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Rethinking Indonesia's lighting standard for urban kampung roads
Case study: Siwalankerto

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ABSTRACT

The latest lighting standard in Indonesia, SNI 7391:2008, emphasizes uniform distribution for road lighting to ensure the safety and accuracy of motorists. However, in urban kampungs, local roads serve as non-commercial public spaces and require lighting that is suitable for human-scale activities. This study examines road lighting in Siwalankerto, Surabaya, and explores how residents' nighttime experiences relate to their perceived adequacy of illumination (PAI). The research involved 26 participants who rated their experiences while using the local road after dark. Nighttime experiences, including pleasantness, willingness to stay, and safety, were compared to illuminance levels and PAI. The findings show a correlation between perceived adequacy of illumination and pleasantness, as well as the willingness to stay in the road space. There was no significant correlation between safety and PAI.

Introduction

The constant increase in the number of vehicles in Indonesia (Badan Pusat Statistik 2021) has significant implications for the quality of life within communities (Olwig 1989), both during the day and night. As a result, the Indonesian government has set artificial lighting standards for local roads at night, as outlined by Badan Standarisasi Nasional (BSN). The primary objective of road lighting at night, as per this manual, is to ensure uniform light distribution on the horizontal working plane, providing security, smoothness, and comfort for road users (Badan Standarisasi Nasional 2008). However, this lighting standard mostly focuses on artificial lighting as a navigation aid and achieving consistent light distribution between different roads using a quantitative approach. It is worth noting that this standard is commonly applied only on large-scale roads (Sumantri, Rifai, and Ferial 2022).

In Surabaya, one of the cities in Indonesia, the SNI 7391:2008 lighting standard is implemented. The urban *kampung* roads in Surabaya can be classified as local roads, serving local motorists with characteristics such as short distances, low average speed, and numerous points of entry. As a result, it is recommended that local roads should have an average illuminance (E"av") of 2-5 lux and a uniformity ratio (U"o") of 0.10 (Badan Standarisasi Nasional 2008).

However, it's crucial to understand that the city of Surabaya has developed from the existence of urban *kampungs*, which offer unique identities through various entities. The presence of

kampungs has played a significant role in transforming Surabaya into a metropolitan city (Dewi and Mappajaya 2015).

One such urban *kampung*, Siwalankerto, is located in the southeast corner of Surabaya, near Petra Christian University, established in 1961. While the university's growth led to the development of Siwalankerto from rice fields into buildings, family homes into boarding houses and commercial facilities, many native residents have continued to live in the area for several decades, maintaining its social dynamic. In contrast to modern communities that tend to become exclusive, Siwalankerto's inhabitants uphold amicable lifestyles throughout the day, from morning to evening. However, this positive situation can be marred by inadequate lighting at night, not only in Siwalankerto but potentially in other urban *kampungs* across the city.

Although the lighting standard is already established and applied in the current condition, it mainly focuses on motorists' safety and visibility. Unfortunately, there is limited research on how this road lighting impacts users in Indonesia, particularly in urban *kampung* environments. This research gap hinders our understanding of how road lighting in urban *kampungs* should be designed and treated. Therefore, this study aims to investigate the application of the SNI lighting standard in Indonesia's urban kampungs, using Siwalankerto as a case study, and comparing the effects of its application on the nighttime experiences of Siwalankerto's residents using the PAI concept.

Research precedence

Previous research has highlighted the importance of road lighting and the advantages of higher illuminance levels for road safety (S Fotios 2020). Studies conducted in real environments have found a strong relationship between brightness levels and the feeling of reassurancel (Blöbaum and Hunecke 2005), as well as the positive effect of increased light levels on reassurance and safety (S Fotios and Gibbons 2018). Other researchers have also reported that higher illuminance leads to increased security levels (Vrij and Winkel 1991). Japanese studies suggest that well-lit and bustling areas foster feelings of safety, with lighting playing a vital role in creating a sense of liveliness, openness, cohesion, intimacy, and order (Okuda, Ishii, and Fukagawa 2007; Koga 2003).

While the above studies indicate the benefits of higher illuminance for perceived safety, other research advises against solely focusing on increased illuminance for road lighting. Some experiments equipped with higher illuminance still suggest the need for even higher levels (S Fotios, Unwin, and Farrall 2015; Steve Fotios and Castleton 2016). Marchant et al. also report that brighter road illumination does not necessarily enhance road safety and may even compromise it without reducing harm (Marchant, Hale, and Sadler 2020).

Another critical aspect to consider is the impact of road lighting on immediate residents or surroundings, particularly in complex environments like urban *kampungs*. These areas are part of a system known as Kuta-Negara in Javanese cities, consisting of autonomous village territories with rulers. Residents autonomously organize their social, economic, cultural, and political relations, all of which are reflected in a spatial order and hierarchy ranging from private to public spaces (Sunaryo, Soewarno, and Setiawan 2010). In such environments, local roads can become public spaces, requiring careful consideration to maximize usage by all users and passersby. Elements like lighting may influence certain behaviors within these spaces (Johansson, Rosén, and Küller 2011), and Fotios et al. argue that road lighting should create a safe environment perceived as safe by the users (S Fotios, Unwin, and Farrall 2015).

While road lighting is commonly designed based on photometric measurements, primarily focusing on illuminance levels and uniformity ratios, it is essential to recognize that the visual experience of road lighting differs between motorists and pedestrians. For pedestrians, the environment plays a significant role, making it challenging to measure the impact using only photometric values. The usual road lighting standard for motorists, horizontal illuminance, may not be entirely effective for pedestrian roads (Wänström Lindh and Jägerbrand 2021). Moreover, a high value of uniformity can enhance reassurance, but a fair distribution of light, highlighting natural rather than artificial objects, could further increase reassurance (S Fotios, Unwin, and Farrall 2015). A high perception of brightness also contributes to a greater sense of safety (S Fotios and Goodman 2012), and lighting quality is related to environmental safety (Jedon, Haans, and de Kort 2022).

Based on the literature discussed above, visibility and recognition are not the sole factors to consider when designing road illumination. Prioritizing brighter illumination and uniform light distribution to achieve a sense of security and reassurance may be less relevant, particularly in Indonesia's urban kampung context. Therefore, identifying an appropriate light level that guarantees an acceptable level of perceived safety poses a further challenge in this environment.

The concept of perceived adequacy of illumination (PAI), proposed by Cuttle, offers an alternative criterion in interior lighting design. PAI shifts the emphasis of lighting design from the horizontal working plane to the overall appearance of the space (Cuttle 2013). PAI is defined as the amount of light within a space that is perceived as adequately bright for carrying out specific activities (Duff, Kelly, and Cuttle 2017). In this study, we aim to investigate the effect of lighting on the nighttime experience of Siwalankerto's residents using the PAI concept.

Method

Site observation and illuminance field measurement

This study focuses on a local road in urban kampung Siwalankerto, Surabaya, which serves various users, including motorists, cyclists, and pedestrians. As mentioned earlier, the road is in close proximity to local residential houses and has a unique identity, functioning as both a transportation link and a public space. The area is illuminated by street lighting that is 5 meters high. The light fixtures are positioned on one side of the road, spaced at intervals ranging from 18 to 26 meters, following the SNI standards (Badan Standarisasi Nasional 2008). Figure 1 provides an overview of the road at night, while figure 3 and 4 illustrate the distribution of the light fixture and measurement point in the study area.

Figure 1. General views showing the illumination within the study area

Following SNI 7391:2008, the main consideration for road lighting design is the illumination on the horizontal surface (Badan Standarisasi Nasional 2008). Consequently, this research measured the illuminance level that represents the characteristics of the space. An illuminance meter (Krisbow K06-288) was used to measure the illuminance values, as shown below:

Figure 2. Illuminance meter

The results of the measurements were used to calculate the average illuminance value and uniformity ratio. The average illuminance value in this study is defined as the arithmetic mean (S Fotios and Robbins 2020).

$$E_{av} = \frac{E_1 + E_2 + \cdots + E_n}{n}$$

Where:
E_{av} = Average illuminance (lux)
E = Illuminance on measurement point (lux)
n = Number of measurement points

Uniformity is defined as the ratio of the minimum illuminance at any measurement point to the average illuminance (The Society of Light and Lighting 2012).

$$U_O = \frac{E_{min}}{E_{av}}$$

Where:
U_o = Uniformity ratio
E_{min} = Minimum illuminance (lux)
E_{av} = Average illuminance (lux)

Horizontal illuminance at ground level was measured at a total of 165 points (3 points x 55 rows) along a distance of 177.1 meters with a width of 3.58 meters. The measurements were taken between 18:30 WIB to 20:15 WIB under clear sky conditions. The spacing between each point measurement is shown in figure 3, adapted from Kim and Noh's research (Kim and Noh 2018). The illuminance distribution is presented using a surface plot.

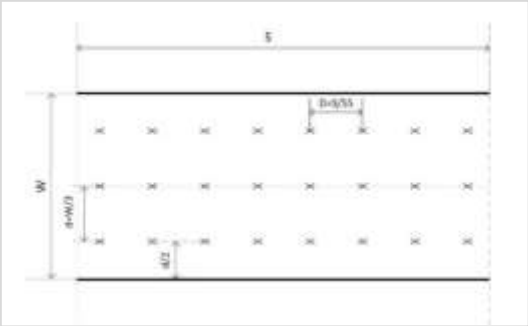

Figure 3. Distribution of illuminance measurement points, X denotes the measurement position on the ground

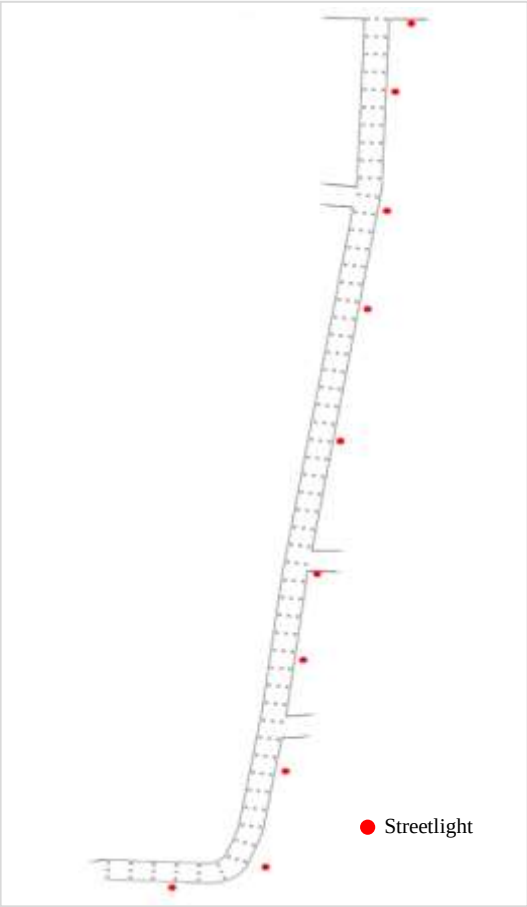

Figure 4. Illuminance measurements points and location of each street light, not to scale

Participants and questionnaire design

Due to time constraints, this study was only able to collect responses from 26 residents of urban *kampung* Siwalankerto to participate in the questionnaire survey. The main objective of the questionnaire was to gather subjective feelings and responses from the residents who are the primary users of the local road. The questionnaire design was adapted from previous research on road lighting (Boyce et al. 2000; Kim and Noh 2018; S Fotios, Unwin, and Farrall 2015), where residents were asked to rank their experiences when using the road at night. The variables tested included the feeling of safety, pleasantness, willingness to stay, and perceived adequacy of illumination (PAI). Table 1 provides a summary of these variables and the scales used in the questionnaire. The relationship between each variable was analyzed using SPSS statistical software and presented using scatter plots.

Table 1. Parameters for the selection of P lighting class – urban *kampung* Siwalankerto road

Variables & question	Scale
Safety	
How safe do you think this space is?	1= very unsafe, 6 = very safe
Pleasantness	
How pleasant do you think the space is?	1= very unpleasant, 6 = very pleasant
Willingness to stay	
Would you consider to stay and talk with your friends in this space?	1= not at all, 6 = completely
PAI	
Overall, how satisfied are you with the lighting in this space?	1 = dissatisfied, 6 = satisfied

Result and discussion

Illuminance level measurement

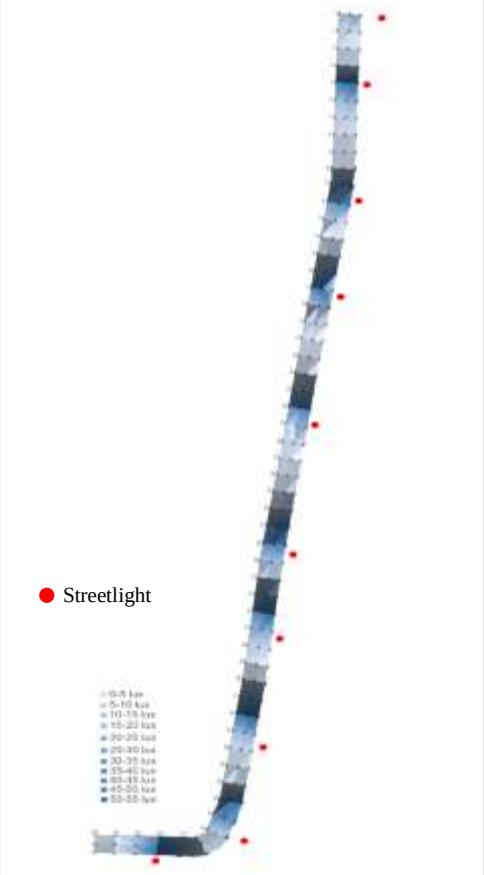

Figure 5. Distribution of illuminance measurement points, X denotes the measurement position on the ground

Figure 5 illustrates the results of illuminance measurements on the road surface using a surface plot. The data shows that the illuminance distribution varies from 40-50 lux directly below the streetlights, but it is not evenly distributed throughout the road surface. The surface plot demonstrates that the illuminance rapidly decreases to 5-0 lux between each luminaire. Consequently, the study found a very low uniformity ratio (U"o") of 0.007 and an average illuminance of illuminance (E"av") of 12.94 lux. Although the average illuminance meets SNI standards, the overall lighting on the road in urban kampung Siwalankerto does not comply with the required standards.

Perceived adequacy of illumination (PAI)

Table 2. Perceived adequacy of illumination – urban *kampung* Siwalankerto road

Number of participants who do not respond with 'satisfied'						
Number of participants who responded 'Satisfied'	Quite satisfied	Tend to satisfied	Tend to not satisfied	Quite dissatisfied	Dissatisfied	Total numbers
1 (3.85%)	6 (23,08%)	3 (11,54%)	2 (7,69%)	6 (23,08%)	8 (30,77)	25 (96,15%)

Table 2 displays the distribution and the percentage of residents who are satisfied with the current lighting condition. Only one respondent (3.85%) expressed satisfaction with the ambience of the road, while the rest of the answers were scattered across the range, with the highest number feeling dissatisfied with the lighting (8 respondents, 30.77%). The scattered distribution may be due to the limited number of study participants, as data collection time was constrained. However, it can also be noted that 61.54% of the respondents tended to have a negative response (ranging from not satisfied to quite dissatisfied and dissatisfied) towards the street lighting condition.

PAI and feeling of a space: Safety

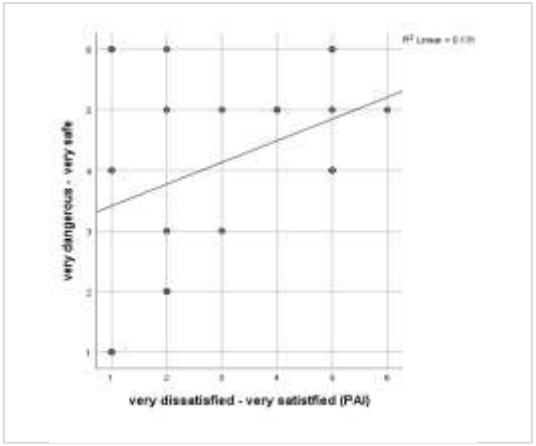

Figure 6. Residents' safety perception at night under PAI, scatter plot

A Spearman's rho correlation analysis was performed to investigate the connection between perceived adequacy of illumination (PAI) and safety perception. The analysis revealed a moderate positive relationship between these variables, with r_s (24) = .252.

The p-value of .214, which is greater than the standard significance level of .05, indicates that this relationship is not significant at the .05 level. Hence, it can be concluded that the association between PAI and a sense of safety may not be particularly strong or statistically significant. Additional research is required to ascertain the nature and extent of this relationship.

PAI and feeling of a space: Pleasantness

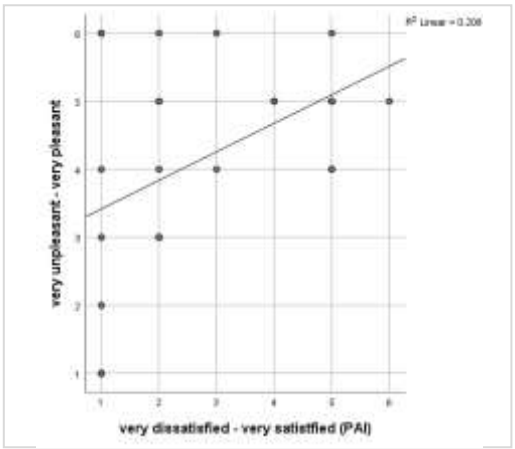

Figure 7. Residents' pleasantness at night under PAI, scatter plot

Based on the statistical analysis and figure 7 above, a moderate relationship was found between PAI and the feeling of pleasantness, with rs (24) = .39 and p < .049. This indicates significance at the 0.05 level (2-tailed).

The result suggests that adequate illumination plays an important role in creating a pleasant environment. The findings indicate that residents are more likely to perceive the road as pleasant when it is adequately illuminated.

PAI and eagerness to stay within the space

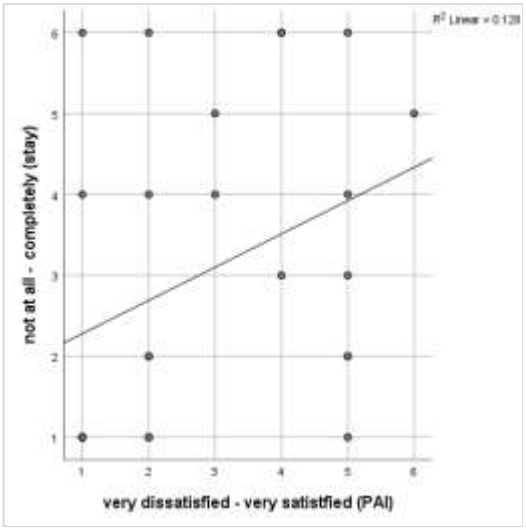

Figure 8. Residents' willingness to stay at night under PAI, scatter plot

Based on the Spearman's rho correlation analysis, there seems to be a moderately positive correlation between PAI and residents' inclination to stay in the area. The value of rs (24) = .471 suggests that as perceived adequacy of illumination increases, so does the desire to remain in the road space. Moreover, with a p-value less than 0.05 (p .034), this relationship is statistically significant at the 0.05 level.

Therefore, these results highlight the importance of adequate lighting in creating a desirable environment that encourages individuals to stay longer.

Conclusion

This paper examines the application of SNI lighting standards in urban kampung Siwalankerto and explores the relationship between residents' nighttime experiences and

perceived adequacy of illumination (PAI). Despite following the guidelines for the placement of streetlight fixtures (Badan Standarisasi Nasional 2008), this study found that it does not ensure proper light distribution. While the average illuminance at urban *kampung* Siwalankerto meets SNI requirements, achieving all the standards simultaneously, particularly the uniformity ratio, is challenging. The area's dense vegetation and obstructions create shadows, making simply increasing the lumen output of the streetlights ineffective. The PAI results indicate that more than 60% of residents tend to be dissatisfied with the condition, considering the street is used for various activities, while the lighting standard is designed for motorists. This findings tend to agree with Jedon et al. and shows that lighting quality could influence participants' response to the space (Jedon, Haans, and de Kort 2022). It is reasonable to assume that other factors, such as vegetation and obstructions, influence the distribution and appearance of the environment (S Fotios, Unwin, and Farrall 2015).

The design and location of streetlight fixtures, prioritizing safety, do not seem to have a significant effect on residents' PAI, in line with Marchant et al., where higher illumination might not directly improve the safety aspect (Marchant, Hale, and Sadler 2020). This finding aligns with the suggestions of Wanstrom Lindh and Jagerbrand (Wänström Lindh and Jägerbrand 2021), indicating that road lighting recommendations and standards for motorists and pedestrians should be considered differently. Urban *kampung* Siwalankerto residents are more likely to prioritize other parameters, such as the space's pleasantness and willingness to stay. This study reveals that the complexity of the road and its immediate surroundings influences the locals' preferences for the appearance of the nighttime illumination, as it could influence certain behaviors within the road space (Johansson, Rosén, and Küller 2011).

Based on the findings and the nature of urban *kampung* in Indonesia (Sunaryo, Soewarno, and Setiawan 2010), the treatment and recommendations for street lighting within urban kampung like Siwalankerto should not be limited to illumination for local roads. This study shows that Siwalankerto's local residents are more concerned about illumination that creates a pleasant and inviting space, as the road serves not only as transportation infrastructure but also as a public space. Therefore, this research proposes that lighting schemes for urban kampungs should consider not only the quantitative aspects (illuminance, uniformity ratio, etc.) but also the qualitative aspects (social context, environment, user preferences, and habits).

As this is a preliminary study, additional research should be conducted with a larger sample of respondents from various Surabaya's urban *kampungs* to gain a more detailed and specific understanding of the requirements and preferences of road illumination within urban *kampung*. The effect of illuminance on residents' reassurance when using the road should also be investigated, as due to time constraints, this research focused more on the effect on safety perception.

Acknowledgment

The author thanks urban kampung Siwalankerto residents.

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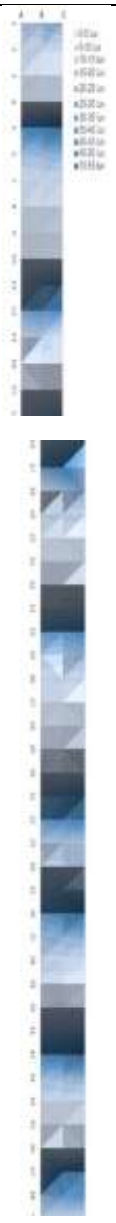
Appendix

Table 3. Illuminance (E) measurement data (left) and its surface plot (right)

***Row* No.**	**E (*lux*) Point A**	**E (*lux*) Point B**	**E (*lux*) Point C**
1	12,3	16,6	22
2	4,3	5,6	5,5
3	0.7	0,9	0,6
4	0,3	0,3	0,2
5	32,9	39,8	47,7
6	15,1	16,7	19,6
7	4	4,8	5,5
8	1	1,2	1,5
9	0,4	0,5	0,3
10	0,4	0,6	0,3
11	13,2	26,1	32,3
12	23,4	29,7	32,6
13	4	9,5	0,1
14	2,4	0,6	0,1
15	1	4,6	4,1
16	11,2	19,3	24,5
17	27,2	37,1	18,3
18	3,7	12,4	22,4
19	5,1	5,9	6,8
20	2,7	2,3	0,8
21	1,5	1,5	1,1
22	3,8	3,7	0,1
23	13,7	14,7	16
24	25,8	30,1	35
25	15,6	12,9	18,9
26	5,1	5,5	5,4
27	1,7	2,1	0,4
28	0,6	0,7	1,4
29	2	2,5	0,7
30	8,6	8,8	10,7
31	22,8	29,1	36,5
32	27	33,6	37,3
33	10,2	12,3	12,4
34	9,2	9,2	10,8
35	17,9	22,7	19,8
36	28,4	34,3	44,1
37	15,1	19,6	21,2
38	7	7,6	7,2
39	2,9	3,1	2,3
40	4,6	5,8	4,4
41	18,6	21	24,1
42	33,9	41,2	51
43	14,7	16,9	19,4
44	4,5	4,9	5,2
45	2,6	3,4	2,9
46	4,1	2	5,3
47	20,7	36,3	41,6
48	22,8	30	31,8
49	5,1	5,7	5,3



50	3,49	5,8	4,6	
51	17,8	26,6	26,5	
52	29,3	37	44,5	
53	11,7	13,5	16,8	
54	3,1	1	1	
55	1	2	2	

Table 4. Average Illuminance (E_{av}) and Uniformity ratio calculation (U_o)

	Formula	Result
Total illuminance ΣE	$E_1 + E_2 + \cdots + E_n$	2136,56 lux
Minimum illuminance E_{min}	−	0,1 lux
Average illuminance E_{av}	$E_{av} = \frac{E_1 + E_2 + \cdots + E_n}{n}$	12,94 lux
Uniformity ratio U_o	$U_O = \frac{E_{min}}{E_{av}}$	0,007