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The Influence of Urban Road Lighting on Pedestrian Safety

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Abstract **– As a weaker in the transport system, pedestrians deserve special protection. However, there are few relatively studies on road lighting and pedestrian protection. By analyzing the visual requirements of pedestrians for road lighting, this paper summarizes the evaluation index of road lighting: illumination level, uniformity, lighting in surrounding environment and glare restrictions. Then the author discusses the impact on pedestrian safety. By studying the weakest components of the transportation system - "one person" in the context of increasing motorization increases the psychological stress and risk of accidents, drawing some conclusions that good road lighting can increase the sense of security for pedestrians, but the excessive color quality will increasing pressure on the environment , which can give engineers, urban planners and city managers some ideas and rational suggestions during lighting design.**

Keywords **– Road Lighting; Quality Analysis; Pedestrian Safety; Visual Requirements.**

I. INTRODUCTION

Compared with daytime, people's vision decreases due to the decrease of illumination. At this time, the driver's observation and perception are affected, and it is easy to cause an accident due to lack of visual information. According to statistics, pedestrians involved in road traffic accidents (RTA) account for about 22% of road traffic-related deaths. For pedestrians traveling at night, it is very important to be able to see the approaching vehicles because they can determine the distance, speed and direction of approaching the vehicle. In addition, pedestrians should also be able to find obstacles or other violations in their path in a timely manner to avoid tripping or wrestling, such as potential dangers such as parked or abandoned bikes, frames, roadblocks, and street furniture, as well as more difficult-to-find sidewalks or road surface hazards such as pits, cracks, bumps, or prominent curbstones.

With the rapid development of China's urban economy, the traffic at night is rapidly increased. Under this circumstance, the in-depth study of road lighting and pedestrian safety has important practical significance for optimizing the construction of urban lighting facilities, protecting the safety of pedestrians, and preventing and reducing the occurrence of traffic accidents [1].

II. PEDESTRIANS' VISUAL REQUIREMENTS FOR ROAD LIGHTING

Pedestrians are worried about their safety. The real problem lies in the dangerous and irregular phenomena that may appear on the sidewalks, such as holes, cracks, bulges or raised kerbstones. The need for proper horizontal illumination allows pedestrians to clearly discover these unconventional phenomena. Many pedestrians are afraid after dark, and sufficient illumination on the streets and surrounding areas allows them to scan the entire area and feel the sense of security (including actual security and sovereign security). The required brightness depends not only on the level of illumination but also on the light source used.

Road lighting can improve pedestrian safety, community safety and visual orientation. Many pedestrians feel scared after dark. Compared to daytime, they are more vulnerable to threats and even attacks at night, especially in unsafe areas. Good road lighting should enable pedestrians to have good visual function, comfort and pleasure. In order to ensure the safety of pedestrians, the requirements for road lighting are as follows:

(1) *Suitable Horizontal Illumination*

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(2) *Suitable Brightness*

A street that is bright enough for both the surrounding environment and itself is a necessary condition for people to feel pleasant. The test of pleasure shows that when the lighting level is lower than 3~5lx, the subjective perceived brightness of the street environment becomes the only determinant of subjective pleasure. When the lighting level is higher than 3~5lx, the spectrum of the light source plays a more important role in determining the degree of subjective pleasure.

(3) *Suitable Glare Restrictions* [2]

The eyes of residents and pedestrians are often more random than the driver's eyes. Their sight is not only in front of the road, but also includes the sight of the lamps. Pedestrians in residential areas experience discomfort due to individual bright luminaires close to the line of sight. Therefore, the intensity of light emitted by individual luminaires at critical angles must be limited.

(4) *Requirements for Installation Height of Lamps*

Larger pole spacing reduces the number of fixtures needed, but it also raises higher installation height requirements. The higher installation height enhances the clear visibility of the dark outline of the lamp post in the high-luminance sky background. Therefore, the installation height of the lamp should be as high as possible, but it should not exceed half the height of the external wall of the surrounding building.

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III. Road Lighting Quality Analysis

A Lighting Level

When calculating the lighting level $E_{hor,av}$, use the average horizontal illuminance in combination with the local minimum horizontal illuminance value $E_{hor,min}$. The requirement for the average illuminance value should be sufficient to ensure that the level of adaptation is sufficiently high at this illuminance, and thus gives sufficient sensitivity to the contrast of the vision. At the same time, the local minimum level of illumination should also ensure the safety of pedestrians and cyclists by providing good visibility of obstacles in all areas of sidewalks (or bicycle lanes).

For areas where lighting can deter crimes, the minimum half-column illumination $E_{semi-cyl,min}$ on face illumination (set at 1.5m) is added as an illumination quality standard. In some cases, half-cylinder illuminance can also be replaced with the minimum vertical illuminance of the face height.

B. Evenness

In the lighting level, the average level of illumination and the minimum level of illumination are used at the same time. However, there is still a need to propose separate requirements for uniformity. If the local minimum illuminance is low and the average illuminance is at a relatively high level, this situation may just meet the requirement for uniformity, but it will lead to obstructions in the dark can not be found. This is due to the higher average illuminance, which is caused by the eyes being kept in a state that is adapted to very high lighting levels. This standard, which is usually aimed at uniformity, is the maximum value of horizontal illuminance.

C. Lighting of the Surrounding Environment

For ambient lighting, the parameters that represent the quality of the lighting are the vertical illuminance at the locations that should be fully illuminated. These locations usually refer to the sidewalk of a pedestrian passage or the house next to a bicycle lane. In some cases, using average vertical plane illumination E_{plane} (orE) sometimes using an absolute minimum plane illuminance value $E_{plane,\ min}(orE_{facade,\ min})$ to represent the lighting quality parameters here.

D. Glare Limitation

Threshold increment [3] the concept of TI is commonly used to limit the glare of motor vehicle traffic, and this concept can also help cyclists and residents achieve the desired clear visual orientation on the driving route or street for the same purpose. In these areas, people's eyes are more random (such as looking at a bright luminaire), and therefore require a different concept to limit glare. Limiting the light intensity of the luminaire at some critical angle can limit the glare in the above situation. The standard specifies the maximum light intensity at elevation angles of 70°, 80°, and 90° [4]. see picture 1: $I_{\max\ at\ 70^\circ}, I_{man\ at\ 80^\circ} and\ I_{man\ at\ 90^\circ}$

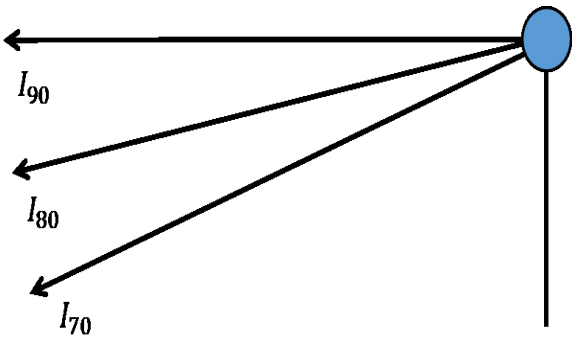

Fig. 3.1 Principle of grading system for glare control of residential lamps

Based on these light intensities, CIE defines the so-called "light intensity level" ($G1 \sim G6$) of a luminaire. These grades are specifically given in Table 3.1.

Table 3.1 CIE Light Intensity Level [CIE, 2010]

	$I_{\max}$ and over/（cd/km）			
	70°	80°	90°	95°
G_5	500	100	10	1
G_5	350	100	10	1
G_6	350	100	1	1

However, the unpleasant glare effect of a street lighting fixture does not only depend on the light intensity of the fixture, but also on the size of the light emitting surface area of the fixture. There is a lighting quality parameter that takes into account both the light intensity and the light emitting area effect. This parameter is the glare index of the lamp. Define this parameter as

$$\text{Lamp glare index} = \frac{I_{85}}{A^{0.5}}$$

The experimental results show [5] that the index is less than 19 for comfort glare.

IV. Conclusions

This article summarizes the four evaluation indicators of road lighting based on the visual requirements of pedestrians for road lighting, where the quality parameters of the lighting level are the average horizontal illumination [6], the purpose of deterrence crime with minimum horizontal illumination, and the minimum semi-cylinder height. The illumination quality parameter of the degree is the maximum value of the average horizontal illuminance, the quality parameter of the peripheral illumination is the average or minimum wall outer plane illuminance, and the illumination quality parameters of the glare restriction are the threshold increment, the light intensity limit at the elevation angle, and the lamp flare index.

Most studies show that good road lighting can reduce the

number of traffic accidents at night. In buildings and residential areas, road lighting should be able to provide visual information needed for slow traffic such as pedestrians and cyclists, allowing them to identify their routes while avoiding potential hazards such as collisions or trips. In these areas, road lighting should also play a role in preventing violence, sabotage, and crime in order to improve pedestrian safety.

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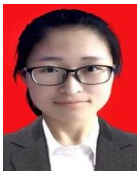
AUTHORS' PROFILES



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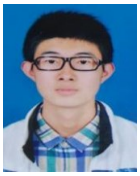

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