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TOPSIS-based Evaluation and Recommendations for Global Resistance to the Epidemic

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Abstract

In order to comprehensively reflect the level of social resistance to the epidemic and the sustainability of social development, five sub-evaluation dimensions were selected for the model, namely, the ability to rescue and treat, the ability to prevent, the difficulty factor, the level of economic development and the epidemic control cycle. In order to quantify the qualitative dimensions, we introduced 10 indicators that can be measured quantitatively, such as mortality rate and prevalence rate, whose values can be determined according to the calculation formula. The evaluation values of each dimension were then calculated from the bottom up, using the TOPSIS method. The values for each dimension are combined to obtain an overall evaluation score. The total score represents the level of resistance to the epidemic in each country, with each country having a corresponding total score. The global ranking of countries in terms of resistance to the epidemic is obtained from the total score.

Keywords

TOPSIS; New Coronary Pneumonia; Global Anti-epidemic Ranking; Vaccination Recommendations.

1. Background

According to the latest data released by the World Health Organisation, by 13 August 2021, the cumulative number of confirmed cases of new coronas worldwide reached 205,338,159, and the global epidemic control situation is moving towards normalisation. At the same time, the development of the epidemic has been further polarised by the different policies of individual countries. In this context, the level of social resistance to the epidemic and the sustainability of social development have become the main directions for evaluating the epidemic. We will use this as a basis for establishing a comprehensive evaluation system to rank the level of resistance to the epidemic in countries around the world and to make recommendations to the relevant national authorities.

2. Analysis of the Problem

For the issue of global ranking of new crown resistance, we need to first develop a set of criteria for evaluating the level of resistance to the epidemic, also known as the evaluation category issue. There are two main aspects to consider when evaluating, namely the level of social resistance to the epidemic and the sustainability of social development. So the problem can be solved in two steps.

1. scoring the level of social resistance to the epidemic and the sustainability of social development separately.

2. Combining the above two scores to obtain an overall score.

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And to complete the first step, for the abstract concept, it is important to analyse which aspects it contains and what are the main influencing factors. Continuously decompose and grade the concept, and finally implement it into concrete indicators to facilitate quantitative evaluation.

3. Model Building and Solving

According to the question, the main criteria for evaluating the level of national resistance to the epidemic are: the level of social resistance to the epidemic and the sustainability of social development. Therefore, the model should include two evaluation dimensions: the level of social resistance to the epidemic and the sustainability of social development. Each evaluation dimension includes one to three sub-evaluation dimensions as the main influencing factors to be measured. In total, the model includes five sub-evaluation dimensions, namely the ability to rescue and treat, the ability to prevent, the difficulty factor, the level of economic development and the epidemic control cycle. The evaluation dimensions and their sub-evaluation dimensions will be referred to as "dimensions" in the following sections.

The bottom-level indicators are data that can be found directly on the web and other sources, while the next-bottom-level indicators can be calculated from the formula at the bottom. After determining the value of each indicator, the evaluation value of each dimension is calculated from the bottom up using the TOPSIS method in turn. The total score represents the level of resistance to the epidemic in each country, and each country has a corresponding total score, based on which the final ranking of resistance to the epidemic is made.

3.1. Calculation and Description of Indicators

3.1.1. Mortality (M)

$$\text{Mortality}(M) = \frac{\text{Cumulative number of deaths}}{\text{Cumulative number of confirmed cases}} \tag{1}$$

Mortality rate indicates the mortality rate of newly crowned pneumonia patients in the country.

3.1.2. Prevalence(P)

$$\text{Prevalence(P)} = \frac{\text{Cumulative number of confirmed cases}}{\text{Total population}} \tag{2}$$

The prevalence rate indicates the prevalence of new coronary pneumonia among the population in the country.

3.1.3. New Prevalence(NP)

$$\text{New prevalence(NP)} = \frac{\text{Number of new confirmed cases}}{\text{Total population}} \tag{3}$$

The new prevalence rate represents the recent prevention effect in the country. Since the number of existing diagnoses is small compared to the total population, the number of existing diagnoses is the sum of the number of new diagnoses in the country on a single day in the last month, and the new prevalence rate can be considered as the prevalence rate of the healthy population in the country in the last month, which can indicate the recent prevention effect in the country.

3.1.4. Vaccination Status(V)

$$\text{Vaccination status(V)} = \frac{\text{Number of people vaccinated}}{\text{Total population}} \tag{4}$$

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The vaccination status indicates the vaccination status of the new crown pneumonia vaccine in the country. At a given total population of the society, the more people are effectively vaccinated, the stronger the preventive effect.

3.1.5. Level of Openness (O)

The level of openness indicates the level of domestic openness to the outside world, as measured by the number of arrivals in 2019.

3.1.6. Population Density (PD)

$$\text{Populationdensity}(PD) = \frac{\text{Total population}}{\text{Land area}} \tag{5}$$

Population density indicates the average population density in the country.

3.1.7. Level of Medical GDP 2019 Care (MC)

The level of medical care indicates the level of comprehensive medical care in the country, measured by HAQ (Access and Quality of Health Care), which takes into account the lethality of 32 diseases that do not kill under effective treatment and indicates the comprehensive medical care in the country.

3.1.8. Impact Resistance (IR)

$$\begin{aligned}\text{Impact resistanceIR} &= \text{GDP growth rate in 2020} \\ &= \frac{\text{GDP 2020} - \text{GDP 2019}}{\text{GDP 2019}}\end{aligned} \tag{6}$$

Resilience to shocks indicates the ability of the domestic economy to withstand epidemic shocks; in 2019 the world is not yet affected by the epidemic, in 2020 the epidemic spreads globally and the global economy is hit by the epidemic, therefore the GDP growth rate in 2020 can be used to reflect the resilience of the domestic economy to epidemic shocks.

3.1.9. Resilience (R)

$$\begin{aligned}\text{Resilience(R)} &= \text{GDP growth forecast for 2021} \\ &= \frac{\text{Expected GDP in 2021} - \text{GDP in 2020}}{\text{GDP 2020}}\end{aligned} \tag{7}$$

In 2020, when the epidemic spreads globally and the global economy is hit by the epidemic, and in 2021 countries take measures to balance epidemic prevention and economic development, GDP growth in 2021 can be used to reflect the ability of the domestic economy to recover from the impact of the epidemic.

The outbreak control cycle refers to the duration from the beginning to the end of the first outbreak in the country, with the threshold α and β as the beginning and end respectively. The outbreak control cycle is considered to have started when the number of new confirmed cases in a single day in the country exceeds the threshold α. The outbreak control cycle is considered to have ended when the number of new confirmed cases in a single day in the country falls below the threshold β for t consecutive days.

3.2. Description of the Evaluation Dimensions

The model includes two evaluation dimensions: the level of social resistance to the epidemic and the sustainability of social development. The level of social resistance to the epidemic includes the ability to rescue and treat, the ability to prevent and the difficulty factor, with three sub-dimensions. The sustainability of social development includes the level of economic development and the epidemic control cycle, with two sub-dimensions in total.

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3.2.1. Level of Social Resistance to the Epidemic

Treatment and prevention are two important aspects of epidemic response. The capacity for treatment reflects the ability to save the lives and health of patients after an outbreak, while the capacity for prevention reflects the ability to protect the lives and health of people who are not sick before an outbreak.

Different countries have different contexts, including geography, population, infrastructure and policy development. We want to reflect the differences in the difficulty of fighting the epidemic in different countries due to their different circumstances, so that the evaluation of this dimension can more fairly reflect the true level of social resistance to the epidemic. For example, if country A, which has a high level of resistance to the epidemic, can achieve the same level of resistance as country B, which has a low level of resistance, then we consider country A to have a better level of social resistance to the epidemic than country B.

3.2.2. Socially Sustainable Development

The epidemic is not only a threat to human life and health, it is also a deterrent to economic development. If economic production remains stagnant for a long time, society will not be able to develop sustainably. We use the level of economic development to measure this aspect.

If there is an epidemic in the country, but the government is always able to take effective measures to contain it, then the country's sustainable social development is not affected much by the epidemic and it can be said that the country has somehow adapted to the unexpected epidemic. We use the epidemic control cycle to measure this aspect.

3.2.3. Treatment Capacity

The ability to save the lives of patients after an outbreak, and therefore can be directly expressed in terms of the mortality rate M.

3.2.4. Prevention Capacity

Prevention capacity is the ability to protect the health of people who are not sick before an outbreak, and consists of three indicators: prevalence P, new prevalence NP and vaccination status V.

Prevalence P is cumulative and reflects the country's past capacity for prevention; new prevalence NP is new and reflects the country's capacity for prevention in the recent past; and vaccination V reflects the country's capacity for prevention now and in the future. It is therefore important to combine these three indicators in order to evaluate the country's prevention capacity in a comprehensive manner.

3.2.5. Difficulty Factor

The Difficulty Factor hopes to reflect the differences in the difficulty of fighting the epidemic in different countries due to different national conditions. There are three main indicators: level of openness of the country, population density and level of medical care, which correspond to three factors: policy development, geographical population and infrastructure, respectively.

In the context of a global pandemic, stopping the movement of people is what facilitates epidemic prevention; opening up to the outside world increases the difficulty and uncertainty of epidemic prevention; countries with higher population density make it easier for people to come into close contact, thus increasing the difficulty of epidemic prevention; countries with low levels of medical care make both prevention and treatment more difficult. It is therefore important to combine these three indicators in order to fully evaluate a country's difficulty factor in combating the epidemic.

3.2.6. Level of Economic Development

In order to comprehensively consider the impact of the epidemic on economic development and measure the level of economic development of the country under the impact of the

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epidemic, we have divided the level of economic development into two components: the shock resistance IR and the recovery capacity R.

Resilience IR indicates the domestic economy's ability to withstand the shock of the epidemic, which can be measured by the GDP growth rate in 2020; and Resilience R indicates the domestic economy's ability to recover from the shock of the epidemic, which can be measured by the expected GDP growth in 2021. It is therefore important to combine these two indicators in order to fully evaluate the country's level of economic development under the impact of the epidemic.

3.2.7. Epidemic Prevention and Control Cycle

The epidemic prevention and control cycle reflects a country's resilience to sudden outbreaks of epidemics. In the context of a global epidemic that cannot be eliminated in a short time, only countries that adapt to epidemics and normalise epidemic prevention and control will be able to develop sustainably.

3.3. Calculation of the Evaluation Value of the Dimensions

3.3.1. Background of Topsis Model

TOPSIS, or the distance between superior and inferior solutions, is a common comprehensive evaluation method that makes full use of the information in the original data, and its results can accurately reflect the gap between the evaluation solutions. The distance between each evaluation object and the optimal solution and the worst solution is then calculated separately to obtain the relative proximity of each evaluation object to the optimal solution. This method does not impose strict restrictions on data distribution and sample content, and the data calculation is simple and easy. Here we use TOPSIS to calculate the evaluation value of the dimensions.

3.3.2. TOPSIS Algorithm Steps

From 5.2 all the required indicators can be calculated as inputs to the algorithm; the output is the evaluation value of each country on a dimension. With countries as rows, let the total number of countries be n; with indicators as columns, let the evaluation of that dimension contain m indicators and construct the original matrix X0.

Step1: Firstly, we normalise the original matrix X0, i.e. all the indicator types are uniformly transformed into very large indicators, and the formula for normalisation is as follows:

$$x_{ij} = \max_{1 \le i \le n} |x_{0ij}| - x_{0ij} \tag{8}$$

where,$x_{0ij}(i = 1 \sim n,\ j = 1 \sim m)$ denotes the elements of the i-th row and j-th column of the original matrix X0， $x_{ij}(i = 1 \sim n,\ j = 1 \sim m)$ denotes the elements of the i-th row and j-th column of the normalized matrix X.

The n-row and m-column normalized matrix X is obtained as follows:

$$\mathrm{X} = \begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1j} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2j} & \cdots & x_{2m} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{i1} & x_{i2} & \cdots & x_{ij} & \cdots & x_{im} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nj} & \cdots & x_{nm} \end{pmatrix} \tag{9}$$

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Where, $x_{ij}(i = 1\sim n,\ j = 1\sim m)$ denotes the positive value of the jth indicator for the ith country.

Step2: In order to eliminate the influence of different indicator magnitudes on the evaluation results, we standardize the data of matrix X. The standardization formula is as follows.

$$z_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} {x_{ij}}^2}} \tag{10}$$

A normalized matrix Z with n rows and m columns is obtained:

$$\mathrm{Z} = \begin{pmatrix} z_{11} & z_{12} & \cdots & z_{1j} & \cdots & z_{1m} \\ z_{21} & z_{22} & \cdots & z_{2j} & \cdots & z_{2m} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ z_{i1} & z_{i2} & \cdots & z_{ij} & \cdots & z_{im} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ z_{n1} & z_{n2} & \cdots & z_{nj} & \cdots & z_{nm} \end{pmatrix} \tag{11}$$

Where, $z_{ij}(i = 1\sim n,\ j = 1\sim m)$ denotes the standardised value of the jth indicator for the i-th country.

Step3: Define the optimal indicator vector $\boldsymbol{Z}^{+}$and the inferior indicator vector $\boldsymbol{Z}^{-}$， indicating the optimal and inferiority of each indicator, calculated as follows:

$$z_j{}^{+} = \max_{1\le i\le n} |z_{ij}| \tag{12}$$

$$z_j{}^{-} = \min_{1\le i\le m} |z_{ij}| \tag{13}$$

Obtain the m-dimensional vectors Z^{+} and Z^{-}.

Obtain an m-dimensional vector sum:

$$Z^{+} = (z_1{}^{+} \quad z_2{}^{+} \quad \cdots \quad z_j{}^{+} \quad \cdots \quad z_m{}^{+}) \tag{14}$$

$$Z^{-} = (z_1{}^{-} \quad z_2{}^{-} \quad \cdots \quad z_j{}^{-} \quad \cdots \quad z_m{}^{-}) \tag{15}$$

Where, $z_j{}^{+}(\ j = 1\sim m)$ denotes the optimal value of the jth indicator for all countries. $z_j{}^{-}(\ j = 1\sim m)$ denotes the worst value of indicator j for all countries.

Step4: Define the optimal distance $D_i{}^{+}$, which represents the distance between each indicator of the ith country and the optimal indicator vector Z^{+},and the inferior distance $D_i{}^{-}$, which represents the distance between each indicator of the ith country and the optimal indicator vector Z^{+}. Using the Euclidean distance, the formula is as follows:

$$D_i{}^{+} = \sqrt{\sum_{j=1}^{m} \left(z_j{}^{+} - z_{ij}\right)^2} \tag{16}$$

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$$D_i^- = \sqrt{\sum_{j=1}^{m} \left(z_j^- - z_{ij}\right)^2} \tag{17}$$

Step5: Define the closeness of the indicator of the ith country to the optimal indicator, S_i as the evaluation value of the ith country in this dimension. The calculation formula is as follows.

$$S_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{18}$$

3.4. Solving the Model

The evaluation value of each dimension can be found from 2.4. Let the total score of each country i be Fi and the evaluation value of its kth dimension be Sik, with a total of m dimensions. In order to combine the impact of each dimension, we need to determine the weight of each dimension wik and finally weight the sum to get the total score. The calculation formula is as follows:

$$F_i = \sum_{k=1}^{m} w_{ik} S_{ik} \tag{19}$$

The importance of each dimension is as follows:

Overall, the level of social resistance to epidemics is slightly greater than the sustainability of social development, because life and health are the most important rights of human beings. But if we are to achieve sustainable epidemic resilience, social sustainability must not be neglected either. Therefore, on balance, the level of social resilience and the sustainability of social development have a weighting of 6:4.

The level of social resistance to the epidemic includes the capacity for treatment, the capacity for prevention and the difficulty factor, of which the capacity for treatment and the capacity for prevention concentrate the country's level of resistance to the epidemic and should account for the major part. Logically, if prevention capacity is high, there will be no large-scale outbreaks and no test of rescue capacity. Therefore, prevention is more important than treatment, and prevention should be the main focus of epidemic prevention efforts. Therefore, the weighting of prevention, treatment and difficulty factors is 3:2:1.

The sustainability of social development includes the level of economic development and the epidemic control cycle. The shortening of the epidemic control cycle ensures sustainable economic development, which in turn can support the country's standing epidemic prevention. So taken together, the level of economic development and the epidemic control cycle have a weighting of 1:1.

Taking the weights into equation 19 to solve for them gives the overall score for each country, with the top ten ranked from highest to lowest as follows:

Where the colour scale indicates that green indicates that the country is ranked highly in that dimension and red indicates that the country is ranked low in that dimension. The results of the overall ranking and the ratings for each indicator in each dimension are shown in the Appendix.

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Table 1. Country scores and rankings

Country	Prevention	Relief	Difficulty	Sustainability	Total Score
Singapore	0.0093	0.0062	0.0451	0.0058	0.1479
USA	0.0066	0.0058	0.0227	0.0059	0.0945
China	0.0067	0.0051	0.0225	0.0064	0.0944
Spain	0.0076	0.0058	0.0196	0.0053	0.0894
Italy	0.0079	0.0055	0.0151	0.0059	0.0827
Bahrain	0.0067	0.0061	0.0146	0.0056	0.0781
Mexico	0.0063	0.0042	0.0155	0.0059	0.0757
Poland	0.0066	0.0056	0.0142	0.0053	0.0754
Hungary	0.0073	0.0053	0.0120	0.0055	0.0728

4. Sensitivity Analysis of the Model

From Equation 19, the total score is linearly related to each dimension, and the total score is also linearly related to the weight of each dimension, i.e.

$$\Delta F_i = k_{ij}\Delta w_{ij} \tag{20}$$

$$\Delta F_i = k_{ij}\Delta S_{ij} \tag{21}$$

Where ΔFi denotes a small change in the total score for country i, Δwij denotes a small change in the weight of the jth dimension for country i, and ΔSij denotes a small change in the rating value of the jth dimension for country i.

Calculated for China as an example, so that the rating value of each dimension oscillates up and down by 5%, the following table is obtained:

Table 2. 5% increase in relevant indicators

	Prevention	Relief	Difficulty	Sustainability
Original data	0.0067	0.0051	0.0225	0.0064
5% reduction	0.0064	0.0048	0.0214	0.0061
Dimensional Difference	0.0003	0.0003	0.0011	0.0003
Total score difference	0.0001	0.0001	0.0001	0.0001
Ranking regression	0	0	0	0

Table 3. 5% decrease in relevant indicators

	Prevention	Relief	Difficulty	Sustainability
Original data	0.0067	0.0051	0.0225	0.0064
5% reduction	0.007	0.0054	0.0236	0.0067
Dimensional Difference	0.0003	0.0003	0.0011	0.0003
Total score difference	0.0001	0.0001	0.0001	0.0001
Ranking improvement	1	1	1	1

As can be seen from Tables 2 and 3, the total evaluation score remained relatively stable for small changes in each dimension.

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