Team Control Number

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Problem Chosen

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ShuWei Cup

COVID-19 epidemic control and economic recovery model

Summary

The COVID-19 crisis in 2020 has brought the world to a standstill with huge social, political and economic impacts. Through the establishment of mathematical models, we formulate reasonable COVID-19 prevention strategies to help to overcome the epidemic.

Task 1: In this problem, we take Wuhan City as an example. Firstly, the indicators are screened based on PCA. Then we normalize the relevant data, and use the information entropy and topiss methods to classify the epidemic degree of each district in the city to distribute the materials to ensure the basic life of residents.

Task 2: Due to the spread of COVID-19 has a great impact on tourism industry, tourism industry is chosen for analysis. Taking Shanghai Disneyland as an example, we established SEIR model to predict the spread of the epidemic and PD model to predict the change of passengers' demand under the epidemic situation. Then, according to improved SEIR and PD models, we put forward the planning and suggestions for Shanghai Disneyland under different epidemic levels.

Task 3: Under COVID-19, the government should weigh the interests of all parties and ensure the maximization of the interests of all parties. Therefore, we introduce the game theory model to solve the conflict of interests between the epidemic prevention experts and business operators, and provide a case for the government to formulate policies.

Task 4: Transportation industry belongs to capital intensive industry, while catering industry belongs to labor-intensive industry. Both are not conducive to the control of the epidemic situation. We regard the spread of virus in transportation and catering industry as the same type. Based on the principle of indoor virus droplet transmission mechanism, we established a dual objective programming model of epidemic spread with the goal of maximizing the industry revenue and minimizing the spread of the epidemic, so as to propose control strategies for the two industries.

Key word: Game theory model; Improved SEIR model; PD model; PCA; TOPSIS; Multi objective optimization

Content

1. Introduction

1.1 Background

Since the beginning of the 21st century, global problems have emerged, which include financial crisis, nuclear leakage pollution, malignant infectious diseases，cyber crime and even cyber war. Among them, the new coronavirus crisis in 2020 has brought the world to a standstill, causing huge social, political and economic impacts. It is a "perfect storm", containing a deadly and highly contagious virus, a global economic recession, and a weakening of global governance. At the same time, the cumulative number of confirmed cases and deaths in the United States, Italy and other countries are on the rise， as presented in Fig.1. The new coronavirus poses a great threat to people's lives and health.

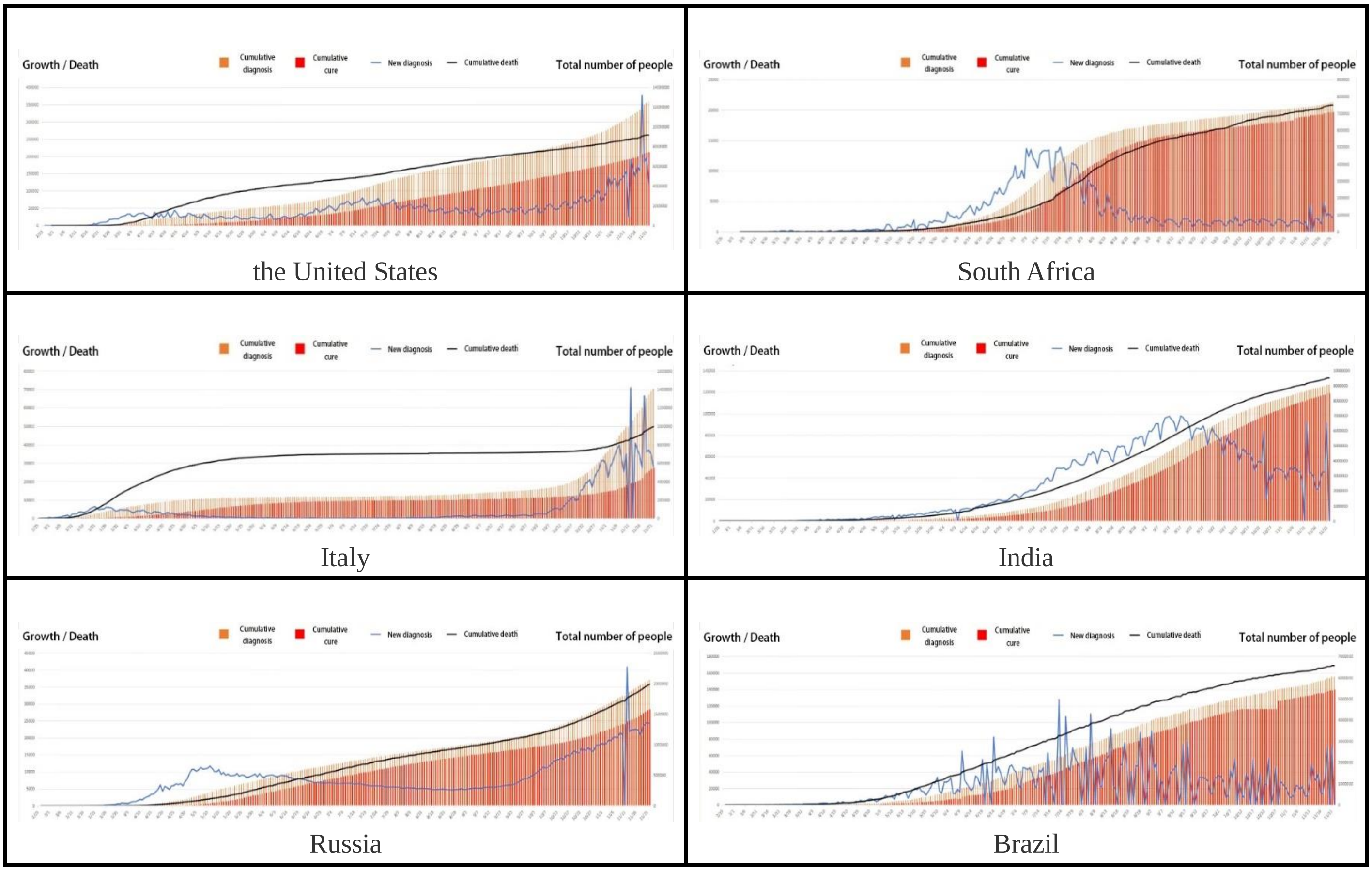
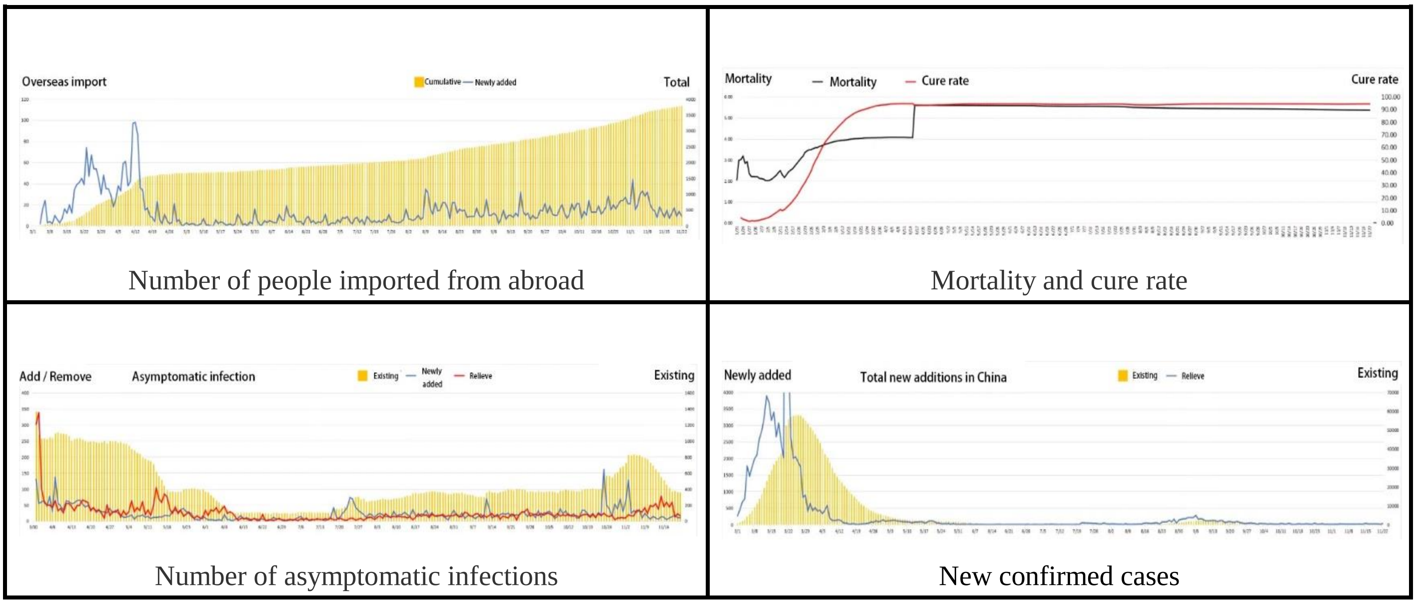


Fig.1. New COVID-19 outbreaks and deaths in countries from February 25 to November 21

The novel coronavirus pneumonia is the most rapid and widespread infection and the most difficult public health emergency since the founding of new China. It is a serious crisis for China. Although the large-scale spread of the epidemic has been effectively controlled, many industries are still affected to varying degrees, which has a great impact on the national economic development. Fig.1 shows most of the new cases in China were imported from abroad, and the infected and mortality rate decreased slowly, and the cure rate gradually increased.



Number of people imported from abroad | Mortality and cure rate
Number of asymptomatic infections | New confirmed cases

Fig.2. Development of epidemic situation in China

1.2 Purpose

In the process of epidemic prevention and control, material distribution is one of the key factors for the success of fighting against the epidemic. The outbreak of novel coronavirus pneumonia has a serious negative impact on the national economic development, which is extremely unfavorable to the development of enterprises and countries. Therefore, this paper establishes a scientific material distribution model. In addition, the relationship, which includes the relationship between the spread of the epidemic and the dynamic changes of product demand, the relationship between national development and epidemic prevention and control, and the relationship between the development of public transport and catering industry and the prevention and control of epidemic situation, was considered respectively, so as to establish the mathematical models of enterprise resumption plan and long-term National Development Strategy under the epidemic situation.

1.3 Work

Based on the website data of the Bureau of statistics, this paper tries to solve the following problems:

1. We select Wuhan city for analysis, determine the impact index of residents' basic necessities of life, grade all regions of Wuhan City, and put forward the basic daily necessities security plan for residents at all levels.

2. We choose the tourism industry for analysis, and take Shanghai Disneyland as an example. The improved SEIR model and tourist demand model were established. Finally, considering the two models comprehensively, this paper puts forward the

planning and suggestions for the return to work and production of Disney tourism company under different epidemic levels.

3. We establish game theory model to weigh the interests of all parties, and draw the relationship between epidemic prevention and control and enterprise loss / profit.

4. Considering various factors, the income model and epidemic transmission mo del of transportation industry and catering industry are established. Then, the dual obj ective programming models of the two industries are established with the goal of max imizing the revenue and minimizing the spread of the epidemic, so as to provide contr ol policies for the relevant industries.Through this relationship, we formulate a long-term national development strategy.

2. Problem analysis

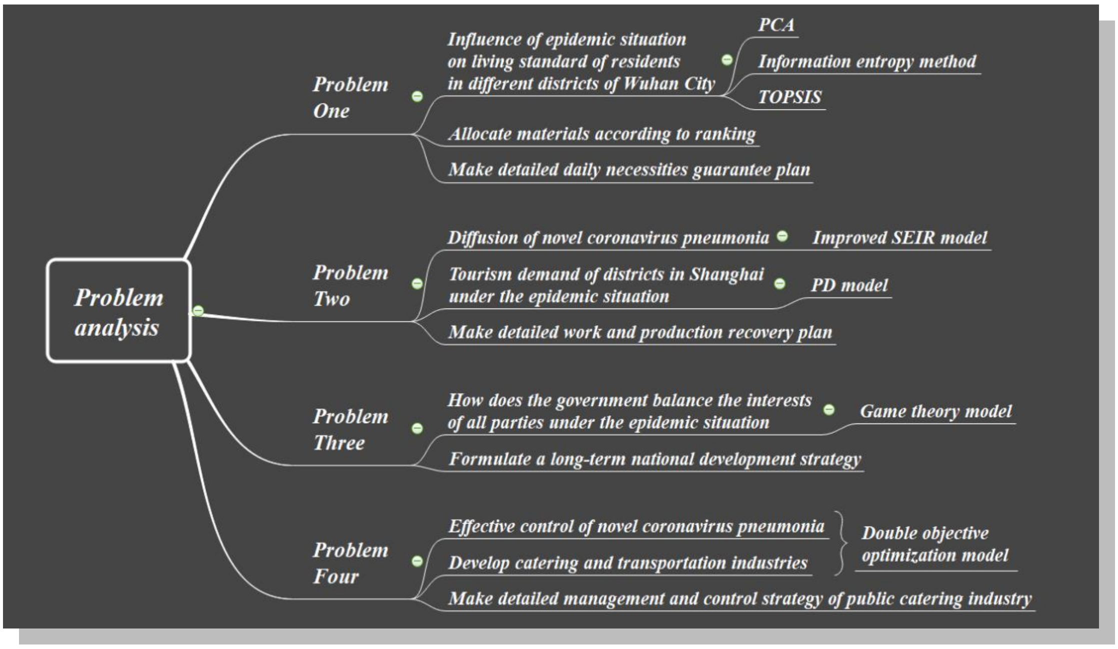


Fig.3. Mind map

According to the mind map in Fig.3, the four questions raised in this paper are analyzed as follows:

2.1 Data Sources

In most cases, the selection of data is of great significance to the model. The authenticity and universality of data make the model more practical. After repeated searches, novel coronavirus pneumonia data and data collected from Wuhan City Statistical Bureau, new crown pneumonia epidemic inquiry and service authority platform and Shanghai Disney official website were found.

2.2 Analysis of question one

For the first question, we divided the problem into two aspects. On the one hand, we determined the living security ranking of residents affected by the epidemic situation in each district of Wuhan city; on the other hand, we distributed materials according to the ranking.

Specifically, the first aspect is to determine the impact index of material shortage in the region, and based on the principal component analysis method, the dimension of the index is reduced and the main index is selected. Then the data were normalized, and the weights of the main indicators were obtained by using the information entropy method, and the life security ranking of the residents affected by the epidemic situation could be obtained by using the TOPSIS method. On the second hand, according to the ranking, we formulate the standard of material distribution and distribute the materials in different places.

2.3 Analysis of question two

Due to the spread of novel coronavirus pneumonia has a great impact on tourism industry, we choose tourism industry to analyze. On the one hand novel coronavirus pneumonia spread. In this paper, we established a system of susceptible population - latent population - infected population - cured population. Then, based on the actual data, we modified the SEIR transmission model by considering the viral transmission capacity of patients in incubation period and the effect of tracking and isolation interventions on the epidemic situation. Taking the epidemic situation in Shanghai as an example, this paper analyzes the impact of prevention, control, isolation and centralized treatment on the development of the epidemic situation. On the other hand, tourist demand changes. During the epidemic period, according to the change of tourist demand with days, and considering various factors, the change model of tourist demand was established. Finally, considering the epidemic diffusion model and the demand dynamic change model of the tourism industry in the market, this paper puts forward planning and suggestions for the resumption of work and production of Shanghai Disneyland tourism company under different epidemic levels.

2.4 Analysis of question three

Novel coronavirus pneumonia is spreading in the long term, and the government must weigh the interests of all parties to ensure the maximum interests of all parties in order to formulate long-term national development strategies and maintain the normal and stable development of the country. Therefore, we establish a game theory model. This paper analyzes and solves the conflict of interests between the experts of epidemic prevention and control and enterprise operators, establishes the game system of epidemic prevention and control experts and enterprise operators, analyzes the system in detail considering the level of experts and enterprise scale, so as to obtain the probability of enterprise loss / profit caused by the decision of experts and operators to return to work. Based on this probability, the game result is defined in the form of competition, and the corresponding implementation scheme is provided.

2.5 Analysis of question four

Transportation industry belongs to capital intensive industry, while catering industry belongs to labor-intensive industry. Both are not conducive to the control of the epidemic situation.

To solve this problem, we regard the virus spread in transportation and catering industry as the same type. Based on the basic principle of indoor virus droplet transmission mechanism, we established a two-objective programming model for epidemic spread. First of all, we established the epidemic transmission model of the transportation industry and the catering industry, taking into account various factors. Moreover, the two models are suitable for the second problem. Finally, the dual objective programming models of the two industries are established with the goal of maximizing the revenue and minimizing the spread of the epidemic, so as to provide control strategies for related industries.

3. Symbol and Assumptions

3.1 Symbol Description

Symbol	Description
S	*Susceptible*
E	*Exposed*
H	*Hospitalized patients*
R	*Recovered*
I	*Infected*
E_q	*Exposed quarantine*
S_q	*Susceptible quarantine*
ψ_q	*Recovery rate of quarantine infected persons*
ψ_I	*Recovery rate of infected persons*
χ_I	*Recovery isolation of infected persons*

χ_q	*Recovery rate of quarantine infected persons*
ω	*Mortality*
ε	*The contact rate*
π	*The ratio of latent person to infected person's transmission ability*
μ	*Isolation release rate*
Ω	*Rate of transformation from exposed to infected*
ℓ	*Effective contact coefficient*
σ	*Probability of infection*
τ	*Isolation ratio*
w_i	*Consumption amount of consumers in place i*
γ_{ij}	*The influence factors of j area on i area change*
α_i	*Consumption under the influence of traffic, personal, environment, climate and other factors*
β_i	*Epidemic transmission factors*
p	*Respiratory rate of indoor customers*
q	*Rate of infectious substances produced by indoor infected persons*
S	*Number of indoor susceptible population*
I	*Number of indoor infected persons*
T	*Indoor exposure time*
Q	*Indoor air supply rate*
D	*Number of patients*
P	*Virus transmission probability*
N	*Indoor rated number of people*
F	*Indoor rated area*
y	*Side length of square occupied by indoor customers*
x	*Full occupancy rate*
k	*Visitor rate*
τ	*Departure interval*
θ	*Liquidity rate*
Y	*Number of employees*
Pr	*Commodity price of a catering company*

3.2 Fundamental assumptions

1. Suppose that Wuhan municipal government has sufficient supplies such as household goods.

2. It is assumed that the susceptible person becomes exposed after effective contact with the sick person, and the exposed person becomes the sick person after the average incubation period, and the sick person can be cured and become the rehabilitative person

3. It is assumed that the contradiction between the epidemic prevention and control experts and the enterprise operators only faces the problem of whether to return to work.

4. It is assumed that the offline catering industry is of the type with dining area for guests.

5. It is assumed that the transmission of virus in public transport vehicles and restaurants conforms to the indoor virus droplet transmission mechanism.

4. Model

4.1 The model of question one

For the first question, we determine the impact index of regional material shortage, and based on the principal component analysis method to reduce the dimensions of the indicators, select the main indicators, so as to determine the level of living security of residents affected by the epidemic situation in each district of Wuhan city; then, we distribute materials according to the ranking as presented in Fig.1..

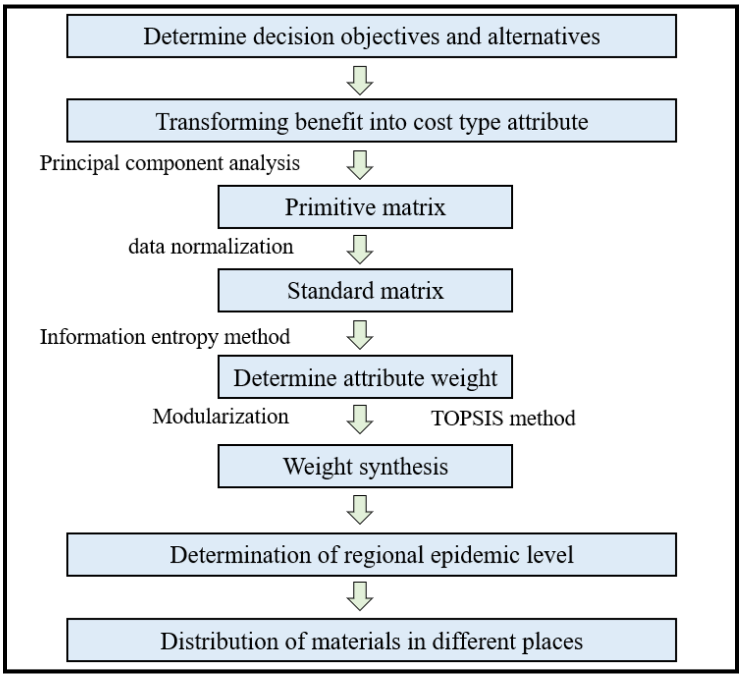


Fig.4. Process of establishing material distribution model

4.1.1 Determination of indicators by PCA

1. Index selection and correlation analysis

When the epidemic situation is serious, we take the number of infected people, GDP, material delivery time, medical level, population density and consumer price index as the basic factors affecting the living security of residents in Wuhan, and analyze the correlation between the above indicators.

Table 1. Selection of index variables

Index	Variable definition
X_1	Number of infected people
X_2	Economic situation
X_3	Material delivery time
X_4	Medical level
X_5	Population density
X_6	Consumer price index

Table 2. correlation coefficient matrix

	Number of infections	Economic situation	Material delivery time	Medical level	Population density	Consumer price index
Number of infections	1	0.261	-0.793	0.641	0.699	0.302
Economic situation	0.261	1	-0.264	0.311	0.058	0.974
Material delivery time	-0.793	-0.264	1	-0.484	-0.753	-0.228

Medical level	0.641	0.311	-0.484	1	0.223	0.393
Population density	0.699	0.058	-0.753	0.223	1	0.099
Consumer price index	0.302	0.974	-0.228	0.393	0.099	1

2. New characteristic variables are obtained by PCA

PCA transforms a group of variables that may have correlation into a group of linearly unrelated variables by orthogonal transformation, so as to achieve the purpose of dimensionality reduction. PCA is used to reduce the dimension of index variables. Based on correlation matrix and component score coefficient matrix, the independent effective characteristic variables X_7 and X_8 are extracted.

Table 3. Component score matrix

	Principal Component	
	1	2
Number of infected people	0.881	-0.318
Economic situation	0.600	0.768
Material delivery time	-0.841	0.378
Medical level	0.707	0.042
Population density	0.682	-0.540
Consumer price index	0.629	0.757

4.1.2 Multi attribute decision making for material allocation

1. Constructing decision matrix

The original weight is d_{ij} (i=1,2,3,…13， j=1,2). According to this table, the original decision matrix D = $(d_{ij})_{13\times 2}$ can be obtained. Since the units of each index variable in the decision matrix are unified, we can normalize the original decision matrix. The elements of the new matrix are defined as r_{ij}, $r_{ij} \in (0,1)$. When and only if d_{ij}=0, r_{ij}=0. The resulting matrix is called the standard matrix R.

2. Determination of attribute weight by information entropy method

Information entropy method is an objective method to measure the uncertainty of indicators. We take w_1 and w_2 as the weights of new index variables X_7 and X_8, where $\sum_i^2 w_i = 1$. Because the influence degree of different index variables on the final decision-making target is not the same, we adopt the information entropy method to give the weight of each index variable, so that the final decision-making target will give different attention when selecting each index variable, so that the result is more accurate.

Based on this, the column vector of the decision matrix R obtained by normalization is the probability distribution of information quantity, and the entropy

E_j of each scheme with respect to each index variable is obtained. The formula is as follows:

$$E_j = -k\sum_{i=1}^{13} r_{ij} \ln r_{ij} \qquad k = 1/\ln 13,\ j = 1,2 \tag{1}$$

By introducing discrimination F_j=1-E_j, $F_j \in [0,1]$, the weight w_j of each index variable X_j is calculated as follows:

$$w_j = \frac{F_j}{\sum_{j=1}^{2} F_j} \qquad \left(j = 1,2\right) \tag{2}$$

The weights under different index variables are obtained as follows:

Table 4. Weight of decision matrix

Index	Weight
X_7	65.4%
X_8	34.6%

3. TOPSIS to determine the ranking of regions affected by epidemic situation

Step1: the decision matrix is normalized and the attribute weight is multiplied to obtain v_{ij}

Step2: Find positive ideal solution and negative ideal solution, positive ideal solution v^+ = (0.6528, 0.1479), negative ideal solution v^- = (0.5912, 0.0209)

Step3: We define the Euclidean distance between each region and positive and negative ideal solutions

$$S_i^+ = \sqrt{\sum_{i=1}^{2} (v_{ij} - v_j^+)^2}$$
$$S_i^- = \sqrt{\sum_{i=1}^{2} (v_{ij} - v_j^-)^2} \tag{3}$$

Step4: Define the relative closeness C^+ of positive ideal solution

$$C_i^+ = \frac{S_i^-}{S_i^+ + S_i^-} \qquad (0 < C_i^+ < 1) \tag{4}$$

Step5: By normalizing the relative closeness C^+ , we can get the ranking of the living security of the residents affected by the epidemic in each district of Wuhan city. The final solution results are shown in the table below.

Table 5. Ranking of living security of residents affected by epidemic situation in different districts of Wuhan City

Districts	S^+	S^-	C^+	TOPSIS（Rank）
Huangpi District	0.127	0.06158	0.32656	0.05608
Caidian District	0.11524	0.061	0.34612	0.05944
Dongxihu District	0.11043	0.06122	0.35665	0.06124
Jianghan District	0.10395	0.06194	0.37338	0.06412

Qingshan District	0.10392	0.06194	0.37345	0.06413
Hongshan District	0.0994	0.06275	0.38697	0.06645
Wuchang District	0.09343	0.06418	0.4072	0.06992
Jiangan District	0.09334	0.06421	0.40754	0.06998
Hanyang District	0.08193	0.06819	0.45425	0.078
Qiaokou District	0.07137	0.07344	0.50714	0.08709
Xinzhou District	0.06453	0.07783	0.54672	0.09388
Jiangxia District	0.04896	0.09675	0.664	0.11402
Hannan District	0.06158	0.127	0.67344	0.11564

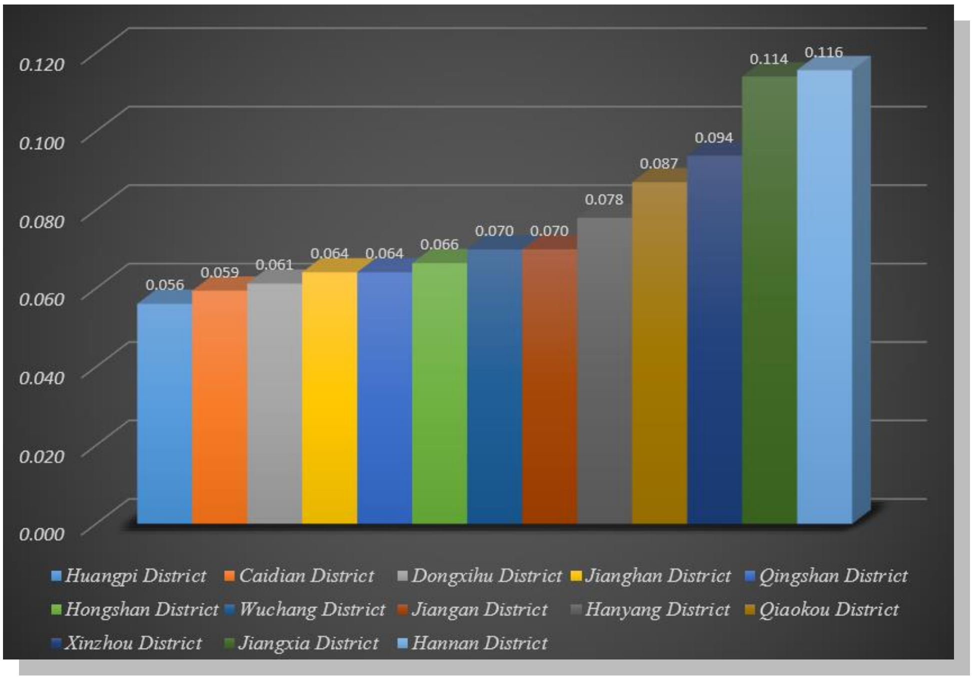


Fig.5. Life security rating of residents affected by epidemic in Wuhan

Finally, the model calculates the life security ranking of residents affected by the epidemic in Wuhan, it can be seen from Fig.5. that the epidemic situation in Jiangxia District and Hannan District is relatively serious, and the residents in these two areas are in short supply of basic living materials; the epidemic situation of Huangpi District and Caidian District is relatively light, and the residents in these two areas are abundant in basic living materials.

4.1.3 Basic daily necessities guarantee plan

According to the TOPSIS value, this paper classifies the basic necessities security into A, B, C, D, as shown in Table 6.

Table 6. classification of basic daily necessities security level of residents in different regions of Wuhan City

TOPSIS	Rank
0.05-0.06	A
0.06-0.07	B
0.07-0.095	C
0.095-0.15	D

1. According to the principle of "centralized overall planning, professional management, urgent support, special materials for special use", Wuhan Municipal Bureau of industry and information technology designates a special warehouse for unified management. The custodians check, verify, register and put into storage on time. The management files of epidemic prevention and control materials are established, and the situation of reserves and receiving of epidemic prevention and control materials is reported daily.

2. The following three principles should be adhered to in material allocation: first, priority should be given to emergency use, medical rescue personnel should be guaranteed, and the prevention and control line of key services should be provided; second, priority should be given to key areas without equal distribution; third, timely allocation should be made.

3. The following is a detailed plan for each level:

(1) For the A-level areas, we first investigate the living materials owned by the local residents' families, and distribute them according to the average amount of materials owned and the amount of materials required. The distribution amount is 10% of the total materials, which is planned to be distributed once every 10 days.

(2) The distribution volume of class B area shall be 20% of the total materials prior to area A. It is planned to distribute once every 5 days.

(3) The distribution of materials in C-level areas should be prior to those in areas a and B, and the distribution volume is 30% of the total materials. It is planned to distribute once every three days.

(4) Priority should be given to residents in D-class areas. The materials needed in the area should be distributed in time, that is, once a day, and the distribution volume is 40% of the total materials. And the local government should cooperate with non-governmental organizations, local charities and other departments to improve the distribution speed of basic necessities for residents in D-level areas.

4. After the materials are distributed, regular return visits should be conducted to all levels of areas to understand the use of materials by local residents in detail, and adjustments should be made accordingly.

4.2 The Model of question two

4.2.1 Establish an improved SEIR model for epidemic spread

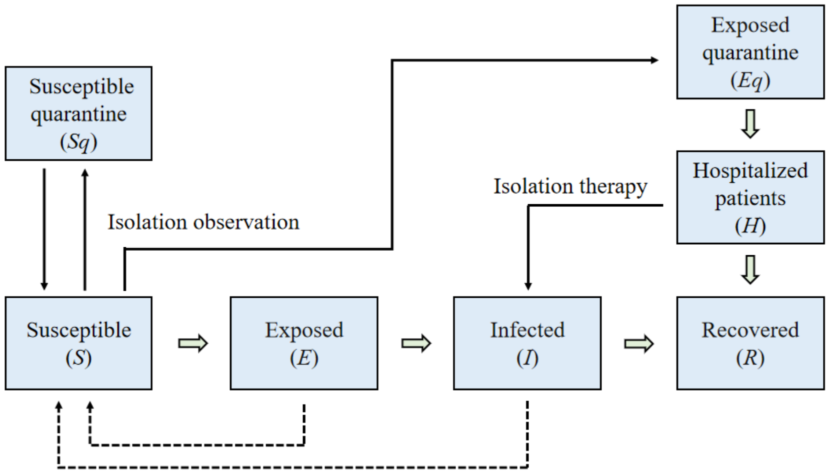


Fig.6. Schematic diagram of improved SEIR model

SEIR is a system of susceptible, latent, infected and cured population, as shown in Fig.6. Through the establishment of differential equation model for the time change rate of different population, the relationship between the number of different population and time was studied. The model is as follows:

1. Control equation of susceptible population. When the epidemic situation has not been completely controlled, the number of healthy people infected by the existing infected population and latent population will decrease over time, and the isolated population can be transformed into susceptible population.

$$\frac{dS}{dt} = \mu S_q - \left[\varepsilon\sigma\ell + \varepsilon\tau\ell(1-\sigma)\right]S(I+\pi E) \tag{5}$$

2. Latent population control equation. In the background of novel coronavirus pneumonia, the infected population in incubation period has infection ability, and the rate of change is determined by the number of potential infected persons. The number of potential infected people came from the existing infected persons and the undetected people who were infected again. At the same time, the potential population can be transformed into normal people.

$$\frac{dE}{dt} = -\Omega E + \varepsilon\sigma\ell(1-\tau)S(I+\pi E) \tag{6}$$

3. Control equation of infected population. The infected population has gone through three stages: the normal stage, the latent carrying stage and the isolation stage.

$$\frac{dI}{dt} = \Omega E - (\chi_I + \omega + \psi_I)I \tag{7}$$

4. Control equation of isolation susceptible population. The isolated susceptible group comes from the susceptible group, and some susceptible groups can be transformed into the susceptible group after observation.

$$\frac{dS_q}{dt} = -\mu S_q + \varepsilon\tau\ell(1-\sigma)S(I+\pi E) \tag{8}$$

5. Control equation of isolating latent population. Isolation latent population comes from susceptible population, and part of the isolated population can be transformed into isolated infection.

$$\frac{dE_q}{dt} = -\chi_q E_q + \varepsilon\tau\sigma\ell(I+\pi E)S \tag{9}$$

6. Control equation of inpatients. The inpatients included the number of patients who were isolated and the number of patients who were transformed into patients from the latent population. At the same time, patients will have two situations of death and cure.

$$\frac{dH}{dt} = \chi_I I + \chi_q E_q - (\psi_q + \omega)H \tag{10}$$

7. Control equation of rehabilitation population. It depends on the number of people recovering from infection.

$$\frac{dR}{dt} = \psi_q H + \psi_I I \tag{11}$$

- **The differential equations are as follows**

$$\begin{cases} \dfrac{dS}{dt} = \mu S_q - \left[\varepsilon\sigma\ell + \varepsilon\tau\ell(1-\sigma)\right]S(I+\pi E) \\ \dfrac{dE}{dt} = -\Omega E + \varepsilon\sigma\ell(1-\tau)S(I+\pi E) \\ \dfrac{dI}{dt} = \Omega E - (\chi_I + \omega + \psi_I)I \\ \dfrac{dS_q}{dt} = -\mu S_q + \varepsilon\tau\ell(1-\sigma)S(I+\pi E) \\ \dfrac{dE_q}{dt} = -\chi_q E_q + \varepsilon\tau\sigma\ell(I+\pi E)S \\ \dfrac{dH}{dt} = \chi_I I + \chi_q E_q - (\psi_q + \omega)H \\ \dfrac{dR}{dt} = \psi_q H + \psi_I I \end{cases}$$

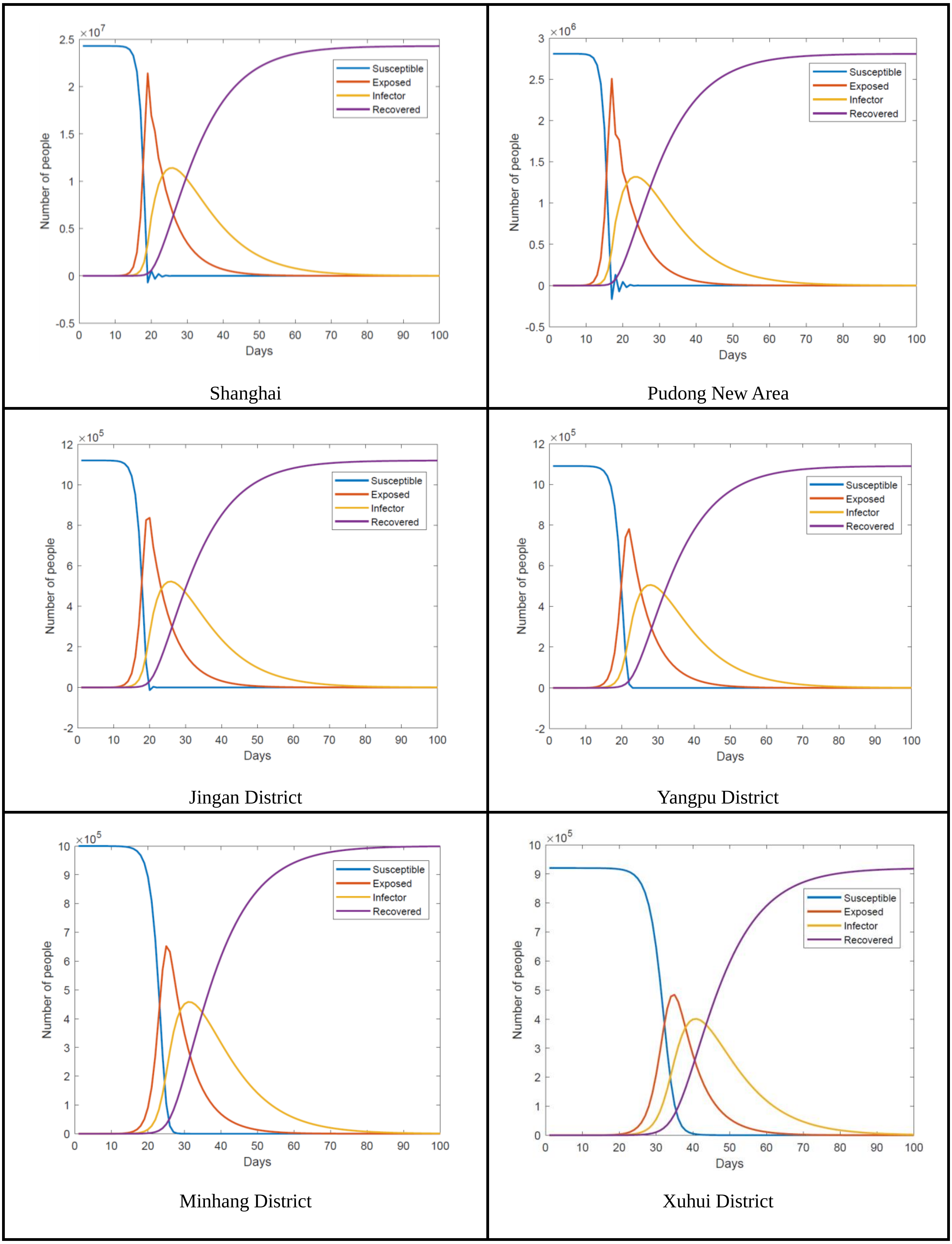


Fig.7. Changes of S, E, I, R population with epidemic days in Shanghai and its districts

Using MATLAB software to calculate the model, we can get the change of the number of susceptible, infected, latent and rehabilitated population with the number of epidemic days. Fig.7. shows that the trend of Shanghai and its districts is roughly the same. Among them, the number of easily infected persons decreased sharply about 20 days after the outbreak of the epidemic, and changed into the other three groups; the number of infected and latent people increased rapidly with the decrease of the number of susceptible people, and then gradually decreased to the initial value; the number of convalescent people increased gradually with the decrease of the number of susceptible people, and finally reached a stable level.

4.2.2 PD Model

Under the influence of the epidemic situation, tourists' consumption demand has declined sharply for various reasons. With the initial control of the epidemic situation, the number of people traveling increased gradually, but safety still need to be considered. At this time, the number of people traveling in different areas will be affected by the commodity price of the tourist destination, the severity of the epidemic situation, the personal preferences of tourists and other tourism areas. Considering all factors, we choose i,j (i,j=1,2,3,...n) as tourist destinations and introduce 0-1 variable to establish the change model of tourist demand to describe the severity of the epidemic situation.

$$\frac{dw_i}{dt} = \alpha_i + 0.5\beta_i(1-x_i)\log(M_i / P) - kx_i\log(M_j / P_i) + 0.3x_iQ_i \tag{12}$$

Among them， $k = \sum_{j=1}^{n}\gamma_{ij}\log(M_j/P)$ is called regional influence factors.

Through MATLAB programming, the demand for tourists decreased rapidly with the increase of time and turned around about 30 days.With the control of the epidemic situation and the increase of time, it gradually increased and finally returned to the original demand state, as shown in Fig.8.

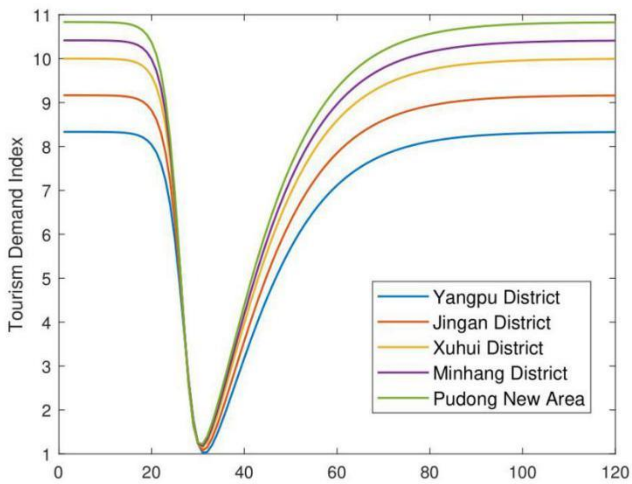


Fig.8. Tourist demand changes with time

4.2.3 Disney's plan to return to work

The epidemic has brought a huge impact on the economy. But the economy needs development. Therefore, according to the different epidemic levels, we put forward the plan for Disney to return to work.

1. Severe stage

(1) Stop work, stop production and get ready to go. According to the improved SEIR model, the epidemic situation in Shanghai will reach the peak between 20 and 30 days after the outbreak. During the peak period, Disney can maintain the company's strength and repair its internal culture by reasonably controlling its internal operations and strengthening its care for its employees and customers.

(2) Online promotion. Spread the Disney brand on the network platform, and deepen the brand recognition and popularity.

2.Initial stage of the epidemic

(1) Multi dimensional revaluation, slow down. According to the tourism demand change model, the panic and anxiety caused by the epidemic situation will last for some time. In this stage, Disney can make a multi-dimensional evaluation on the enterprise itself, resources and market, and clarify the development direction and security control measures after the epidemic. Slow down the recovery rate to avoid the spread of the epidemic.

(2) Safety measures, emergency attitude. Disney needs to include "security" and "emergency" into the operation plan, comprehensively improve the emergency support system and provide a safe travel environment.

3.improvement stage of epidemic situation

(1) Increase consumption and control the flow of people. Disney needs to increase the added value of tourism products and create more consumption opportunities. At the same time, improve the quality of tourism activities and control the number of tourists.

(2) With the help of science and technology, smart tourism. Disney can make full use of the advantages of information technology, and increase the intelligence and digitization of most tourism services to facilitate tourists' information collection and tourism decision-making, and reduce tourists' blind going out.

4.3 The Model of question three

In order to novel coronavirus pneumonia and the development of the country, we must introduce a game theory model to the problem of how to balance the interests of all parties and ensure the interests of all parties to be the most urgent problem. In game theory, if the two sides want to achieve their own interests, they can not consider their own interests, but achieve a win-win situation. This paper analyzes and solves the case for the government to formulate policies through the epidemic prevention and control experts and business operators.

4.3.1 Model preparation

Game theory contains four basic elements: player, game theory set, winning function and payment function.

1.Player: I={1,2,3⋯n} , which means the participants who have the right to decide their own action plan

2. Game theory set: S_i means a feasible and complete action plan that the players can choose, i∈I

3. Winning function: $H(s)=(H_1(s),\ldots, H_n(s))$, where $H_i(s)$ is a function of situation s, situation $s=(s_1, s_2, s_3,\ldots, s_n)$

Game games are divided into zero sum game and non-zero sum game. Zero sum game is a special case of constant sum game. It has pure strategy game and mixed strategy game. The game between experts and business operators of epidemic prevention and control belongs to the type of mixed strategy countermeasures, and the optimal solution is needed to establish the model.

Let this mixed game problem be a game G = {S1, S2, C} 1, C2}. If there is a game satisfying the following equation,

$$\begin{cases} x^T C^1 \overline{y} \le \overline{x}^T C^1 \overline{y}, & \forall x \in S_1^* \\ \overline{x}^T C^2 y \le \overline{x}^T C^2 \overline{y}, & \forall y \in S_2^* \end{cases} \tag{13}$$

$$v_1 = \overline{x}^T C^1 \overline{y} \tag{14}$$

$$v_2 = \overline{x}^T C^2 \overline{y} \tag{15}$$

then ($\overline{x}$, $\overline{y}$) is a non cooperative equilibrium point of G, and mixed strategies v_1 and v_1 are players' earned value. The necessary and sufficient conditions for the mixed strategy to be the equilibrium point of game G are as follows:

$$\begin{cases} \sum_{j=1}^{n} c_{ij}^1 \overline{y}_j \le \overline{x}^T C^1 \overline{y}, & i = 1,2,\ldots,m \\ \sum_{i=1}^{m} c_{ij}^2 \overline{x}_i \le \overline{x}^T C^2 \overline{y}, & j = 1,2,\ldots,n \end{cases} \tag{16}$$

moreover, the mixed game problem satisfies that each bimatrix game has at least one non cooperative equilibrium point.

4.3.2 Establish a game model between experts and enterprises

The game system of epidemic prevention and control experts enterprise operators is subdivided. It is assumed that the level of epidemic prevention and control experts is divided into three levels: senior, intermediate and general; the enterprise where the enterprise operator belongs is divided into three levels: large, medium and small; and there are six players participating in the countermeasures. The experts and operators of epidemic prevention and control will conduct Game Analysis on the situation of returning to work, and analyze the probability of loss and profit caused by the decision of experts and operators, as shown in Table 7.

Table 7. probability of loss / profit caused by the decision of experts and operators to return to work

	Epidemic control experts			Business operators		
	Senior	Intermediate	General	large enterprises	Medium Enterprise	Small Enterprise
Return to work	0.05	0.1	0.3	0.08	0.21	0.37
No return to work	0.9	0.8	0.6	0.82	0.78	0.54
Partial return to work	0.5	0.6	0.65	0.52	0.61	0.73

Due to the high risk of the opinions provided by general level experts, whether large enterprises resume work or not has a great impact on the spread of the epidemic. Therefore, we assume that experts at the general level and managers of large enterprises can only provide two decision-making plans, and the others can provide three.

The strategy set of the epidemic prevention and control expert group is α={α1, α2, α3}, the strategy combination of enterprise operator group is β={β1, β2, β3}, α means that the general level experts in the epidemic prevention and control expert group will not provide decision-making suggestions on returning to work, not returning to work, and part of returning to work; β means that the large-scale enterprise operators in the enterprise operators will not provide decision-making suggestions for returning to work, not returning to work, and part of returning to work. Assuming that the game result is defined in the form of competition, different points are set for the winner, in which the first place gets 5 points, the second place gets 3 points, and the third place gets 1 point. The final result of the score will provide the corresponding implementation scheme for this game.

The results,using MATLAB software to program and calculate, are shown in Table 8.

Table 8. Game results

	α_1	α_2	α_3
β_1	(10,17)	(12, 15)	(10, 17)
β_2	(12, 15)	(14, 13)	(12, 15)
β_3	(10, 17)	(12, 15)	(10, 17)

When large-scale enterprises do not return to work or part of them return to work, the expert group wins, that is, the expert group's recommendations shall prevail. The government formulates policies to consider the national epidemic situation first, and requires enterprises to abide by the basic rules of epidemic prevention and control to ensure the health of employees. When large-scale enterprises return to work and epidemic experts suggest that they return to work or part of them, the government can focus on the development of market economy, encourage enterprises to return to work partly, and take safety precautions.

LINGO software is used for programming calculation. The score of the expert group for epidemic prevention and control is 15.2, and the score of enterprise operators is 12.2. When the government formulates policies, the experts' suggestions should be the first priority, and the interests of enterprises should be protected as much as possible.

4.3.3 Long term national development strategy

1. Consulting experts, the government formulates policies. From the results of the above model, we can see that in the case of epidemic spread, we should make policies for national economic development based on the opinions of epidemic prevention and control experts to promote the process of national resumption of work and production under the condition of meeting the interests of enterprises.

2. We will firmly implement the strategy of expanding domestic demand. Enterprise development is a powerful driving force for national development. Building a complete domestic demand system is related to China's long-term development and long-term stability. Therefore, the government should formulate measures to control the spread of the epidemic when listening to the opinions of experts, and at the same time, promote the development of enterprises and stimulate the market demand under the epidemic situation.

3. Optimize and stabilize the industrial chain and supply chain of enterprises. In order to ensure China's industrial security and national security, we should strive to build an independent, controllable, safe and reliable enterprise industrial chain and supply chain, strive to have at least one alternative source for important products and supply channels, and form a necessary industrial backup system.

4. Adjust and optimize the input and output structure of science and technology of enterprises. We should innovate the mechanism for the transformation of scientific and technological achievements, give full play to the role of enterprises as the main body and the role of the government as a whole, promote the docking of capital, technology, application, market and other elements, and open up the innovation chain and value chain of industry, University and research.

5. Strengthen the construction of public health system in enterprises. In this epidemic prevention and control, the construction of public health system is related to the spread of the epidemic. Combined with the opinions of epidemic experts, we should build a reasonable public health system to ensure that even if enterprises return to work, the epidemic will not spread in a large scale.

6. Human and nature coexist harmoniously. It is necessary to enhance the whole nation's awareness of ecological and environmental protection, encourage green production and consumption, and promote the formation of a healthy and civilized production and lifestyle.

4.4 The Model of question four

In the case of the spread of the epidemic, various industries are affected to varying degrees. Limited by the epidemic situation, the catering and transportation industries have greatly reduced their economic income. At the same time, the cost in different aspects has increased, and the economic growth is in a slow down stage. The transportation industry and catering industry are both highly mobile and densely populated industries, which are not only impacted by the epidemic, but also spread rapidly. Therefore, how to maximize the industry revenue and minimize the spread of the epidemic is an urgent problem for the two industries.

The solution of this problem is shown in Fig.9.

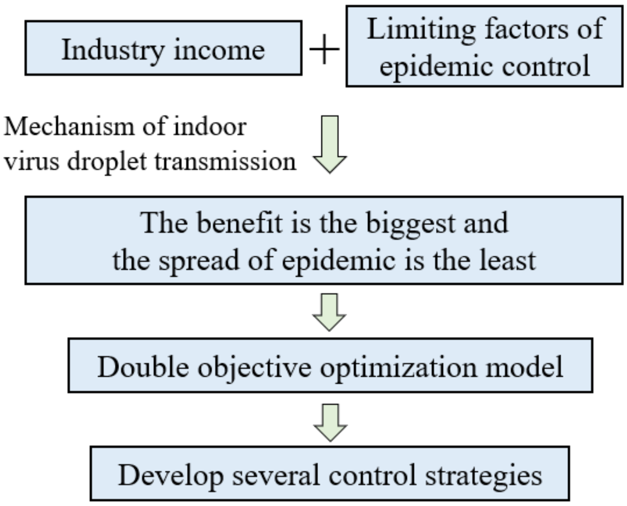


Fig.9. Solutions to question 4

4.4.1 Related indicators

1. Full load ratio

$$x = \frac{Actual\ \ passenger\ \ flow}{Rated\ \ passenger\ \ flow} = \frac{c}{N} \tag{17}$$

Assuming that the vehicle operation limit during the epidemic period is 3 persons / m^2, then

$$N = 3F = 3cy^2 \tag{18}$$

$$x = \frac{1}{3y^2} \tag{19}$$

Similarly, the catering industry can obtain

$$x = \frac{1}{2y^2} \tag{20}$$

2. Departure interval (service interval)

$$\tau = \frac{Maximum\ section\ passenger\ flow}{Rated\ carrying\ capacity} = \frac{\max(N(j))}{N} \tag{21}$$

3. In car exposure time

$$T = \frac{L}{u} \tag{22}$$

4. Introduce 0-1 variable

$$b_i = \begin{cases} 0 & The\ mileage\ is\ close \\ 1 & The\ mileage\ is\ far\ away \end{cases} \tag{23}$$

4.4.2 Establish the dual objective programming model of industry income and epidemic spread

We regard the virus diffusion in transportation and catering industry as the same type, take the indoor virus droplet transmission mechanism as the basic principle, and regard the catering industry as the carriage and seat as the seat. The difference lies in the profit-making behavior of the two business modes.

1. Establish the transportation industry model

The maximum profit model is established as follows:

$$\max w = (12 - 10b_i)\frac{k\sigma N(j)}{3y^2 N} \tag{24}$$

The minimum epidemic transmission model is as follows:

$$\min D = \frac{k\sigma N(j)}{3y^2 N}[1 - \exp(-\frac{IpqL}{uQ})] \tag{25}$$

The constraints are as follows:

$$0 \le N(j) \le \frac{3y^2 N^2 \sigma}{k} \tag{26}$$

$$0 \le L \le 50 \tag{27}$$

- The dual objective programming model is established, which is represented by $\min z = V - \min(D, -w)$.

$$\min z = \frac{kN(j)\sigma}{3y^2 N}[0.7 - 0.7\exp(-\frac{IpqL}{Q}) - 3.6 + 3b_i] \tag{28}$$

$$\begin{cases} 0 \le N(j) \le \dfrac{3y^2 N^2 \sigma}{k} \\ 0 \le L \le 50 \end{cases}$$

2. Establishment of catering industry model

The establishment of catering industry model is similar to that of transportation industry, only considering the difference of consumption mode between them.
The maximum profit model is established as follows:

$$\max w = (\Pr_{\max} + \Pr_{\min})\frac{1}{2} \times \frac{k\sigma N(j)}{2y^2 N} \tag{29}$$

The minimum epidemic transmission model is as follows:

$$\min D = \frac{k\sigma N(j)}{2y^2 N}[1 - \exp(-\frac{Ipqt}{Q})] \tag{30}$$

The constraints are as follows:

$$0 \le N(j) \le \frac{2y^2 N^2 \sigma}{k} \tag{31}$$

$$0 \le t \le 40 \tag{32}$$

- The dual objective programming model is established as follows:

$$\min z = \frac{kN(j)\sigma}{4y^2 N}[0.7 - 0.7\exp(-\frac{Ipqt}{Q}) - 0.3(\Pr_{\max} + \Pr_{\min})] \tag{33}$$

$$\begin{cases} 0 \le N(j) \le \dfrac{2y^2 N^2 \sigma}{k} \\ 0 \le t \le 40 \end{cases}$$

4.4.3 Model calculation results and conclusions

In the transportation industry, at a certain time, when the average maximum cross-section passenger flow of each vehicle at each station is 22, the flow rate is 0.1, and the mileage of passengers taking the bus is less than 15 km, it can effectively prevent the spread of the epidemic and obtain the maximum benefits under the condition of self safety prevention and control. At this time, the side length of the square occupied by passengers is 1 m, and the full load rate of the bus is about 16%. In the catering industry, at a certain time, when the average number of people in each medium-sized restaurant reaches 28, the maximum dining time of customers is 20 minutes, and the turnover rate of the restaurant is 2.1, the spread of epidemic can be effectively prevented and the maximum benefits can be obtained under the condition of customers' self-protection and restaurant's good food protection.

4.4.4 Control strategy of public transport and catering industry

- **For the transportation industry:**

1. Strengthen operation monitoring and timely grasp the change of bus section passenger flow.

2. On the basis of ensuring the transportation capacity of buses, reasonably shorten the departure interval and control the full load rate of buses.
3. According to the passenger transport hub, the operation mode of connecting bus lines should be adjusted flexibly to reduce the concentration of passenger flow.
4. Check the temperature of passengers before boarding and strengthen the health protection measures of drivers and passengers.
5. Strictly implement the cleaning and disinfection of buses and strengthen the training of employees.
6. According to the passenger flow demand, flexible and reasonable development of customized bus or temporary bus lines, shorten the travel distance of passengers.
7. Reasonable opening of express trains at major stations, rapid evacuation of passenger flow, to meet the rapid travel needs of citizens.
8. Optimize vehicle ventilation conditions.

- **For the catering industry:**

1. Short term personnel and inventory diversion.
2. Seek help from the government to reduce the tax rate.
3. Reduce variable costs, such as rent and bonus.
4. Business model innovation, online development scale increased.
5. To control the transmission probability of virus by separate meals.

5.Test the Models

5.1 Scree test

According to the first question, this paper tests the model by gravel test. Gravel inspection is a method to determine the number of factors according to the gravel map. It can be seen from the figure that the point line of the first two characteristic roots constitutes a "cliff". From the third, the eigenvalues decrease slowly and are all below 1. Therefore, it is appropriate to extract two new feature variables based on PCA.

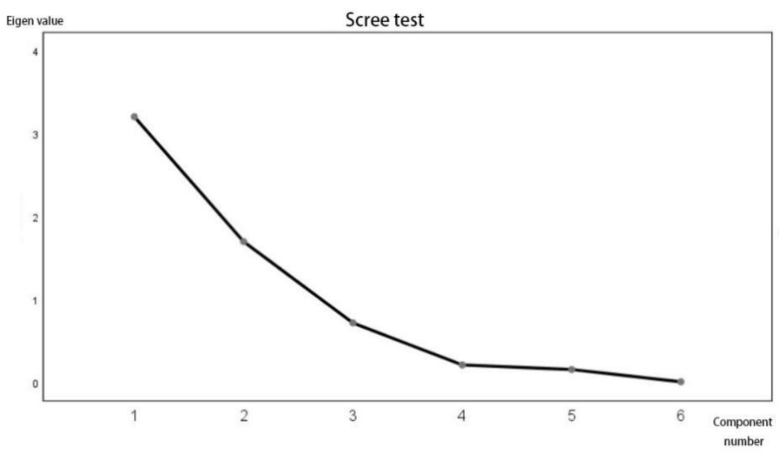


Fig.10. Scree test

5.2 Improved SEIR model test

According to the second question, based on the correlation analysis of the above models, it can be concluded that from February 25, the effective control time range of the epidemic situation in all districts of Shanghai is 70 to 80 days. We compare the actual operation time of Shanghai Disneyland. According to the query data, Shanghai Disneyland will be reopened to people from May 11, and will be reopened to all districts of Shanghai in about 76 days, which is consistent with the results of the model.

5.3 Double objective programming model test of industry income and epidemic spread

In view of the fourth question, the curve of the relationship between the full load rate of the bus and the length of the square side occupied by passengers is as follows:

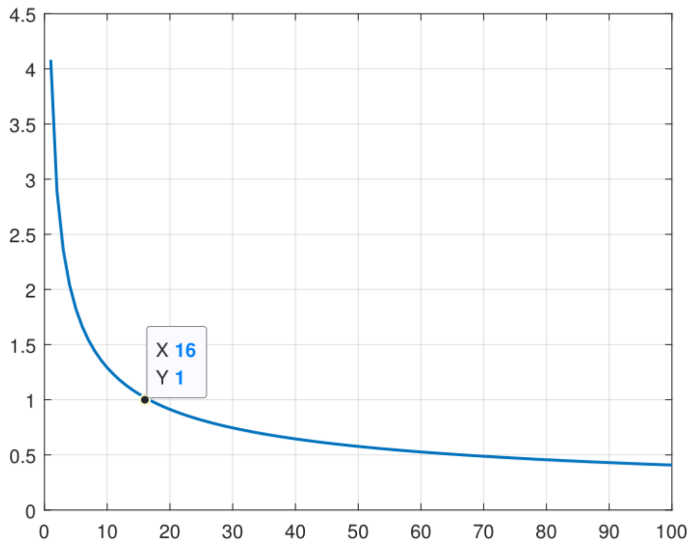


Fig.11. Relationship between bus load factor and side length of passenger occupied area

When the maximum section passenger flow is 22, the full load ratio of bus is about 16%, which is consistent with the conclusion and the model is correct.

6.Strengths and Weakness

6.1 Strengths

1. In the four questions, we collect a lot of data, mainly based on official data, and build models. Therefore, the model has a high degree of authenticity and accuracy.

2. Considering the problem from various angles and in all directions, there are many kinds of model comparison and optimization, and the model has good effect and reliability.

3. For question 1, we put forward targeted suggestions on the residents' needs for daily necessities in various areas of Wuhan according to the epidemic situation and economic situation, which is of great significance for epidemic control.

4. For the second problem, we establish an improved SEIR model, which has stronger applicability and universality.

5. For the third problem, the game model can fully guarantee the interests of both sides.

6. For the fourth problem, the double objective optimization model is used to realize the unified decision of two different factors, which is convenient and fast.

7. By using gravel test and other methods, the results of the model are compared with the actual situation, and the results are in good agreement.

6.2Weakness

1. In principal component analysis, we should first ensure that the cumulative contribution rate of the first several extracted principal components reaches a high level (that is, the information content after variable dimensionality reduction must be kept at a higher level), and then, the extracted principal components must be able to give explanations that are in accordance with the actual background and significance (otherwise, the principal components will have no actual meaning but empty information);

2. The tasks of Bi objective optimization model may interact with each other.

3. In the calculation of mathematical software, the decimal calculation results will be reserved, which will cause some errors in the subsequent calculation or statistical results

4. In the process of modeling, the consideration of influencing factors is not very comprehensive.

7.Conclusion

(1) Wuhan city is selected as the research object. Through the establishment of multi-attribute decision-making model, it is concluded that in order to ensure the sufficiency of basic daily necessities for urban residents, we should "adjust measures to local conditions" and allocate basic daily necessities in different regions according to GDP and epidemic severity of different regions, so as to meet the basic living needs of residents.

(2) Taking Shanghai Disneyland as the main research object, through the analysis of the spread of the epidemic situation and the change of passenger demand, it is concluded that in the severe stage of the epidemic, enterprises should stop work, maintain the strength of the enterprise and optimize the brand; in the early stage of the

improvement of the epidemic situation, the enterprise should consider various factors, do a good job in the synchronization of epidemic prevention and slow development, and improve the epidemic situation At the same time, enterprises can increase the consumption opportunities of customers, and at the same time, combine with intelligent technology to do a good job of epidemic prevention inspection and improve revenue.

(3) Considering the main contradiction between the epidemic prevention and control experts and the enterprise operators, this paper adopts the game model to analyze, and concludes that the government should give priority to the suggestions of epidemic prevention and control experts when formulating policies, and try to meet the development interests of enterprises and the needs of social economic development.

(4) Establish an indoor virus model, consider the differences between public transport and catering industry, establish models separately, and draw the conclusion that the public transport industry should control the traffic volume, ventilation rate and the number of passengers to control the spread of the epidemic; the catering industry should prevent the spread of the epidemic through controlling the flow of the inside of the restaurant and adopting a separate meal system.

8. Future Work

In question one, we have made a detailed analysis of Wuhan City, through the establishment of a mathematical model to grade the districts of Wuhan City, so as to determine the material distribution. In future work, we can extend the established model to other cities to determine the distribution of epidemic materials in other cities.

In the second question, we take the tourism industry as the analysis object, establish an improved SEIR model to predict the epidemic situation in various districts of Shanghai, and establish a tourist demand model to measure the change of tourists' demand for tourism. In the future work, we can extend the model to other tourism companies to formulate a more comprehensive and scientific plan for returning to work and production.

In question three, we build a game theory model to compete experts and enterprise decision makers, and give management advice to the government on the premise of balancing the interests of all parties. In the future work, we can establish the optimization model and compare with the game model, so as to provide the government with a more comprehensive national development strategy.

For the fourth problem, we establish a dual objective programming model to pro vide management and control strategies for public catering industry at different epide mic levels. In the future work, we can study other industries, through the establishmen t of optimization model to solve, so as to propose more scientific management and co ntrol strategy.

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Appendix

```
clc;clear;
a=[0.05 0.1 0.3 0.08 0.21 0.37;
0.9 0.8 0.6 0.82 0.78 0.54;
0.5 0.6 0.65 0.52 0.61 0.73];
m=3;n=3;kk=3;T=1000;
sc1=[5:-2:1,zeros(1,3)];    %Scores from first to sixth place
sc2=repmat(sc1,kk,1);
for i=1:m
for j=1:n
b=a;
b(i,3)=T;b(j,4)=T;    % If you don't take part in the competition, you should take the time as the most important
[b,ind]=sort(b,2);    % Sort each row of b
for k=1:m
sc2(k,ind(k,:))=sc1;    % Calculate the score
end
A_sc(i,j)=sum(sum(sc2(:,1:m)));    % Statistical score
B_sc(i,j)=sum(sum(sc2(:,m+1:end)));
end
end
A_sc,B_sc
fid=fopen('text2.txt','w');
fprintf(fid,'%f\n',A_sc');
```

```
fwrite(fid,'~','char'); % Write lingo data separator to plain text file
fprintf(fid,'%f\n',B_sc');
fclose(fid);

model:
sets:
pa/1..3/:x;    % Defining variables
pb/1..3/:y;    % Defining variables
link(pa,pb):c1,c2;
endsets
data:
c1=@file(text2.txt);
c2=@file(text2.txt);
enddata
v1=@sum(link(i,j):c1(i,j)*x(i)*y(j));          % Variable calculation
v2=@sum(link(i,j):c2(i,j)*x(i)*y(j));          % Variable calculation
@for(pa(i):@sum(pb(j):c1(i,j)*y(j))<v1);    % constraint condition
@for(pb(j):@sum(pa(i):c2(i,j)*x(i))<v2);    % constraint condition
@sum(pa:x)=1;@sum(pb:y)=1;
@free(v1);@free(v2);
end

function createfigure(X1, YMatrix1)
%CREATEFIGURE(X1, YMatrix1)
%    X1:    x Vector of data
%    YMATRIX1:    y Matrix of data
% create figure
figure1 = figure;
% create axes
axes1 = axes('Parent',figure1);
hold(axes1,'on');
% Using matrix input of plot to create multiple rows
plot1 = plot(X1,YMatrix1,'LineWidth',1.2,'Parent',axes1);
set(plot1(1),'DisplayName','Yangpu District');
set(plot1(2),'DisplayName','Jingan District');
set(plot1(3),'DisplayName','Xuhui District');
set(plot1(4),'DisplayName','Minhang District');
set(plot1(5),'DisplayName','Pudong New Area');
% create ylabel
ylabel('Tourism Demand Index');
% create xlabel
xlabel('Days');
box(axes1,'on');
% create legend
```

```
legend1 = legend(axes1,'show');
set(legend1,'Position',[0.567738090622993 0.186984121988697 0.303928576503481
0.242857148306711],'FontSize',11);

N = 120000;       %Total population
E = 0;            %Latent carriers of virus
I = 1;            %Virus infector
S = N - I;        %Susceptible population
R = 0;            %Number of convalescent
r = 20;           %Number of people who have been exposed to susceptible persons
B = 0.03;         %Probability of infection
a = 0.1;          %Probability of latent to infected
r2 = 20;          %The number of people who have contact with the susceptible
B2 = 0.03;        %The probability of latent infecting normal people
y = 0.1;          %Recovery probability
```

	Number of infections (as of March 13)	Economic situation GDP (100 million yuan)	Material delivery time (h)	Medical level	Population density (10000 / km2)	Consumer price index
Hongshan District	4677	3034	0.4	0.2500	0.571429	2.22
Hannan District	1085	1644	1.3	0.1000	0.027003	1.54
Wuchang District	7455	1522	0	1.0000	1.252336	1.44
Dongxihu District	5087	1351	1.1	0.5000	0.102059	1.47
Jiangan District	6549	1335	0.4	0.3333	1.72242	1.38
Jianghan District	5181	1255	0.2	0.2000	2.933899	1.32
Huangpi District	2114	1071	1.3	0.1111	0.054061	1.13
Xinzhou District	1072	951	1.6	0.1429	0.069969	1.07
Jiangxia District	848	948	1.3	0.1250	0.040628	0.98
Qiaokou District	6833	850	0.7	0.1667	1.543657	0.91
Hanyang District	4670	761	0.5	0.0909	0.79792	0.85
Qingshan District	2782	673	0.5	0.0833	0.671058	0.73
Caidian District	1416	401	1	0.0769	0.052123	0.61