COVID-19 Epidemic Spread Model and Resumption of Work and Production Strategies

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Problem Chosen

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Summary

Since the first case report in Wuhan, China, **COVID-19** has rapidly swept the world in a few months. Now, our primary task of people all over the world is to fight against the epidemic.The most important task is to **predict** the development and change of the epidemic situation. After studying a classic model,**SEIR**, we combine it with practice,we add three new categories and several **parameter** to it, establishing a new model– **Improved SEIR Model**,and successfully **predict** the epidemic situation in Hubei Province within 60 days.

After that, our next step is to put our theory into practice.Knowing the future trend of the epidemic situation, we can change the development of the epidemic situation by **adjusting parameters**, such as reducing the growth rate or changing the arrival time of the peak. We can also **design different type of parameters** to show different aspects on the spread of the epidemic.

In this paper, we use dozens of parameters to evaluate public transport industry, catering industry and long-term development strategy of our country.

Keywords:COVID-19; Improved SEIR Model; Prediction; Parameter adjustment;Policies

Content

1 Intouduction

1.1 Background

The spread of COVID-19 this year has seriously affected the development of many countries, including China. Many large enterprises close down, and various economic sectors have suffered to some extent. At present, the epidemic situation in many places has rebounded, whose main reason is the resumption of work and production. In order to effectively prevent the epidemic from raging again and help various industries to resume work and operations in a stable and orderly manner, we need to develop a reasonable plan for resuming work and production.

1.2 Restatement of the Problem

Recently, the epidemic has rebounded in many parts of the world, and new locally confirmed cases have appeared in many cities in China. There are many reasons for the spread of the epidemic, the most common of which is that people begin to work, attend parties and go shopping. Therefore, we need to work out a reasonable COVID-19 prevention strategy to control the epidemic as soon as possible. We need to establish a mathematical mode to solve the following four problems :
(1) How to guarantee a basic living supplies residents in a city, whose situation is quite sever?
(2) Please provide work and production recovery plans under different epidemic levels, fully considering the spread of epidemics and dynamic changes in product demand.
(3) How to weigh the interests of all parties from the perspective of government management to formulate a long-term national development strategy?
(4) Work out a management and control strategy for the public transportation and catering industries under different epidemic levels, so that the economy can develop steadily and control the spread of the epidemic to the maximum extent.

1.3 Our Work

We use the classic SEIR model to make assumptions and research on the spread of the epidemic. We divide the population into several categories and describe the changes of various populations over time with curves, build a mathematics model to simulate the spread of COVID-19. Then, we convert the government’s plan for resuming work and production into parameters which have some impact on this model, and through continuous fitting, a plan for resuming work in which economic develops steadily and epidemic is well-controlled can be found.

2 Assumptions

2.1 The spread of COVID-19 can be predicted through modeling analysis

The propagation of covid-19 can be predicted by modeling analysis During the epidemic period ,although the movement track, exposure, contact number and immunity of each individual are different, but according to the big data theory, in an area with enough population, the average number of people exposed, infection rate, isolation rate, conversion rate and other factors are consistent with the statistical and epidemiological characteristics. Therefore, mathematical models can be used to analyze and predict the development of the over all epidemic situation in this area.

2.2 COVID-19 and people's medical level has not mutated during the period

During the prediction period of the model, there was no mutation in covid-19, and people's medical level was almost unchanged. Although the above factors will affect the spread and development of the epidemic, but this is not the research direction of this paper. In order to better reflect the impact of living material security, return to work and production, as well as the control of transportation and catering industry on the epidemic situation, we should control the variables, keep the virus mutation and medical level unchanged, so as to obtain meaningful research results

2.3 The statistics used in this article are accurate

The statistical data used in this paper are all accurate. The statistical data used in this paper are all from government agencies and academic journals, with strong authority. We assume that the statistical data used in the modeling are accurate, so that we can conduct modeling and do in-depth analysis on this basis

2.4 The parameters used in this model are in line with the actual situation

In order to select the appropriate model parameters, we consulted a large number of references, and according to the actual policy, epidemiological characteristics of new coronavirus and other kinds of actual situation, combined with references and statistical data, comprehensively selected the model parameter values. At the same time, all parameters in this paper are consistent with people's conventional cognition. Therefore, it is assumed that the parameters used in the model are in accordance with the actual situation within the allowable error range.

3 Module Establishment and Solution

3.1 Model Overview

We selected a representative example, Hubei Province as our research object for three reasons. First of all, there is a lot of research on the province, which can be a good reference and we can learn from the results of others. Secondly, the amount of official data in Hubei Province is large enough to effectively reduce accidental errors. Thirdly, the existing data in Hubei Province is comprehensive and can basically summarize the different prevalence levels of the epidemic. After accessing some data, our group improve the SEIR model. We divide the population into

7 categories: susceptible population S, exposed population E, symptomatic population I, recovered population R, quarantined susceptible population Sq, quarantined exposed population Eq, quarantined infected population H=I+Eq (symptomatic population + quarantined exposed population). Initial values are as follows.

Tab.1 Initial value of seven categories of people

Initial Values	**Definitions**	**Estimated Mean Value**	**Data Source**
S	Initial susceptible population	5.917×10^7	[3]
E	Initial exposed population	4007	[3]
I	Initial symptomatic infected population	786	[3]
A	Initial asymptomatic infected population	30	[3]
S_q	Initial quarantined susceptible population	2776	[3]
E_q	Initial quanrantined exposed population	400	[3]
H	Initial quarantined infected population	$I + E_q$	[3]
R	Initial recovered population	31	[3]

All the dynamics are governed by the following system of equation:

$$dS/dt = -[\rho c\beta + \rho cq(1-\beta)]S(1+\theta E) + \lambda S_q \tag{3.1.1}$$

$$dE/dt = \rho c\beta(1-q)S(I+\theta E) - \sigma E \tag{3.1.2}$$

$$dI/dt = \sigma E - (\delta_I + \alpha + \gamma_I)I \tag{3.1.3}$$

$$dS_q/dt = \rho cq(1-\beta)S(I+\theta E) - \lambda S_q \tag{3.1.4}$$

$$dE_q/dt = \rho c\beta qS(I+\theta E) - \delta_q E_q \tag{3.1.5}$$

$$dH/dt = \delta_I I + \delta_q E_q - (\alpha + \gamma_H)H \tag{3.1.6}$$

$$dR/dt = \gamma_I I + \gamma_H H$$

We can establish a model to generate a graph which shows the number of people in 7 categories over time. All the following mathematics modules are based on this. Our improved SEIR model uses the data of Hubei Province before January 23 as the initial parameters, which well fits the time when the number of infected people reach the peak and the trend of actual infected data afterwards.

Also, we drew a picture to describe the relationship between various groups of people.

Tab.2 Parameters

Parameter	Definition	Estimated Mean Value	Data Source
c	Contact rate	13.04	[1]
δ_I	solation rate of infected persons	0.13	Estimated
δ_q	Transmission rate of quarantined individuals to quarantined infected class	0.13	Estimated
γ_I	Recovery rate of sympotmimatic infected individuals	0.007	Estimated
γ_H	Recovery rate of quarantined infected individuals	0.014	Estimated
β	Probanility of transmission per contact	2×10^{-9}	Estimated
q	Quarantined rate of exposed individuals	10^{-6}	Estimated
α	Disease-induced death rate	2.7×10^{-4}	Estimated
ρ	Symptoms among infected individuals	1	Estimated
θ	Ratio of transmission capacity of the contact to infected person	1	Estimated
λ	Rate at which uninfected contacts were released into the wider community	1/14	[2]

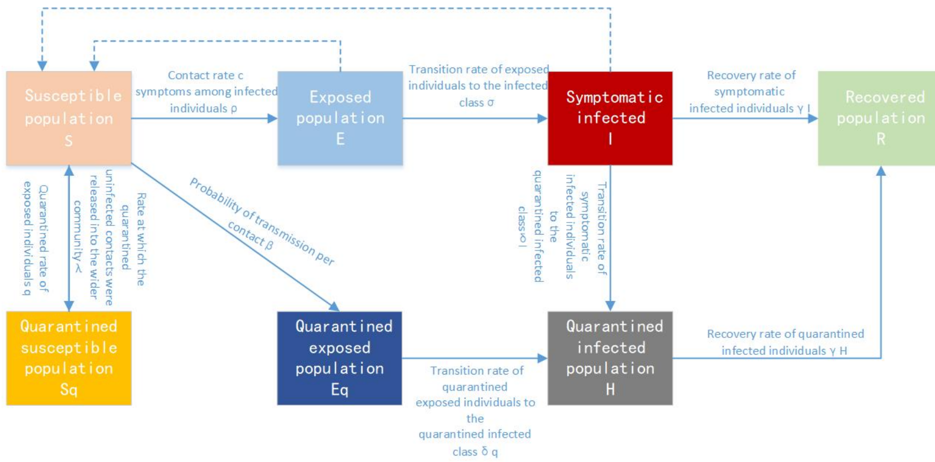


Fig.1 seven categories of population

3.2 Question One

3.2.1 Supply of Daily Necessities

Communities with infected persons: If there is one infected man in a community, all the neighbors in this area should be quarantined at home. Each household reports the number of people at home, and the government determines the amount of daily necessities to be distributed to each household on the base of the reported number and the number of registered populations. Then government sends special person to deliver the daily necessities such as grain, oil, vegetables, meat, poultry and egg to the community and place the necessities outside the community. This is the first process of delivery. Then the neighborhood committee or the residents voluntarily organize the second process of delivery, sending the materials to the door of each house, and each family will transport the materials back to their house after the delivery personnel leave. In this way, we can achieve zero-contact distribution and reduce the contact between people, which will control the spread of COVID-19.

Communities without infected persons: Communities without infected persons can moderately open dime stores in or nearby the community. Goods is provided by both government and purchasers. As the government needs to take many aspects into account at the same time, especially the needs of living supplies in quarantined communities and medical institutions, dim stores should be mainly sourced by purchasers. If the purchasers cannot deliver goods in time due to road closures and other reasons, government assists to supply the necessities needed in this area. Residents in nearby communities should go out for shopping with protective measures. Each household is issued a pass, and when entering and leaving the community, the card is swiped to record your travel time. One pass can only allow one person to travel at a time. Through these methods, we can limit the travel time of residents and the number of people who goes out in each household.

3.2.2 Supply of Medical Supplies

Supply of masks: Masks must be worn when entering and leaving public places during the epidemic. According to the information obtained, at the stage of the outbreak, masks are in short supply. First of all, medical staff and families of the infected in medical structures should be guaranteed. Then, we need to try to meet the needs of common urban residents. In order to benefit as many residents as possible, the number of masks purchased by each person should be limited. For example, we can rule that before you buy masks, you should make an appointment, registering how many masks you are going to buy. The number for each one every day is limited. In the middle and late stages of the epidemic, with the resumption of work and production in some factories, the amount of masks increase and the shortage is no longer as serious as before. The supply of masks can be appropriately increased. However, there shouldn’ t be too many masks available for residents. The supply of masks can just meet the basic needs for each household, not too much or too little. In this way, through the supply of masks, we can control the number of travelers indirectly and furthermore, control the spread of the epidemic. It is also important to store some masks in case of emergencies and prevent the shortage of masks during the second recurrence of the epidemic. At the same time, the government can encourage residents to use masks correctly and reuse them reasonably.

Supply of disinfection supplies: These products are divided into two types: medical and non-medical. For medical products, such as medical alcohol, disinfection water, etc., medical institutions’ needs should be met first. If there is surplus and the medical institution has a certain amount of storage, it can be appropriately distributed to quarantined communities. If there is still surplus, it can be on sale to common residents, with prices set by government. Also, we can refer to the front method which we use for masks. For non-medical products, a supply plan similar to the aforementioned masks can also be adopted.

3.3 Question Two

We select the public transportation industry as our research object. According to the number of symptomatic infected population I, we divide the spread level of epidemic into five levels: mild risk, low risk, medium risk, high risk, and martial law. The symptomatic infected population I of each level is as follows:

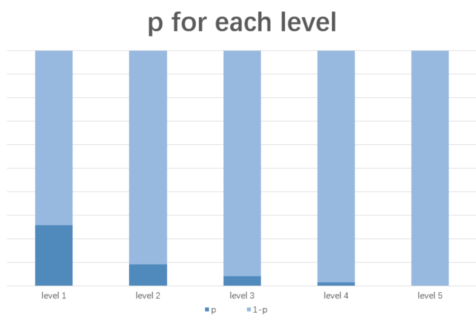
Tab.3 Symptomatic infected population I of each level

Level of epidemic	mild risk	low risk	medium risk	high risk	martial law
I	<20	20∼200	201∼800	>800	>60000

According to the reference, we define I as the number of initially infected persons in each epidemic level, c as the contact rate, n as the travel frequency at different levels, c_0 as the contact rate without public transportation and c_p as the exposure by public transportation rate, p is the willingness of people to take public transportation under different epidemic levels (p is 100% when there is no risk). After referring to data, the p, and n of the five epidemic levels and c of mild risk level are known. Also, the initial value of I can be assumed according to Fig.1. Among the five groups of data, the martial law level (in Hubei Province) deviated seriously. In fact, martial law has already started when the symptomatic infected population was about 1,000. Therefore, the symptomatic infected population of martial law level is initially set at about 1,000. The relevant values for each level are as follows.

Tab.4 p n c for each level

Level of epidemic	mild risk	low risk	medium risk	high risk	martial law
p	0.257	0.049	0.051	0.039	0
n	0.61488	0.35457	0.31143	0.33190	0.23167
c	13.40				



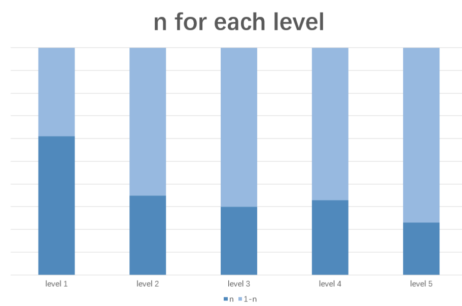


Fig.1 & Fig.2

According to the folowing two equations:

$$c = n[c_0(1-p) + c_p p] \tag{3.3.1}$$

$$c_p = 4c_0 \tag{3.3.2}$$

We can work out the value of c_0 and c_p for minor risks:

$$c_0 = 12.6156 \qquad c_p = 50.462$$

Since people have not fully realized the importance of prevention at the beginning of the epidemic, they have not taken any corresponding preventive measures. So we can assume that the contact rate of taking or not taking public transportation is the same at all levels of the epidemic. We take the calculated c0 and cp as constants, and then substitute the n and p of other levels to calculate the initial c values of the five epidemic levels. The initial c values of the five levels are as follows.

Tab.5 c for each level

Level of epidemic	mild risk	low risk	medium risk	high risk	martial law
$c(\%)$	13.60	6.0893	4.1177	3.7235	3.4249

Taking the spread of the epidemic and the impact of changes in the number of infected people on people' s willingness to travel and travel frequency into account, we improved the SEIR model with adding the iterative process of c to the differential equation. Now c is not a steady value. When the number of infected people increases and people's willingness to travel and travel frequency decreases, c decreases accordingly; otherwise, c increases.

Since continuous n and p values are required during iteration while values obtained from the previous review of the data are discrete and cannot form a function to participate in the iteration of the epidemic model, we use the fitting toolbox in MATLAB for fitting.The fitting figures are as follows.

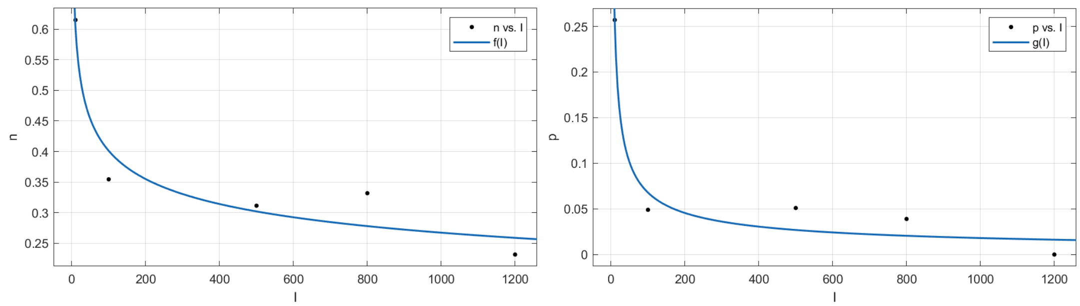


Fig.3 fitting figures

Then we get the n, p function of I as follow.

$$n = f(I) = aI^b \qquad a = 0.9029 \qquad b = -0.1762 \tag{3.3.3}$$

$$p = g(I) = cI^d \qquad c = 0.9587 \qquad d = -0.5752 \tag{3.3.4}$$

Using constraints (3.1.1) $\sim$ (3.1.7) and formulas (3.3.1) $\sim$ (3.3.4), we can simulate the spread of the epidemic in different situations, and then study the company's resumption of work and production plans.

3.3.1 The level of the epidemic situation at which bus companies start to resume work and production

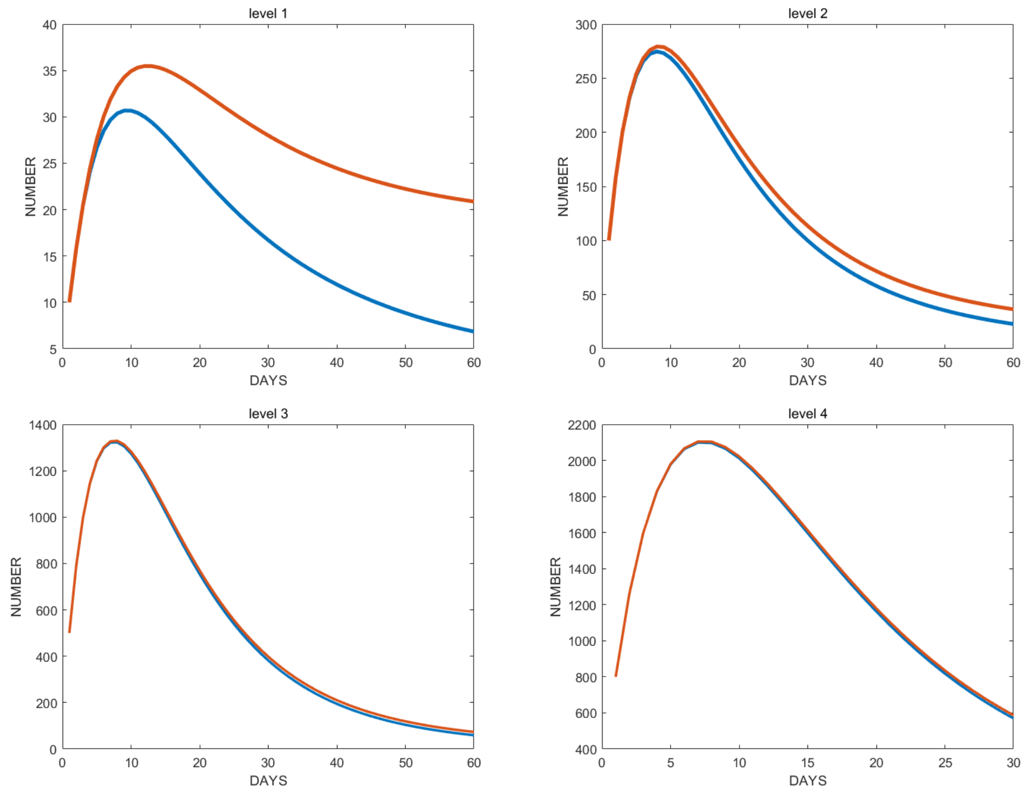
We discuss the impact of the resumption of work by bus companies on the epidemic (whether it will lead to an increase in the number of infected people) under different levels of yiq. The parameter values under different epidemic levels are as follows

Tab.6 Symptomatic infected population I of each level

Level of epidemic	mild risk	low risk	medium risk	high risk	martial law	Data Source
r	30%	30%	30%	30%	30%	Parameter estimation
$I(0)$	10	100	500	800	1200	Calculations
$S_q(0)$	35	350	1750	2800	4200	Calculations
$E_q(0)$	5	50	250	400	600	Calculations
$E0$	50	500	2500	4000	6000	Calculations

It is assumed here that the government has taken some necessary prevention and control measures (wearing masks, etc.) when resuming work and production, and the effective contact rate is reduced to 30%

We have drawn a bar graph to describe people's williness to take public transportation at different epidemic levels, with the abscissa the days and the ordinate the number of people traveling by bus.



red-resume work blue-not resume work

Fig.4 people's williness to take public transportation at different epidemic levels

Combining the four charts, we can conclude that:

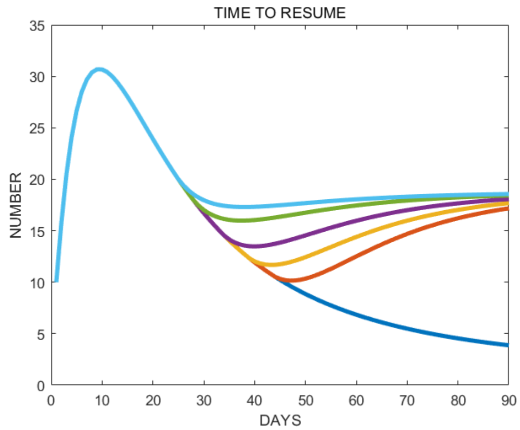
Minor risk: People are more willing to take public transportation, and there are more passengers. Therefore, if companies do not take measures to prevent when resuming work and production, it will inevitably cause an increase in the number of infected people and a prolonged period Therefore, if bus companies want to resume work, they must take additional preventive and control measures.

Low risk: People have a certain demand for public transportation, but the demand is not large, and resumption of work will have little impact on the epidemic (according to this model, less than 5 people will be added)

Medium risk and high risk: The willingness to travel and the willingness to take public transportation are both small. Almost no one wants to travel by public transportation anymore. This can also be reflected from the changes in public transport to the epidemic (too little to have an impact on the spread of the epidemic). Therefore, it is not recommended to resume work. The fifth level is a state of martial law. Therefore, resuming work at this time is not in line with reality, and no one travels by bus, so work will not resume.

3.3.2 Strategies of resumption of work and production

Minor risk: In order to prevent the current minor epidemic from rebounding or spreading, public transportation companies need to determine the timing of resuming work and production based on the current development trend of the epidemic. According to common sense, if the company’ s reunification leads to an increase in the epidemic, then it should resume work during the decline period of the epidemic. The time to resume work here is 75%, 65%, 55%, 45%, and 35% of the peak of the epidemic. The model/fitting result picture are as follow.

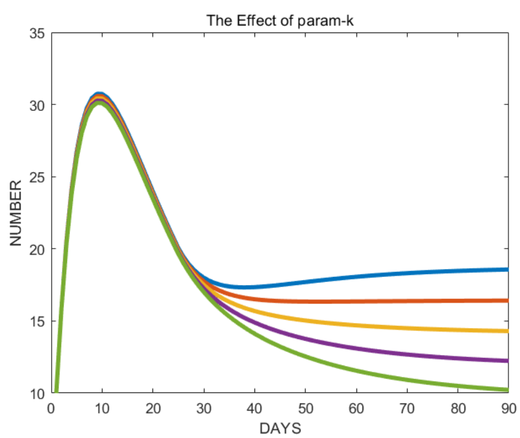


Blue means no resumption of work and production, light blue to red is 75%-35%

Fig.5 different resume time

It can be seen that if no additional measures are taken to control the epidemic, the resumption of work at different times will eventually increase the number of infected people and converge to about 75% of the peak of the epidemic. Taking into account the profitability of the company, the time to resume work is chosen to be 75% of the peak of the epidemic

At this time, if the bus adjusts the full load rate k to reduce the contact rate on the bus, it is possible to bring the epidemic under control. Take k=1, 0.9, 0.8, 0.7, 0.6 to get pictures as below.



light blue-dark blue k : 0.9-0.7

Fig.6 different full load rate

It can be seen that the full load rate is 0.9-0.6

Under the above conditions, take k=0.6 and observe the dynamic change of the number of people taking public transportation after resuming work.

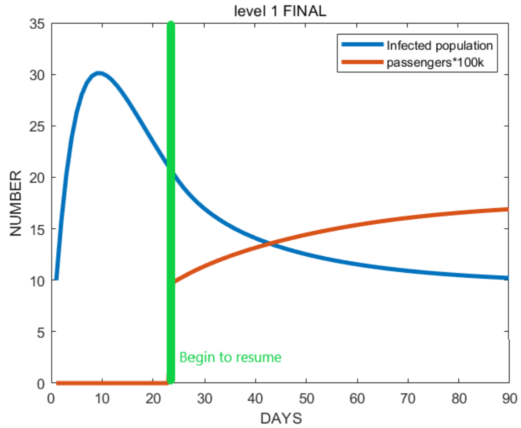


Fig.7 k=0.6 dynamic change of the number of people taking public transportation after resuming work

It can be seen from the figure that the number of bus trips has steadily increased and stabilized after the resumption of work. The final willingness to travel by bus was about 25%, which has basically returned to the initial level of the epidemic.

Low risk: Since the resumption of work has less impact on the epidemic, the bus company only needs to implement government epidemic prevention measures. The dynamic change of the number of people taking the bus at this time is shown in the figure.

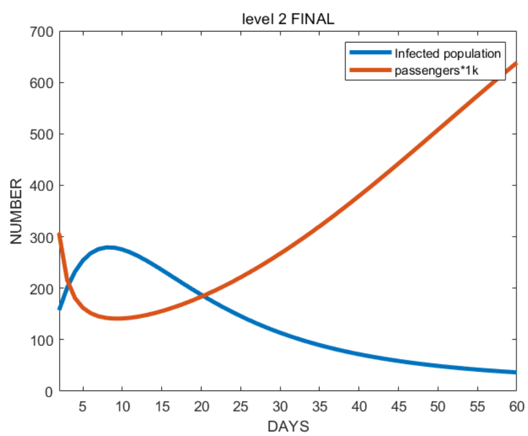


Fig.8 dynamic change of the number of people taking the bus

As can be seen from the figure, due to the increase in the number of confirmed cases in the early stage of the epidemic, the willingness to take public transportation will decrease. However, as the epidemic is gradually brought under control in the later period, the number of people taking public transportation will gradually increase. However, the number of people taking public transportation under this epidemic level is not very large. The willingness to take public transportation within 90 days is less than 9%. Therefore, the bus company can appropriately reduce the operating frequency and reduce the number of stops.

In conclusion, people are more willing to take public transportation during periods of mild risk, and the number of passengers is large. The bus company needs to take certain measures or the epidemic will spread rapidly; the willingness to travel during medium-risk and high-risk periods is very small, so it is not recommended to resume work.

If work is to be resumed in mild or low-risk areas, the resumption time is 75% of the peak of the epidemic, and the full load rate is 0.6-0.7. In low-risk areas, because the resumption of work has less impact on the epidemic, the bus company only needs to implement government epidemic prevention measures. The bus company can appropriately reduce the operating frequency and reduce the number of stops.

3.4 Question Three

3.4.1 Resumption Rate and Epidemic Prevention and Control Measures after Resumption

The resumption of work and production will lead to an increase in population mobility and cause crowd gathering. However, if production is suspended for a long time, the economy cannot develop. Therefore, it is necessary to weigh the interests of all parties and to restore some industries in an orderly manner while ensuring that the epidemic will not become more serious. After the resumption of work and production, the epidemic level should be mild risk, and the value of the parameter should meet the level standard. To control variables, we believe that the government's prevention and control strategies will not change over time after the resumption of work and production. Without loss of generality, we can regard the impact of population movement on the development of the epidemic after the city' s resumption of work and production as a result of the resumption of work and production in major cities across the country.

Our country's urban employment ratio w_p is 52.15%.Resumption rate is p_m, contact rate in the workplace is c_w, and the effective contact coefficient is ρ_w.

Conditions or assumptions: The epidemic has been initially brought under control. Since the proportion of the quarantined, ill, and hospitalized labor population in the total labor population is very low, the impact of quarantine, morbidity, and hospitalization on the proportion of the employed population is considered to be the proportion of employees after resumption. The frequent contact of non-working personnel is mainly on the way to and from work and at work. The model can be modified to test how these parameters are made by adjusting the resumption rate pm and the effective contact rate pw at work.

Actual contact rate changes over time:

$$c = c + w_p * c_w p_m p_w$$

Parameter estimation:

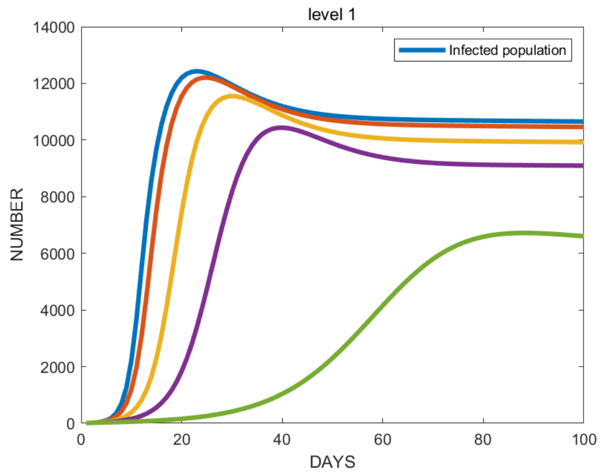
$$c_w = 1.5 c_p$$

(cp is the contact rate by bus, plus 0.5 is the extra contact at office)

We can adjust p_w, p_m, from our referrnces, we know that

$$I = 10 \quad S = 11212000 \quad E = 50$$

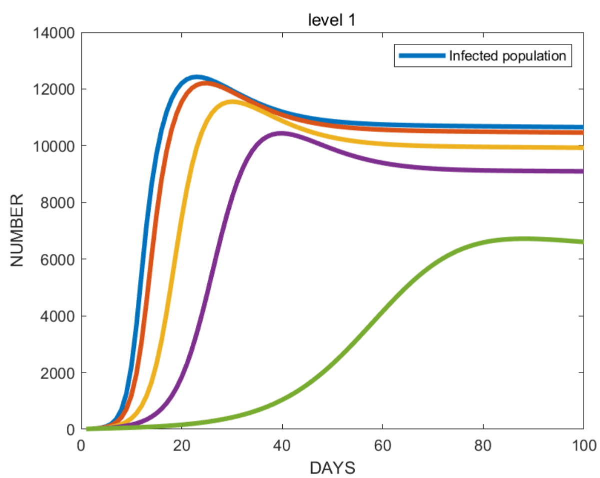
Due to the low level of the epidemic, priority should be given to the rate of resumption of work and production. When p_w=1, adjust the p_m value to obtain the following picture.



p_m: blue-1 red-0.8 orange-0.5 purple-0.3 green-0.1

Fig.9

p_m=1, adjust p_w to get the following figure

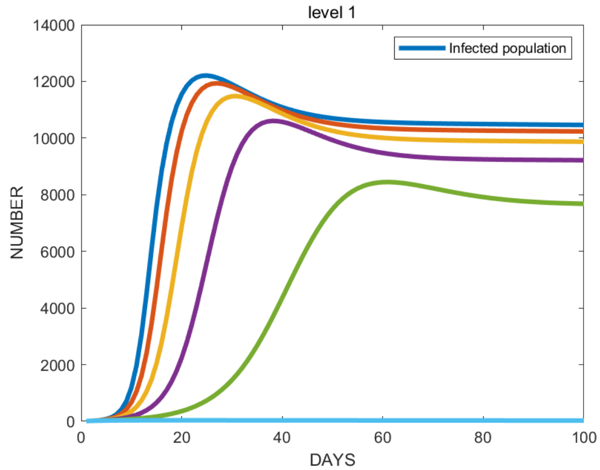


p_w: blue-1 red-0.8 orange-0.5 purple-0.3 green-0.1

Fig.10

Combining the two figures shows that pm and pw can effectively reduce the recurrence of the epidemic. In order to ensure economic development, more production should be resumed, so the resumption rate is set to 0.8. Let's explore the value of pw effective contact coefficient.

When pm=0.8, change pw to get the following figure



p_w: blue-1 red-0.8 orange-0.5 purple-0.3 green-0.1

Fig.11

It can be seen from the figure that by reducing the effective contact coefficient, the outbreak of the epidemic can be avoided to a great extent.

From the perspective of government management, the government should strengthen management and control for the resumption of work and production under the epidemic situation, compulsory people wearing masks, mandatory work station isolation, etc.. They should reduce the effective contact coefficient as much as possible, and take strict precautions while maintaining a high resumption rate in case of epidemic broke out again.

3.4.2 Order of 42 Industries to Resume Work and Production

After consulting to information, we learned that there are 42 major industries at present. How to determine the order of resumption of work and production among these 42 industries is the problem we need to solve. We use two parameters, influence coefficient φ and inductance coefficient θ_c to describe the influence these industries have on the national economy and other industries. The influence coefficient reflects the extent to which an industry affects other industries, and industrial sector with a larger influence coefficient has a larger radiation capacity for social production. The sensitivity coefficient is the degree of demand sensitivity that a certain department receives when each department of the national economy increases by one unit for final use, that is, the amount of output that the department needs to provide for the production of other departments. It reflects the extent to which an industry is affected by other industries, and a larger induction coefficient an industry has, a greater effect it has on economic development. Using these parameters to calculate, we can determine a reasonable sequence for resuming work and production. From the data, the values and rankings of φ and θ_c of 42 industries are are already known.

According to the importance of resuming work and production, we divide the industries into five levels: very urgent, relatively urgent, urgent, general, and not urgent. Using fuzzy mathematics, the membership degree of each industry to the five levels is calculated. The figure of membership functions of the five levels are as follows.

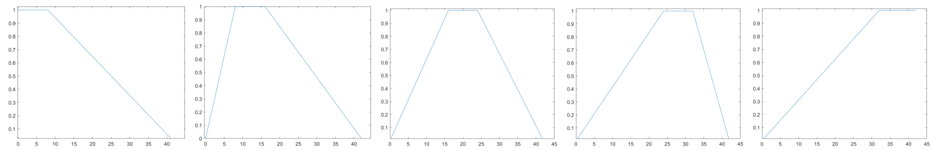


Fig.12 figures of membership functions of the five levels

Bring the ranking of influence coefficient and sensitivity coefficient of each industry into the five-level membership function to obtain a membership matrix R for each industry.

$$R = \begin{pmatrix} r_{11} & r_{12} & r_{13} & r_{14} & r_{15} \\ r_{21} & r_{22} & r_{23} & r_{24} & r_{25} \end{pmatrix}$$

In the matrix, $r_{11} \sim r_{15}$ are the membership degrees of the industry's influence coefficient to the five levels, and $r_{21} \sim r_{25}$ are the membership degrees of the industry's sensitivity coefficient to the five levels. Next, we need to calculate the five-level membership matrix of each industry with comprehensively considering the influence coefficient and the sensitivity coefficient, that is, the normalized membership degree. We believe that the importance of θ_c and φ to an industry is equal, so the weights of θ_c equals with φ, both 1. Therefore, the membership matrix of each industry is

$$B = \begin{pmatrix} b_1 & b_2 & b_3 & b_4 & b_5 \end{pmatrix}$$

$$b_j = r_{1j} + r_{2j} \tag{3.4.1}$$

After getting the normalized membership degree, we use the formula below to calculate the evaluation score of each industry.

$$c = \sum_{i=1}^{5} (6 - i)\, b_i = 5b_1 + 4b_2 + 3b_3 + 2b_4 + 1b_5 \tag{3.4.2}$$

The evaluation score of each industry now has been calculated. The higher the score is, the more urgent to resume work as soon as possible. Finally, we conclude that computer, communications and other electronic equipment manufacturing, chemical industry, metal smelting and rolling, electrical machinery and equipment manufacturing, and transportation equipment manufacturing have higher scores, respectively 10.4214, 10.0361, 9.6410, 9.6410, 8.8633, These industries are relatively urgent and need to resume work as soon as possible. Education, public management, waste resource utilization industry, tobacco processing industry, entertainment industry scores are lower, respectively 1.4037, 2.2115, 2.2289, 2.8762, 3.2165, these industries do not have to resume work in a hurry.

3.5 Question Four

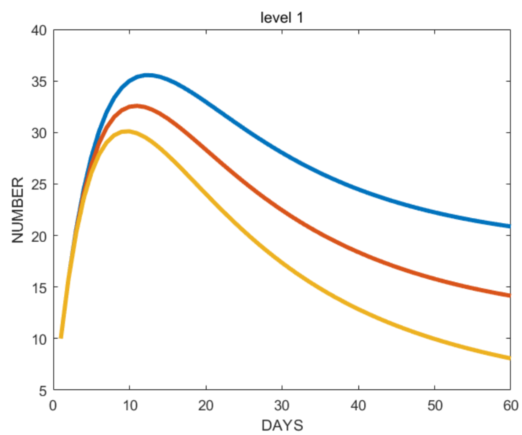
3.5.1 Public Transportation Industry

Public transportation can provide guarantee for the resumption of work and production, and the resumption of work and production can provide support for economic development. This section uses modeling to see how to maximize the control of the spread of the epidemic and ensure the maximum normal operation of public transport.

Impact of Wearing Masks on the Epidemic

Suppose that the public transportation industry changes effective exposure and controls the epidemic by arranging staff on buses to supervise passengers wearing masks and spaced seats, and adjust the degree of control by changing the number of staff, thereby changing the effective contact rate ρ.Without loss of generality, the contact rate ρ in the SEIR model is divided into the contact coefficient ρ_p when taking a bus and the contact coefficient ρ_1 in other situations.

To control the variable, fix ρ_1 unchanged (assuming $= 0.3$), and adjust ρ_p to observe the impact of wearing masks on buses on controlling the spread of the epidemic. According to the analysis of the second question, when the epidemic is at the first level, the effect of changing prevention and control measures is obvious. Therefore, without loss of generality, the first level is taken as an example here. Adjust $\rho_p$to 0.3 (the same as government prevention and control), 0.2 (most people wear masks), and 0.1 (everyone wear masks). The results are shown in the figure



blue-0.3 red-0.2 yellow-0.1

Fig.13

It can be seen from the figure that if everyone on the bus wears a mask, the number of infected people will drop significantly and the epidemic control cycle will be greatly improved. Therefore, during the epidemic, the government requires everyone on the bus to wear a mask. Has a great positive effect on epidemic prevention and control.

Impact of Bus Operations on the Epidemic

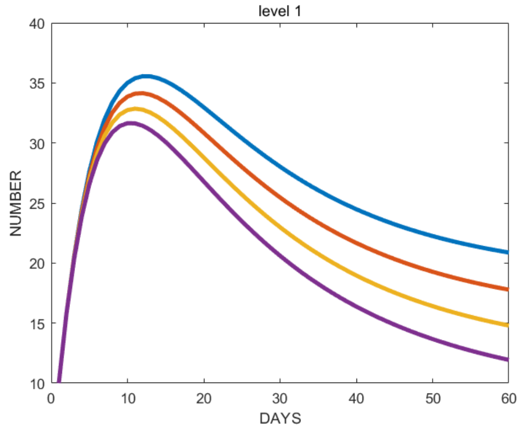
As we all know, taking public transportation during the epidemic will increase the spread of the epidemic and the infection rate, and will have an adverse impact on the prevention and control of the epidemic. Therefore, the government needs to adjust the bus operation schedule during the epidemic. Calculate k_p=operating shifts during the epidemic period/weekdays operating shifts, then k_p belongs to (0,1) at this time

$$p = k_p p$$

Let

$$\rho$$

=0.3 at this time, adjust k_p to 1, 0.8, 0.6, 0.4, and the results are shown in the figure



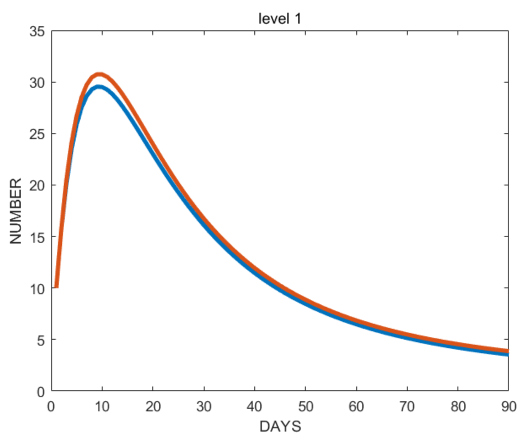
blue-1 red-0.8 yellow-0.6 purple-0.4

Fig.14

Public Transport Management and Control Strategies at Different Levels

level 1

According to the discussion of the second question, when the epidemic situation is in the first level, the resumption time should be 75% of the peak of the epidemic situation and the number of infections, and the full load rate is 0.6-0.7. Here, the full load rate is 0.7 At the same time, based on the above discussion, take ROUp=0.1. As the epidemic level is low, the rate of resumption of work and production is higher. In order to meet the demand for work, take kp=1 at this time. Taking the epidemic growth curve of the suspended bus as a control, draw the epidemic growth curve at this time, as shown in the figure



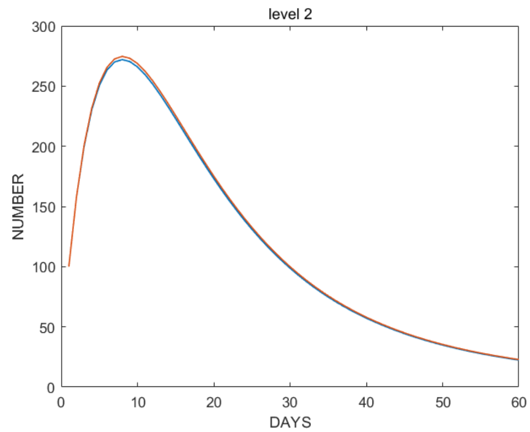
blue - control group for the suspension of buses red line - spread of the control strategy

Fig.15

It can be seen from the image that this prevention and control strategy will not have a major impact on the development of the epidemic. At the same time, according to the discussion of the second question, the number of people taking public transportation will gradually return to the normal value at this time, which shows that this strategy can guarantee the residents' work and travel needs. Therefore, government policies can be appropriately relaxed at this level.

level 2

According to the above discussion, when the epidemic is at the second level, the full load rate is also adjusted to k=0.7,ρ_p=0.1. At this time, assuming k_p=1, draw the picture below



blue - control group for the suspension of buses   red line - spread of the control strategy

Fig.16

It was found that taking public transportation under this control strategy had little impact on the development of the epidemic. According to the discussion in the second question, the ratio of the number of people who take public transportation at this level to the number of people who take public transportation on weekdays is about 9%/25%=36%. Therefore, the government can reduce the bus operation frequency to 30% to 40% of the weekdays. To meet demand, it is also possible to reduce public transport investment by closing branch roads and retaining trunk roads.

other levels

According to the discussion of the second question, there are very few people taking public transportation at other levels, and most companies have not resumed work and production. Therefore, the government does not need to carry out large-scale municipal and public operations. However, in order to meet the needs of medical material production, food and drug production, and medical personnel, some shifts can be temporarily opened to transport personnel working at the frontline of the fight against the epidemic such as medical companies, pharmaceutical companies, food processing companies, and hospitals.

3.5.2 Public Catering Industry

Similar to the second question, it can be considered that the initial contact rate c is the same under different epidemic levels, which is 3. Compared with the previous value 13.04, it decreases because in the later stage of the epidemic, people' s awareness of epidemic prevention has increased so the contact rate effectively decreases. The only parameters which varied from each other are the initial values of the Symptomatic infected I and Exposed population E (estimated by parameters, I/E=1/5). P_p is the return to work rate; p_r is effective contact coefficient when dining; k_r is restaurant attendance rate; c_r is dining contact rate; p_{r0} is probability of eating out under non-epidemic conditions. N_r is the number of people eating out. According to reference, there are

$$Nr = NP_p p_r k_r$$

At the initial value of c of 3, increasing dining will lead to an increase in the contact rate, so c changes dynamically every day, and its expression is as follows

$$c = c + p_r c_r k_r^2 P_p$$

Since the contact rate c mentioned above is estimated based on the references when the catering industry is closed, it is assumed that the contact rate c mentioned above does not include contact caused by eating out. According to parameter estimation, it can be considered that the contact rate of dining out

$$c_r = 2c_0$$

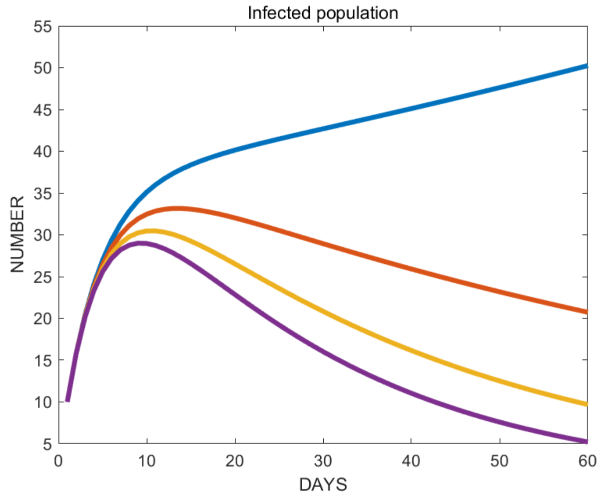
The purpose of our model is to increase return to work rate P_r and restaurant occupancy rate K_r as much as possible (increase the number of people eating out at the end, N_r) while ensuring that the epidemic does not break out again (the number of infected persons I does not increase). Combining with daily experience, the number of people going out for dinner in a normal day is about 0.3, so

$$p_{r0} = 0.3$$

Restaurants can control the contact rate by adjusting the resumption rate and occupancy rate under different epidemic levels, that is, adjusting the k_r and to observe the changes in the number of Symptomatic infected, so as to determine that N_r is as high as possible when E does not increase.

After constantly adjusting the parameters, we get the following results.

Mild Risk: The resumption rate can be set to 0.8, and the occupancy rate can be changed to 0.6, 0.5, 0.4 and 0.3. The results are shown in the figure. We find that when kr is 0.5, the epidemic can be controlled. At this time, the number of diners N is 1.34544 million person per day.



k_r : blue-0.6 red-0.5 yellow-0.4 purple-0.3

Fig.17 Mild Risk

Low Risk: The resumption rate can be set to 0.8, and the occupancy rate can be changed to 0.6, 0.5, 0.4, 0.3. The results are shown in the figure, and it is found to be almost the same as the minor risk. When kr=0.5, the epidemic can be controlled. At this time, the number of diners Nr is about 1.34544 million per day.

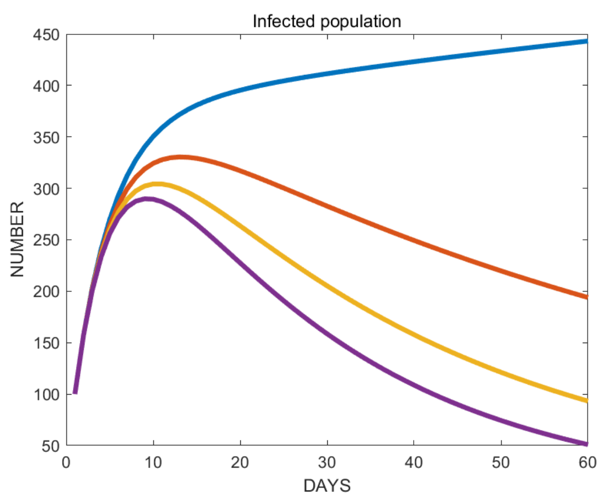


Fig.18 Low Risk

k_r : blue-0.6 red-0.5 yellow-0.4 purple-0.3

Medium Risk: At this time, the resumption rate will decrease slightly and we set it to 0.6. Change kr o 0.8, 0.7, 0.6, 0.5. Since the number of the epidemic has exceeded one thousand, a tougher control strategy should be selected, so we choose kr to be 0.5. The number of people eating out at this time is about 1.00908 million per day.

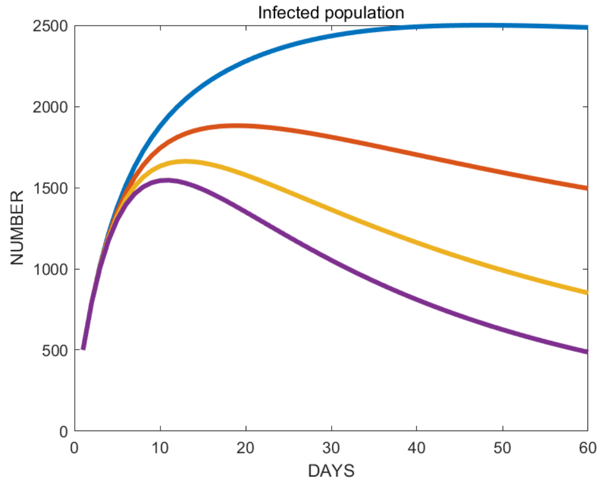


Fig.19 Medium Risk

k_r : blue-0.8 red-0.7 yellow-0.6 purple-0.5

High Risk: The epidemic is quite serious and only a few restaurants can opene. The resumption rate is set to 0.4, and kr is changed to be 0.8,0.6,0.4,0.2 . When kr is 0.8, the number of people rises to nearly 3000, and it is still over safety level after 60 days. It is already a high-risk situation, so we should pay attention to prevention and control. We choose to be 0.4, which can effectively suppress the recurrence of the epidemic while taking the efficiency of resuming work and production into account. The number of people eating out at this time is about 538,200.

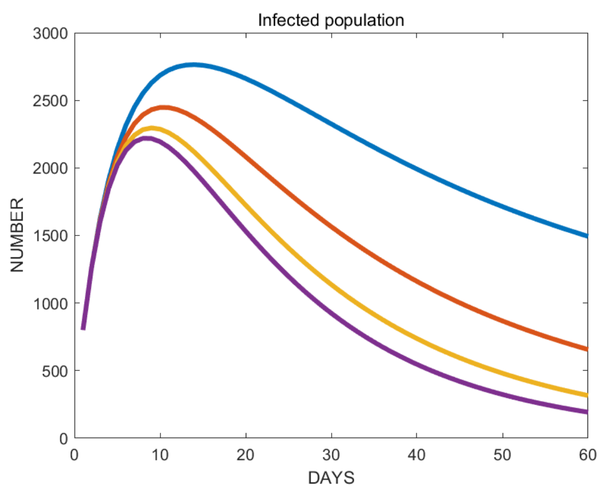


Fig.20 High Risk

k_r : blue-0.8 red-0.6 yellow-0.4 purple-0.2

Martial Law: The epidemic is extremely serious, so the rate of resumption of production is reduced to 0.2, and kr is chosed to be 0.5. Even so, the number of infected people exceeded 3,000 on the fifth day. Therefore, it is not recommended to resume work and production at this risk level.

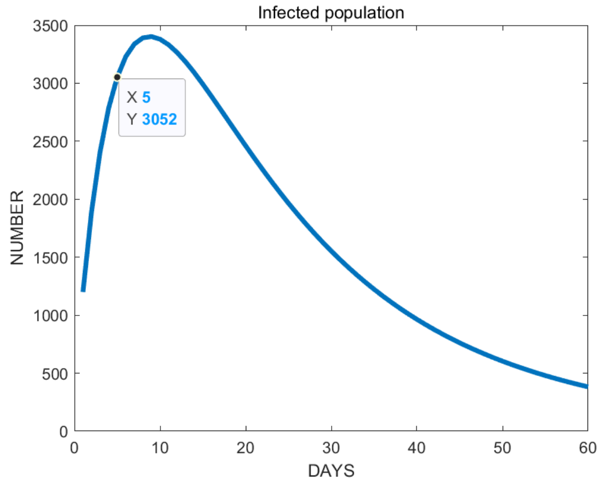


Fig.21 Martial Law

k_r : blue-0.5

4 Analysis of the Advantages and Disadvantages of the Model

4.1 Model Evaluation

4.1.1 Advantages of the Model

(1)With the deepening of research, our improved SEIR model proved to be the more realistic one. Refer to the classic SEIR model, Based on the current complex reality,we add three new categories and several parameter to it. Taking the epidemic data in Hubei as an initial value in January 23rd. The number of infected population in the next 30 days predicted by our model is basically the same as the actual value in Wuhan

(2)Our model has stronger universality. For the public transport industry, catering industry and the country's long-term development strategy, We designed different parameters. By adjusting these parameters, We can intuitively understand the impact of different policy plans on the development of the epidemic, so that we can customize the optimal strategy for it.

4.1.2 Shortcomings of the Model

Our model is established under specific control conditions, so it can achieve good prediction fitting effect in a short time (within 60 days), but it may lead to large deviation when used in long-term prediction. Moreover, due to the accurate parameter setting, complex parameter estimation is needed in policy making under epidemic situation in other fields, otherwise over fitting may occur.

4.2 Promotion of the Model

In order to simulate the actual epidemic situation more truly, we can add conditional statements to the iterative function to simulate the policy changes with the change of epidemic level, So that we can better complete long-term prediction.

5 References

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3 $http://tjj.wuhan.gov.cn/tjfw/tjgb/202004/t20200429_1191417.shtml$

4 Estimation of the Transmission Risk of the 2019 nCoVand Its Implication for Public Health Interventions,Biao Tang, Xia Wang , Qian Li , Nicola Luigi Bragazzi , Sanyi Tang , Yanni Xiao and Jianhong Wu