Luminance measurements for urban lighting environment qualitative analysis by the example of Tula

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Abstract: Development of technical lighting capabilities made it possible for lighting designers to implement any ideas. Although the structure of the human eye as a biological receiver of radiation is still the same despite lighting equipment progression. Many urban lighting design solutions implemented in various cities all over the world leads to promptly considering the issue of lighting quality assessment.

A comprehensive study of an urban environment supported by town planning analysis allows drawing conclusions about the rationality of expended energy resources and the quality of realized objects. The relevance of luminance distribution analysis in a night city environment increases every year, especially for cities with lighting strategies aimed at a quantitative increasing of illuminated objects without hierarchy of priorities. For the central part of Tula city an integrated approach to the analysis of evening image of the city has been considered, the luminance ratios were estimated for the facades located on 11 central city streets. This quantitative luminance levels analysis allows to draw objectively conclusions about the quality of existing light environment of the city and to understand possible steps for its further development.

Keywords: urban lighting, lighting environment, architectural lighting, luminance distribution, luminance measurements, qualitative analysis, photometric analysis

Introduction

The existing urban lighting environment often does not meet requirements of regulatory documents due to lack of quality control procedures. Methods of complex investigation of luminance distribution are significant as a tool aimed at identifying objects with high level of quality and outlining further changes in the light-planning structure of the city taking into account examples of objects with exceed value of luminance characteristics. The aim of research was practical evaluation of the method of complex luminance distribution analysis by the example of central streets of Tula city. The research of luminance distribution on facades allows objectively estimate conditions of architectural objects' perception from observer's position and quality assessment both for separate facades and for the fragments of the city. By the example of the central part Tula city there was

considered an integrated approach to the analysis of lighting quality in accordance with luminance ratios of the vertical surfaces located on 11 central city streets.

Research methodology

Luminance measurement were performed using photometer LMK Mobile Advanced based on a CCD matrix with spectral sensitivity corrected in accordance with relative spectral sensitivity of a standard observer's eye with the use of LMK LabSoft specialized software for analysis of the results obtained. The main technical characteristics of measuring device: diaphragm values from F4 to F11, focal length from 18 to 50 mm, available ISO sensitivity value from 100 to 1600, resolution 5566x3706 (effective signals 2748x1834), exposure time 30 - 1/1000 s [1-3].

For luminance contrast measurements contrast is defined by equation

$$C = \left| (Lt - Lb)/Lb \right| \quad (1)$$

where Lt is target and Lb is background luminance.

As preliminary study of research urban planning analysis included: brief description of the location and the most important characteristics of the city; structural analysis of the city center and of the separate urban areas; the main thoroughfares of the city; pedestrian paths; transport hubs; squares and public centers; important centers of attraction – objects of administrative nature, culture, education, religion, sports, dominant architectural ensembles, memorials, parks and landscape areas; analysis of the existing situation of the evening light and color environment of the city on the components (utilitarian, architectural, landscape, holiday lighting, analysis of materials for the future development of the city. Comprehensive assessment of urban planning, analysis of zones of visibility of architectural dominants, compositional centers and activity points were evaluated, and the luminance characteristics of the existing light environment of the central

streets of the city were analyzed in order to identify the most problematic areas that adversely affect perception [4-8].

In the study, 11 central streets of the city of Tula were examined, full list of them is shown in Fig. 1, a hierarchy of objects in the city structure was made, and the luminance ratios of the objects were analyzed.

Fig 1. The list and an arrangement of the analyzed streets.

The town-planning analysis and assessment of visibility ranges of architectural dominants has been based on use of the GIS-systems allowing to put layer-by-layer data with the purpose of the subsequent analysis in various combinations. The main layers of a research on the basis of use of GIS-systems: intensity of the pedestrian movement; analysis of the composite centers; analysis of objects of cultural heritage; research of visibility ranges of architectural dominants; formation of hierarchy of proponent objects [9-10].

Each of the layers of the study was considered separately, then, by analytical overlap, all layers were analyzed together.

Fig. 2 - The main layers of research based on the use of GIS-systems: pedestrian movement intensity (left), analysis of composition center of the city.

Measured luminance levels and luminance contrast data represent powerful metric for human-centered lighting design in urban environment [11]. According to Gary Steffy's recommendations for lighting designers "lighting is all about planning and maintaining luminance". For a given point in space, a luminance value is discrete and quantifiable; multiple luminance values in combination describe the qualities of light in a space. Steffy's idea was to create recipe for visual hierarchy and visual attraction. Steffy ranks luminance contrasts in terms of their 'attraction power' combining ideas from John E. Flynn's work and quantifying with a luminance contrast ratio. For example, a 2:1 focal-to-background ratio is considered to have 'negligible' attraction power, with the effect of providing a 'barely recognizable focal' whereas a 10:1 ratio would have 'marginal' attraction power setting a 'minimum meaningful focal.' Creation of a 'strong significant centerpiece' effect, the contrast between the focal luminance and its background could approach 100:1.

In addition to varying the intensities of the luminance as described above, chromatic contrast through manipulation of light source color and receiving surface material color can establish visual hierarchy and attraction. The ideas of Steffy and Cattle are presented as indicators that the luminance concept is gaining renewed importance in the design of quality of lighting environments. Luminance distribution, luminance contrast ratios analysis in accordance with human visual perception leads to optimization of lighting environment.

Results

During the research the structural analysis of the city in general has been carried out and the developed urban areas, historical formation of planning structure of the city has been analyzed, the town-planning analysis, composite

center analysis, the analysis of objects of cultural heritage were carried out, classification of architectural dominants was developed on an equal basis with visibility ranges of architectural dominants. In a town-planning context 56 objects with the existing architectural lighting were considered with analysis of façade stylistics. Measurements of luminance distribution for those objects in order to analyze average luminance, maximum luminance values and luminance contrast were processed by use of LMK Lab Soft. Data of results of measurements have also been entered in the general database of objects, the example buildings included to Ensemble of the Gleb Uspensky Square and Ensemble of the Uspensky Cathedral and Lenin Square is given in table 1.

Table 1. Example buildings included to Ensemble of the Gleb Uspensky Square and Ensemble of the Uspensky Cathedral and Lenin Square in general database of objects.

Adress	Part of architectural ensemble	Facade plastic	Dominants	Av. Luminance	Max. Luminance
Mendeleyevskaya street, 1	Ensemble of the Gleb Uspensky Square	destroyed	2	59	138
Staronikitskaya street, 1	Ensemble of the Gleb Uspensky Square	destroyed	2	68	113
Sovetskaya Street, 67	Ensemble of the Gleb Uspensky Square	destroyed	2	62	130
Sovetskaya Street, 59	Ensemble of the Gleb Uspensky Square	destroyed	2	65	138
Mendeleyevskaya street, 8	Ensemble of the Uspensky Cathedral and Lenin Square	destroyed	3	78	185
Mendeleevskaya street, 8/2	Ensemble of the Uspensky Cathedral and Lenin Square	emphasized	1	52	106
Turgenevskaya Street, 2	Ensemble of the Uspensky Cathedral and Lenin Square	emphasized	3	37	65
Mendeleyevskaya street, 13k1	Ensemble of the Uspensky Cathedral and Lenin Square	emphasized	2	21	34
Prospekt Lenina, 2	Ensemble of the Uspensky Cathedral and Lenin Square	emphasized	3	54	110
Sovetskaya Street, 47	Ensemble of the Uspensky Cathedral and Lenin Square	destroyed	-	82	185

For the buildings which are forming together architectural ensemble around the Gleb Uspensky Square at the intersection of Chapaevsky Proezd, Mendeleevskaya and Sovetskaya streets lighting solution of 4 buildings destroys the architectural

facades plastics without forming lighting composition. Facades are visually destroyed by architectural lighting, which creates a strong difference in luminance characteristics that leads to revealing of the characteristic of composition features on the building as it shown in the figure 3.

Fig.3 Example of buildings which are forming architectural ensemble around the Gleb Uspensky Square.

Analysis of luminance contrast for the buildings of Gleb Uspensky Square ensemble showed that ratio level is higher than 20 to 1 which relates to strong luminance contrast with strong focal effect, glary in most situations [6].

For the buildings which are forming together architectural ensemble of the Uspensky Cathedral and Lenin Square lighting solution of 2 buildings destroys the architectural facades plastics without forming lighting composition while 4 buildings are emphasized, but without hierarchy of dominants by level.

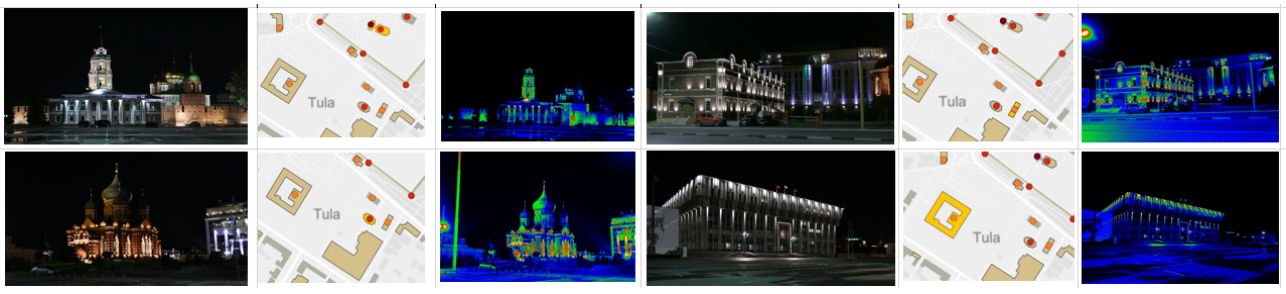

Fig.4 Example of buildings which are forming architectural ensemble of Uspensky Cathedral and Lenin Square.

Luminance contrast for 4 emphasized buildings of Uspensky Cathedral and Lenin Square reaches ratio 10 to 1 which relates to marginal perception of contrast with meaningful focal effect in accordance with Gary Stafey's idea of contrast ranking.

For 2 destroyed by light buildings luminance contrast reaches ration 20 to 1 with

strong perception of contrasts. Luminance characteristics of 12 objects from 56 are executed with observance of standard requirements; for a number of objects excess of luminance reaches 10 times higher.

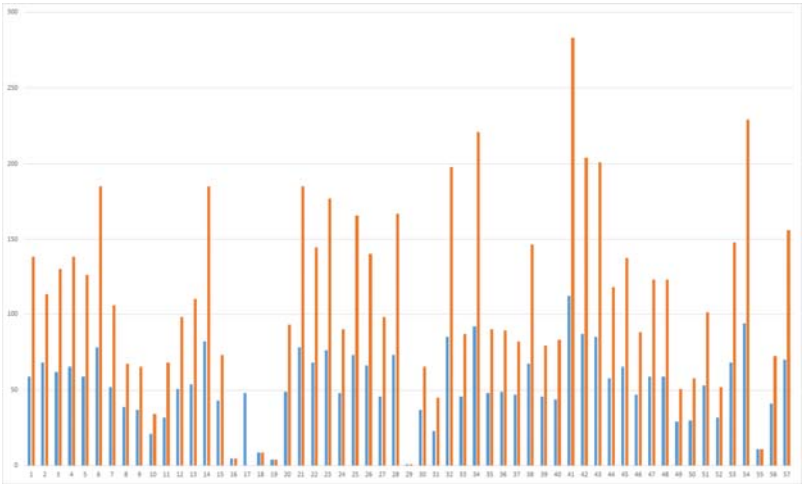

Fig.5 Average luminance for 57 buildings (blue lines) combining with maximum values of luminance (red lines).

Luminance distribution in the field of view of the observer is an important factor in assessing the quality of the light environment. Analysis of the existing urban lighting environment shows that, because of local lighting solutions without general lighting master plan luminance levels of the facades are not harmonized, nor properly aligned, thereby semantic content of some urban fragments is destroyed. For the city of Tula, the mean brightness values are 3 – 715 cd/m2. As a result of the analysis of the obtained data, the following was revealed: 44 facades are executed with excess of normalized values of brightness, which leads to composite destruction of urban fragments, irrational use of energy resources, negative influence on visual perception. For the central streets 49 facades are compositionally destroyed, which leads to incorrect reading of the architectural appearance of the city at night.

Conclusion

The study allowed to identify the most qualitatively performed fragments of the city, to reveal the general trends of the existing coverage of the city of Tula, to analyze it for compliance with the main objectives of lighting regulation: providing comfortable and safe conditions and efficient use of resources.

A comprehensive analysis made it possible to outline the main ways of further development of the light environment of the city of Tula. The greatest results to improve the appearance of the city can be achieved through the strengthening of compositional centers, the creation of interrelations between them, the hierarchy of objects by luminance levels relative to the dominant in the panorama of the city.

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