Problem Chosen	2023 MCM/ICM Summary Sheet	Team Control Number
E		2300050

Measuring and Mitigating the Impacts of Light Pollution with EWM-TOPSIS Method

Summary

Keywords: Entropy weight method, TOPSIS, ;

Contents

1 Basic Introduction

1.1 Background

Light pollution is a term used to describe the excessive or inappropriate use of artificial light, which can take the form of light trespass, over-illumination, and light clutter. These phenomena are often visible as a glow in the night sky in large cities, but they can also occur in more remote areas. Light pollution affects our environment, health, and safety by altering our view of the night sky, delaying or accelerating plant maturation, disrupting wildlife migration patterns, and affecting our circadian rhythms. Excessive artificial light can lead to poor sleep quality and may contribute to physical and mental health problems, while glare from artificial lights can increase the risk of motor vehicle accidents.

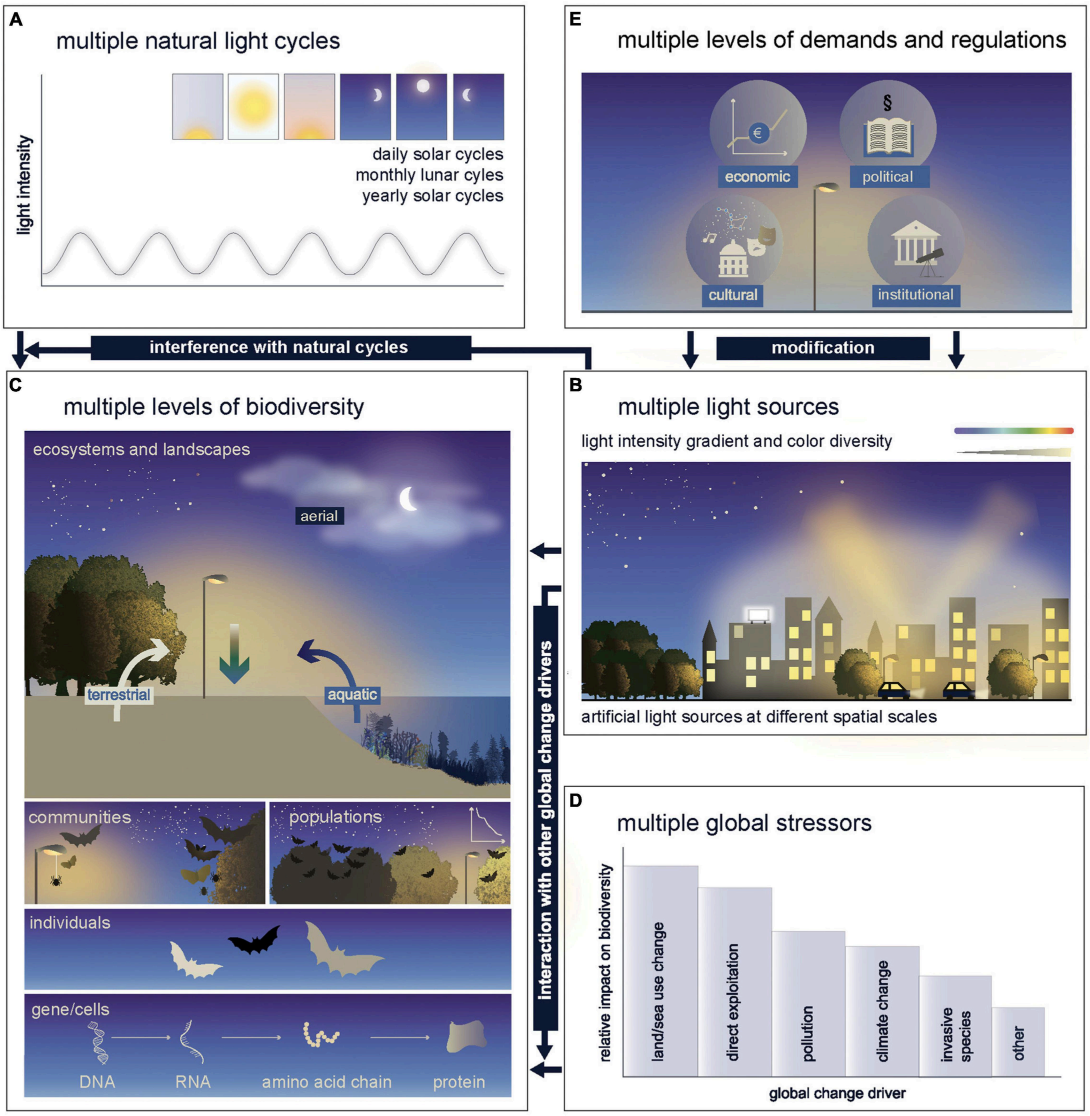

Figure 1: Artificial light at night: Potential sources, biodiversity impacts and responses are complex. Different natural light cycles (A) are affected by multiple forms of artificial light at night (B) at multiple levels of biodiversity in multiple realms (e.g. from bottom up: gene expression; phenotypes; population dynamics, e.g. decline; community composition; species dispersal and/or organismic fluxes across ecosystem boundaries and bioms) (C). Artificial light at night can interact with multiple global change stressors (D). Due to the potentially conflicting demands of artificial light at night a transition to a more sustainable use is extremely challenging and requires multiple levels of regulations (E) [1]

However, artificial light has both positive and negative impacts that can vary based on location. The effects of light pollution can depend on factors such as a location's level of development, population, biodiversity, geography, and climate. Therefore, assessing the extent of the effects and potential impacts of intervention strategies must be tailored to the specific location, and intervention strategies are needed to mitigate the negative effects of light pollution.

Light pollution is a serious problem with implications for wildlife, human health, scientific research, energy consumption, global warming, and the ageless pastime of observing the night sky. Pristinely dark skies are very scarce in the developed world and most of the world's population—and nearly all of those living in the EU or the US—live under skies with at least some light pollution[2].

For biodiversity studies, nocturnal light ideally would be measured in biologically relevant ways, based on thresholds and spectral sensitivities of the species, because different light sources interfere differently with the large diversity of sensory systems in nature[3].

1.2 Problem Restatement

- The indicators of the EWM-TOPSIS model should be determined, in other words, it is equal to build a broadly applicable metric for identifying the light pollution risk level.
- Apply the indicators and the related data to the EWM-TOPSIS model, then analyse the result in the four diverse types of locations.
- Design 3 possible strategies for addressing light pollution, and how the indicators change with the strategies.
- Select 2 locations, and implement the most effective intervention strategies for each of them. See how the indicators change and the impact of the chosen intervention strategy.
- Write a 1-page flyer to community officials or local groups in a specific location to promote the most-effective intervention strategy tailored for the location.

1.3 Our works

First of all, we selected 9 cities as evaluation objects and 9 indicators for the EWM-TOPSIS Model. Both benefit-attributed and cost-attributed indicators are taken into account. Then we use the Entropy Weight Method (EWM) to get the weight of indicators. After getting the weights, we use the TOPSIS method to determine the best option from a set of alternatives.

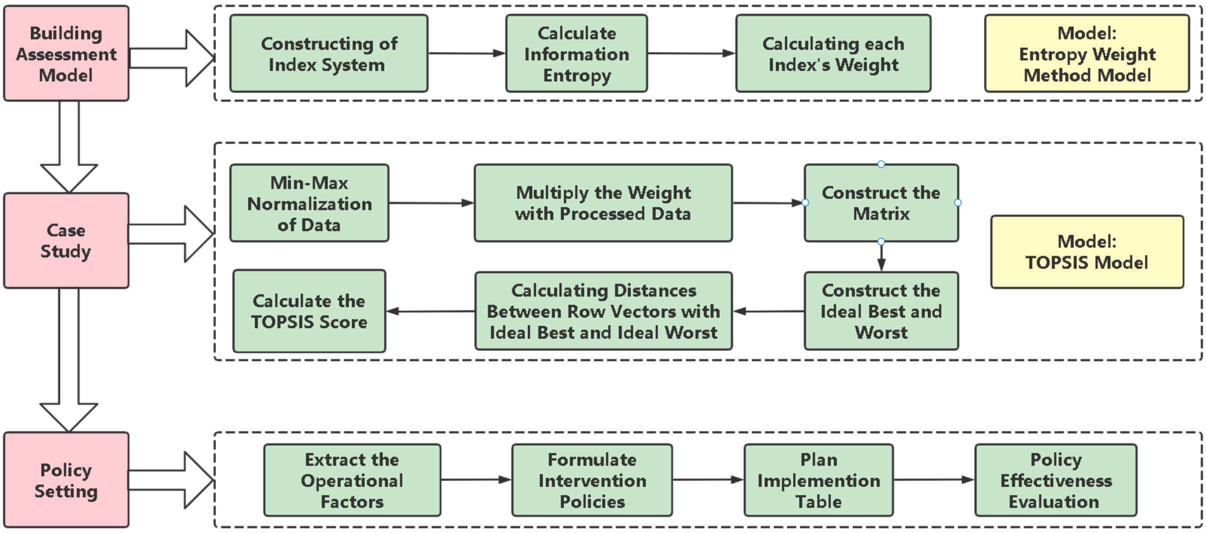

Figure 2: Our workflow.

2 Assumptions and Justifications

To simplify the problem, we make the following basic assumptions.

- Assume that all the light pollution is from night-time light, so we just need to consider night-time light intensity.

  Justifications: According to the Wikipedia[4], the definition of light pollution is the presence of anthropogenic artificial light in otherwise dark conditions.

- Citizens will not reduce the basic consumption of living illumination for the purpose of reducing light pollution.

  Justifications: To simplify the problem, we didn't take people's awareness of light pollution into account.

- Precipitation occurs in the day and night with equal probability and intensity.

  Justifications: As we use year precipitation to evaluate the cloudness of one location, and the light pollution occurs in the night-time, only rainy at night that the precipitation data is valid. So that the year precipitation can be comparable.

- Night-time light intensity is closely related with economics.

  Justifications: According to fractional logit models[2], both population and GDP are significant explanatory variables, similar to other types of pollution.

- We ignored the differences of light colors.

  Justifications: It's hard for us to get the using percentage of each light color.

3 Notations

Symbols used and their definitions are defined below(Table 1).

Table 1: Notations of symbols

Symbol	Description
a_{ij}	The value of the j-th indicator of the i-th city to be evaluated.
$A = (a_{ij})_{i\times j}$	Data matrix composed by a_{ij}.
p_{ij}	The proportion of the i-th evaluation objective to the j-th indicator.
e_j	The entropy value of the j-th indicator.
w_j	The weight of the j-th indicator.
b_{ij}	The data from a_{ij} after standard 0-1 transformation.
$B = (b_{ij})_{i\times j}$	The decision matrix composed by b_{ij} after processing.
$C = W * B$	The weighted-normalised decision matrix.
C_i	The i-th roll of the C matrix.
$C^* = [b_1^{max}, b_2^{max}, \cdots, b_j^{max}]$	The positive ideal solution.
$C^* = [b_1^{min}, b_2^{min}, \cdots, b_j^{min}]$	The negative ideal solution.
s_i^*	The distance from C_i to the positive ideal solution.
s_i^0	The distance from C_i to the negative ideal solution.
f_i	The night-time light intensity of the i-th city.

4 The EWM-TOPSIS Model

4.1 Indicators of the Model

We selected 12 states in the USA as evaluation objects. As the night-time light intensity directly reflects the extent of light pollution, so it is regarded as the direct evaluation indicator, and we chose 9 indirect indicators as evaluation indicator variables to evaluate the night light level of the city. The value of the j-th index variable of the i-th city evaluated is a_{ij}, building a matrix $A = (a_{ij})_{12\times 9}$.

The 12 states in the USA we selected are Massachusetts, New York, New Jersey, California, Pennsylvania, Washington, Nevada, Mississippi, Missouri, Wyoming, Montana, and Alaska. The first three states are taken as urban communities, the second three states are taken as suburban communities, the third three states are taken as rural communities, and the last three states are taken as protected land locations.

The 9 indirect indicators we selected are population density, night-time electricity consumption, per capita GDP, regional industrial structure, regional average working hours, the last bus time of public transportation, night life index, year precipitation, limiting magnitude, etc. Among these indicators, only the limiting magnitude is an objective indicator and cannot be changed.

To explain the selection of indicators, We divide the indicators into two categories. One is the benefit-attributed indicators. The larger the data index, the higher the night-time light intensity. The other is the cost-attributed indicators. The smaller the data index, the higher the night-time light intensity.

For the benefit-attributed indicators, there are 7 indicators which are listed below.

1. **Population density**. With the increase of population density in a region, the illumination demand of this region's public space also increases, thus increasing the night-time light intensity.

2. **Night-time electricity consumption**. A large part of night-time electricity consumption is used for lighting, so it can also reflect the night-time light intensity to a certain extent, which is a benefit data.

3. **GDP per capita**. GDP per capita reflects the degree of local development. The more developed and prosperous the region, the more shopping malls and high-rise buildings in prosperous areas. And we believe the LED lights in shopping malls and the glass curtain walls of high-rise buildings lead to an increase in night-time light intensity, which may lead to the light pollution.

4. **Regional industrial structure**. The demand for illumination in various industries is different. The primary industry has little demand for light. Some industries in the secondary industry have requirements for light, and the tertiary industry service industry is extremely dependent on light to attract customers. So the industrial structure also has an impact on the local night-time light intensity, and we believe that the more the proportion of the tertiary industry, the higher the night-time light intensity is.

5. **Nightlife index**. Nightlife is a collective term for entertainment that is available and generally more popular from the late evening into the early hours of the morning. As long as nightlife prevails, the lighting demand increases. The higher the nightlife index of a region, the higher the night-time light level, which belongs to the benefit data.

6. **Year precipitation**. The more rainy days, the more precipitation, which also means the thicker clouds, thus increasing the reflectivity of light.

7. **The last bus time of public transportation**. The operation guarantee condition of ground public transportation is lighting, so the lighting will naturally increase during the traffic operation time. And also to some extent, the last subway train time is connected with the night-time living. The later the last bus is, the higher the night-time lighting level will be, so it belongs to the benefit data.

For the cost-attributed indicators, there are 2 indicators which are listed below.

1. **The average working hours in the region**. The earlier people leave work, the earlier the end of the evening commute. So the demand for high-beam lights will become less, and the demand for night lighting time will become less, so it will affect the level of night-time lighting.

2. **Limit magnitude**. Limit magnitude refers to the darkest magnitude that can be observed through a telescope. The higher the limit magnitude that can be seen, the lower the brightness on the ground, that is equal to lower level of illumination at night, so it belongs to the cost data.

4.2 Data Collection

We got our data from these websites listed below:

Table 2: Data Sources

Data	Source
Population density	Census.gov [5]
Power consumption	U.S. Energy Information Administration (EIA) [6]
GDP per capita	Bureau of Economic Analysis (BEA)[7]
Regional industrial structure	Bureau of Economic Analysis (BEA)[7]
Average working hours in the region	Business.org [8]
The last bus time of public transportion	Google Map [9]
Nightlife index	Google Trends [10]
Limit magnitude	DarkMap [11]
Average Annual Precipitation	CurrentResults.com [12]

4.3 The Optmized Entropy Weight Method (EWM)

We use the Entropy Weight Method (EWM) to get the weight of indicators. The Entropy Weight Method is an object weighting method, which uses the information entropy idea for reference. It is used to determine the relative weights of different criteria in a decision-making process. It determines the weight of the indicators by calculating the information entropy of the index, according to the impact of the relative change of the index on the overall system.

In other words, the weight of each indicator is given according to the difference degree of the indicator value, and the corresponding weight of each indicator is obtained. The indicator with relatively large change degree has larger weight.

The greater the entropy, the more chaotic the system is, the less information it carries and the less weight it has. Otherwise, the higher the entropy, the more orderly the system is, the more information it carries, and the greater the weight is.

The first step of the Entropy Weight Method is the standardization of measured values. The standardized value of the jth index in the ith sample is denoted as p_{ij}, and its calculation method is as follows:

$$p_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}, i = 1, 2 \cdots , , 9, j = 1, 2, \cdots , 9$$

Secondly, in the EWM, the entropy value e_i of the jth index is defined as:

$$e_j = -\frac{1}{ln(9)} \sum_{i=1}^{n} p_{ij} ln(p_{ij}), j = 1, 2, \cdots , 9$$

The range of entropy value e_j is [0, 1]. The larger the e_j is, the greater the differentiation degree of index j is, and more information can be derived. Hence, higher weight should be given to the index.

Therefore, in the traditional EWM, the calculation method of weight is:

$$w_j = \frac{1 - e_j}{\sum_{j=1}^{m} e_j}, j = 1, 2, \cdots, 9$$

It can be seen from the above equation that when $e_j \rightarrow 1$,the difference in the entropy value of different evaluation indexes is small, but the difference in the entropy weight is large. Therefore, we use the following equation to calculate entropy weight instead of traditional equation.

$$w_j^{'} = \frac{1 + e_j + \sum_{k=1}^{n} e_k}{\sum_{l=1}^{n}(1 - 2e_l + \sum_{k=1}^{n} e_k)}$$

In the above method, the different entropy weights for different indicators (e.g. p and q)become

$$\Delta w = 2\Delta e/C$$

where

$$\Delta e = e_p - e_q, C = \sum_{l=1}^{n}(1 - 2e_l + \sum_{k=1}^{n} e_k)$$

It indicates that the entropy value changes slightly, and its corresponding entropy weight also changes slightly. For the factor with equivalent useful information, the weight information is consistent with the corresponding entropy level.

Table 3: Weights of the Indicators Calculated from optimized EWM method

Indicators	Weights
All industry total	0.12709
All tertiary industry percentage	0.12376
Population Density	0.12742
Limiting Magnitude	0.12390
Last Bus Time	0.12436
Power Consumption per Capita per Month	0.12378
Annual Precipitation(in millimetre)	0.12411
Work hours per Week	0.12581
Nightlife index	0.12402

4.4 The TOPSIS Method

The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is a multi-criteria decision-making method that is used to determine the best option from a set of alternatives based on multiple criteria.

First of all, we use Min-Max normalization to process the data.

For the benefit-attributed data,

$$b_{ij} = \frac{a_{ij} - a_j^{min}}{a_j^{max} - a_j^{min}}$$

And for the cost-attributed data,

$$b_{ij} = \frac{a_j^{max} - a_{ij}}{a_j^{max} - a_j^{min}}$$

All these data form the normalized matrix B. We then multiply each value in a column with the corresponding weight given, and get weighted-normalised decision matrix, which

$$C = W * B$$

Secondly, calculating the positive ideal solution C^* and the negative ideal solution C_0, which

$$C^* = [b_1^{max}, b_2^{max}, \cdots, b_8^{max}]$$
$$C_0 = [b_1^{min}, b_2^{min}, \cdots, b_8^{min}]$$

Now we need to calculate Euclidean distance s_i^0 for elements in all rows from the positive ideal solution and the negative ideal solution.

$$s_i^0 = \sqrt{\sum_{i=1}^{3}(b_{ij} - C_i^*)^2}, j = 1, 2 \cdots, 9$$

Here, s_i^* is the best distance calculated on the i-th row, where b_{ij} is element value and C_i^* is the ideal best for that column. Similarly, we can find s_i^0, which is the worst distance calculated on the i-th row.

Finally, calculate the TOPSIS Score and Ranking. For $C_i, i = 1, 2, \cdots, 9$, solve s_i^*, the distance to the positive ideal solution C^*, and s_i^0, the distance to the negative ideal solution C_0

Now that we have s_i^* and s_i^0. Then calculate the Topsis score for each row, and get the final score and ranking.

$$f_i = \frac{s_i^0}{s_i^* + s_i^0}$$

4.5 Application of the Model on the Four Locations

4.5.1 A Protected Land Location: Wyoming

For a protected land location, we choose Wyoming. Wyoming is a state in the Mountain West subregion of the Western United States. Almost half of the land in Wyoming is owned by the federal government, generally protected for public uses.

Wyoming is the least populous state despite being the 10th largest by area, with the second-lowest population density after Alaska. And it's population density is 5.9 men per km^2. Since the sparse population, it's GDP is only 41510.2 million dollars per year. Without much demand for transportation, it's local bus deadline is 5 p.m., which largely reduce it's demand for road illumination. The nightlife index is only 37, which reason is closely related to the indicators above. This may account for the low power consumption, which is only 128.9 kWh.

Today, Wyoming's economy is largely based on tourism. So its tertiary industry percentage of GDP is similar to New York, which is one of the most prosperous city in the world. And the detailed data for tertiary industry percentage of GDP is 0.247. To support it's tourism, people should work for more hours, so we can see it's working hour is 40.3 hours per week.

Due to it's geographical position, it's annual precipitation is 390 millimeters. And with its vast land, the limiting magnitude in Wyoming is 8.3, which means you can see several faint planet.

According to the indicators we mentioned before, it's night-light intensity score in our model is 0.18786, which ranks the lowest in our selected locations. This shows that our model's application for protected location is in line with the reality.

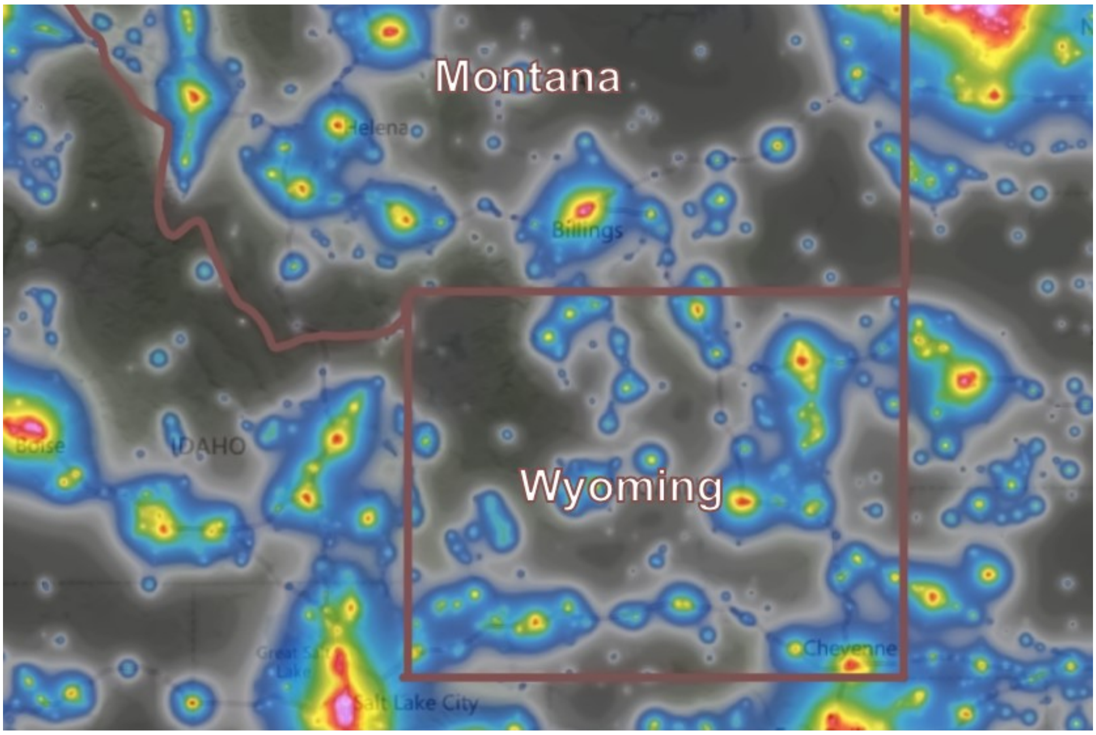

Figure 3: Night-time Light Intensity of Wyoming

4.5.2 A Rural Community: Nevada

For a rural community, we choose Nevada. Nevada is the 7th-most extensive, the 32nd-most populous, and the 9th-least densely populated of the US states. Its population density is 28.3 men per km^2. And its working hour belongs to the average level in US.

As we all know, Las Vegas is located in Nevada. This may account for its night-life index of up to 70.Nevada's power consumption is 362.8 kWh per month, far more than protected locations, but similar to other locations.

Legalized gambling and lenient marriage and divorce laws transformed Nevada into a major tourist destination in the 20th century, which promote local economy. Its GDP is 194486.6 per year and its tertiary industry percentage of GDP is 0.284. The early deadline of bus is mainly because of tourism. Its local bus deadline is 3 p.m.

Nevada is the driest state, and its annual precipitation is 241 millimeters. Its limiting magnitude is 8.3, which means you can rarely see faint planet.

According to the indicators we mentioned before, its night-light intensity score in our model is 0.38081, which ranks above all the protected locations in our selected locations, but below all the more prosperous states. This shows that our model's application for rural community is in line with the reality.

4.5.3 A Suburban Community: California

Although California is full of modern metropolises such as Los Angeles and San Fransisco, we categorize it as a suburban community, since most area of California is not cities but suburban areas and hilly areas.

California is the third-largest state by area, and more than this, it also has a high population density of 253.7 men per km^2, resulting in the most populated state in the U.S.

Due to its huge population, the economy of California is no doubt the largest in the United States. Its GDP is 3373240.7 per year, far more than any other state, and it's night-life index is 65. It's working hour is 38.3 hours per week, similar to other states.

Sacramento is the state's capital, while Los Angeles is the most populous city in the state and the second most populous city in the country. So it has the highest power consumption among suburban communities, which values 394.2. And it also has the latest deadline of local bus, which is 11:30 p.m.

California has a Mediterranean climate, depending on latitude, elevation, and proximity to the Pacific Coast. Its terrain varies widely from hot desert to alpine tundra. The average annual precipitation is 563 millimeters. And its limiting magnitude is 6, which means it's hard for you to see the stars by eyes.

According to the indicators we mentioned before, its night-light intensity score in our model is 0.59146, highest in the suburban locations, but lower than Massachusetts and New York. It clearly reflects the high density of the suburban regions of California, and the result is in line with the reality.

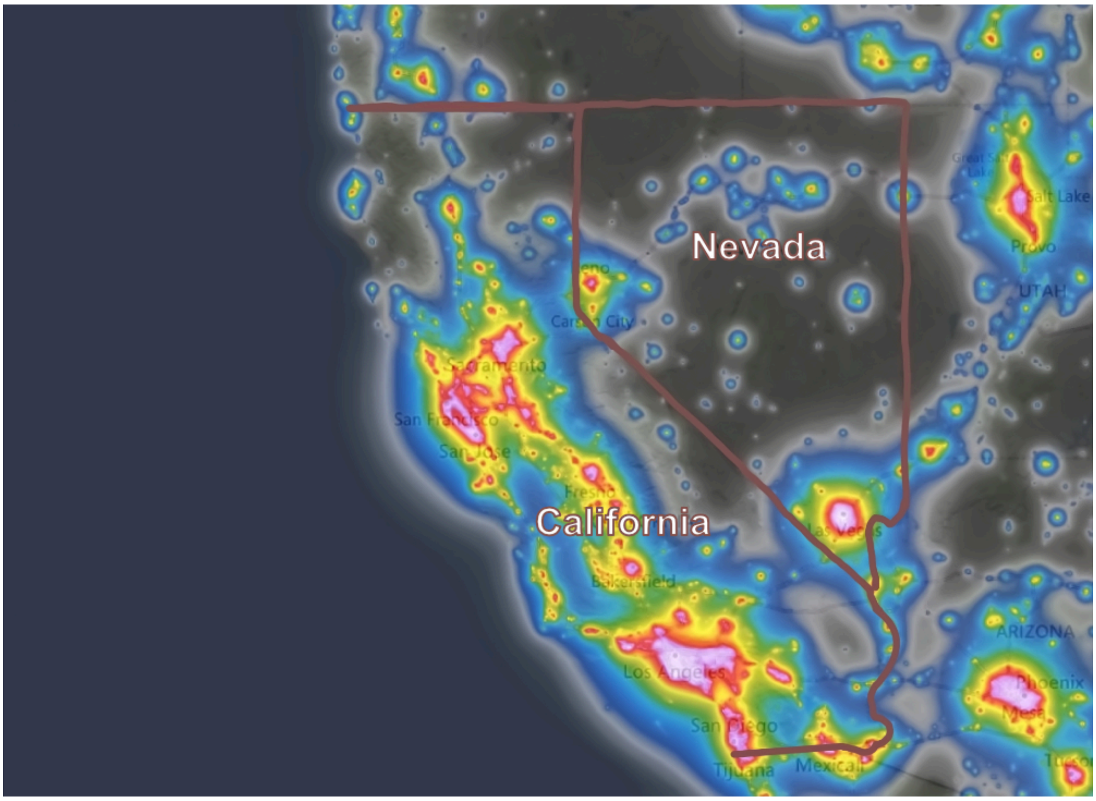

Figure 4: Night-time Light Intensity of California and Nevada

4.5.4 An Urban Community: New York

New York State is a highly developed state with a world famous international metropolis, New York. State of New York was one of the original Thirteen Colonies forming the United States. With a total area of 54,556 square miles (141,300 km^2), New York is the 27th-largest U.S. state by area. But also, it is the fourth-most-populous state in the United States as of 2021, with 20.2 million people.

Due to its great importance in USA's and international economy, it's GDP is 1901296.5 million dollars per year. And in serving its highly developed service industry, it's local bus deadline is 1 a.m, and the nightlife index is 83, ranks the top of the chosen locations. And this leads to a huge power consumption, which is 412.8 kWh.

Since New York is famous for its economy, its tertiary industry percentage is the highest among the chosen locations. And it seems that people in New York States enjoys their life, as their average working hour is 38.4 hours per week.

New York State has a temperate continental humid climate, with an annual precipitation 1062 millimeters. And with its well-explored land, the limiting magnitude in New York State is 4, which means you can seldom see faint planets.

According to the model, New York State night-light intensity score is 0.69031, which ranks the highest in all, in line with the reality.

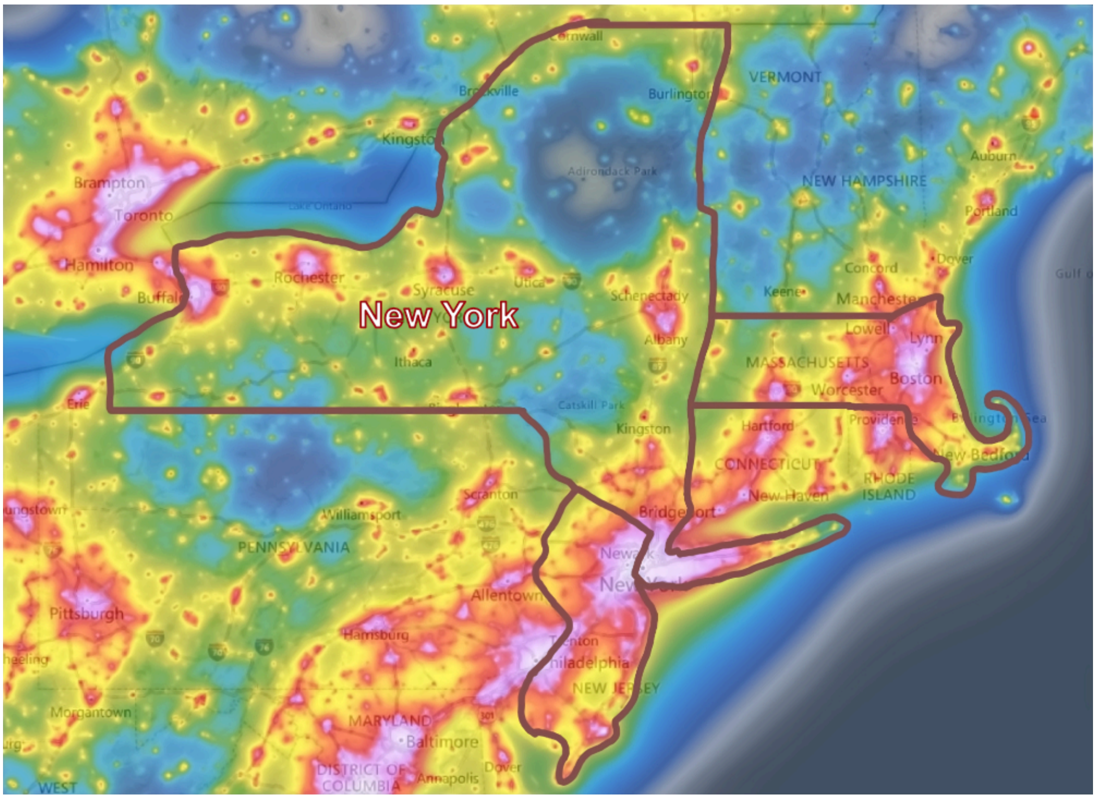

Figure 5: Night-time Light Intensity of New York State

4.5.5 Result of the TOPSIS Score and Ranking

Table 4: Result of the TOPSIS Score and Ranking

Types of Locations	States	Score	Ranking
Urban Communities	New York	0.69031	1
	Massachusetts	0.60754	2
	New Jersey	0.59492	3
Suburban Communities	California	0.59146	4
	Pennsylvania	0.48859	5
	Washington	0.40662	6
Rural Communities	Missouri	0.40527	7
	Nevada	0.38081	8
	Mississippi	0.36775	9
Protected Land Locations	Montana	0.34936	10
	Alaska	0.21363	11
	Wyoming	0.18786	12

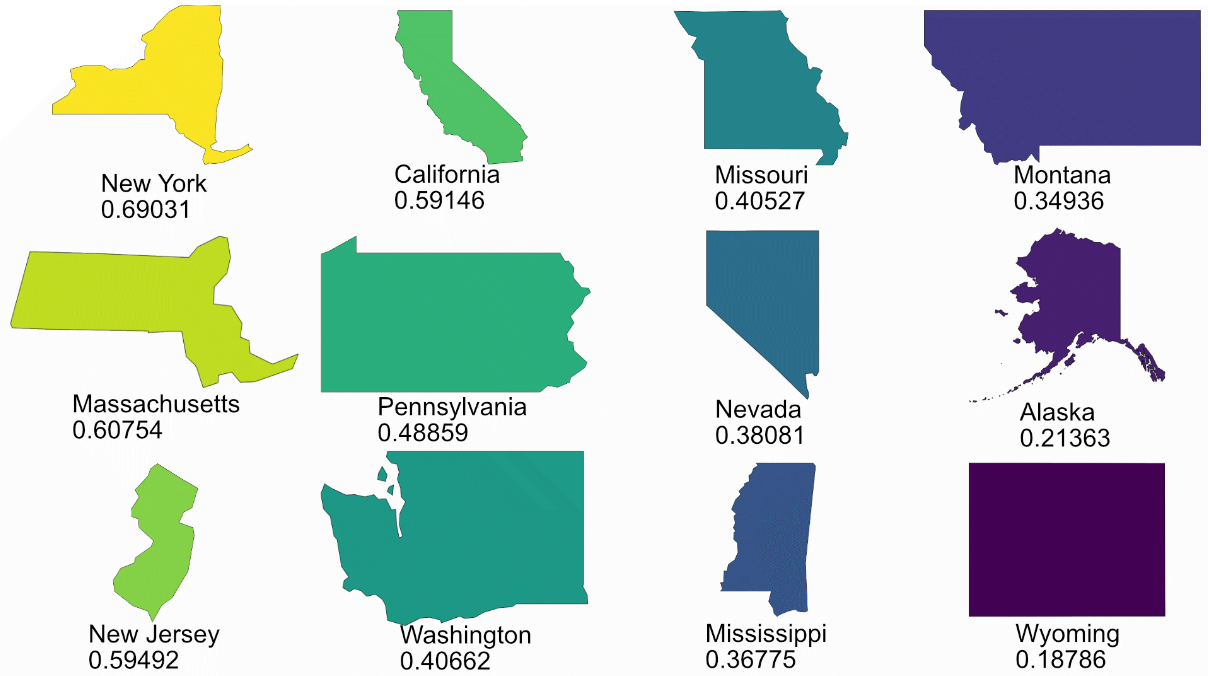

Figure 6: Result of the TOPSIS Score and Ranking

5 Strategy Making and Implementation

5.1 Strategies for Addressing Light Pollution

According to the problem 3, to address light pollution, we designed three possible intervention startegies as follows.

5.1.1 Lighting Design and Technology

Lighting design and technology play a crucial role in reducing light pollution. Poor lighting design and the use of outdated lighting products can result in excessive glare, sky glow, and light trespass, which can disrupt ecosystems and interfere with human sleep cycles. Our goal is to promote research and development of new lighting technologies that are designed to minimize light pollution while still meeting lighting needs. Here are some actions that can be taken into account.

- **Develop and implement smart lighting technologies that reduce light pollution and save energy.**
  - **Install sensors that adjust lighting levels based on natural lighting conditions, such as sunlight and moonlight.**
  - **Install motion sensors and timers to reduce the amount of unnecessary outdoor lighting.**
  - **Develop and deploy smart city technologies that optimize lighting efficiency and minimize light pollution in public spaces.**

- **Use directional lighting that illuminates only the areas that need to be lit, rather than casting light in all directions.**

  Directional lighting can also be used in landscape lighting to highlight specific features, such as trees or statues, while minimizing light pollution and unwanted glare. This creates a more visually appealing and sustainable lighting solution for outdoor spaces.

  – **Use lighting fixtures that direct light downward, reducing sky glow and light trespass.**
  – **Use shielding to direct light only where it is needed.**

- **Avoid blue-rich white light sources at night.**

These actions not only help protect the environment, but also save energy and reduce the cost of outdoor lighting.

We hope these regulations and policies can make influence to these indicators:

- **Power Consumption per Capita per Month**
- **All tertiary industry percentage**

5.1.2 Government Regulations and Policies

Government regulations and policies can help reduce light pollution in a more compulsory way, and lead a environment-friendly social trend. Among the policies listed below, the dark-sky-areas-related plans take a big part, and also are easier and better for government to realize the idea to some extent.

- **Establish lighting standards that require businesses and homeowners to use lighting fixtures that minimize light pollution.**
- **Develop and enforce outdoor lighting regulations that reduce glare, sky glow, and light trespass.**
- **Encourage the use of energy-efficient lighting through tax credits and rebates.**
- **Establish and designate dark-sky areas that are free of artificial light pollution.**

  Dark-sky areas are becomming less and less because of human expansion. The dark-sky-area plan can be regarded as one of the most practical and considerable plans in consideration of human development and urbanization.

  There are many actions can be taken for the dark-sky area plan. For example,

  – **Implement and enforce regulations that prohibit outdoor lighting in designated dark-sky areas.**
  – **Encourage the use of low-intensity lighting in dark-sky areas to minimize light pollution while still providing visibility.**

  - **Work with community leaders, landowners, local organizations,and stakeholders to establish dark-sky areas and develop sustainable tourism opportunities around them.**

We hope these regulations and policies can make influence to these indicators:

- **Limiting Magnitude**
- **Population Density**
- **Work Hours per Week**

5.1.3 Promoting Responsible Lighting Practices

Promoting responsible lighting practices raises awareness about the negative impacts of excessive lighting and encourages individuals and organizations to take action and develop awarenesses of sustainable action series. Through these actions, we hope it can help create more sustainable and livable communities for all.

- **Implement lighting ordinances and regulations for outdoor lighting to reduce unnecessary and excessive lighting.**
- **Promote the use of energy-efficient lighting technologies such as LED lights that reduce energy consumption and light pollution.**
- **Encourage homeowners and businesses to turn off non-essential lighting during late-night hours to reduce light pollution.**
- **Propagandize and educate the public on responsible lighting practices and the negative impacts of light pollution, and develop awarenesses of action.**

We hope these regulations and policies can make influence to these indicators:

- **Last Bus Time**
- **Nightlife index**
- **Work Hours per Week**

5.2 Tailored Strategy Implementation

5.2.1 California: Govern

5.2.2 New York: Tech and Prac

6 Sensitivity Analysis

We chose California to test the sensitivity of our model. We selected two indicators, regional industrial structure and limit magnitude, which are cost-based and benefit-based, to test the sensitivity of our model.

1. Regional industrial structure

California's regional industrial structure is 0.2229. We have studied the change of California's light-light intensity when the regional industrial structure changes from 0.20 to 0.25. From the ***chart***, we can see that the night-light intensity of California is 0.52997 at this time. When the regional industrial structure changes to 0.20, the night-light intensity decreases to whatwhatwhatwhat, and the relative change rate is. The relative change rate from 0.2229 to 0.20 is whatwhatwhatwhat, and the ratio of the two relative change rates is. When the regional industrial structure changes to 0.25, the night-light intensity increases to whatwhatwhatwhat, and the relative change rate is whatwhatwhatwhat. The relative change rate from 0.2229 to 0.20 is whatwhatwhatwhat, and the ratio of the two relative change rates is whatwhatwhatwhat. Therefore, we can see that our model will not deviate greatly due to the deviation of the regional industrial structure.

2. Limit magnitude

California's limit magnitude is 6. We have studied the change of California's light-light intensity when the limit magnitude changes from 5 to 7. From the chart, we can see that the night-light intensity of California is 0.52997 at this time. When the limit magnitude changes to 5, the night-light intensity decreases to whatwhatwhatwhat, and the relative change rate is whatwhatwhatwhat. The relative change rate from 0.2229 to 5 is whatwhatwhatwhat, and the ratio of the two relative change rates is whatwhatwhatwhat. When the limit magnitude changes to 7, the night-light intensity increases to whatwhatwhatwhat, and the relative change rate is whatwhatwhatwhat. The relative change rate from 0.2229 to 7 is whatwhatwhatwhat, and the ratio of the two relative change rates is whatwhatwhatwhat. Therefore, we can see that our model will not have a large deviation due to the deviation of Limit Magnitude.

7 Strengths and Weaknesses

7.1 Strengths

- The selection of evaluation indicators is scientific and comprehensive. We get the data from The U.S. Bureau of Economic Analysis and other scientific databases. We also make necessary modifications to better address our purpose, including involving the education context and adjust specific indicators.
- It's convenient for governor to propose strategy based on our model. Since our indicators are specific and operational, governors can propose targeted strategies.
- We used improved EWM to calculate the weight instead of traditional EWM, which overcomes shortcoming of unrealistic weights.
- Comprehensive application of multiple methods. We use relatively objective methods - EWM to identify the weights of the multiple indicators. Then, we use TOPSIS to calculate night-light intensity of each location. The combination of multiple methods has constructed a scientific evaluation system.

- The evaluation model is robust. We did a sensitivity analysis on the night-light intensity. We made several indicators fluctuate in a small range and found that the list of locations' night-light intensity did not change significantly, indicating that our evaluation model has high stability. Weaknesses:

7.2 Weaknessess

- The model does not consider differences between light colors. Based on several researches of light pollution, specific use of light color can reduce light pollution in some extend.
- We didn't get the specific data of how much consumption is on lighting, so we use another index to instead. But the indicator of Power Consumption per Capita per Month just reflects residents' usage on lighting in some extend.

8 Conclusion

9 Flyer

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