Entropy-TOPSIS Method to Study the Factors Affecting Light Pollution

Qirui Ding [1, #], Yongshuai Huang [2, #, *], Chenhao Zhu [1, #]

[1] International of Education Institute, Dalian Jiaotong University, Liaoning, China, 116028

[2] College of Locomotive and Rolling stock Engineering, Dalian Jiaotong University, Liaoning, China, 116028

* Corresponding Author Email: yongshuai.h328@foxmail.com

[#]These authors contributed equally.

Abstract. The problem of light pollution, which arises from the excessive or poor use of artificial light sources, has become a global issue. Identifying and solving the light pollution problem will have a positive impact on human and ecological environment. In this paper, the entropy-TOPSIS method addresses the degree of influence of each factor on light pollution and finds appropriate improvement measures based on the characteristics of data that may affect light pollution factors. The entropy-weighting method is used to score different areas with different degrees of light pollution, and then the weights of each factor are obtained, and the TOPSIS method is used to score the degree of light pollution in each area based on the superiority and inferiority distances. Finally, the light pollution evaluation model is obtained.

Keywords: Entropy-TOPSIS, Light Pollution, Math Modelling.

1. Introduction

The problem of light pollution was first raised by the international astronomical community in the 1930s. Light pollution refers to the excessive or poor use of artificial light, mainly including white bright pollution and artificial daylight pollution. The hazards of light pollution are mainly damage to ecology and affect human health. The ecological damage of light pollution is irreversible, white bright pollution affects the natural life pattern of animals, making the mobility of animals problematic, which in turn interferes with the migration of wild animals.[1] Light pollution hinders the growth of plants, causing their stems and roots to change color and die, thus destroying the ecological balance of plants; light pollution also poses a great threat to human health, as unnatural light tends to suppress the human immune system, thus destroying the endocrine balance and leading to cancer.

Identifying light pollution is to develop a widely applicable metric by selecting indicators related to light pollution, and to raise awareness of light pollution by measuring the level of light pollution risk in an area; taking measures to improve it is to develop targeted intervention strategies to mitigate the effects caused by light pollution according to the different social contexts of a region.

Selected indicators:

Average hours of light, visibility, glare, illumination, average annual temperature, GDP, total social electricity consumption, population, and urbanization rate.

Selected areas:

To explain the level of light pollution and the causes of the level of light pollution in a protected land location, a rural community, a suburban community, and an urban community, therefore, Vanjung Mountain, Traverse City, Michigan, Jimo District, and Kunshan City were selected as the subjects of this paper.

2. Entropy-TOPSIS method

2.1. Entropy-TOPSIS method modeling

PART 1 Entropy method: the principle is shown in Figure 1 shown.

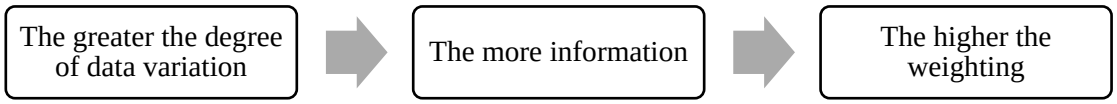


Figure 1 Principle of entropy method

According to the principle of entropy method and this problem scenario, the steps of entropy method in this paper are as follows.[2]

According to the n evaluation samples in this paper, where n can be 6 for the first category, or 4 for the second category. 6 evaluation indicators, using the data after the first part of pre-processing, the data normalization matrix is constructed as shown in Equation 1.

$$R = \begin{pmatrix} r_{11}\, r_{12} \cdots r_{16} \\ r_{21}\, r_{22} \cdots r_{26} \\ \cdots \quad \cdots\, r_{ij} \cdots \\ r_{n\,1} r_{n\,2} \cdots r_{n\,6} \end{pmatrix}_{n\times 6} \tag{1}$$

(1) The percentage of the ith evaluation object in the jth index is calculated as Equation 2.

$$p_{ij} = \frac{r_{ij}}{\sum_{i=1}^{n} r_{ij}} \tag{2}$$

(2) The entropy value of the jth indicator is calculated as shown in Equation 3.

$$e_j = -\frac{\sum_{i=1}^{6} p_{ij} \times \ln p_{ij}}{\ln n} \tag{3}$$

(3) The entropy weight of the jth indicator is calculated as shown in Equation 4.

$$w_j = \frac{1-e_j}{\sum_{j=1}^{6}(1-e_j)} \tag{4}$$

PART 2 TOPSIS Solution Method

TOPSIS method is an effective comprehensive evaluation method to solve multi-level and multi-indicator decision problems. TOPSIS method uses distance scales to measure the sample gap, and using distance scales requires isotropic treatment of indicator attributes. The model construction steps are as follows.[3]

The original matrix is normalized to form a normalized decision matrix as in Equation 5.

$$z_{ij} = \frac{r_{ij}}{\sqrt{\sum_{i=1}^{n} r_{ij}^2}}, i = 1, \ldots n; j = 1, \ldots, 6 \tag{5}$$

(1) The weight obtained from the entropy weight calculation is multiplied by the normalized decision matrix to obtain the weighted decision evaluation matrix, as shown in Equation 6.

$$x_{ij} = w_j \cdot z_{ij}, i = 1, \ldots n; j = 1, \ldots, 8 \tag{6}$$

(2) Calculate the optimal ideal type and the worst ideal type for each index.

$$\begin{cases} x^{+} = \left\{ \max\limits_{i=1}(x_{i1}), \max\limits_{i=1}(x_{i2}), \max\limits_{i=1}(x_{i3}) \right\} \\ x^{-} = \left\{ \min\limits_{i=1}(x_{i1}), \min\limits_{i=1}(x_{i2}), \min\limits_{i=1}(x_{i3}) \right\} \end{cases} \tag{7}$$

(3) Calculate the distance from each object to the optimal and the worst ideal type, respectively.

$$\begin{cases} d^{+} = \sqrt{\sum_{j=1}^{6}\left(x_{ij} - x^{+}\right)^{2}}, i = 1, \ldots, n \\ d^{-} = \sqrt{\sum_{j=1}^{6}\left(x_{ij} - x^{-}\right)^{2}}, i = 1, \ldots, n \end{cases} \quad (8)$$

(4) Closeness of each object to the optimal ideal type is calculated. The closeness of each country's evaluation target to the optimal target is expressed in the range of [0,1], and the larger the value, the closer the country's social stability level performance is to the optimal level.

$$f = \frac{d^{+}}{(d^{+}+d^{-})}, i = 1, \ldots, n \quad (9)$$

According to the above method, the positive ideal distance solution and negative ideal distance solution of the selected samples can be obtained, and finally the get each index score.

3. Specific case studies of the model

Using the model constructed in this paper to explain the degree of light pollution and the causes of the degree of light pollution in a protected land location, a rural community, a suburban community and an urban community, respectively, Fanjingshan, Traverse City, Michigan, Jimo District and Kunshan City were selected as the subjects of this paper.

According to K-means cluster analysis, Fanjingshan and Traverse City, Michigan belong to the second category of low light pollution level, and Jimo District and Kunshan City belong to the first category of high light pollution level, which are brought into the above model for analysis respectively.[4][5]

The different areas selected belong to different categories, but will be described in the same expression in this paper, mainly describing the following aspects.

- Introduction to the basic information of the selected area

Ranking of selected regions in the category

- The higher the ranking, the higher the degree of light pollution.

Percentage of distance of each indicator in the selected area

The percentage is calculated as the ratio between the distance between an indicator of the selected region and the positive ideal solution of the indicator of that category and the positive ideal solution of the indicator of that category, as shown in Equation 10.

$$Per = \frac{z_{ij} - d^{+}}{d^{+}} \times 100\% \quad (10)$$

The higher the percentage, the closer the indicator is to the positive ideal solution, and the closer the indicator is to the optimal solution, indicating that the indicator is one of the important factors causing light pollution.[6][7]

3.1. Analysis of light pollution in protected areas and rural cases

The data was obtained from the GeoNames website, and the results of the study of selected evaluation indicators for the two selected groups of regions were obtained as follows:

PART 1 Analysis of Protected Areas - Analysis of Fanjingshan Mountain as a Case Study

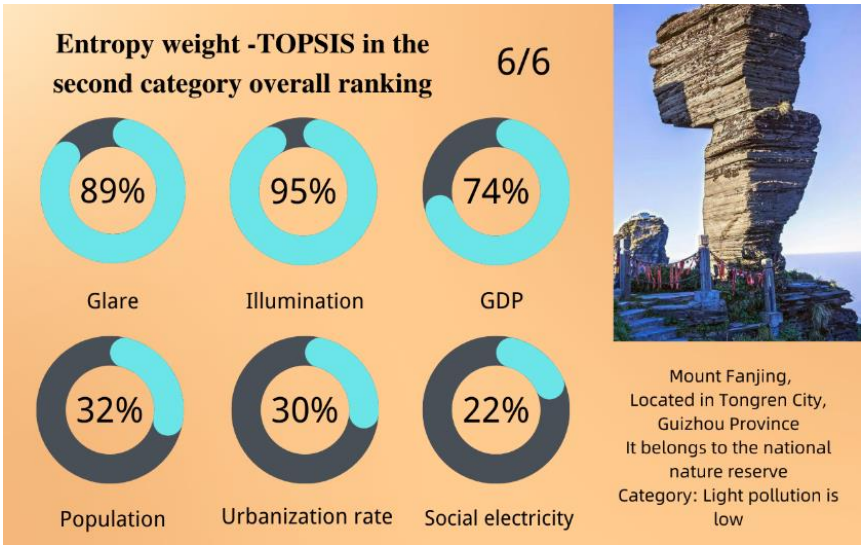


Figure 2 Fanjingshan Analysis

According to Figure 2, it can be seen that the degree of light pollution in Fanjingshan is relatively low, glare, illumination and other natural factors on the degree of light pollution caused by the area is relatively large, so in the protected area, the government should also take shading measures to ensure the destruction of human activities, but should not be too much, too much shading measures will instead affect other indicators and thus cause light pollution.[6] [7]

PART 2 Rural Case Study - Traverse City, Michigan as a Case Study

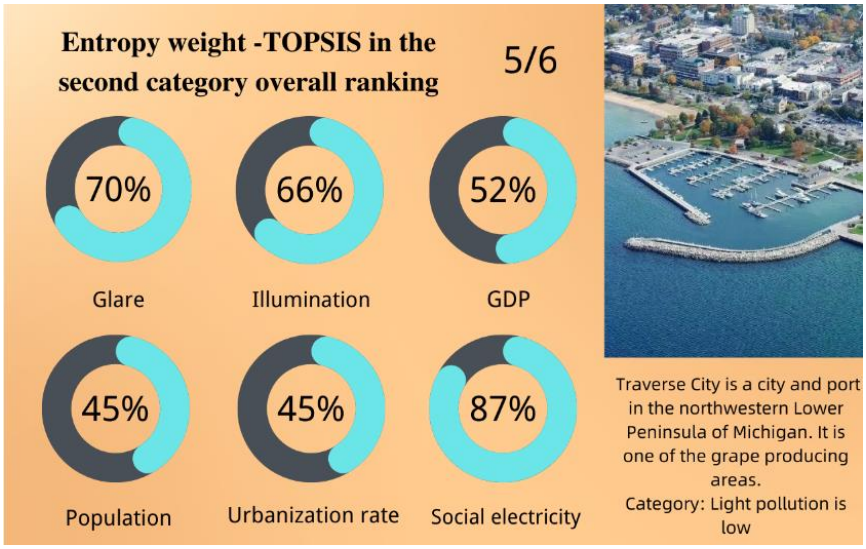


Figure 3 Traverse City, Michigan Analysis

According to Figure 3, it can be seen that the degree of light pollution in the city is relatively low, glare, total social electricity consumption and other natural factors have a large impact on the degree of light pollution caused by the area, so in the countryside, if you want to further control the degree of light pollution, then you should control the electricity consumption, but this is obviously unrealistic, most of the rural electricity consumption for basic lighting, so rural areas should continue to maintain the current ecological and infrastructure construction. [8]

3.2. Analysis of light pollution in urban and suburban cases

PART 1 Analysis of suburban areas-analysis with the case of Jimo

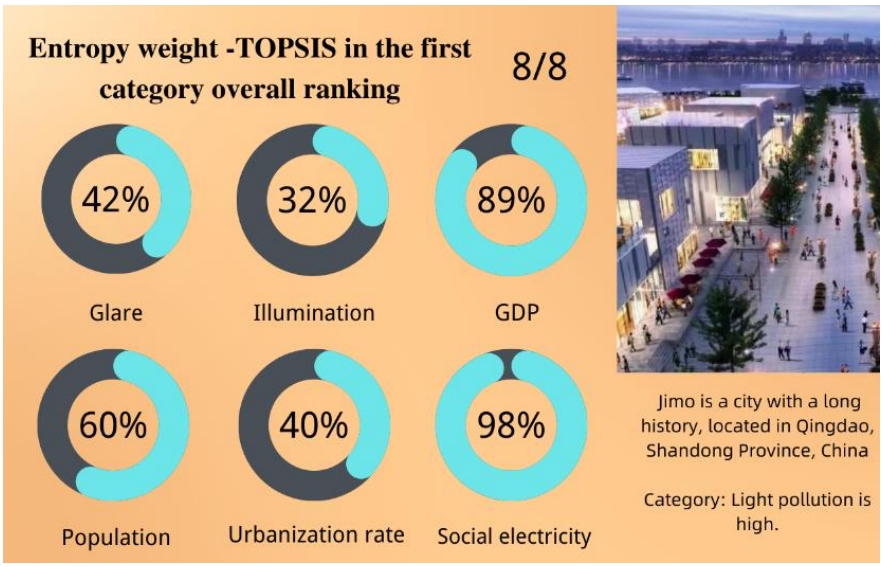


Figure 4 Analysis of Jimo District

According to the analysis of Fig. 4, Jimo belongs to the suburbs of Qingdao city, and its light pollution level is low compared with that of the city. The main factors causing light pollution in Jimo are electricity consumption and GDP aspects, and according to the analysis of three types of industries in Jimo, its heavy industry accounts for more, and this reason is one of the important reasons for light pollution in Jimo.

PART 2 Rural Case Study - Kunshan City as a Case Study

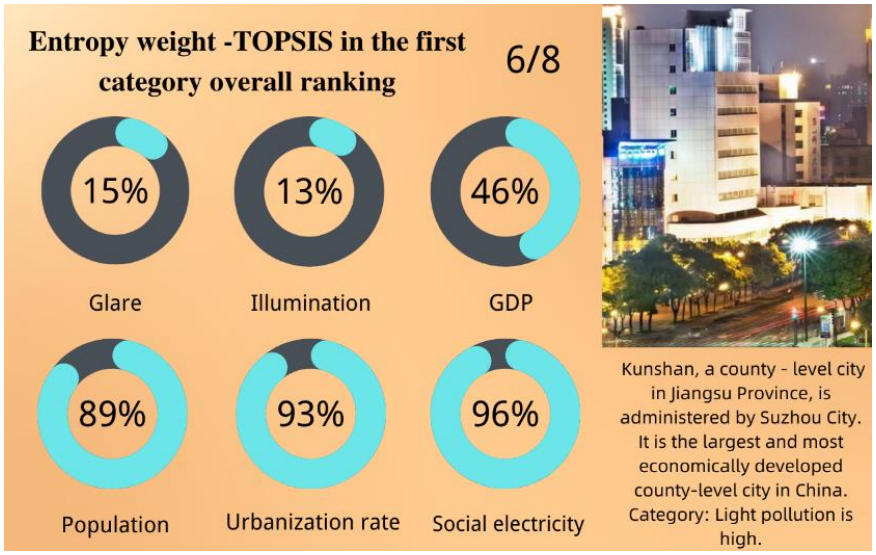


Figure 5 Analysis of Kunshan City

According to the analysis of Figure 5, the degree of light pollution in Kunshan City is relatively high, the main factors causing light pollution in Jimo are electricity, population and urbanization, Kunshan City is a relatively developed city, the tertiary industry accounts for more, more modern urban construction, electronic screens in the city as an important part of its light pollution, so electricity restrictions and reduce the "light show" may alleviate the degree of light pollution in Kunshan City.[8]

4. Conclusions

In this paper, the entropy-weight-TOPSIS method is used as a method to assess the degree of light pollution, and this method is able to take into account the weights of several indicators and comprehensive evaluation, which has a certain degree of feasibility. By constructing a light pollution assessment model, it provides a new analytical method for studying the light pollution problem.

However, more data and empirical findings may be needed in the article to support the validity and accuracy of your light pollution assessment model. Therefore, more light pollution related data should be collected and analyzed in depth in the future to increase the reliability and accuracy of the model. Technical tools such as remote sensing data and geographic information systems (GIS) can be considered to acquire and process data.

In terms of methodology, other effective assessment methods and indicators can be explored to further improve the accuracy and applicability of light pollution assessment models. Consider combining machine learning and artificial intelligence techniques to deal with complex light pollution problems. [9] [10] [11]

Currently, the entropy-TOPSIS method light pollution assessment model proposed in this paper can be widely used in the fields of urban planning and environmental protection to help decision makers develop more scientific and effective light pollution management strategies.

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