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The nocturnal characteristics of Seoul city: Focused on light color

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Abstract

The color temperature and light color of nighttime lighting in a particular city is an important factor in determining its nighttime identity. To quantitatively analyze the nocturnal characteristics of Seoul, this study focuses on the light color of the lighting sources that used in the places included in the Seoul Night View 100 Photobook. As a result, the color temperature of white light in the surveyed places is in the range of 2,500~3,500K, of which 3,000~3,500K represents the highest proportion. In addition, the color temperature in the 2,500~3,500K range was found to be evenly distributed across the five surveyed regions. Apart from white light, blue color hue accounts for a high percentage in the monochromic light category, and the excitation purity was measured to be 71.6% on average. In addition, 46% of the buildings with monochromic light are in urban centers.

Keywords: *Light color, Nightscape, Urban Identity, Seoul Metropolitan City, Urban Lighting, Correlated Color Temperature*

1. INTRODUCTION

Awareness of the significance and benefits of properly designed urban lighting masterplans has been growing since the early 21st century. There are many factors driving this notable change, such as developments in lighting technology, energy conservation, city branding design and economics, environmental impacts, human health and wellbeing, and people-oriented sociological aspects[1]. Kevin Lynch's urban design theory of legibility, presented in the book The Image of the City, has become in recent years the starting point for many contemporary night-time illumination projects[2]. When designing night-time illumination, according to Lynch's theory, such elements of space management as edges, nodes, paths, landmarks and districts have to be taken into consideration. The illumination of all these components after dark affects the perception of urban space, as well as the atmosphere and quality of life of the inhabitants of modern metropolises [2].

Around 1994, a new approach for the lighting masterplan for the Civic District of Singapore was developed in France, using a combination of illuminance and color temperature for streets, pedestrian paths, buildings, structures, parks, open spaces and landscaping, in order to highlight the identity of the area and establish a visual hierarchy[3]. The concept for color temperature and brightness rose from low-level, very warm white lighting of 2,200K to warm white lighting of 2,500K and 3,200K, medium bright ㄴ ness to cool white light from 4,000K to 5,000K and high brightness. Additionally, vehicular and pedestrian routes received deferent street lighting luminaires with regard to height, form and lighting distribution/optics based on their importance, location and character. Also, modern high-rise buildings and bridges were lit with cool white bright lighting

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of 5,000K, whereas traditional historical low-rise buildings were illuminated with warm white, gold and orange lighting of 2,200K. Typically, green areas were highlighted with cool white lighting of 4,000K to emphasize their green color. The main objective of this new approach was to enhance the architectural and landscape elements of this part of the city with the use of artificial lighting at night. This determined and promoted the district's night-time identity in a way previously unheard of in Asia[4].

As such, the color temperature of city lights is an important factor in determining the nighttime identity of a region. Starting with the 'Seoul Nightscape Basic Plan Study' in 2000, the Seoul Metropolitan Government has been steadily preparing measures to create and efficiently manage the city's night scape in a systematic approach. In 2015, the 'Seoul Nightscape Guidelines' were revised to provide nightscape guidelines for buildings, roads, open spaces, urban infrastructure, and cultural assets. The 'Seoul Nightscape Guideline' is a guideline for night lighting standards and design principles for 25 objects in five categories according to district, and for 13 of them, it stipulates the color temperature of light sources to be applied when planning lighting[5].

In 2021, the Seoul Metropolitan Government published a photobook to document and share with citizens the development and excellence of Seoul's nightscape. The 2021 Seoul Night View 100 Photobook is a record of Seoul's representative nightscape attractions and is the result of the city's urban lighting master plan, which has been ongoing since 2000[6]. To provide basic data for identifying Seoul's nocturnal identity, this study focuses on the places included in the Seoul Night View 100 Photobook and measures the color temperature of the light sources and analyzes them to identify the light color characteristics of Seoul's urban lighting.

2. REASERCH METHODS

2.1 Research Framework

To quantitatively analyze the nocturnal characteristics of Seoul, this study focuses on the light color of the light sources that make up each place in the Seoul Night View 100 Photobook. To this end, the study was divided into a preliminary survey and measurement process.

First, we visited the places selected in the 'Seoul Night View 100 Photobook' in advance and conducted a survey related to the type of building, lighting facility operation, and basic light color status at the time of the survey. We then classified the places into 1) those using white light, 2) those using monochromatic light, and 3) those using RGB color mixing. Places with real-time RGB color mixing were excluded from the light color measurement and listed separately. For the places using white light, the color temperature distribution and characteristics by region were identified, and for the places using monochromatic light, the dominant wavelength and excitation purity were measured and the characteristics by region were analyzed.

The light color measurement of the places in this study using white light and monochromatic light was carried out using a spectrophotometer for spectral analysis. This identified the correlated color temperature, dominant wavelength and excitation purity of the locations. The color temperature was selected as the assessment metrics of the survey analysis to identify the distribution of white light among the nightscape places in Seoul, and the wavelength and excitation purity were selected to identify the color characteristics of the nightscape created by monochromatic light.

2.2 Measurement tools

The spectrometer used for photochromic measurements in this study is the MK350S. In order to minimize the measurement error rate, a pre-calibration process was carried out.

Table 1. Measuring instrument specifications

Category	Description
Sensor	CMOS Linear Image Sensor
Wavelength Range	380 to 780 nm
Measurement Range	5 to 100,000 lx

Illuminance Accuracy	± 2.5%
Color Accuracy	x y : ± 0.002 (100 to 100,000 lx)
CCT Accuracy	± 2%
CRI Accuracy @ Ra	± 1.5%

2.3 The Measuring region

The study area for this research is the places featured in the Seoul Night View 100 Photobook, published by the Seoul Metropolitan Government in 2021. The photobook divides Seoul into five districts and presents representative nightscapes of each district. The number of measuring places and detailed measuring points for each area are shown in the table.

Table 2. Measuring region and number of Measuring points

Region	Districts of Seoul	Number of places	Number of measuring points
The Downtown Region(DT)	Yongsan, Jongno, Jung-gu	39	79
The Southeast Region(SE)	Gangnam, Seocho, Songpa, Gangdong	32	57
The Northeast Region(NE)	Nowon, Dobong, Gangbuk, Seongbuk, Junglang, Seongdong, Kwangjin, Dongdaemun	14	9
The Southwest Region(SW)	Gangseo, Yangcheon, Yeongdeungpo, Guro, Geumcheon, Dongjak, Gwanak	17	39
The Northwest Region(NW)	Mapo,Seodaemun, Eunpyeong	11	10

2.4 Assessment metrics

There are several metrics used to quantitatively analyze the color of light. The most commonly used metrics are CIE 1931 xy chromaticity, correlated color temperature (CCT), dominant wavelength and excitation purity.

(1) The CIE 1931 xy chromaticity

The CIE 1931 xy chromaticity diagram is a color space that provides a quantitative link between distributions of wavelengths in the electromagnetic visible spectrum and physiologically perceived colors in human color vision. It was designed in 1931 by CIE (Commission Internationale de l'Éclairage). The diagram represents the chromaticity coordinates, x and y, which are calculated from the tristimulus values of color. The tristimulus values are based on the principle that any color can be matched by a mixture of three primary colors[7].

(2) Correlated Color Temperature (CCT)

CCT is a measure of the color of a light source, expressed in Kelvin (K). It corresponds to the temperature of an ideal black body that would emit light of a similar color. CCT is a one-dimensional metric that aims to quantify the perceived visual quality of nominal white light sources[8].

(3) Dominant Wavelength(nm)

Dominant Wavelength is a method of characterizing a color's hue. It is the wavelength(nm) of monochromatic spectral light that evokes an identical perception of hue. Along with purity, it makes up one half of the Helmholtz coordinates [9].

(4) Excitation Purity (%)

Excitation Purity is a measure of the saturation of a color. It is defined by the ratio of two collinear distances on the chromaticity diagram of the CIE 1931 or 1964 standard colorimetric systems[9].

3. RESULTS

3.1 Results: Building Type Category Rating

The following are the results of the general data analysis of the 113 places in the " Seoul Night View 100 Photobook " regardless of building type.

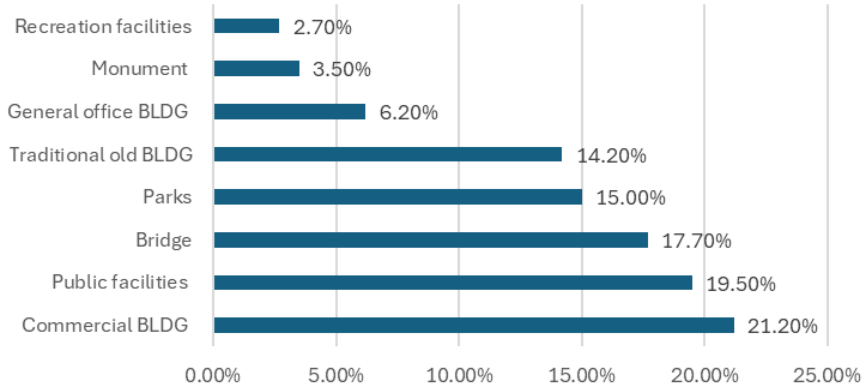

Figure 1. Types of buildings in Seoul Night View 100 Photobook

3.2 Results: Light Color by Region

According to a preliminary survey of the 113 places included in the Seoul Night View 100 Photobook, the percentage of places selected for the Seoul Night View 100 Photobook was highest in the DT (34.5%) and lowest in the NW (9.7%). Of these, 84 (74.3%) are currently operational, while 29 are not. The percentage of non-operation by region was the highest in the NE at 50%, while the SE had the highest percentage of night lighting operation at 9.4%. The distribution of light color types by survey region is shown in Table 3.

Table 3. Light color types by region

Region	White light	RGB	Monochromatic	Unlit	Total
DT	22	1	3	13	39
SE	20	7	2	3	32
NE	3	2	2	7	14
SW	11	2	1	3	17
NE	2	5	1	3	11
Total	58	17	9	29	113

3.3 Results: White Light

The distribution of white light in the five districts of Seoul was analyzed by region, and it was found that the DT was dominated by the 2500-3000K range, the NW by 2400-2800K, the SW by 2500-3000K, the SE by 3000-3500K, and the NE by 2000-4000K. The distribution of the 181 measuring points in 113 places is shown in the figure below. 29.8% in the 3000-3500K range and 27% in the 2500-3000K range, or 56.8% of all white light in the 2500-3500K range.(Figure 2)

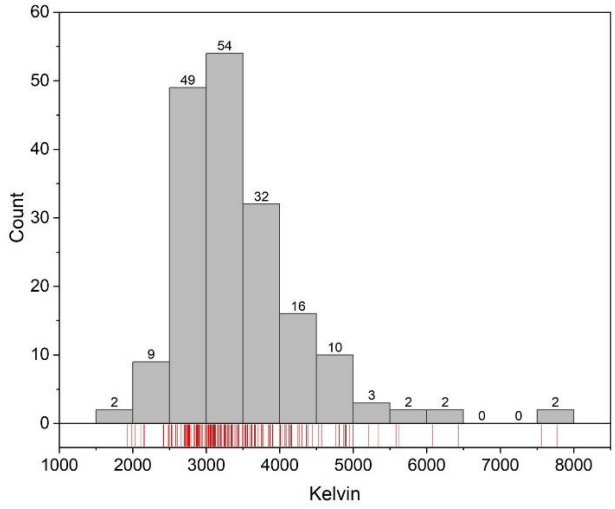

Figure 2. Distribution of the white light (CCT)

The chromaticity (xy) of white light irradiated at 181 measurement points in 113 places is plotted on the CIE1931 chromaticity diagram. (Figure 3) The distribution is concentrated in the 2500-3500 K region of the Blackbody Locus line.

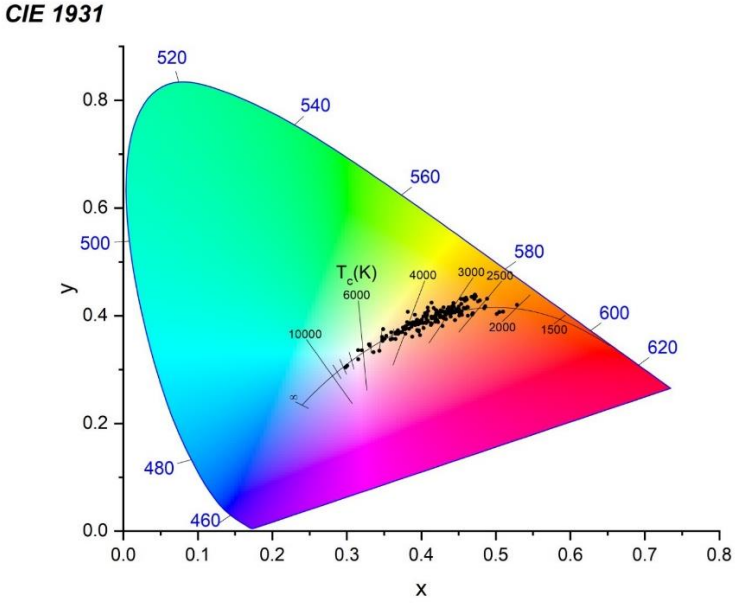

Figure 3. Chromaticity (xy) of white light

3.4 Results: Dominant Wavelength of Monochromic Light Color

Of the 113 places in the Seoul Night View 100 Photobook, 9 places have monochromatic landscape lighting. The wavelength distribution of monochromatic light at 13 measurement points in 9 places was found to be concentrated in the 434-470 nm range and 591-625 nm range. The colors corresponding to the wavelengths 434-470 nm are dark blue and light blue. In addition, the colors corresponding to the frequency range of 591~625nm are golden yellow and orange. In other words, the monochromatic light that makes up the night view of Seoul is divided into the blue color hue range and the red color hue range.

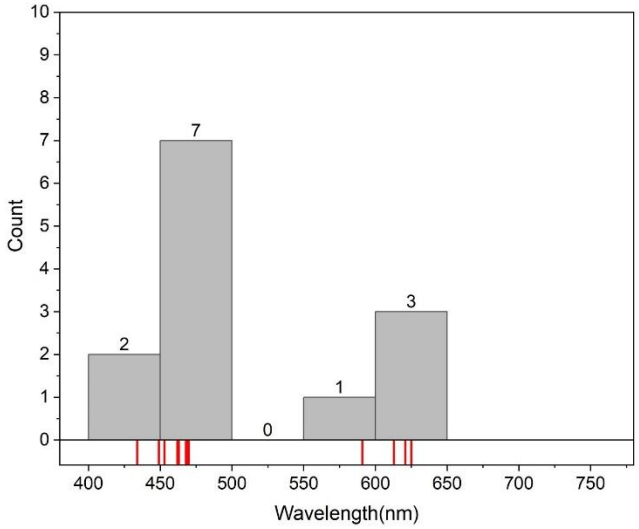

Figure 4. Wavelength distribution of the monochromatic light(nm)

3.5 Results: Excitation Purity of Monochromatic Light Color

Monochromatic Light Color has an average excitation purity of 87.76% for the red hue and 71.6% for the blue hue. The excitation purity of the place using the red color hue was rated as high.

Table 4. Excitation Purity

Wavelength(nm)	RGB	CIE xy		Excitation Purity(%)
		x	y	
434	40, 0, 255	0.282	0.2329	30.8
449	0, 65, 255	0.2555	0.1933	44.26
453	0, 87, 255	0.2112	0.1216	73.2
462	0, 132, 255	0.148494	0.046	95.7
463	0, 137, 255	0.19435	0.118484	71.9
468	0, 160, 255	0.200412	0.14932	64.9
469	0, 165, 255	0.146585	0.080999	90.2
470	0, 169, 255	0.1449	0.084	91.7
470	0, 169, 255	0.162474	0.108141	81.7
591	255, 220, 0	0.581867	0.415	99.5
613	255, 145, 0	0.560839	0.328563	66.6
621	255, 115, 0	0.675264	0.306934	94.95
625	255, 99, 0	0.664	0.3032	90.02

4. CONCLUSIONS

To quantitatively analyze the characteristics of Seoul's nightscape, this study focuses on the light color of

the lighting sources that used in each place in the Seoul Night View 100 Photobook. As a result of the survey, it was found that the types of buildings where lighting is installed and operated are Commercial BLDG, Public facilities, and Bridges, which account for more than 50% of the total nightscape.

Of the 113 places in the Seoul Night View 100 Photobook, the light color distribution of currently operating was found to be 69% white light, 20.2% RGB color mixing, and 10.7% monochromatic light. In other words, about 70% of the representative Seoul nightscape is lit with white light, and more than 30% of the nightscape is lit with non-white light. The highest proportion of white light in nightscape is in the SW (64.7%), while the lowest proportion of white light is in the NW (18.2%). There are 17 places that produce night lighting by real-time color mixing using RGB trichromatic colors, and most of these are operating in the SE and NW regions. In contrast, only Cheong-gye-cheon in the DT has RGB. This is because traditional BLDGs are mainly located in the city center. The highest percentage of monochromatic light without color mixing was found in the NE region (14.3%). The results of the light color measurement show that the color temperature of white light representative of Seoul is in the range of 2500 to 3500 K, with 3000 to 3500 K representing the highest percentage. The color temperature in the 2500-3500K range was evenly distributed across the five surveyed districts. Apart from white light, blue hue color light is the dominant color in the monochromatic light category, with an average excitation purity of 71.6%. 46% of buildings with monochromatic lighting installations are in urban centers.

The color temperature and light color of a city's nighttime lighting is an important factor in determining the nocturnal identity of a region. This study only measured the light color of the places included in the Seoul Night View 100 Photobook, so the results cannot fully describe the nocturnal characteristics of Seoul. Future studies should expand the scope and number of measurement sites to analyze Seoul's nocturnal identity in more detail.

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