

Scientific management of subsistence materials during the COVID-19 outbreak in Changchun

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Abstract. In this paper, we firstly constructed an improved SEIR model to predict the development of the epidemic in Changchun without control measures and compared it with the actual situation; meanwhile, we introduced regenerative numbers to calculate OR using realistic data and observed the interval of OR before and after the distribution of vegetable packs. Secondly, the problem of planning multi-level logistics network planning for supply-demand balance is addressed for the design of preplanning for the orderly distribution of residents' living materials in the case of large-scale closure control. Meanwhile, according to the measurement standard of 400 grams of vegetables consumed per person per day, the material demand of each cell in the downstream of all networks is obtained. The real street route distance between each node is used as the weight of the edge in the ordered network graph, and then the transshipment volume of each midstream of the network is introduced, and similarly the transshipment volume of the midstream can be derived from the supply volume of supplies that need to be guaranteed to be provided in the upstream of the network. After that, large trucks (10T load) and small trucks (4T load) are used to transport materials respectively for comparison and analysis. In actual material distribution, trucks with corresponding load should be selected reasonably according to the scale of demand.

Keywords: SEIR, Multi-level logistics network planning.

1. Introduction

Since the rapid spread of the new coronavirus and the outbreak of the epidemic in 2019, China's economic development and social security have been significantly affected, and this disaster is one of the most serious challenges in the field of public health in China. Considering the highly infectious virus and the intricate population, universal home quarantine is currently the optimal choice [1]. However, due to the temporary absence of a standardized epidemic clearance mechanism, many residents are panicking in the procurement of household materials under the immature community closure and control management, fearing both the lack of access to adequate supplies and the secondary spread of the epidemic. How to manage living materials scientifically is an important issue to effectively prevent and control the epidemic and protect residents' lives [2].

2. Establishment of SEIR model

The SEIR model divides the population into four categories: susceptible individuals, those who are not infected with the virus but are at risk of being infected by other individuals. Latent, people who have been infected with the virus but have no obvious symptoms; infected people, people who have developed symptoms of infection and will also infect healthy population; and emigrants, people who have recovered from illness, died, or have existing antibodies [3]. Incubators in a new coronary pneumonia outbreak can also be seen as Asymptomatic infected persons can also transmit the virus because the virus is highly infectious; in this case, infected persons are equivalent to indigenous infected persons. The susceptible individuals in this case are equivalent to the indigenous infected

individuals. The relationship between susceptible, latent, infected, and emigrants in the SEIR model is shown in Figure 1.

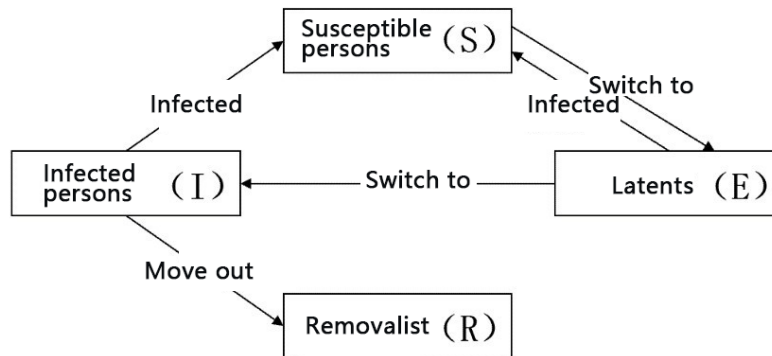


Figure 1. The relationship between the various populations in the improved SEIR model

Specifically, by establishing ordinary differential equations to express the rules of dynamic changes in the number of these four types of populations over time, through simulation experiments, the reveal the kinetic characteristics of the spread of the new coronavirus in Changchun City, and compare and analyze the differences from before and after the distribution of vegetable packs:

(1) Infection coefficient $\beta = nb$ [4]. n refers specifically to the average daily number of contacts with healthy people for cases capable of transmitting the virus. b represents the infection rate of a single contact, and according to the literature, the value of b is 0.0525 [5].

(2) In this paper, α is set as the probability of a latent person turning into an infected person. According to data from the National Health and Wellness Commission, the virus has a

The average incubation period is 7 days at the shortest and 14 days at the longest, so $\alpha = 0.1$ is taken.

(3) Migration rate γ . The migration rate depends on the average duration from diagnosis to cure or death and is taken as $\gamma = 0.2$ [6].

(4) N, S_0, E_0, I_0, R_0 Refer to the data published by Changchun Statistical Yearbook, Health and Health Commission.

Table 1. Related parameter values

Parameters	Value	Parameters	Value
N	908.72 million		0.1
n_1	5		0.2
n_2	10	S_0	$N E_0 I_0 R_0$
b	0.0525	E_0	5
1	0.2625	I_0	12
2	0.5250	R_0	0

In this study, the SEIR model was used to solve problem 1, and some improvements were made to the original model: during a new coronary pneumonia epidemic, the incubators in this model are as infectious as the infected due to the strong contagiousness of the virus, and there is a certain probability that the susceptible person will be infected with the virus when they have close or such close contact with the susceptible person. The SEIR model in this paper is expressed as follows.

$$\frac{dS}{dt} = \beta_1 \frac{SI}{N} - \beta_2 \frac{SI}{N}, \tag{1}$$

$$\frac{dE}{dt} = \beta_1 \frac{SI}{N} + \beta_2 \frac{SE}{N} - \alpha E \tag{2}$$

$$\frac{dI}{dt} = \alpha E - \gamma I \tag{3}$$

$$\frac{dR}{dt} = \gamma I \tag{4}$$

$$N = S + E + I + R \tag{5}$$

where $S(t)$, $E(t)$, $I(t)$, and $R(t)$ denote the number of people who were susceptible, latent, infected, and emigrated at moment t , respectively. At this time, the basic regeneration number can be expressed as:

$$R_0 = (1 + \frac{\lambda}{\alpha}) + (1 + \frac{\lambda}{\gamma}) \tag{6}$$

Where $\lambda = \frac{\ln Y(t)}{t}$, $Y(t)$ is the total number of infections up to moment t . Here, the incubation period $T_E = \frac{1}{\alpha}$, the period of infection $T_I = \frac{1}{\gamma}$, generation time $T_g = T_E + T_I$, and to expand, the basic regeneration number is also:

$$R_0 = 1 + \lambda T_g + \rho(1 - \rho)(\lambda T)^2 \tag{7}$$

3. The determination of the number of network layers

The set: let Me be the set of sources of each living material in the upstream of the network; let U be the set of distribution points of each living material in the midstream of the network; let P be the set of demand ends of each living material in the downstream of the network. The set of demand side of each commodity in the downstream of the network is P .

The symbolic parameters: let m_i be the supply quantity of material at source i ; let u_i be the transfer quantity of material at distribution site i ; let q_i be the demand side of material. The demand side i is the number of residents in the district; v is the daily consumption of vegetables per person; p_i is the demand of the demand side i , $p_i = q_i v$; let d_{ij} be the distance from node i to node j ; let c_{ij} be the supply quantity of each material transported from node i to node j . c_{ij} is the supply of each material transported from node i to node j ; let ξ be the load of the means of transport; let t_{ij} be the number of times each material is transported from node i to node j , $t_{ij} = \lceil c_{ij} / \xi \rceil$.

Decision variables: x_{ij} is a 0-1 variable, 1 if there is a transport relationship between upstream node i and midstream node j , 0 otherwise. y_{ij} is a 0-1 variable, 1 if a transport relationship exists between midstream node i and downstream node j , and 0 otherwise.

Objective function: The total workload of the staff (i.e., calculated as the product of transportation mileage and the number of residents in the district) is minimized as the optimal optimization objective, as follows.

$$\min \sum \sum y_{ij} t_{ij} d_{ij} q_j \tag{8}$$

Constraints.: to reduce the problem of direct or indirect human contact during outbreak prevention and control, it is stipulated that all demand-side nodes downstream of the network can and can only be provided with subsistence distribution services by a midstream node.

$$\sum \sum y_{ij} = 1 \tag{9}$$

To ensure that accurate prevention and efficient use of all living materials can be achieved, the supply of all materials upstream of the network should be in line with the supply and demand should be in balance with the demand at the downstream end of the network.

$$\sum m_i = \sum \sum p_j y_{ij} \tag{10}$$

The receipt and transfer of materials in the midstream distribution network should be consistent.

$$u_j = \sum \sum c_{ij} x_{ij} = \sum \sum p_j y_{ij} \tag{11}$$

4. Results

4.1. The establishment of SEIR model

By constructing a model with Python and making predictions, we can obtain the trend of susceptible, latent, and infected and emigrants' trends over time, as shown in Figure 3-6.

(1) When no vegetable packets are distributed and the virus spreads freely, the number of incubators of NCCV in Changchun will peak 45 days after the start of the epidemic (March 4, 2022), and the number of asymptomatic infected will reach 51392100, and the number of infected will peak 49 days later at 20910900. The number of infected persons will peak at 20910900 after 49 days.

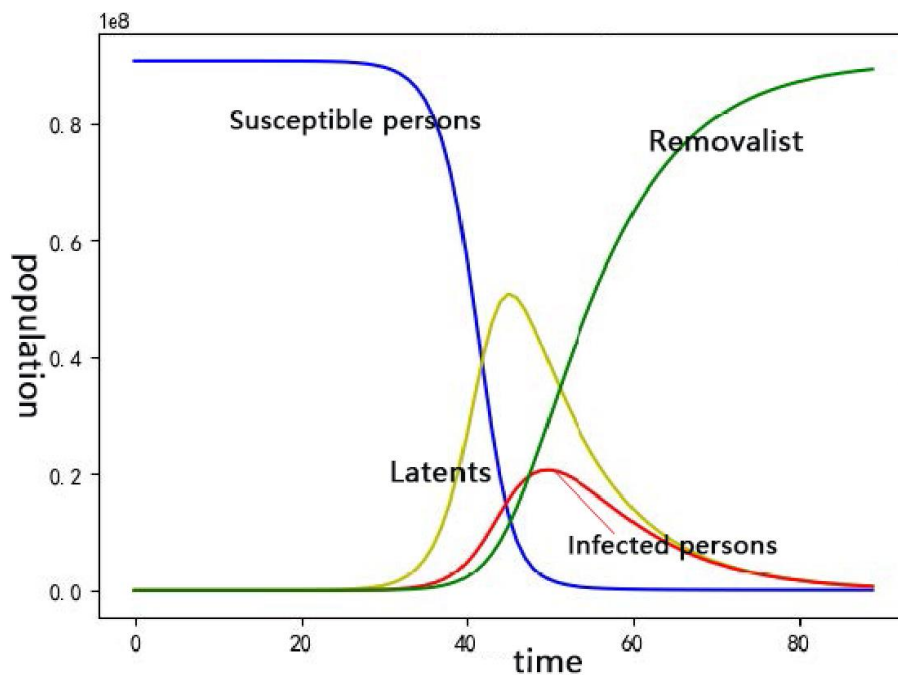


Figure 2. New coronavirus transmission in the absence of control measures

(2) When vegetable packs were distributed, the regions of Changchun began distributing vegetable packs for the home isolation population on or about March 27. The number of new infections peaked at 1979 on March 27, and the number of latent infections peaked at 3100 on April 1. As of May 14, the number of asymptomatic infections was 21,440, and the cumulative number of infected persons was 25,021 as of 24:00 on May 31.

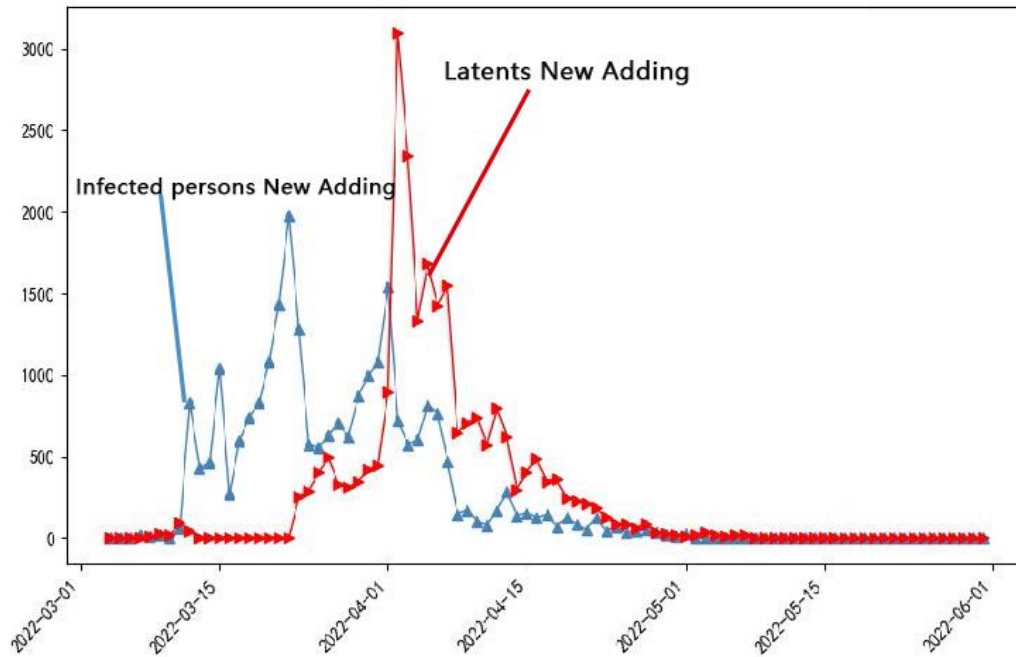


Figure 3. Number of new infections in Changchun

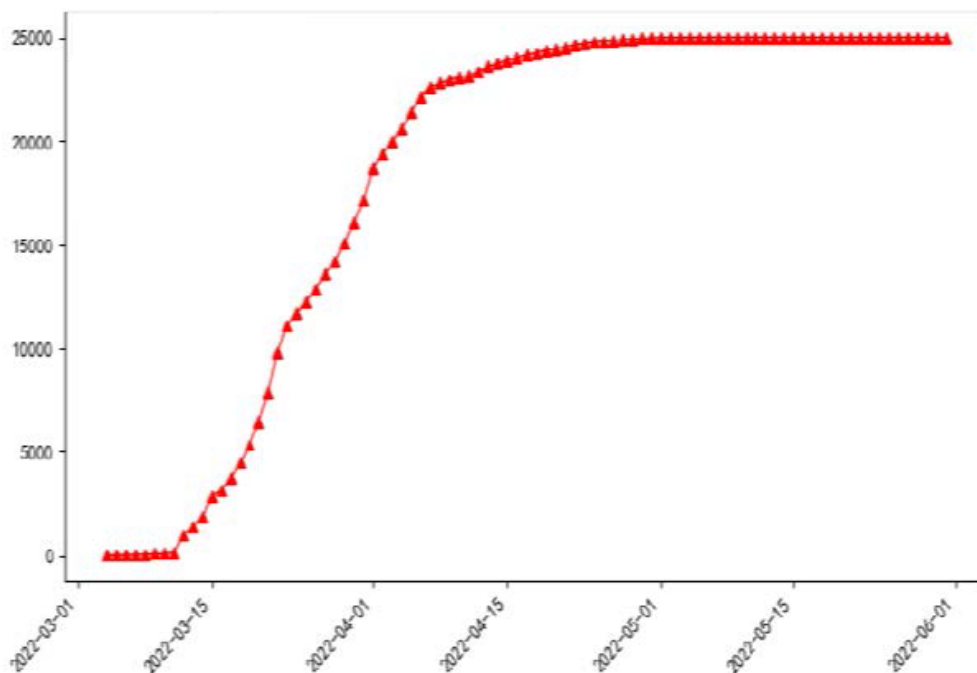


Figure 4. Cumulative number of infected persons

(3) Comparison of Changchun City with and without control measures. the simulation results of the SEIR model and the actual cumulative number of infections in Changchun City are shown in Table. As shown in Table 1, it can be seen that the virus spread exponentially when the vegetable packets were not distributed; after the distribution of vegetable packets, the infected and latent. After the distribution of vegetable kits, the contact population of infected and latent individuals decreased, and the transmission rate of the virus decreased, which led to the development of the epidemic in a positive direction.

Table 2. Comparison before and after distribution of vegetable packets

Date	Situation	Infected persons
5.31	the vegetable packets were not distributed	900886(now)
	distribution of vegetable packets	25021(accumulation)

The number of new indigenous infections and asymptomatic infections (latent) as of May 15, 2022 is zero, so we selected the data as of May 14, 2022 for calculation. Thus, we selected the data up to May 14, 2022 for calculation. From Table 1, we can see that from March 1, 2022 to March 26, 2022, Changchun was the first city in the world to have a total of 0 new infections. From March 1, 2022 to March 26, 2022, the basic regeneration number in Changchun was within the range of [2.89, 3.3], and from March 27, 2022 to May 14, 2022, the basic regeneration number in Changchun was within the range of [2.89, 3.3]. November From March 27, 2022 to May 31, 2022, the range of basic regeneration in Changchun is [2.49, 2.84]. "The interval of the basic regeneration number can be judged from the interval of the basic regeneration number that this prevention and control method has curbed the spread of the disease to a certain extent. The spread of the virus has been curbed to some extent. During the outbreak, residents should raise awareness of the virus, make rational judgments, and reduce their exposure to the virus by wearing masks and isolating at home. Isolation and other means to reduce their contact with infected and latent people to reduce the infection rate; meanwhile, the government implements certain measures At the same time, the government should implement certain measures, such as distributing vegetable kits and other programs to scientifically manage the living materials of the residents, so as to protect their lives while avoiding large scale At the same time, the government has implemented a series of measures, such as the distribution of vegetable kits, to scientifically manage the living materials of the residents, to protect their lives and avoid mass gatherings, and to reduce the probability of transmission of NCCV.

4.2. Analysis of detailed plans for the supply of materials for residential life

According to the location of each regional household goods drop-off point, the number of cells in the jurisdiction and the number of population in the jurisdiction, this paper assigns all the cell nodes in the downstream of the network to the corresponding distribution points (household goods drop-off points) in the midstream of the network, and at the same time, according to the measurement standard of 400 grams of vegetables per person per day in the Workbook for Guaranteeing the Supply of Life Essentials Market (Version 2021) issued by the Ministry of Commerce [7], we can The demand for supplies in the downstream of the network is obtained. From the demand of each cell in the downstream of the network, we can invert the transshipment volume of each midstream of the network, and similarly the transshipment volume of the midstream can find the supply volume that needs to be guaranteed to be provided in the upstream of the network. For the convenience of calculation, this paper approximates the Manhattan distance between each cell, distribution site and material supply site as the transportation mileage.

The calculation results of the supply quantity of upstream nodes are shown in Table 3.

Table 3. Supply of upstream nodes

Area	Number of people under the jurisdiction of upstream nodes	Total supply of materials to upstream nodes (tons)
Changchun New District (High-tech)	338274	135.3096
Jing Yue District	204056	81.6224
Green Park	372541	149.0164
Chaoyang District	548179	219.2716
Economic Development Zone	189240	75.6960
Kuancheng District	306143	122.4572
Nanguan District	462146	184.8584
Jiaokai District	193462	77.3848
Erdao District	405784	162.3136

After completing the ordered network diagram, trucks of different load types are used for loading and transportation, and in order to further reflect the significant degree of influence of different load types on the material supply plan, the following three transportation plans are adopted: (1) Plan 1: upstream node to midstream node and midstream node to downstream node are loaded with large trucks; (2) Plan 2: upstream node to midstream node and midstream node to downstream node are loaded with small trucks; (3) Plan 3: upstream node to midstream node are loaded with large trucks, and midstream node to downstream node are loaded with small trucks. (3) Option 3: the upstream node to the midstream node is loaded by large trucks, and the midstream node to the downstream node is loaded by small trucks. The calculation results of different transportation scenarios are shown in Table 4.

Table 4. Calculated results for different load types of trucking solutions

	Transportation Solutions	Large truck delivery	Small truck delivery	Total transported miles (km)
Program 1	Upstream node to midstream node	121	0	1.523
	Midstream node to downstream node	121	0	54.0656
Program 2	Upstream node to midstream node	0	242	3.539
	Midstream node to downstream node	0	242	54.7567
Program 3	Upstream node to midstream node	121	0	1.523
	Midstream node to downstream node	0	242	54.7567

From the calculation results in Table 4, it can be seen that there is no significant difference in the total transportation mileage between different schemes, because the location from the upstream node is obtained from the center of gravity of the corresponding midstream node location, and the number of corresponding midstream nodes is small, so the total transportation mileage is smaller; while usually the number of cells to be put in the midstream node is larger, and the distance of different cells from the distribution point is farther, so the total transportation mileage is larger. The total transportation mileage is larger. In the actual material distribution, trucks with corresponding load should be reasonably selected according to the scale of demand, and when supplying some downstream nodes with smaller demand, trucks with smaller load can be used for distribution as a priority, so as to achieve accurate scientific management under the situation of large-scale closure and control, improve the efficiency of epidemic prevention and control, and save relevant personnel input and financial expenditure.

5. Conclusion

Combining mathematical model and computer simulation, this paper firstly designs an improved SEIR model through theoretical analysis and simulation verification with high credibility of the conclusion, and secondly constructs a mathematical planning model of multi-level logistics network with supply and demand balance, which integrates the objectives of reducing human workload and personnel contact, realizing accurate and scientific management of residents' living materials in logistics network nodes at all levels under large-scale wind control, improving the efficiency of epidemic prevention and control, and saving relevant personnel input and financial expenditure.

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