Outdoor Lighting Quality and Glare Rating Evaluation of Night-Time Community Parks

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ABSTRACT

There are many community parks use the improper lighting creates light pollution. The study aims to address the issue of glare reduction for outdoor lighting as well as to encourage the installation of lighting with fitting design and style. These eight community parks located in Taichung City were selected for the study, the information collected on-site allows for an analysis of the lighting quality at night-time community parks.

The present absence of proper light shade lead to the problems of glare, uneven illumination and excessive brilliance. An analysis based on the field data reports that all community parks share similar background luminance. In terms of glare rating, Taichung Wen-Hsin Park has the highest outdoor glare rating at 53.56 for the area along the walking trail adjacent to the in-park facilities. The average illumination on the ground of walking trails in some parks are two to four times more intense than the regulation standard because the lighting installations are not properly shaded, and the distance interval between the street lamps are overly concentrated. In terms of brilliance, Taichung Park and Wen-Hsin Park has the highest brilliance index at 1.5 times in excess of the regulation standard. The high brilliance is a sign of excessive spill light, frequently leading to glare. Finally, use the DIALux, a lighting design program, is used to simulate lighting along the trail with various lighting conditions and types of installations.

Light shades are recommended to reduce brilliance so the park users do not feel harsh on the eyes. For those areas with insufficient illumination, direct lighting is recommended to enhance illumination to the ground. For the types of installations, direct and indirect lighting installations are recommended to create a properly-lit night-time environment and prevent light pollution.

Keywords: *sustainable neighbourhood, community park, glare rating, background luminance*

1. RESEARCH ORIGIN AND PURPOSES

The light hazard, like noise or air pollution, can cause adverse effect on physiology and ecology, so it is also known as "light pollution". The trails in the community parks in Taiwan are universally provided with excessive lamps, but the light environment quality is poor, resulting in glare, ecological disturbance and energy waste. At present, the evaluation of light environment quality is still neglected in the selection and setup of park trail lamps in Taiwan, this study is expected to provide reference for the future planning of park trail lamps.

- The night-time light environment quality of community parks is measured, so as to know the community park lighting design quality in Taiwan.
- The night illumination problem in Taiwan's community parks is analyzed, the improvement method and lamp selection strategy are proposed.
- The lighting evaluation software DIALux is used to simulate the effect of the lamps of different specifications and setup modes for park trails on the light environment quality and glare index of park trails, to provide reference for the future park lighting design.

2. LIGHT ENVIRONMENT QUALITY ASSESSMENT METHOD

2.1 Outdoor lighting glare rating evaluation

The outdoor glare discomforts the user's eyes and increases the danger. The glare evaluation is to establish the glare rating for different lighting occasions, for example, the unified glare rating (UGR) assessment method is applicable to indoor lighting environment; whereas the park lighting is of outdoor lighting, in order to know the lamp glare rating in the community parks in Taichung City, the outdoor glare rating (GR) is used for assessment. According to the International Commission on Illumination CIE 112-1994, the GR represents the glare level, the

GR lower than 50 means the glare is acceptable, that higher than 50 means the glare is unacceptable. Therefore, the lower the glare rating is, the lower is the glare degree, unlikely to discomfort vision (Table 1).

GR	Glare degree	GR	Glare degree	GR	Glare degree
90	Severely glaring	60	Disturbing	30	Slightly sensible
80	Intolerable	50	Slight discomfort	20	Noticeable
70	Glaring	40	Acceptable	10	Unnoticeable

Table 1: Glare rating evaluation relationships (CIE 112-1994)

2.2 Outdoor illumination evaluation

The illumination is most frequently used to evaluate the outdoor lighting environment, for evaluating the brightness in different places, so as to meet the optimal activity requirement. As the light source type, pattern and spacing of lamps can influence the pavement illumination, the "illumination meter" is used to measure the illumination of trails in various community parks, and the illumination in the parks is evaluated according to CNS15015 outdoor landscape lighting lamp specifications to check whether it is proper or not (Table 2).

Object of lighting		Average illumination (lux)	Illumination standard (lux)
Passageways	Trail	5	1~10
	Green corridor	3	1~10
	Recreation trail	3	1~10

Table 2: Illumination standard for various zones in outdoor space (CNS 15115)

2.3 Outdoor lighting brightness evaluation

The brightness is the brightness degree of the light source or the illuminated surface perceived by human eye, its unit is [cd/m^2]. The brightness depends on the area of the illuminated surface and the intensity of light reflected from the illuminated surface to the naked eye. A good brightness is closely related to the lamp cut-off design. This study uses "brightness meter" to measure the brightness of lighting fixtures in various community parks, and evaluates the lamp brightness in the parks according to IS Z 9111 road lighting standard. The brightness of trail lighting fixtures is supposed not to exceed 6,000 [cd/m^2], the brightness at the visual center can be reduced, so as to avoid discomforting the pedestrians.

3. FIELD MEASUREMENT OF LIGHT ENVIRONMENT QUALITY

As the community park is the minimum park for recreational activity and social gathering, this study takes eight 4~20 ha community parks in service radius of 1.5km in "Taichung City" in central Taiwan as the subjects investigated (Table 3). There are three types of arrangement of the lamps in the parks, unilateral arrangement, bilaterally opposite arrangement and bilaterally staggered arrangement (Table 4). The trail width, lamp type and setup spacing are investigated, and the trails frequently used by common people are taken as analytes. The "image color analyzer, illuminance meter and brightness meter" are used to measure the lamp glare, pavement illumination and lamp brightness data in parks at night, so as to know current park trail lamp setup situation and quality of lighting, contributing to proposing the way of improvement in the future.

Code	Parks Name（Brief Name）	Construction Year	Area [ha]	Measured Zone
A	Bei-Tun Park（BT Park）	1983	4.6	4
B	Jiu-She Park（JS Park）	1994	4	5
C	Chong-Zheng Park（CZ Park）	1975	7.3	4
D	Taichung Park（TA Park）	1977	10.5	5
E	Museum of Art's Park（MU Park）	1982	10.1	4
F	Wen-Sin Park（WS Park）	2006	7.6	6
G	Chong-Lun Park（CL Park）	1990	6.2	3
H	JianKang Park（JK Park）	1991	5.6	4

Table 3: Community park sample data

Unilateral arrangement	Bilaterally opposite arrangement	Bilaterally staggered arrangement

Table 4: Arrangement modes of park road lamps

3.1 Glare rating measurement method and result

In order to measure the glare quality received by the eyes when the pedestrian is walking on the trail, the "DIC image color analyzer (laboratory corrected lens and single lens camera)" is used to take two digital images in front of and behind the measuring point, the images are imported into the DIC analysis program to calculate the average glare rating at the measuring point. As the glare rating is influenced by the lamp brightness and environmental background brightness, but if the difference in background brightness is slight, in unilateral arrangement, bilaterally opposite or bilaterally staggered arrangement of lamps, the glare rating does not vary too much with the arrangement mode, it is mainly influenced by the lamp pattern. For the spot-light well controlled lamps, for example, CZ Park-C Zone keeps the glare rating at 23.92. Only the maximum and minimum results of glare rating in different lamp arrangement modes are listed (Table 5).

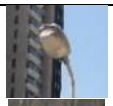
Arrangement modes	Park/ Zone	Trail width	Lamp form	Light distribution curve type	GR	Lb
Unilateral arrangement	WS Park C Zone	2			53.56 (Max)	1.47
	CZ Park C Zone	3			23.92 (Min)	1.59
Bilaterally opposite arrangement	BT Park C Zone	9.6			45.07 (Max)	1.85
	WS Park D Zone	5			30.17 (Min)	1.69
Bilaterally staggered arrangement	BT Park B Zone	4.6			50.06 (Max)	1.79
	JS Park E Zone	4			40.62 (Min)	0.51

Table 5: Relationship between community park trail lamps and glare rating

3.2 Illumination measurement method and result

The horizontal illumination of trails is measured by using high precision illumination meter. In this experiment, five measuring points are arranged between two lamps on average, and a train of measuring points is taken along the center line of the trail in width less than 3M; there are two rows of measuring points on the trail in width of 3~10M; there are three rows of measuring points on the trail in width greater than 10M. According to the field measurement, the average illumination value of most of the present trails can reach the minimum illumination 5[lx] required by CNS15015, but the illumination of 21~38 [lx] is too wasteful. A few zones below 5[lx] are related to the trail width, lamp spacing and tree shading. Sparse lamps and trail width will result in insufficient illumination of trail. Only the maximum and minimum results of illumination in different lamp arrangement modes are listed (Table 6).

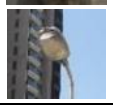
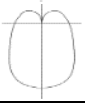
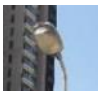
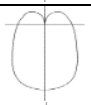
Arrangement modes	Park/ Zone	Trail width	Lamp form	Light distribution curve type	Lux
Unilateral arrangement	MU Park C Zone	2			38.18 (Max)
	MU Park B Zone	3			0.47 (Min)
Bilaterally opposite arrangement	WS Park D Zone	5			29.94 (Max)
	BT Park C Zone	9.6			20.20 (Min)
Bilaterally staggered arrangement	BT Park B Zone	4.6			21.24 (Max)
	JS Park A Zone	3.4			4.01 （Min）

Table 6: Relationship between community park trail lamps and illumination

3.3 Brightness measurement method and result

According to CNS 5064, the brightness meter is mounted at the measuring point at 1.5m above the ground, at vertical included angle of 85° to the observed lamp light source to measure the lamp brightness value. If the lampshade is transparent, unable to resist the horizontal projection effectively, there will be high brightness value. The lamp brightness situation in the parks is evaluated according to JIS Z9111 road lighting standard, the brightness of lighting fixtures for trails should not exceed 6,000 [cd/m^2]. However, it is found in this survey that if the projecting angle of the lamps for park trails is improper, the brightness is 7500~9200 [cd/m^2] which is likely to cause discomfort. Only the maximum and minimum results of brightness value in different lamp arrangement modes are listed (Table 7).

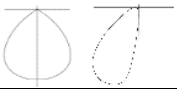
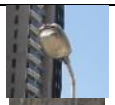
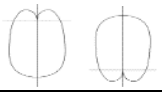
Arrangement modes	Park/ Zone	Trail width	Lamp form	Light distribution curve type	Brightness
Unilateral arrangement	WS Park B Zone	6			8854 (Max)
	CZ Park C Zone	3			1413 (Min)
Bilaterally opposite arrangement	BT Park C Zone	9.6			7567 (Max)
	WS Park D Zone	5			3422 (Min)
Bilaterally staggered arrangement	WS Park A Zone	6			9221 (Max)
	TA Park D Zone	15			1937 （Min）

Table 7: Relationship between community park trail lamps and brightness

4. SIMULATION OF CONFIGURATION OF PARK ROAD LAMPS

4.1 Lighting simulation mode

Due to the limitations of the measured objects, the lighting situation of all park trails cannot be obtained, the quality of lighting in different cases can be known by computer program simulation. This study uses DIALux software for lighting simulation, which is a lighting design software developed by Germany lamp manufacturer DIAL. It has been approved by many lamp manufacturers and lighting designers in the world. The lamp data files provided by lamp manufacturers are installed in the software for simulation. According to current condition of trail lighting, the light distribution curves of lamps in Taiwan's community parks are divided into five classes, and 135 lighting combination modes are studied out according to the road width, lamp spacing and lamp arrangement mode (Table 8), the quality of lighting of park trails is calculated one by one as reference for the selection and arrangement mode of park trail lamps in the future.

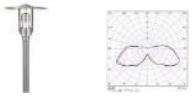
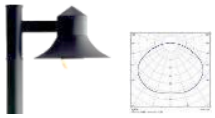
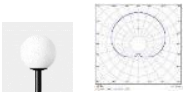
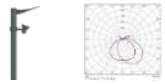
Simulated item	Simulation type	Description
Lamp type	A Type: Direct	A Type 3200 (lm)2800 (k) 
	B Type: Semi-direct	B Type 1200 (lm) 3000 (k) 
	C Type: Perfect diffusion	C Type 950 (lm) 3200 (k) 
	D Type: Semi-indirect	D Type 1800 (lm) 3500 (k) 
	E Type: Indirect	E Type 1497 (lm) 4000 (k) 
Trail width	3m, 5m, 10m	The park trails in width of 3m~10m and over 10m are main passageways.
Lamp spacing	10m, 15m, 20m	The three spacings are the major road lamp spacings
Lamp arrangement mode	The three modes are the major road lamp arrangement modes - Unilateral arrangement - bilaterally opposite arrangement - bilaterally staggered arrangement	
Simulation combinations:5 lamp types, 3 trail widths, 3 lamp spacings, 3 arrangement modes=5*3*3*3=135 simulation combinations		

Table 8: Park road lamps simulation conditions

4.2 Analysis of park road lamps lighting simulation results

Road lamp type-based comparison

- Semi-direct lamp: 27 situations of this type of lamp are simulated, the trail width or lamp arrangement mode results in glare rating of 51~69, which is an uncomfortable glaring environment.
- Direct lamp: Whatever the trail width or lamp arrangement mode is, the glare rating is about 50, mostly acceptable (Figure 1). When the trail width is 3m and the lamp spacing is greater than 20m, the illumination is 2.1~4.4 [lx]. When the trail width is 5m and the lamp spacing is greater than 15m, the illumination is 1.5~3.9 [lx]. When the trail width is 10m and the lamp spacing is greater than 10m, the illumination is 0.7~3.3 [lx].

- Perfect diffusion and semi-indirect lamps: In whatever configuration mode, the glare rating of the two types of lamps is 51~61, which is likely to cause uncomfortable glare. The illumination of this type of lamp varies with the light source capacity. The types selected for this study generate low illumination of 0.63~4.6 [lx].
- Indirect lamp: Whatever the trail width or lamp arrangement mode is, the glare rating is acceptable 36~49, the pavement illumination is quite high, almost higher than 5[lx] (Figure 2).

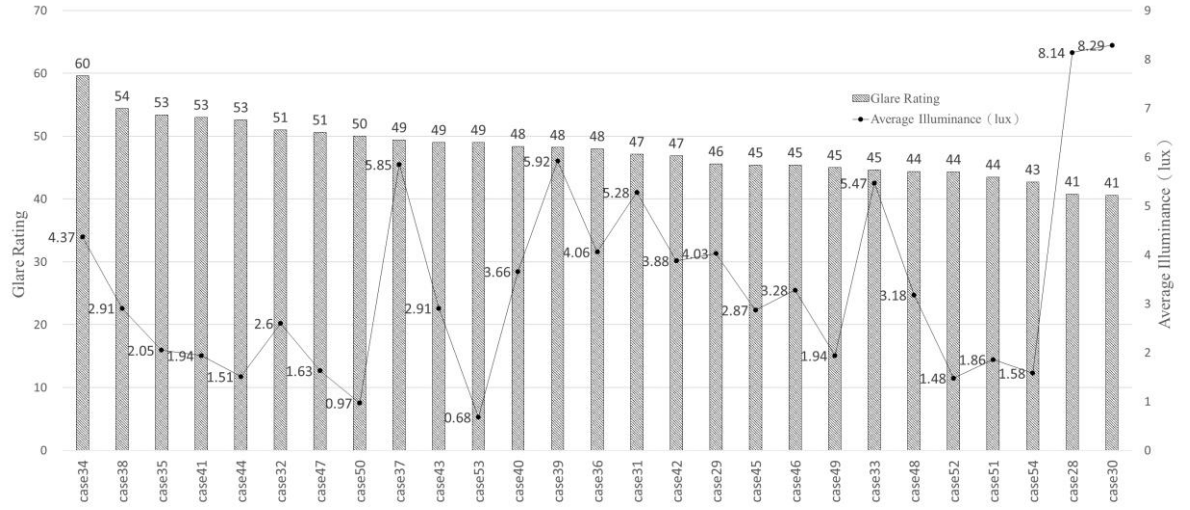


Figure 1: Semi-direct lamp simulation results

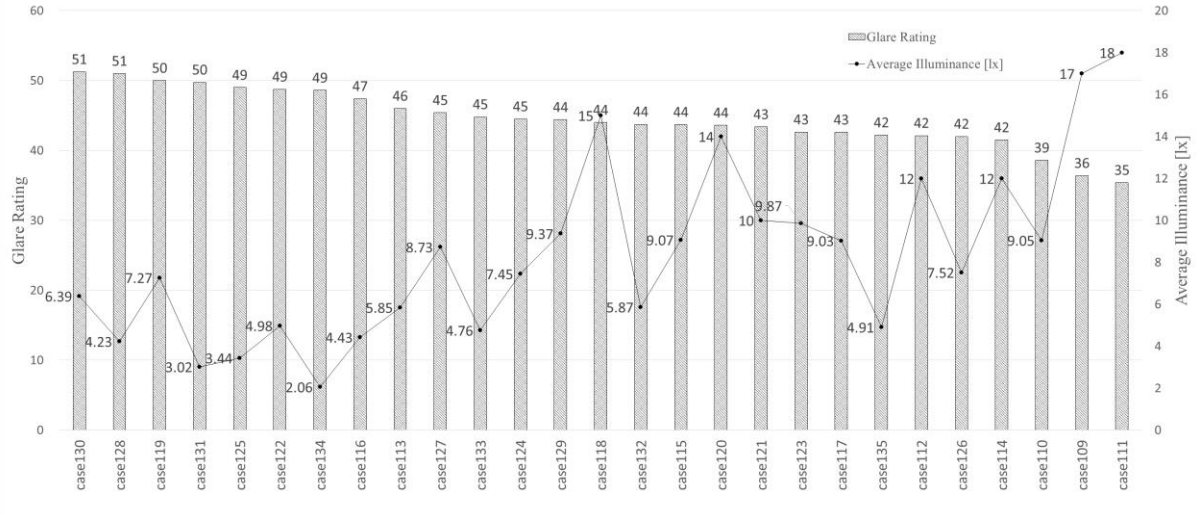


Figure 2: Indirect lamp simulation results

Park trail width-based comparison

- In terms of trail width 3m, the recommended lamp spacing is 15m, and the direct lamps are used for bilaterally staggered arrangement and bilaterally opposite arrangement.
- In terms of trail width 5m, the recommended lamp spacing is 10m, and the direct lamps are used for bilaterally staggered arrangement and bilaterally opposite arrangement.
- In terms of trail width 10m, the recommended lamp spacing is 10m, the direct lamps are used for bilaterally staggered arrangement and bilaterally opposite arrangement, but the pavement illumination is likely to be insufficient, the lamp spacing shall be shortened.

5. CONCLUSION

- A few lamps in the community parks have high brightness and glare problems. The glare level of most lamps in the eight community parks investigated by this study is acceptable. In unilateral arrangement, bilaterally opposite or bilaterally staggered arrangement of lamps, the glare rating does not vary too much with the arrangement mode. The lampshades are transparent in a few zones, which cannot shield light source effectively, so the brightness is relatively high, generating uncomfortable glare.
- The trail illumination is sufficient but relatively high: The average pavement illumination is related to the lamp setup density, the average illumination value of the trails in current community parks is higher than 5[lx], conforming to CNS 15015, but generally speaking, the illumination of 21~38[lx] is too wasteful. Although it is required to avoid too long lamp spacing causing insufficient average illumination, the excessive illumination and energy waste resulted from short spacing shall be noticed.
- The glare rating of park trails using direct or indirect lamps is relatively ideal: This study simulates 135 lighting combinations according to common lighting conditions of the parks in Taiwan, the findings show that when the "direct lamp" or "indirect lamp" is used, whatever the trail width or lamp arrangement mode is, the glare rating is 50 and 36~49 respectively, which is acceptable.

The setup of park trail lamps shall be evaluated carefully, in order to provide an appropriate park lighting environment, the lamps shall refer to the light distribution curve at the design stage, selecting the types which can prevent light rays from dissipating effectively can reduce visual and ecological impacts.

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