Research on the assessment indicators for crime prevention lighting in residential areas based on AHP and Entropy Weight

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Abstract. Lighting can affect the probability of crime. In order to establish safe and secure residential areas' lighting environment, the elements for crime prevention are researched. Originally propose 14 assessment indicators of lighting environment which can be recognized subjectively and may influence crime rate. They are horizontal illuminance、illuminance uniformity、surround ratio、vertical illuminance、three-dimensional、color rendering、glare、lamp pole height、light pole distance、lamp aesthetic、lamp conciseness、color temperature、lamp distribution、light source. The data came from residents in China. Through screening and giving weights by Analytic Hierarchy Process, there are 7 key assessment indicators left. Then give weights to the ultimate 7 key assessment indicators by Entropy Weight to verify their rank. The results show that 7 key assessment indicators have the same rank in contrast of the two methods. According to the crime prevention influence of the lighting environment, the sort is: vertical illuminance, horizontal illuminance, three-dimensional, color temperature, glare, uniformity of illuminance, color rendering.

1 Introduction

Darkness has a certain relationship with the occurrence of crime [1-2]. The crime prevention lighting aims at reducing crime occurrence through lighting design [3-4]. The main purpose using it in residential area is to provide security and comfort environment for people [5-6].

In someplace of America, the level of street lighting was improved in order to prevent crime, since then, the crime rate was reduced by 37% [7-8]. In Essex, turn off the street lights between midnight and 5.30am of one year, and the night-time crime has almost halved in Saffron Walden and reduced by over a third in Dunmow [9]. In Japan, the crime rate showed a downward trend when using anti-encroachment lamps, and they had proved that blue light contained in the lamp have deterrent effect on the criminal [10]. In China, Tongji University studied the impact of spectral power distribution of LED on crime prevention lighting. The results showed that yellow-rich LED was better for facial recognition compared to blue-rich LED [11-12]. Chongqing University researched the indicators of crime prevention lighting, and verified that the semi-cylindrical illumination and three-dimensional elements are the most appropriate indicators in the evaluation of crime lighting environment [13].

The study of crime prevention lighting is mainly focus on facial recognition. But for residential areas, lighting should create a security environment from psychological and physiological. In the paper through investigating residents in China, analyze the data by Analytic Hierarchy Process and Entropy Weight. To reduce crime rate, improve the sense of security, research the lighting assessment indicators and their rank for crime prevention.

2 Investigation methods

2.1 Investigation process

Faced with the current status of lighting, and existing problems of residential lighting environment, our school undergraduates investigated crime prevention lighting environment in residential areas. Through professional training, students understood the purpose and significance of investigation deeply. After the written test and interview, trainers exercised investigation to meet the fieldwork. Investigators used their holiday to visit the residential areas in hometown. 450 questionnaires were issued, which cover 24 provinces and cities. And 425 of them were returned, the effective rate was 86.82%.

2.2 Investigation content

Contrasting national standards of lighting environment in residential areas and related research, extract the factors that can prevent crime. Combine with lighting experts' recommendations, 14 preliminary elements obtained, as shown in the Table 1.

Questionnaire is scoring form. Scores are from -10 to 0 to 10. Negative scores mean this element promotes crime. Positive scores mean this element prevents crime.

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Table 1. The original crime prevention elements.

No.	Element	Presentation
1	Horizontal illuminance	Bright degree of the road
2	Illuminance uniformity	Light uniformity degree on road
3	Surround ratio	Brightness difference of roads and surroundings
4	Vertical illuminance	Deciding action and face whether can to be identified
5	Three-dimensional	Determine deviation degree of facial expressions
6	Color rendering	The color deviation degree compared original object with irradiated by light
7	Glare	The light produce an uncomfortable feeling
8	Lamp pole height	The height of the light pole
9	Lamp pole distance	The distance between the poles on one side
10	Lamp aesthetic	Lamp shape is beautiful or not
11	Lamp conciseness	Lamp shape is simple or not
12	Color temperature	Light color
13	Lamp distribution	Mutual position between the poles
14	Light source	Incandescent lamp、CFL、LED and so on

0 point indicates that the factors have no effect on crime prevention lighting environment. Low absolute values indicate little influence; High absolute values represent great influence. With the increasing of scores in the questionnaire, the degree of impact is increasing at the same time.

3 Investigation results

Firstly, analyze the reliability of survey data. Cronbach's alpha coefficient can measure the consistency of the project. When between 0.7 and 0.98, it can be considered a high confidence value. After calculation, the coefficient is 0.837. So the questionnaire is reasonable and data is consistency.

Negative scores can be seen as the option of "negative affect". Positive scores can be seen as the option of "positive affect". And 0 point can be seen as the option of "no affect". Figure 1 and 2 show the results of every assessment indicator. In Figure 2, each element has three styles. Low 、 midterm and high color temperature represent the color of warm、 warm white and cold. Lamp distribution has three styles which are symmetrical、stagger and unilateral distribution. And select three kinds of typical light sources. They are incandescent lamp、CFL and LED. As we can see, for residents, each element will give them a different sense of security. For most elements, the proportion of "positive affect" is higher than "negative affect" except of glare and lamp pole distance. And some elements have the highest proportion of "no affect". Remove the elements of which the "no

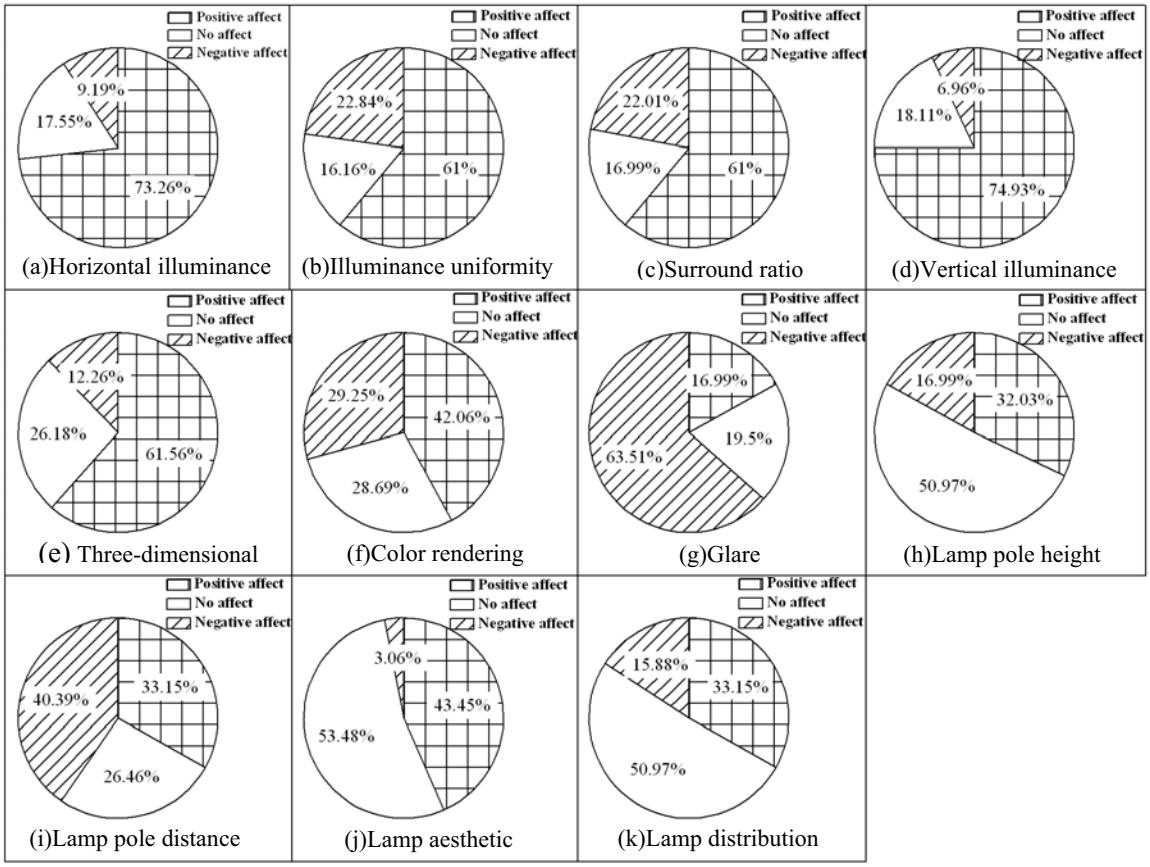

Figure 1. The results of every assessment indicator.

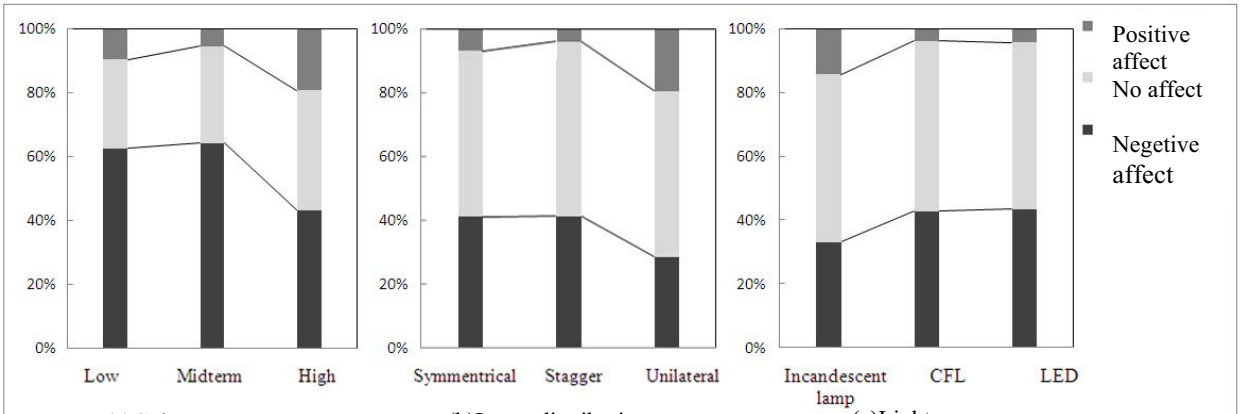

Figure 2. The results of color temperature、lamp distribution and light source.

affect" percentage is more than 50%. So the elements of lamp pole height、lamp aesthetic、lamp conciseness、lamp distribution、light source are removed. And the rest elements are：horizontal illuminance、illuminance uniformity、surround ratio、vertical illuminance、three-dimensional、color rendering、glare、light pole distance、color temperature.

4 Analysis

4.1 AHP

The Analytic Hierarchy Process (AHP) is a systematic approach that can solve complex multi-program decision-making problems. Calculate the weight of levels and total sorting by the method of qualitative indicators fuzzy quantification. It is now widely used in the environmental assessment and selection decision programs [14-15].

Use AHP evaluation method to screening deep for nine factors after initial screening. This method main utilize eigenvector method (EM) [16]. The importance ratio of every elements form a comparison matrix. The weight vector is the right feature vectors of the comparison matrix.

According to these elements, B1-B9 are: horizontal illuminance、illuminance uniformity、surround ratio、vertical illuminance、three-dimensional、color rendering、glare、light pole distance、color temperature. After comparing the importance of each element, the comparison matrix is:

$$A=\begin{bmatrix} 1 & 2 & 5 & 1 & 1 & 2 & 1 & 8 & 1 \\ 1/2 & 2 & 1 & 1/2 & 1/2 & 1 & 1/2 & 4 & 2 \\ 1/5 & 1/2 & 1 & 1/6 & 1/4 & 1/2 & 1/4 & 2 & 1/4 \\ 1 & 2 & 6 & 1 & 2 & 3 & 2 & 9 & 2 \\ 1 & 2 & 4 & 1/2 & 1 & 2 & 1 & 6 & 1 \\ 1/2 & 1 & 2 & 1/3 & 1/2 & 1 & 1/2 & 3 & 1/2 \\ 1 & 1/2 & 4 & 1/2 & 1 & 2 & 1 & 6 & 1 \\ 1/8 & 1/4 & 1/2 & 1/9 & 1/6 & 1/3 & 1/6 & 1 & 6 \\ 1 & 1/2 & 4 & 1/2 & 1 & 2 & 1 & 6 & 1 \end{bmatrix}$$

After calculation, the weight vector is $W=(w_1, w_2, w_3, w_4, w_5, w_6, w_7, w_8, w_9)^T=(0.1616, 0.0993, 0.0365, 0.2188, 0.1408, 0.0724, 0.1244, 0.0218, 0.1244)^T$.

Define index trade-off weight $\xi=0.05$. As the results, B3's relative weights $w_3=0.0365$, B8's relative weights $w_8=0.0218$, less than ξ.They are weak weight indicators, so get rid of surround ratio and light pole distance. The remaining 7 indicators were normalized. The weight vectors are $W=(0.1716, 0.1054, 0.2324, 0.1495, 0.0769, 0.1321, 0.1321)^T$.

4.2 Entropy Weight

Entropy Weight is an objective weighting method which can determine the index weight based on the amount of information contained in each index [17]. According to basic principles of information theory, information is a measure of ordering degree in the system, but the entropy is a measure of disorder degree in the system [18-19]. Information augment means the entropy reduction. In the questionnaire with the increasing of the information amount for a factor's data, its entropy is decreasing to the contrary. It should be given a greater weight.

Validate the rank of the final 7 elements by Entropy Weight. Through calculation, the weights are $W'=(0.1933, 0.1904, 0.1669, 0.1601, 0.1118, 0.0912, 0.0863)^T$.

4.3 Comparison

In contrast of the two methods' results, the weights of 7 elements are different, but they have the same rank. According to the crime prevention influence of the lighting environment, the sort is: vertical illuminance、horizontal illuminance、three-dimensional、color temperature、glare、illuminance uniformity、color rendering. The impact of each key element is shown in Table 2. The only negative factor is glare, and the others can prevent crime.

Table 2. The impact of each key element.

No.	Element	AHP	Entropy Weight	Effect
1	Vertical illuminance	0.2324	0.1933	Allow pedestrians to see the people's face expression, posture around them, to find danger in an emergency.
2	Horizontal illuminance	0.1716	0.1904	Allow pedestrians to see the road ahead, avoid obstacles timely, and protect their own safety.
3	Three-dimensional	0.1495	0.1669	Make people identify objects' true original better, thereby reduce the fear of unkown objects.
4	Color temperature	0.1321	0.1601	Different color temperatures effect different psychological. Color temperature can warn criminal mentality when use reasonably.Thereby reducing the crime rate.
5	Glare	0.1321	0.1118	Extreme glare will cause a loss of visibility. If someone commit a crime, it would threaten residents' personal and property safety.
6	Illuminance uniformity	0.1054	0.0912	Low level illumination uniformity make pavement emerge staggered stripes of bright and dark. Strong chiaroscuro effect pedestrians' vision. However, if there isn't extreme contrast, the human eye can distinguish sudden dangerous due to the slower moving.
7	Color rendering	0.0769	0.0863	The object whether restore the true color. High color rendering helps pedestrians distinguish the faces and bodies come across. But at night, the human eye has llittle sensitive to color. So it rank at the bottom.

5 Conclusions

Originally propose 14 assessment indicators of light environment which can be recognized subjectively and may influence crime rate. They are horizontal illuminance、illuminance uniformity、surround ratio、vertical illuminance 、three-dimensional 、color rendering、glare、lamp pole height、light pole distance、lamp aesthetic、lamp conciseness、color temperature、lamp distribution、light source. Remove the elements of which the "no affect" percentage is more than 50%. So the elements of lamp pole height、lamp aesthetic、lamp conciseness 、lamp distribution 、light source are removed . Through screening further by AHP, get rid of surround ratio and light pole distance. In the removed elements, most of them are related to lamp shape but not light. Thus it can be seen that these elements are not be noticed in the night, nor impact the psychological of resident. But in the daytime, design these elements reasonably will show the residential area better, improve residents' quality of life.

Give weights to the ultimate 7 key assessment indicators by AHP and Entropy Weight. The results show that 7 key assessment indicators have the same rank in contrast of the two methods. According to the crime prevention influence of the lighting environment, the sort is: vertical illuminance, horizontal illuminance, three-dimensional, color temperature, glare, uniformity of illuminance, color rendering. When design the lighting environment, emphasizing these assessment indicators will reduce crime rate, improve the sense of security.

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