, and after conversion to the same luminous intensities, the halogen projector came out better, as it did for the low-beam mode headlamps.

3.2.2. Distance 350 m

Low-beam mode

The 350 m measurement was conducted with the same traffic signs as the 80 m measurement. The LumiDISP measurements at 350 m in low-beam mode showed the highest values for the halogen reflector headlamp for all measured objects. Again, the results were corrected for the intensity of the headlamps used ("Projector +" in Figure 8). Again, in all cases the halogen projector headlamps showed better results. Also, at 350 m, all traffic signs of class RA1 came out worst for both types of headlamps. The markers with the larger white and red areas showed the best average luminance values. High-beam mode From the luminance measurements at 350 m in high-beam mode, the halogen reflector headlamps again performed better. Compared to the halogen projector headlamps, the differences were not significant as with the low-beam headlamps. After correcting the results in relation to the intensity of the headlamps used, the halogen headlamps with projectors performed better in all cases.

High-beam mode

For measurements at 350 m in high beam setting, the full LED headlamps performed best, and the Bixenon headlamps again performed worst. As was the case at 80 m, the Halogen headlamps performed best in the high beam setting. Figure 6 shows comparison of different types of headlamps and beam modes.

3.3. Warning triangles

Within the individual static measurements, interesting observations were made concerning the warning triangles. After comparing the first and second measurements, it was found that there were some similarities between the measurements. Of the two measurements, the best results were obtained for the third warning triangle measured and the worst results for the fourth warning triangle. It can therefore be concluded that, in the case of warning triangles, it is not only the type of headlamps used to illuminate the warning triangles that matters but also, and above all, the construction and material properties of the particular triangles. Furthermore, it has been found that the reflective properties of individual warning triangles vary quite considerably, and these facts may have an impact on their possible use in real traffic (see Figure 9).

Regarding the possibility of influencing the average luminance values of individual pixels, as mentioned in Section 1, also shown in Figure 10, which shows a series of LumiDISP outputs in the form of luminance maps demonstrating the different warning tringles for the halogen headlight with reflector.

4. Discussion

The minimum luminance for recognizability of a traffic sign at night out in the rural area ranges from 35 to 340 $cd\,m^{-2}$ according to [13]. According to AASHTO in the range of 20 to 180 $cd\,m^{-2}$ [14]. According to Elstad et al. [15] in the range of 35 to 70 $cd\,m^{-2}$. According to Bullough et al. [16] ranging up to 280 $cd\,m^{-2}$. According to Fletcher et al. [17] in the range of 20 $cd\,m^{-2}$. According to Freyssinier et al. [18] in the range of 40 $cd\,m^{-2}$. All types of headlamps in a high beam setting met these conditions at 80 m. In a low beam setting, signs with RA1

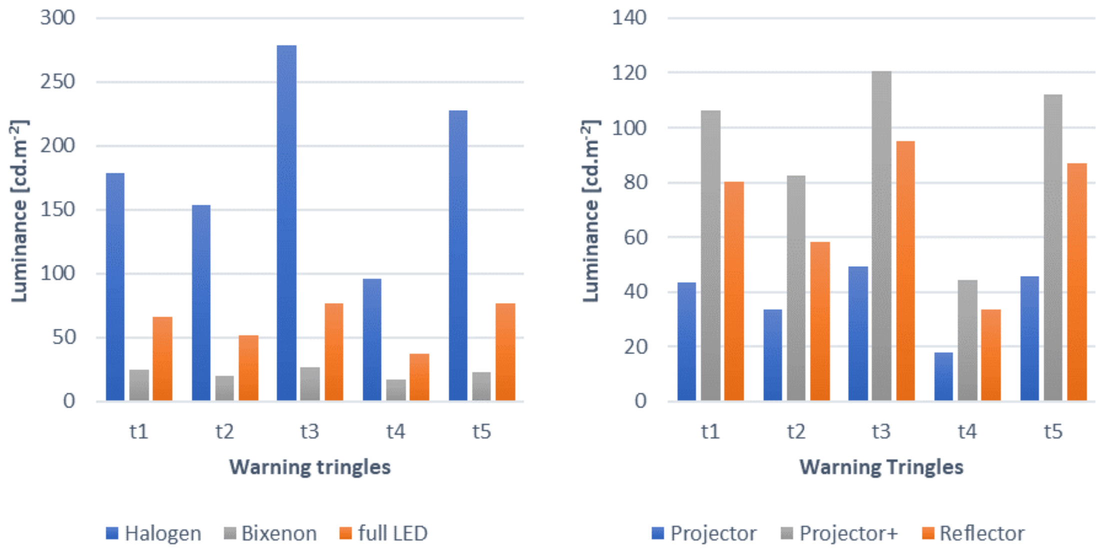

Figure 9. Comparison of luminance values for warning tringles at 80 m using a Low-beam headlamp setting (The first static measurement on the left, the second static measurement on the right).

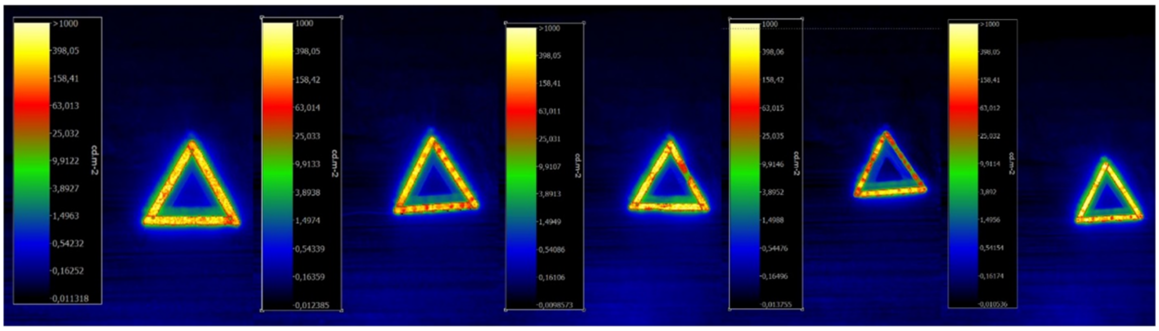

Figure 10. Comparison of luminance values for different warning triangles at 80 m for halogen headlight with reflector using a Low-beam headlamp setting.

background, predominantly amber or blue color, did not meet these values.

5. Conclusions

In this study, average luminance values were measured for selected portable traffic signs as a whole or their sections (e.g., individual colors). These values were determined for the purpose of the first static measurement for different types of headlamps (halogen, full LED, Bixenon) in low beam and high beam modes at distances of 80 and 350 m from the object to be measured. The retroreflection values were compared with the values set by the standards and with the values measured by the LumiDISP device. By comparing the measured values from the two devices with each other, it was observed that in 2/3 of the cases the values showed similar patterns, which could be used to determine the loss of retroreflection for degraded signs. The second static measurement was designed to further understand the design characteristics of the halogen headlamps, and therefore measurements were made on the new portable traffic signs and using only new halogen bulbs, with the intention of eliminating measurement deviations. It was found that although halogen reflector headlamps showed higher measured luminance values, after correcting the results in relation to the intensity of the headlamps used, the halogen projector headlamps would perform better in all cases. In the light of the findings, the interpretation of the results of the first static measurement can be revised so that projector headlamps should show better brightness values than reflector headlamps. Thus, it can be concluded that the Bixenon headlamps used in the first static measurement must have had an overall lower illuminance which was not, however, related to the design characteristics. The aim of the measurements was to determine how the type of headlamp and the different design and material properties affect the visibility of the warning triangles. For the measurements, warning triangles already in use, as well as new triangles purchased for the purpose of the measurements, were used. After evaluating the results from both measurements, it was found that the visibility of the triangles is significantly influenced by their construction and material. In addition, the use of different types of headlamps also affects the results.

All warning triangles met the minimum brightness limit for visibility set by [14]. Further measurements on a larger scale would be necessary to achieve more accurate results. These measurements served as a basis for the implementation of measurements in regular traffic, where drivers' reactions to portable road signs will be verified using eye-tracking.

6. Acknowledgements

The authors would like to express appreciation for the support of: Transport Research Centre (CDV) (https://www.cdv.cz/), LumiDISP (https://lumidisp.eu/), CTU in Prague Faculty of Transportation Sciences Department of Forensic Experts in Transportation (https://www.fd.cvut.cz/), and Michal Křižák, Brno University of Technology (https://www.vut.cz/). This article was produced with the use of measurement equipment with the financial support of the Ministry of Transport within the program of long-term conceptual development of research organizations. This study was part of the project Quality internal grants of BUT (KInG BUT); reg. number: CZ.02.2.69/0.0/0.0/19_073/0016948.

EUROPEAN UNION
European Structural and Investment Funds
Operational Programme Research,
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