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STUDY OF DIFFERENCES IN ILLUMINATION INSIDE BUSES FOR CITY TRANSPORT OF PASSENGERS

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Abstract The importance of adequate lighting in buses for urban passenger transport is great, for the reason that adequately designed lighting contributes to the comfort and safety of passengers. In addition to the fact that passengers expect that the buses participating in public transport meet adequate lighting conditions, they also expect that identical or approximately the same lighting conditions (as well as other environmental conditions) exist in all buses, regardless of brand or type of a bus that participates in transportation. In this way, a balanced quality of service is achieved and a positive effect on customer satisfaction. The focus of this paper is to investigate the existence of differences in the distribution of light in different types and brands of buses used for urban passenger transport in Belgrade. For this purpose, five locations where illumination was measured were selected: at eye level for the seated passenger position, at floor level at the aisle location, at floor level at the stair location, at eye level for the standing position of the passenger at the aisle location and at the location of warning signs. The research included 140 buses that have participated in urban passenger transport. As an additional factor, the zones of higher and lower street lighting were taken into account. This factor has not previously been taken into account in considerations of this kind. Based on the testing of statistical hypotheses, the results of the research showed that at none of the five mentioned locations there is a uniform level of illumination in the observed sample of buses. In order to eliminate this shortcoming, certain recommendations have been given for lighting designers of buses.

Keywords: Illumination; lighting; bus; passengers; ergonomics.

1. INTRODUCTION

The quality of passenger transport in buses intended for urban transport depends on a number of factors [1-5]. Ambient conditions in buses, such as noise, temperature, humidity, dust, air quality, vibration, lighting, play an important role in the perception of transport quality by passengers. Of the previously listed factors, the lighting inside the bus was the least studied.

One of the basic tasks when designing the interior of a city bus is to design lighting conditions that will be comfortable and safe for the passenger. Lighting conditions can be observed and analyzed from two aspects. The first aspect is the physical measurements of selected lighting parameters, which are based on obtaining the necessary data using measuring instruments. The second aspect is based on the assessment of lighting conditions in buses by the passengers themselves. This

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assessment is most often done through questionnaires, checklists, interviews, and other methods of similar conception.

GSP Belgrade and other private bus carriers that make up the structure of the city bus transport in Belgrade (Serbia) have a large number of different brands and models of buses, which potentially provide different lighting conditions. For that reason, the assessment of certain determinants of lighting conditions in buses for public transport in Belgrade is of special importance from the point of view of passengers' comfort and safety. It is not known research that previously covered some of the aspects of lighting at the mentioned location. In order to assess the quality of lighting inside a bus for urban passenger transport, it is not only necessary to take into account the level of illumination, but also variations in lighting at bus locations that are of interest to passenger comfort and safety. Therefore, the focus of this paper is on the assessment of the presence of differences in the distribution of light in the space intended for passenger accommodation, between buses used to transport passengers in the urban environment.

2. METHOD

In order to measure the illumination in buses, a photometric method was used. For this purpose, a photometer (lx) was used. Since the lighting in the bus can be affected by external lighting, such as street lighting, this factor is included in the measurements by taking into account the parts of the city with higher and lower street illumination. The division into zones of higher and lower levels of illumination was performed taking into account several factors, such as the presence or absence of street lighting, the density of street lamps and the intensity of light produced by lamps that was determined on the basis of preliminary measurements. In that way, the possibility of the influence of street lighting on the illumination that exists inside the bus is foreseen. In that way, it was taken into account that there are parts of the streets where the street lighting is weak or even non-existent (such as in some peripheral urban zones). In this regard, it was necessary to determine the locations of higher and lower street illumination for each bus line that was included in the measurement. It is not known that this factor has been taken into account in previous studies of interior illumination in urban passenger buses.

The illumination in buses has been measured at five locations:

- at eye level for the sitting position of the passenger (lighting at this location is important because it allows different activities of the passenger, such as reading, etc.)
- at floor level at the aisle location (lighting at this location is important as it allows the passenger to see any obstacles in the aisle)
- at floor height, at the location of the stairs (lighting at this location is important because it allows passengers to see the stairs when entering and exiting the bus)
- at eye level for the standing position of the passenger at the location of the passage (brightness at this location is important because it allows us to find out what the passenger can see at the location where he is)
- at the location of warning signs (refers to the lighting at the location of stickers on the walls of the bus, which contain warning signs or text inscriptions that should be visible and legible).

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When measuring the illumination, the brand (type) of the bus, the time of day (measurement time), as well as the bus line on which the measurement was performed were taken into account. Measurements were performed in conditions of low participation or absence of natural light, in the winter. Therefore, only conditions were selected when there was no participation of daylight, or due to the time of day or weather conditions, the participation of natural light was negligible. Measurements were carried out when there was a need to activate the interior lighting in the buses.

3. RESULTS

Since the measurements were performed taking into account the variation in the level of external lighting (better and less illuminated parts of the city), below will be presented diagrams of the distribution of illumination in buses for urban passenger transport by positions that were of interest for consideration. Diagrams obtained in parts of the city with a higher share will be presented first, and then in parts of the city with a lower share of street lighting. As mentioned, the measurements were carried out in conditions without the participation of daylight or with negligible participation.

Eye-level illumination for seated passenger position was measured in 140 city passenger buses. The average illumination at eye level for the seated position of passengers in public transport buses in better-lit parts of the city was 91.93 lx (SD = 17.76). In the following and all other diagrams related to lighting measurement, the illumination is given in lx.

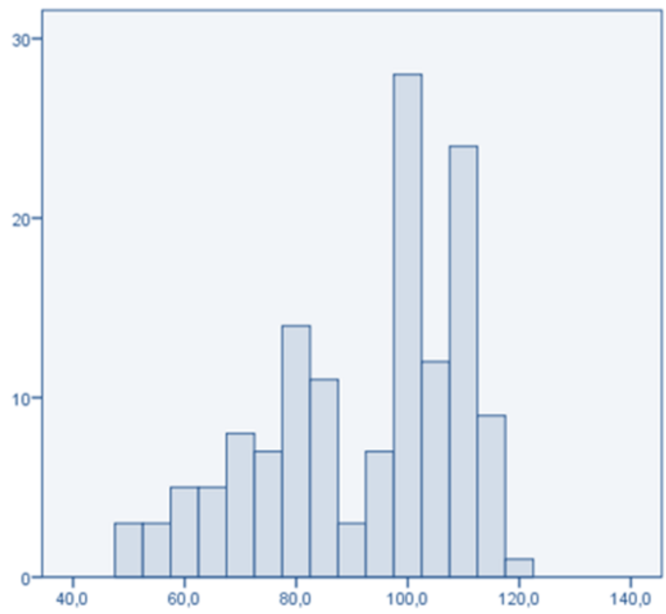

Figure 1. Distribution of illumination levels in buses at the position of the passengers' eyes, measured in better lit parts of the city.

Illumination at floor height (passage) was measured in 140 buses for urban passenger transport. The average illumination in the height of the floor (passage) of the buses for urban passenger transport in better-lit parts of the city was 74.66 lx (SD = 16.88).

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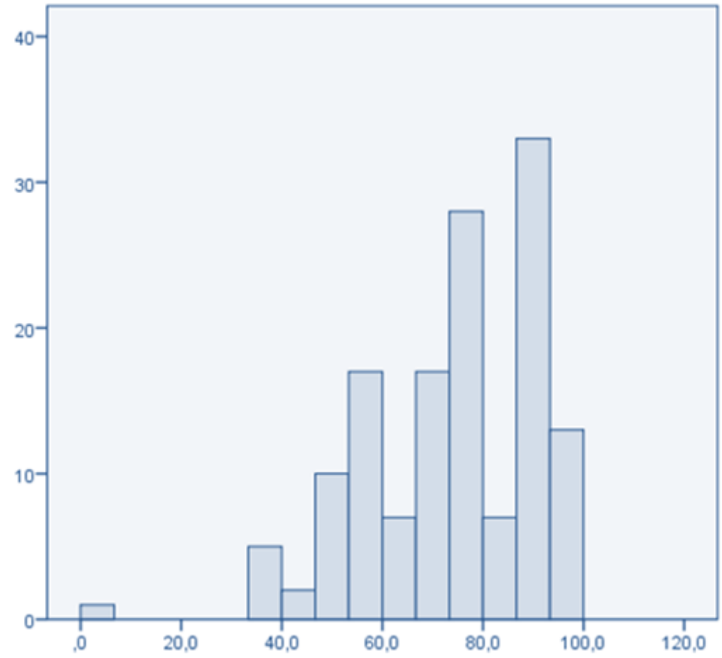

Figure 2. Distribution of light levels in buses at the position of the floor (passage), measured in better-lit parts of the city.

Illumination at floor height (at the location of the stairs) was measured in 140 buses for city passenger transport. The average illumination at floor level (at the location of the steps) of the buses for urban transport of passengers in better-lit parts of the city was 73.96 lx (SD = 17.01).

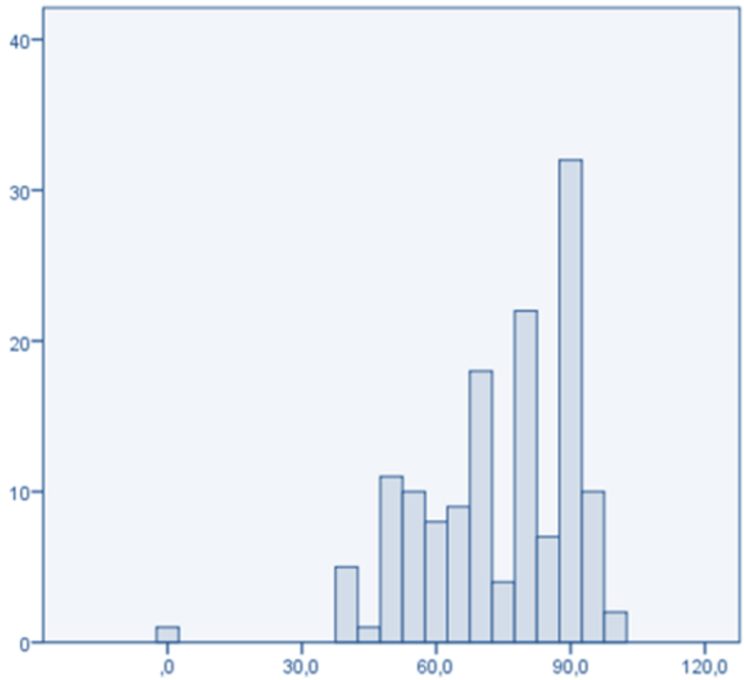

Figure 3. Distribution of illumination levels in buses at the position of the stairs, measured in better-lit parts of the city.

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Eye-level illumination for standing position of passengers was measured in 140 buses for urban passenger transport. The average illumination at eye level for the standing position of passengers in buses for urban passenger transport in better-lit parts of the city was 97.79 lx (SD = 19.93).

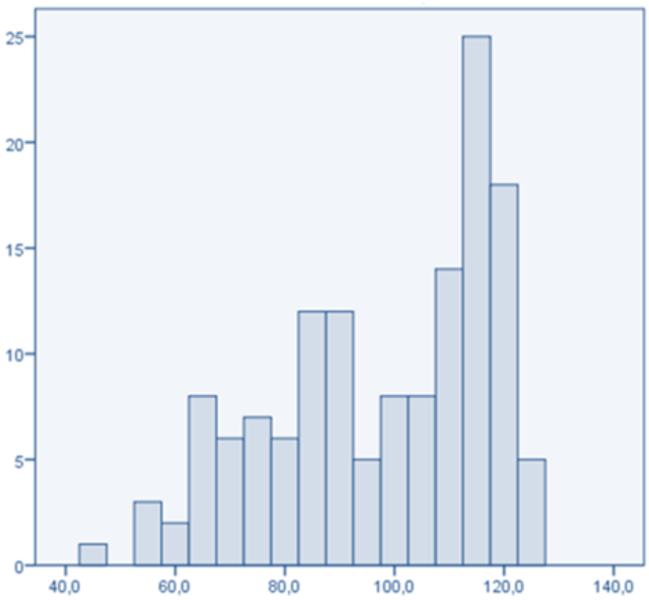

Figure 4. Distribution of illumination levels in buses at the position of the eyes of passengers for a standing position, measured in better-lit parts of the city.

The illumination at the position of the warning signs was measured in 140 buses for city passenger transport. The average illumination at the position of warning signs in the buses for urban passenger transport in better-lit parts of the city was 96.5 lx (SD = 22.69).

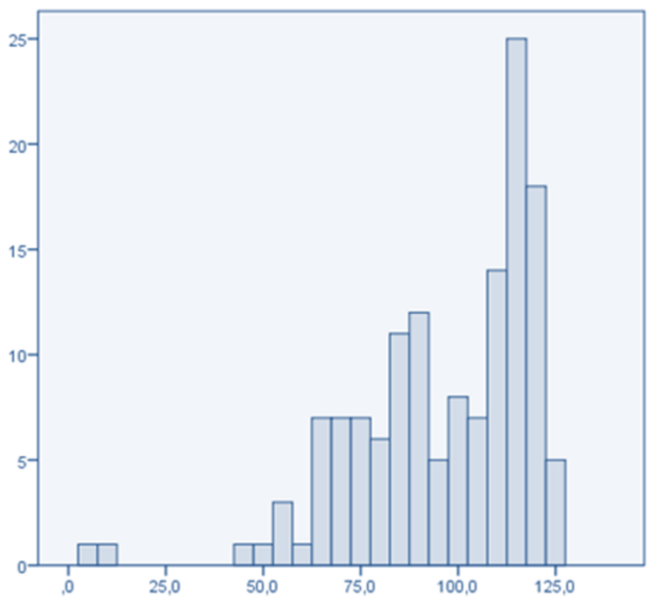

Figure 5. Distribution of illumination levels in buses at the position of warning signs, measured in better-lit parts of the city.

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Illumination at eye level (sitting) was measured in 140 buses for city passenger transport. The average illumination in the buses for city transport of passengers at eye level (sitting) in the zones of weakly lit parts of the city was 79.92 lx (SD = 16.99).

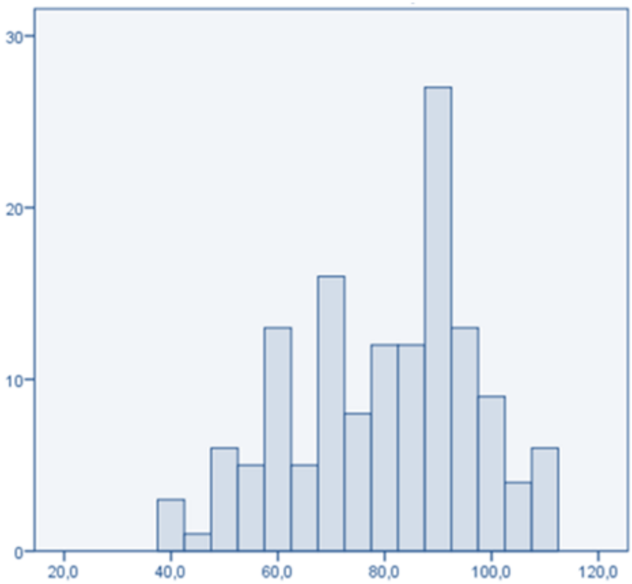

Figure 6. Distribution of illumination levels in buses at the position of the eyes of passengers, measured in weakly lit parts of the city.

The illumination at the height of the floor (passage) was measured on 140 buses for city passenger transport. The average illuminance in the buses for city transport of passengers at the height of the floor (passage) in the zones of weakly lit parts of the city was 66.64 lx (SD = 13.90).

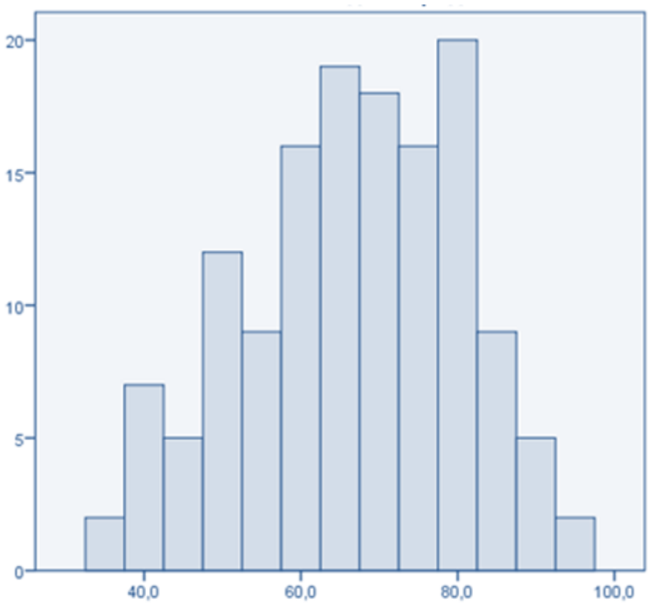

Figure 7. Distribution of illumination levels in buses at the position of the floor (passage), measured in weakly lit parts of the city.

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Illumination at floor height (steps) was measured in 140 buses for city passenger transport. The average illumination in the buses for city transport of passengers at the height of the floor (at the location of the stairs) in the zones of weakly lit parts of the city was 66.43 lx (SD = 13.81).

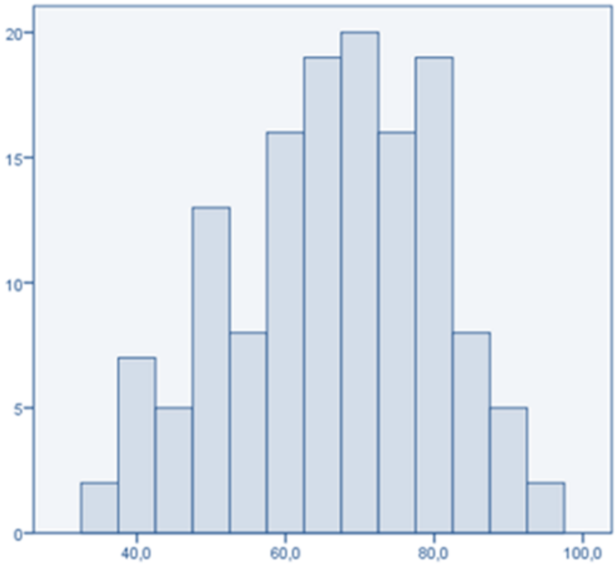

Figure 8. Distribution of illumination levels in buses at the position of stairs, measured in weakly lit parts of the city.

Eye-level illumination for standing position of passengers was measured in 140 buses for urban passenger transport. The average illumination in the buses for urban transport of passengers at eye level for the standing position of passengers in the zones of weakly lit parts of the city was 84.89 lx (SD = 17.17).

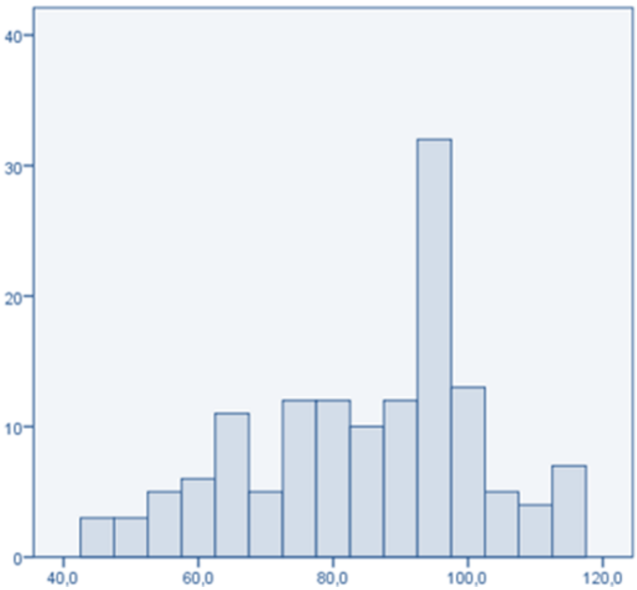

Figure 9. Distribution of illumination levels in buses at the position of the passenger's eyes (standing position), measured in weakly lit parts of the city.

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The illumination at the position of the warning signs was measured in 140 buses for city passenger transport. The average illumination in the buses for urban passenger transport at the position of warning signs in the zones of weakly lit parts of the city was 84.89 lx (SD = 17.17).

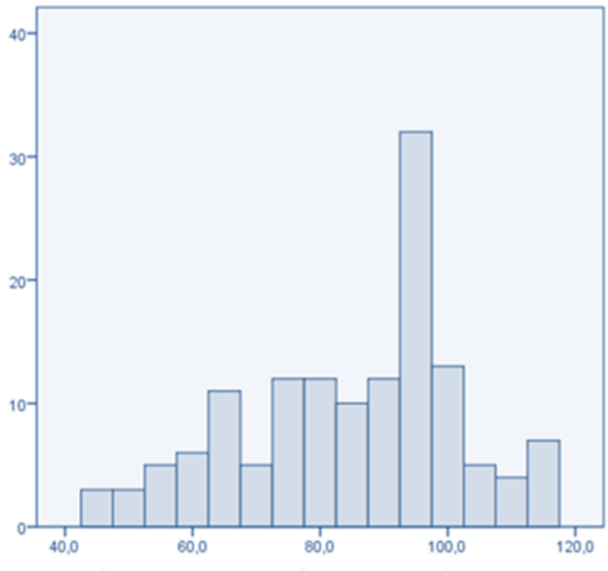

Figure 10. Distribution of illumination levels in buses at the level of warning signs, measured in weakly lit parts of the city.

4. ANALYSIS OF RESULTS

As previously mentioned, the illumination was measured at different locations in the bus, which are of importance for passengers. In addition, the illumination in the buses was measured in conditions of high and low street lighting. Taking this into account, it is of importance to test the hypotheses about the uniform distribution of illumination in buses, depending on the location and measurement conditions (higher and lower external illumination). If there is a uniform distribution of illumination in buses, then it means that there are no significant variations in illumination between individual buses. This would further imply that uniform quality is provided to passengers in terms of lighting. In this regard, the hypotheses regarding the uniform distribution of illumination, depending on the location of the measurement and the measurement conditions, will be tested below.

First, the hypothesis that the illumination at eye level for the sitting position of passengers in buses for urban transport of passengers in better-lit parts of the city has a uniform distribution will be tested. In order to check whether the illumination in the bus at eye level for the seated position of passengers in better-lit parts of the city differs from the uniform distribution, the Kolmogorov-Smirnov goodness-of-fit test was used. This test will also be used to test the remaining hypotheses connected with the illumination. Based on the results of the conducted test, we come to the conclusion that the distribution of illumination at eye level for the sitting position of passengers in the buses in better-lit parts of the city cannot be considered approximately uniform, Z = 2,874; p = 0.00.

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We will now test the hypothesis that the illumination at floor height (aisle) in city buses for passenger transport in better-lit parts of the city has a uniform distribution. Based on the results of the test, we come to the conclusion that the distribution of illumination at floor height (passage) in buses for urban passenger transport in better-lit parts of the city cannot be considered approximately uniform, $Z = 4.93$; $p = 0.00$.

In the continuation, the hypothesis will be tested that the illumination at the height of the floor (at the location of the stairs) in the buses for city transport of passengers in better-lit parts of the city has a uniform distribution. Based on the results of the conducted test, we come to the conclusion that the distribution of illumination at floor height (steps) in buses for urban transport of passengers in better-lit parts of the city cannot be considered approximately uniform, $Z = 5.32$; $p = 0.00$.

The hypothesis that the illumination at eye level for the standing position of passengers in the buses for urban transport of passengers in better-lit parts of the city has a uniform distribution will now be tested. Based on the obtained test results, we come to the conclusion that the distribution of illumination at eye level for the standing position of passengers in buses for urban transport of passengers in better-lit parts of the city cannot be considered approximately uniform, $Z = 3.13$; $p = 0.00$.

The following is a test of the hypothesis that the illumination at the position of the warning signs in the buses for the public transport of passengers in better-lit parts of the city has a uniform distribution. Based on the results of the conducted test, we come to the conclusion that the distribution of illumination at the position of warning signs in buses for urban transport of passengers in better-lit parts of the city cannot be considered approximately uniform, $Z = 5.24$; $p = 0.00$.

The hypothesis that the illumination at eye level for the sitting position of passengers in buses for urban transport of passengers in weakly lit parts of the city has a uniform distribution will now be tested. Based on the test results, it can be concluded that the distribution of illumination at eye level (sitting) in buses for urban passenger transport in the zones of weakly lit parts of the city cannot be considered approximately uniform, $Z = 2.28$; $p = 0.00$.

The next hypothesis that will be tested is that the illumination at the height of the floor (passage) in the buses for urban transport of passengers in weakly lit parts of the city has a uniform distribution. Based on the results of the conducted test, we come to the conclusion that the distribution of lighting at floor height (passage) in buses for urban transport of passengers in the zones of weakly lit parts of the city cannot be considered approximately uniform, $Z = 1.97$; $p = 0.001$.

The hypothesis that the illumination at floor level (at the location of the stairs) in the buses for the public transport of passengers in weakly lit parts of the city has a uniform distribution will now be tested. Based on the results of the test, we come to the conclusion that the distribution of illumination at floor level (at the location of the stairs) in buses for urban passenger transport in the areas of weakly lit parts of the city can not be considered approximately uniform, $Z = 1.97$; $p = 0.001$.

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In the continuation, the hypothesis will be tested that the illumination at eye level for the standing position of passengers in the buses for urban transport of passengers in weakly lit parts of the city has a uniform distribution. Based on the results of the test, we can conclude that the distribution of illumination at eye level for the standing position of passengers in buses for urban passenger transport in the zones of weakly lit parts of the city cannot be considered approximately uniform, $Z = 2.28$; $p = 0.001$.

In the end, the hypothesis that the illumination at the position of the warning signs in the buses for urban transport of passengers in weakly lit parts of the city has a uniform distribution will be tested. Based on the results of the conducted test, it can be concluded that the distribution of illumination in buses for urban transport of passengers at the position of warning signs in the zones of weakly lit parts of the city cannot be considered approximately uniform, $Z = 2.28$; $p = 0.00$.

5. CONCLUSION

Although the focus of this research is not on determining the level of illumination but the uniformity of its distribution, it can be stated that in most cases a low level of illumination was observed in buses, regardless of the position at which the illumination was measured. In most cases, the level of illumination inside the buses meets the criteria prescribed for spaces in which people are easily oriented and in which they stay relatively short, or for public spaces with the dark periphery. However, the achieved level of illumination in buses only in some cases meets the criteria prescribed for workspaces in which visual tasks are performed occasionally. There are certainly more reasons for this situation. One of the reasons may be that the direct light coming from some of the light sources to observed locations has been blocked in some cases by passengers and other objects. The absence of natural light is also one of the reasons. However, certainly, the most important reason is the design of the interior lighting system, which can be improved from the aspect of light intensity provided by light sources inside the bus. A similar problem with low light levels inside buses has been identified in [6]. Low light levels in buses can be a problem for certain categories of passengers, especially those who have a certain form of visual impairment.

Based on the results of the conducted research and testing of statistical hypotheses, it can be stated that the uniformity of the distribution of illumination levels at none of the five locations where the measurements were performed has not been confirmed. This constatation applies to both measurement conditions, at locations with a higher level of street lighting, as well as at locations with a lower level of street lighting. This means that it cannot be considered that there is uniformity in the level of illumination at the measuring locations in the buses for urban transport of passengers that were the subject of consideration. So, there is no uniformity when it comes to lighting conditions that are available to passengers in these buses.

Taking into account the results of the research, both from the aspect of illumination levels and from the aspect of light distribution, it can be concluded that lighting engineers should pay additional attention to this problem. In order to overcome this problem, it can be recommended that they work in cooperation with experts in the field of ergonomics to find a solution. Placing additional light sources in buses in the appropriate locations, even of lower intensity, can provide more favorable effects than

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using stronger light sources in less adequate locations in the bus. In this way, a satisfactory level of illumination can be achieved, but also savings on the scattering of light and electricity.

References

[1] Edvardsson B., 1998, Causes of customer dissatisfaction – studies of public transport by the critical-incident method, Managing Service Quality, Vol. 8 Num. 3, pp. 189–197.

[2] Disney J., 1998, Competing through quality in transport services, Managing Service Quality, Vol. 8 Num. 2, pp. 112-118.

[3] Zunjic A., Sofijanic S., Stojiljkovic E., 2016, Certain ergonomic considerations and design solutions connected with the safety and comfort of city buses, In: Ergonomics in design - Methods and techniques, Edited by Soares M.M. and Rebelo F., pp. 405-422, Taylor & Francis, London.

[4] Zunjic A., Čičević S., 2017, Design of the questionnaire for the assessment of the comfort of urban city buses, In: Ergonomic design and assessment of products and systems, Edited by Zunjic A., pp. 221-243, Nova Science Publishers, New York.

[5] Alcobia C. J. O. P. J. and Silva M. C. G., 1999, A Comfort Field Study in Public Transportation Buses, SAE Technical Paper 1999-01-0894.

[6] Jeric B. Bonostro, Andre A. Borromeo, Carmela Gabrielle D. De Jesus, Danielle Jessa A. Trinidad, Benette P. Custodio, 2017, G4-2 Ergonomic Assessment of the Point-to-point (P2P) Buses: Case of Passengers, The Japanese Journal of Ergonomics, Vol. 53 Suppl. 2, pp. S524-S527.