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Analysis of quarantine resource reserves based on the SEIR model for the new crown pneumonia epidemic

Xianzhe Ma, Yuhan Zhou

Faculty of Electronic Information and Electrical Engineering, Dalian University of Technology, Dalian, China, 116000

Abstract

Isolation is an important part of the response to NCCP, and resource crowding occurs when the isolation resources that currently exist are not sufficient to achieve the required level of isolation resources. Then the trend of the impact of the resource crowding phenomenon on the development of the epidemic is also worth discussing. In this paper, we will develop appropriate models to analyze the characteristics of epidemic spread in two different settings, urban and university. This paper will also simulate the changing situation of the epidemic development after encountering the phenomenon of isolated resource crowding and conclude the impact generated by isolated resource crowding.

Keywords

Reserve Resources; SEIR; Segregation Measures ; City model.

1. Introduction

Five different time points after the outbreak were selected to determine the exact number of people who needed to be quarantined at that time, and the appropriate quarantine resources were allocated according to the number of people needed to be quarantined[1]. By searching for information we learned that the new crown epidemic virus has the characteristics that there is an incubation period, close contacts are not sure whether they are infected or not, and those who are cured will acquire antibodies and will not be reinfected for a longer period of time. Therefore, we decided to build a SEIR infectious disease dynamics model to analyze this problem, using actual data to obtain parameters to build the model, calculating data based on the model, and then using examples to compare and fit the model to test and adjust the model. Finally, the problem is solved accurately.

On this basis in drawing the image 1 at different moments after taking isolation measures using sufficient isolation resources, and finally assuming the isolation resource crowding phenomenon, change the parameters to draw image 2, by comparing image 1 and 2 can obtain the analysis results of this problem.

2. Assumptions and notations

We use the following assumptions.

1. Assume that there are no natural births and natural deaths in the college model.

2. Assume that cured individuals in both the urban and university models will acquire permanent antibodies and will not become susceptible again.

3. Model construction and solving

3.1. City model building and curve drawing

Based on online information search and reasonable extrapolation, we determined the values of the fixed parameters of the probability of transformation of a latent into an infected person α, the probability of contracting the disease after exposure to a patient β1, the probability of contracting the disease after exposure to a latent person β2, the probability of transformation of a latent person back to a susceptible person β3, the average number of contacts per patient per day m1, the average number of contacts per latent person per day m2, the probability of transformation of an infected person into a cured person n, and the mortality rate of an infected person k [2].

After determining the parameters, we analyzed and processed the model, considering the communicative interactions and correlations among the susceptible population S, the latent population E, the infected population I, and the cured population R, and obtained the relationship between the number of people in the four categories.

$$S_{t+1}=S_t-m\beta I_t-m_2\beta_2E_t+\beta_3E_{t-14} \tag{1}$$

$$Et+1= Et+m\beta It+r2\beta 2Et-\beta 3Et-\beta 3\ Et-14 \tag{2}$$

$$It+1=It+\alpha Et-(n+k)\ It \tag{3}$$

$$Rt+1=Rt+y\ It \tag{4}$$

$$Dt+1=Dt+kIt \tag{5}$$

where α is the probability of conversion of latents to positive, β is the probability of transmission (contact, patient), m is the average number of days of contact per patient per day, n is the probability of recovery of patients, β2 is the probability of transmission (contact with latents), β3 is the rate of conversion of latents, m2 is the average number of contacts per day of latents, and k is the mortality rate of patients.

Based on the obtained mathematical equations and expressions modeled and analyzed programmatically in MATLAB, the final curves of population size change for the four populations were obtained as shown in Fig. 1.

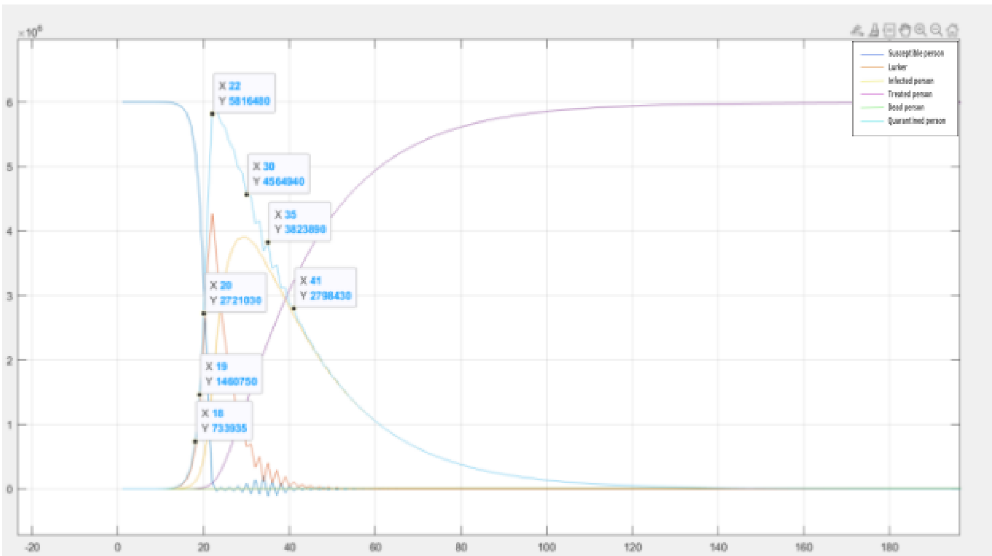

Figure 1 Change curves for four different types of people in the SEIR city model

Based on the image, it can be concluded that the overall percentage of infected persons I tends to increase and then decrease in the state of natural progression of the outbreak. The meaning of isolation resource is the number of people that can be accommodated under the number of people that need to be isolated, so the overall number of infected people I is the size of the

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isolation resource sought in Problem 1. In this image analysis, we take the point analysis of the image and get as Table 1 of the data table.

Table 1 Segregation resources required to start segregation at different moments in the SEIR urban model

Serial number	Number of unit time	Percentage of segregated population in the city	Segregated resources required in cities
1	18	0.12	733935
2	19	0.24	1460750
3	20	0.45	2721030
4	22	0.97	5816480
5	30	0.76	4564940
6	35	0.64	3823890
7	41	0.47	2798430

3.2. High school model building and curve plotting

Similar to the model of urban system, in the university system, we still use the SEIR model for research and analysis. However, considering the university system has the characteristics of dense population, several population movements, wide exposure to people, and high immunity of students. The parameters are then determined differently from those in the urban system[3].

The specific differences were that the total number of people became 50,000, the average daily exposure per person was doubled, the mortality rate was reduced to 10 percent of the original rate, and the recovery rate became four times the original rate.

The final parameters were assigned as shown in Table 2.

Table 2 Constant parameter assignment in the SEIR college model

Fixed parameters	Value
α	0.201
β1	0.1
β2	0.001
β3	0.054
m1	38
m2	40
n	0.2
k	0.00001

After determining the parameters, we analyzed and processed the model to obtain the relationship between the numbers of the four populations by considering the communicative interactions and correlations among the susceptible population S, the latent population E, the infected population I, and the cured population R.

According to the obtained mathematical equations and expressions in MATLAB for programming modeling analysis, the final obtained curves of the population numbers of the four populations are shown in Figure 2.

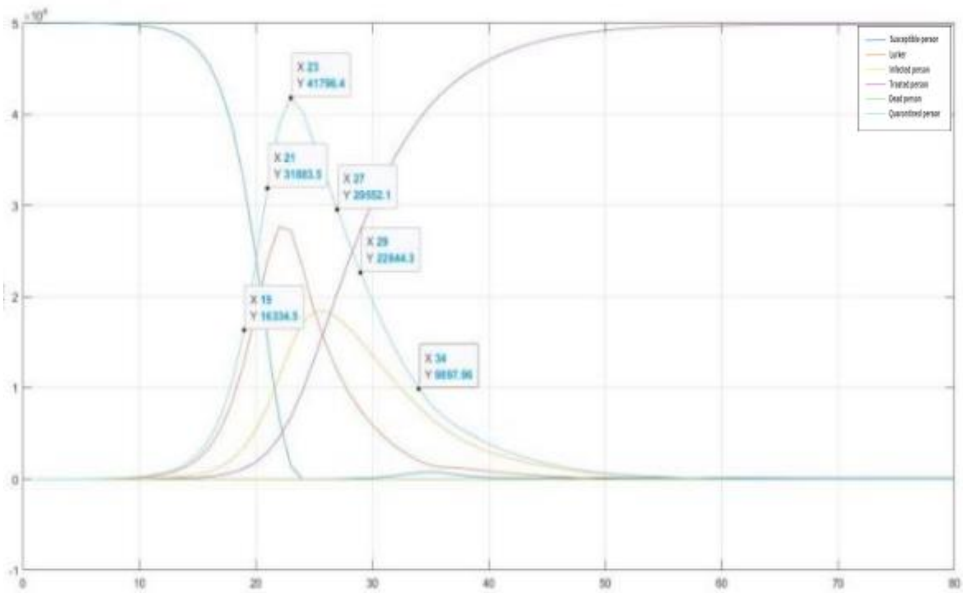

Figure 2 Change curves for four different types of headcount in the SEIR college model

Based on the images, it can be concluded that the overall proportion of infected individuals I in the state of natural progression of the epidemic tends to increase and then decrease. In this image analysis, we took the points of the image and obtained the data table as in Table 3.

Table 3 Isolation resources required to start isolation at different moments in the SEIR college model

Serial number	Number of unit time	Percentage of segregated population in the city	Segregated resources required in cities
1	19	0.33	16334.5
2	21	0.64	31883.5
3	23	0.84	41796.4
4	27	0.59	29552.1
5	29	0.45	22644.3
6	34	0.19	9697.96

3.3. Analysis of the situation when a resource run is encountered in urban systems

Isolation measures are taken to isolate the entire population of latents from the population of infected individuals. This means that the values of E and I are reduced to zero at a certain point in the SEIR model, and then the SEIR modeling simulation is performed again based on the current values of each population. When there is a resource crowding phenomenon, E and I cannot all be isolated, and there will be some people who should be isolated but cannot be isolated[4]. Therefore, E and I will be analyzed in a new round of SEIR modeling with a portion remaining.

Regarding the influence of the adequacy of isolation resources on the model parameters, after reviewing the information, we get that when the isolation resources are fully adequate (100%), m1 is 0.8 and m2 is 1.2, and when there is no isolation at all, m1 is 17 and m2 is 20. Initially, we envision $m1=0.8*g1+17*g2$

When the segregated resources are sufficient, the change curve of the number of the four populations in the SEIR model will be shown in Figure 5.

When the segregated resources are less than adequate (50%), the change curve of the number of the four populations in the SEIR model will be as shown in Figure 5.

When there is a severe shortage of segregated resources (10%), the change curve of the number of the four populations in the SEIR model will be as shown in Figure 5.

The peak points of the E+I curves of the three were extracted and the values of their horizontal and vertical coordinates were read to form the data table in Table 4.

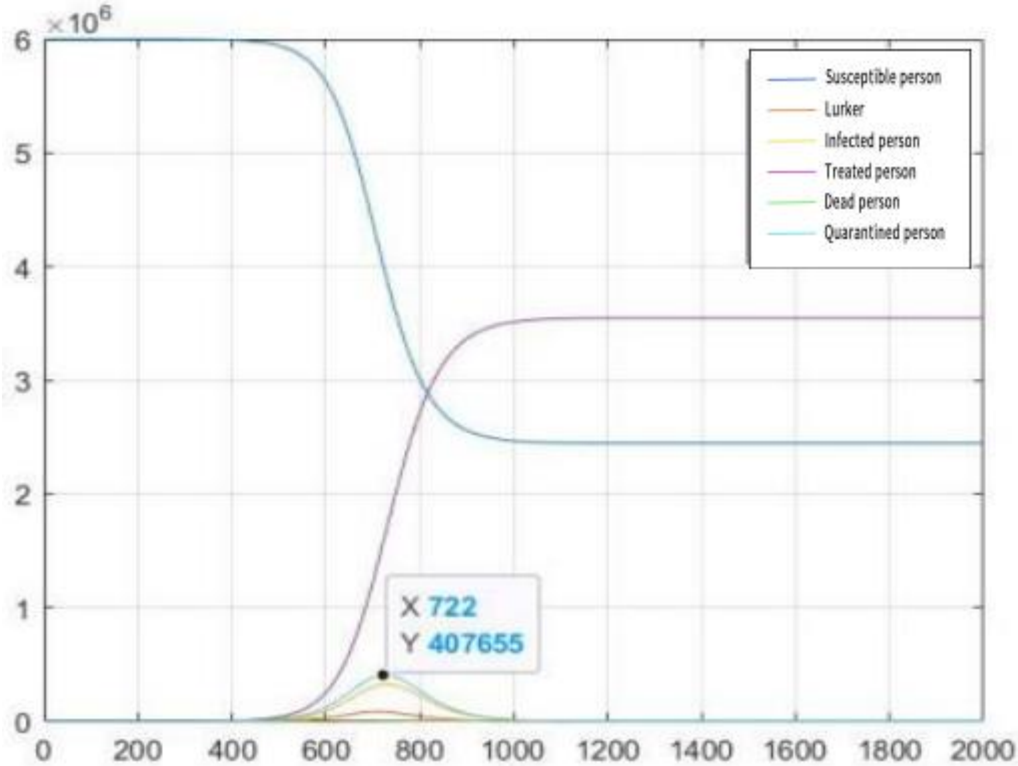

Figure 3 Curve of change in epidemic situation when quarantine resources are sufficient (100%) (epidemic prevention starts at t=0)

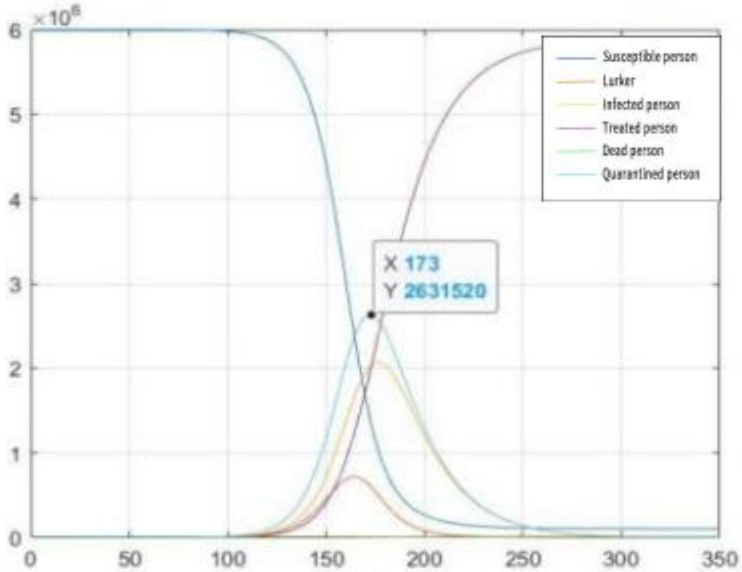

Figure 4 Curve of changes in the epidemic situation when quarantine resources are less than adequate (50%) (epidemic prevention starts at t=0)

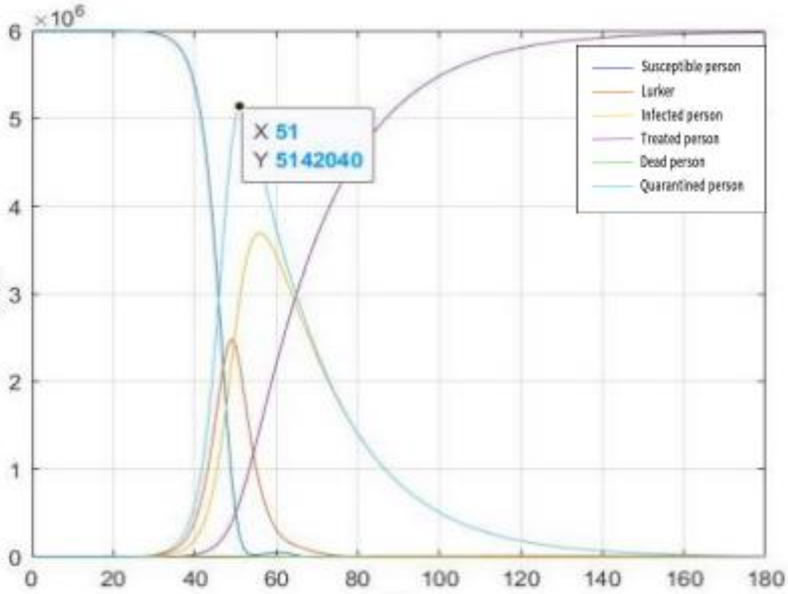

Figure 5 Curve of the change of the epidemic situation in case of severe shortage of quarantine resources (10%) (epidemic prevention starts at t=0)

Table 4 Peak curve points for different isolated resource crowding conditions

Isolated resource status	The peak of the curve corresponds to the horizontal coordinate	Percentage of people isolated	Number of isolated persons
100%	722	0.068	407655
50%	173	0.439	2631520
10%	51	0.857	5142040

A comparison of the three shows that the peak of the epidemic and the quarantine resources are negatively correlated, with the peak of the epidemic being quite small when the quarantine resources are sufficient, while when only 10% of the quarantine resources are available, the peak of the epidemic is comparable to that of the unquarantined. The occurrence of isolation resource crowding affects the forward shift of the horizontal coordinate corresponding to the peak of the curve and affects the sharp increase in the number of isolated persons. Therefore, it can be concluded that isolation resources are a very important part of epidemic prevention and control, and isolation crowding can have a very serious negative impact on the development of the epidemic.

3.4. Analysis of the situation when a resource run is encountered in a university system

Similarly, the moment of taking isolation measures is simulated in the university system by changing the value of the summation of E and I at a certain moment. Afterwards, the data of the new types of populations are modeled and analyzed using the relevant fixed parameters in the university system[5].

When the segregation resources are sufficient (100%), the change curve of the number of the four populations in the SEIR model will be shown in Figure 6.

When the segregation resources are less than adequate (50%), the change curve of the number of the four populations in the SEIR model will be as shown in Figure 7.

When there is a severe shortage of segregated resources (10%), the change curve of the number of the four populations in the SEIR model will be shown in Figure 8.

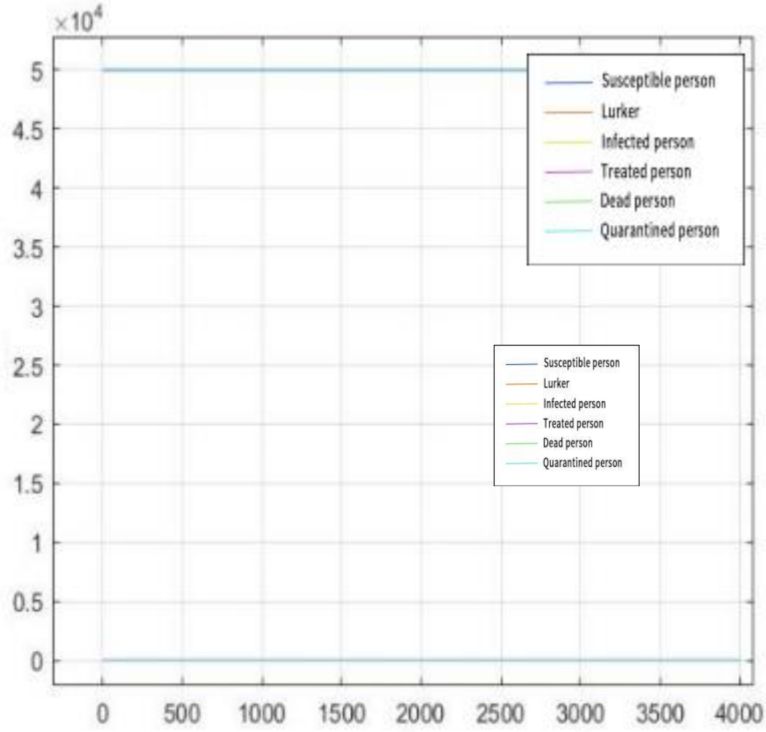

Figure 6 Curve of change in epidemic situation when quarantine resources are sufficient (100%) (epidemic prevention starts at t=0)

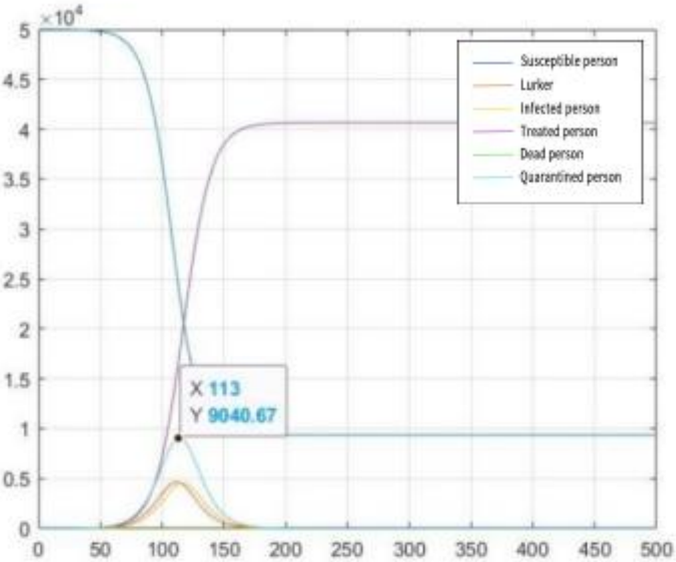

Figure 7 Curve of changes in the epidemic situation when quarantine resources are less than adequate (50%) (epidemic prevention starts at t=0)

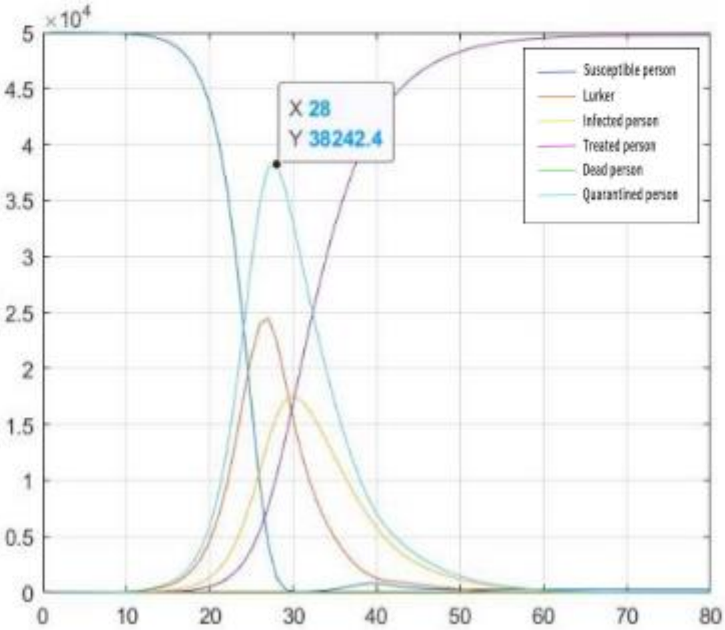

Figure 8 Curve of the change of the epidemic situation in case of severe shortage of quarantine resources (10%) (epidemic prevention starts at t=0)

Table 5 Peak curve points for different isolated resource crowding conditions

Isolated resource status	The peak of the curve corresponds to the horizontal coordinate	Percentage of people isolated	Number of isolated persons
100%	-	0	0
50%	113	0.439	9040.67
10%	28	0.857	38242.4

By comparing the three, it can be found that colleges and universities, because of their smaller numbers and easier management characteristics, even epidemics do not occur when isolation resources are sufficient, while when isolation resources are not so sufficient, they can achieve a fairly good epidemic prevention effect, and the emergence of isolation resource crowding situation will affect the forward shift of the horizontal coordinate corresponding to the peak of the curve, and will affect the sharp increase in the number of isolated personnel.

4. Conclusion

By looking at the analyzed images and data for the city system and the university system under the SEIR model, we can see that the number of people in the system that need to be quarantined, i.e., the required quarantine resources, always shows an overall trend of rising and then falling. For the urban model, the fluctuations in Figure 1 are consistent with the reality of the epidemic, and the peaks in the universities are faster and more violent than in the cities, but they also level off more quickly.

The analysis of the two models with different parameters for the university system and the city system together leads to the same conclusion that the crowding of segregated resources causes a forward shift of the peak as well as an increment in the number of segregated personnel. Therefore, it is important to focus on the related reserves of segregated resources.

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References

[1] Li Zhuo Yu. A study of two novel coronavirus pneumonia (COVID-19) infectious disease prediction model methods [J]. 2022.
[2] Zhuang Yuanyuan . Study on Multi-stage Emergency Material Distribution under Public Health Emergencies [J]. 2022.
[3] Xia Guilin, Zheng Chenyan. Optimal Vaccine Strategy Based on SEIR Dynamics Model [J].2022.
[4] Shu Chengjie, Qin Kaizhou. Analysis of novel coronavirus pneumonia outbreak based on SEIR model [J].2021.
[5] Hu Meiling. Multi-dimensional epidemic evolution simulation prediction study [J]. 2022.