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"Many to many" medical material ordering and distribution planning under health emergencies

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Abstract:

In recent years, due to the frequent occurrence of health emergencies, it is particularly important to establish an efficient order and distribution network in a short time. To deal with the problem, two models are established and solved by the author to build the framework of the paper. Specifically speaking, SEIR, a population dynamics model, is built to predict the trend of the number of susceptible persons, latent persons, infected persons, and rehabilitated persons over time. Then, the model takes the minimum total cost as the objective function based on the number of infected persons and establishes a many-to-many order and distribution model connecting the hospitals, storage centers, and suppliers. It is to say, any storage center can order medical materials from any supplier and distribute medical materials to any hospital according to the actual situation. Additionally, in the case analysis, the author compares the population changing of the SEIR model and ordering and distribution model based on the model above in two different health emergency scenarios— first outbreak of the epidemic when all sectors of society are unprepared" and "fully prepared". The results show that in different cases, the results of the ordering and distribution model are consistent with the trend of the number of infected people in the SEIR model and the actual situation. It is to say the result has practical significance, so the paper can certainly provide a reference for solving health emergencies.

Keywords*: Health emergencies, SEIR dynamic model, medical supplies, Ordering and distribution, Many-to-many.*

I. INTRODUCTION

In recent years, with the continuous development and progress of society, people's lives have been greatly improved at the same time, natural disasters occur frequently and many emergencies have taken people by surprise. Earthquakes, snowstorms, floods, forest fires, etc., have sent signals to people. Among them, health emergencies are a very tricky one. Due to the current trend of continuous internationalization and high population mobility, health emergencies, when they occur, can lead to widespread, rapid and difficult to control consequences. Accordingly, the following definitions have been given for health emergencies at home and abroad - domestic scholars mainly believe that a health emergency refers to a sudden occurrence that causes or may cause an event affecting public health, which may include major

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infectious disease epidemics, mass unexplained diseases, major food poisoning, etc.; while in the international context, it is defined as An unusual event that poses a public health risk to other countries through the international spread of disease and is likely to require a coordinated international response. This shows that all sectors of society attach great importance to health emergencies, which, if they occur, are bound to have a significant impact on a global scale.

The sudden outbreak of the new crown pneumonia outbreak in late 2019 and early 2020 caught many people by surprise. The rapid and widespread spread of this outbreak has made it a global concern whether an effective approach and a rational production and distribution network can be established in the short term. Among them, kinetic models are one of the best methods to predict the size of the population and the trend of change nowadays, Efimov et al. (2021) used the SEIR model to analyze the epidemiological process of the spread of COVID-19 in eight different countries[1], and Rohmah et al. (2020) established the SEIR epidemiological model used to describe the spread of Ebola virus between two regions[2]. Ying Yi et al. (2020) introduced an "intervention parameter" based on the traditional SEIR model, which is very innovative, taking into account the actual situation of population migration of infectious diseases[3], while Zou (2021) also improved the traditional model by collecting relevant data and fitting the data using a particle swarm optimization algorithm[4]. This shows that the SEIR model is widely used to predict the population size of various infectious diseases. In addition to this, Alota, CP et al. (2020) investigated the stochastic nature of the SEIR kinetic model and confirmed that infection and recovery rates have a significant effect on the kinetics of disease transmission[5].Liu, Q et al. (2017) demonstrated the applicability of the SEIR model to stochastic non-autonomous infectious diseases and the existence of at least one periodic solution under a single condition[6].He, SB et al. developed a SEIR epidemic model for New Coronavirus-19 based on general control strategies such as hospital, quarantine and external inputs, and used a particle swarm optimization algorithm to estimate the system parameters, and finally applied the model to the evolution of the epidemic in Hubei Province, showing that the model can be used to predict the New Coronavirus epidemic[7].

According to studies, the healthcare industry has continued to face tremendous pressure over the years to simultaneously reduce costs and be patient-centered[8]. The healthcare industry in China is no exception, and although it is generally at a high level, there is still a need to strengthen the infrastructure and layout planning for an emergency distribution network[9], especially in the early 2020s when the demand for medical equipment and supplies reached unprecedented levels due to the epidemic[10].Tan et al. (2020) analyzed a non-contact meal supply distribution system using the Mount Raytheon Hospital as a study to address innovative initiatives for medical staff and patients' meal problems and balanced nutrition[11]. In the ordering and distribution of medical supplies, Chinese scholars Ji Lei et al. (2005) earlier proposed how to establish a distribution model of supplies with the goal of cost minimization in the case of emergencies, with path optimization as the research object[12].Ming Liu et al. (2017) provided a new perspective for the ordering and distribution scheduling of medical resources based on previous studies——based on suppliers, distribution centers, and hospitals, and considered patients' daily arrival at each designated hospital as a random variable to establish a three-party total cost minimization model, and the test results showed that the model has good practical significance[13]. However, the above study only considered the "one-to-one" relationship between the "hospital" and the "storage center" and the "storage

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center" and the "supplier". Therefore, in this paper, the "multi-point ordering and distribution model" will be taken into consideration.

In this paper, we will build a three-party drug ordering and distribution model based on the number of infected people in the model, based on the real-time change trend of the model, starting from the establishment of the population prediction model SEIR. In the previous studies, the specific situation of the "SEIR model population trend" and the corresponding "multi-point ordering and distribution model" under different scenario models has rarely been considered, therefore, this paper aims to minimize the cost and consider two different emergency situations. Therefore, in this paper, we consider two different health emergency scenarios and multi-point ordering and distribution problems between hospitals and warehouses, and between warehouses and suppliers with the objective of cost minimization, so that any designated warehouse can supply medical supplies to any designated hospital and order medical supplies from any designated warehouse according to the actual situation, and the ordering and distribution of drugs can be completed in the most effective way in emergency situations.

II. CONSTRUCTION OF THE MODEL

2.1 Materials and Methodology

Firstly, in the model, the following preconditions are assumed based on the actual situation.

(1) the initial inventory of the warehouse is not zero.

(2) The number of drugs ordered from the supplier by the warehouse is equal to the number of drugs produced by the supplier.

(3) The production and distribution of medical supplies are "many-to-many" and regulated by the government, and cannot be contracted by individuals.

(4) Patients must go to designated hospitals for treatment, i.e., hospitals are designated to receive patients and patients cannot go to non-designated hospitals for treatment.

(5) The designated supplier can fully meet the hospital's needs at this particular time and the medical supplies are only supplied to the hospital and cannot be sold to individuals individually.

(6) The fixed cost and unit variable cost of the hospital are known; the fixed ordering cost, unit cost, and transportation cost between the warehouse and the hospital are known; the fixed cost of manufacturing the drug by the supplier and the transportation cost between the supplier and the warehouse is known.

(7) The average daily quantity of drugs used per patient, the production capacity of the supplier, the safety stock, and the maximum stock of the warehouse center and the hospital are known and fixed.

The SEIR population forecasting model and the ordering and distribution model symbols are defined as shown in Tables 1 and 2, respectively:

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TABLE 1. Meaning of SEIR population projection model symbols

Symbol	Definition
$S(t)$	Number of susceptible persons at time t
$E(t)$	Number of incubators at time t
$I(t)$	Number of infected persons at time t
$R(t)$	Number of recovered persons at time t
B_1	Number of contacts per day per susceptible person
P_1	Probability of a susceptible person developing into an infected person
B_2	Number of contacts per day per latent
P_2	Probability that a susceptible person will develop into a latent person
β	Probability of a latent person becoming infected by an infected person
μ	Probability of recovery of a latent or infected person
N	Total population of the infected area

TABLE 2. Meaning of Order and Delivery Model Symbols

Known parameter	
N, n	The collection of hospital H， $n = 1, \dots, N$
I, i	The collection of drug supplier S， $i = 1, \dots, I$
J, j	The collection of warehousing centers DC， $j = 1, \dots, J$
m	Average daily medication consumption per patient
X_n	Maximum capacity of the hospital H_n
h_{1n}	Hospital Fixed Costs H_n
h_{2n}	Hospital Variable Costs H_n
C_1	Storage Center Unit Storage Costs
g_j	Storage Center Fixed Ordering Costs DC_j
s_{jn}	Transportation costs between the storage center DC_j and the hospital H_n
D_i	Supplier S_i Maximum Capacity Limit
f_{1i}	Supplier S_i Fixed cost of manufacturing drugs
u_{ij}	Transportation costs between the storage center DC_j and the supplier S_i
V_j	Warehouse Center DC_j Maximum Capacity
v_j^s	Storage center DC_j safety stock level
M	A large number
Decision Variable	
$x_n(t)$	Number of patients received by the hospital at time t
$y_n^j(t)$	The amount of drugs transported from the storage center DC_j to the hospital H_n at time t
$w_{ji}(t)$	The amount of drugs ordered from the supplier at time t by the storage center
$v_j(t)$	The amount of drugs in stock at the storage center DC_j at time t
$\varepsilon_j^i(t)$	0-1 variable, whether the storage center j orders medical supplies i from suppliers at time t
$\alpha_i(t)$	0-1 variable, whether the supplier produces i and orders medical supplies at time t

2.2 Population projection models.

First, this paper uses a population dynamics model to simulate and predict the number of susceptible, latent, infected, and recovered individuals in the transmission of a health emergency, which is usually expressed as:

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$$\begin{cases} S(t+1) = S(t) - \dfrac{B_1 * P_1 * S(t) * I(t)}{N} - \dfrac{B_2 * P_2 * S(t) * I(t)}{N} \\ E(t+1) = E(t) + \dfrac{B_1 * P_1 * S(t) * I(t)}{N} - \beta E(t) + \dfrac{B_2 * P_2 * S(t) * I(t)}{N} \\ I(t+1) = I(t) + \beta E(t) - \mu I(t) \\ R(t+1) = R(t) + \mu E(t) \end{cases} \tag{1}$$

The original S、E、I、R models were modified according to the actual situation with the total population remaining unchanged, and the conversion relationships are shown in Figure 1 below, and the symbolic meanings are shown in Table 1 below. As seen from the figure, the probability of conversion of susceptible to latent is P_2, the probability of conversion to infected is P_1; the probability of conversion of latent to infected is β, the probability of conversion to recovered is μ; the probability of conversion of infected to recovered is μ. The applicability of the model is reflected in the experiment and simulation.

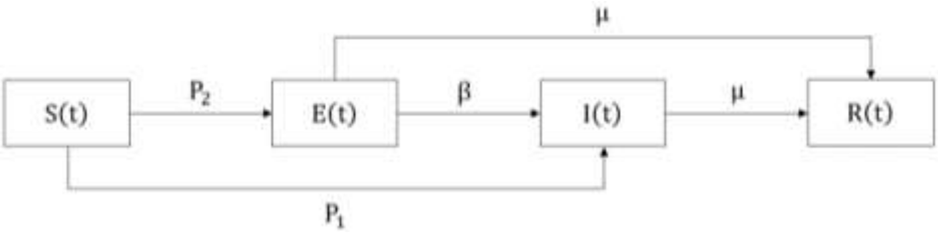

Fig 1: Population relationship conversion diagram

The above SEIR population prediction model describes the logic of the change in the number of people in different states between moment t+1 and moment t, in preparation for the subsequent ordering and distribution model.

2.3 Ordering and Distribution Model

In this paper, we develop a "many-to-many" ordering and distribution model among suppliers, distribution centers and hospitals with the aim of minimizing ordering costs and making population forecasts. The model includes the following aspects.

(1) Hospital operating costs, including "hospital fixed operating costs" and "variable operating costs".

(2) Warehouse center inventory costs, including "fixed storage costs" and "fixed ordering costs for drugs ordered from suppliers at the warehouse";

(3) Supplier production costs, including "fixed production costs" and "variable production costs based on order volume";

(4) In-transit transportation costs between "suppliers" and "distribution centers" and between "distribution centers" and "hospitals". transportation costs between "supplier" and "distribution center" and "distribution center" and "hospital".

The objective function is shown below:

$$MinZ = \sum_{t=1}^{T}\{\sum_{n=1}^{N}(\mathrm{h}_{1n} + \mathrm{h}_{2n}x_n(t)) + \sum_{j=1}^{J}\mathrm{C}_1 v_j(t) + \sum_{i=1}^{I}\sum_{j=1}^{J}(\mathrm{g}_j * w_{ji}(t)\sum_{i=1}^{I}\varepsilon_j^i(t)) + \sum_{n=1}^{N}\sum_{j=1}^{J}(\mathrm{s}_{jn} * y_n^j(t)) + \sum_{j=1}^{J}\sum_{i=1}^{I}(\mathrm{f}_{1i} w_{ji}(t)\alpha_i(t) + \mathrm{u}_{ij} w_{ji}(t))\} \tag{2}$$

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The constraints are shown below:

$$\sum_{n=1}^{N} x_n(t) = \mathrm{I}(t), \forall t \tag{3}$$

$$x_n(t) \le \mathrm{X}_n, \forall n, t \tag{4}$$

$$\mathrm{v}_j^s \le v_j(t) \le \mathrm{V}_j, \forall j, t \tag{5}$$

$$v_j(t) = \sum_{i=1}^{I} w_{ji}(t) - \sum_{n=1}^{N} y_n^j(t), \forall t = 1, \ldots, T, \; j = 1, \ldots, J \tag{6}$$

$$\mathrm{m}\sum_{n=1}^{N} x_n(t) \le \sum_{j=1}^{J} \sum_{n=1}^{N} y_n^j(t), \forall n, t \tag{7}$$

$$w_{ij}(t) \le \mathrm{M}\varepsilon_j^i(t), \forall i, j, t \tag{8}$$

$$\varepsilon_j^i(t) \le \alpha_i(t), \forall i, j, t \tag{9}$$

$$\sum_{j=1}^{J} w_{ji}(t) = \sum_{j=1}^{J} w_{ji}(t) \le \mathrm{D}_i, \forall i, t \tag{10}$$

$$\varepsilon_j^i(t), \alpha_i(t) \in \{0,1\} \tag{11}$$

$$x_n(t), y_n^j(t), v_j(t), w_{ji}(t) \in Int, \forall i, j, n, t \tag{12}$$

In the above model, the constraints are expressed as follows: constraint (3) indicates that all patients are allocated to the hospital; constraint (4) is the capacity limit of the hospital, i.e., the maximum capacity of the hospital is greater than or equal to the number of patients admitted; constraint (5) indicates the safety stock of the storage center, i.e., the stock of drugs in the storage center is greater than or equal to the safety stock and less than or equal to the maximum stock; constraint (6) indicates the flow conservation of the storage center, that is, the sum of the inventory of the storage center and the quantity of medical supplies distributed to the hospital is equal to the total quantity of medical supplies ordered by the storage center to the supplier; constraint (7) indicates that the drug demand of all patients can be satisfied; constraint (8) is a 0-1 constraint, the quantity of medical supplies ordered by warehouse j to supplier i at time t is less than or equal to supplier i at time t 's maximum production capacity; constraint (9) is a 0-1 constraint that warehouse j orders and produces medicines from supplier i at moment t; constraint (10) indicates the capacity limit of the supplier, i.e., the number of accepted orders is less than or equal to the maximum capacity of the supplier; constraints (11) (12) are constraints of variable type.

III. SOLVING OF THE MODEL

In this paper, the model is solved in two parts, firstly, the SEIR model is solved for population trend prediction, and then patients are randomly assigned to designated hospitals, and the "many-to-many" 0-1 mixed integer planning ordering and distribution model is solved.

3.1 SEIR model solving

The SEIR model is first solved as shown in the following steps (Figure 2).

Step 1: Initialize the parameters. Set the original parameter values of the SEIR model, the population size N is set to 10000, the initial number of incubators is set to 0, the number of transmitters is set to 1, and

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the number of recoverers is set to 0.

Step 2: Make t=0.

Step 3: Find the magnitude of each S, E, I, and R values corresponding to time t.

Step 4: Determine whether t>T holds. If yes, proceed to step 5; if not, t=t+1 and return to step 3 until t ⩾T.

Step 5: Draw the change curve of the number of "infected" and record the corresponding values, so as to prepare for the second stage of ordering and distribution model.

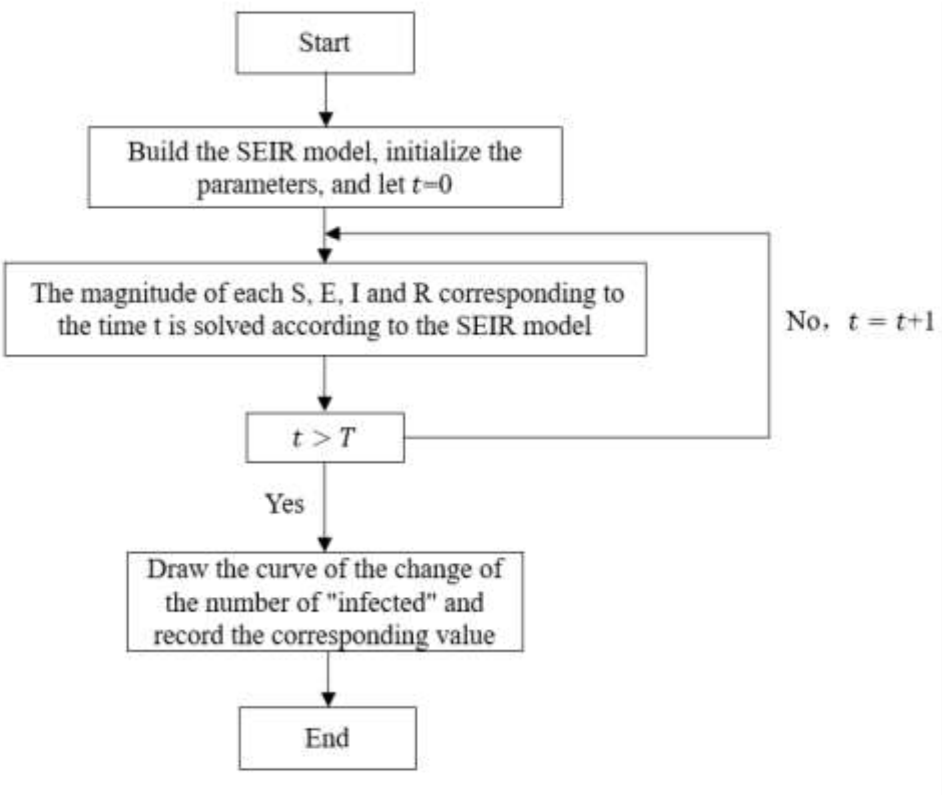

Fig 2: Flowchart of model solving

3.2 Order and delivery model solving

The ordering and distribution model was solved on the basis of the number of infected persons obtained from SEIR, as shown in the following steps (Figure 3).

Step 1: Initialize the parameters. Set the values of the parameters of the "Ordering and Distribution Model". Assume that the known parameter values include the capacity, fixed cost and unit cost of the hospital, the capacity, ordering cost, inventory cost, ordering quantity and safety stock of the storage center, the production capacity, fixed cost and variable cost of the supplier, and the transportation cost between different departments.

Step 2: Let t = 0.

Step 3: With the objective of minimizing the cost of equation (2) of the "ordering and distribution

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model", use matlab to solve for the minimum cost of the model at day t and the values of the decision variables.

Step 4: Determine whether t>T is valid. If yes, proceed to step 5; if not, then t=t+1 and return to step 3 until t⩾T.

Step 5: Derive the results. Record the minimum cost value for each time period, the number of patients received by hospital H_n, the amount of drugs transported from storage center DC_j to hospital H_n, the amount of drugs ordered from suppliers by the storage center, and the amount of drugs in stock at storage center DC_j.

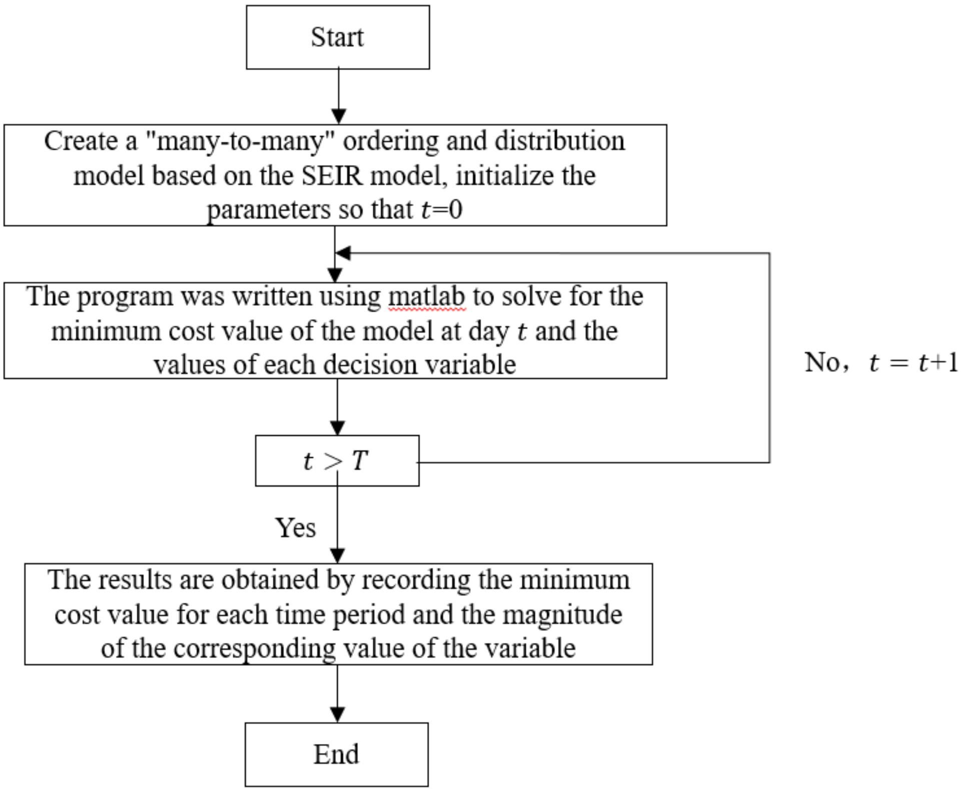

Fig 3: Flow chart of model solving

IV. EXPERIMENTAL SIMULATION AND ANALYSIS

In this section, specific examples are given to compare and analyze the models to demonstrate their usefulness. In this paper, we use Microsoft Windows 10 operating system as the platform, MATLAB R2018a program software as the development environment and cplex as the solver to solve the optimal values of the model on an 11th Gen Intel(R) Core(TM) i5-11300H @ 3.10 GHz 3.11 GHz personal computer. The experiments are carried out on a personal computer with Intel(R) Core(TM) i5-11300H @ 3.10 GHz 3.11 GHz. In order to make the ordering and distribution model realistic in practice, this paper refers to such literature represented by Yu Wei (2018) [14] and combines data related to the Wuhan epidemic in early 2020 and the Yangzhou epidemic in 2021 to analyze "the community is unprepared for

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the first outbreak of the epidemic" and We analyze the population trends of the SEIR model in the two scenarios of "the first outbreak is unprepared" and "late preparation", and the differences between the corresponding ordering and distribution models. After processing the data, the following analysis results were obtained.

4.1 SEIR model analysis

The results of the differential equation equation (1) for the number of infected persons over time in the "first outbreak" and "well-prepared" scenarios were obtained with the cplex solver-based MATLAB R2018a software. The curves are shown in Figure 4 and Figure 5 below.

As shown in Figure 4, the number of infected people grows slowly from day 0 to 15 of the first outbreak, and the number of infected people is small, mainly because the society has little information and knowledge and is unprepared at this time, and the number of infected people is small at the beginning and there is no virus mutation yet, i.e., the base of infected people is small, so the number of infected people increases slowly. The number of infected people was in a rapid increase during the 15th-25th days, because the initial patients were not taken seriously and did not seek medical treatment in time, so the virus gradually spread, medical facilities and medical personnel were not fully equipped at this time, and the population movement was large, so the number of infected people increased at a high rate and reached the peak of the number of patients around the 25th day. From day 25 onward, the number of patients was gradually controlled and reduced due to medical supplies, medical and nursing staff, and national propaganda. However, due to the high population mobility, strong transmission, and wide spread, it was more difficult to treat patients and control the population movement and trace the close contacts of infected people until day 120, when the number of infected people was gradually cleared.

After the first outbreak, the government and the community paid great attention to improving the infrastructure, establishing appropriate laws and regulations, developing more scientific and effective exclusion screening methods for the epidemic, and strengthening the detection of people and goods imported from abroad; at the same time, people also consciously wore masks and received vaccinations to reduce the number of daily contacts, reduce the probability of being infected and increase the probability of recovery through this initiative. In the face of individual cases, the local government and relevant departments quickly took measures such as community closure and full nucleation, which greatly reduced the risk of epidemic transmission and shortened the time period for "infected" to be eliminated, as shown in Figure 5 below. Figure 5 reflects the trend of the number of infected persons over time under the above circumstances, and the comparison with Figure 4 clearly shows that the number of infected persons dropped significantly, the peak of the number of infected persons was earlier and the cure cycle was shorter, which is in line with the actual situation.

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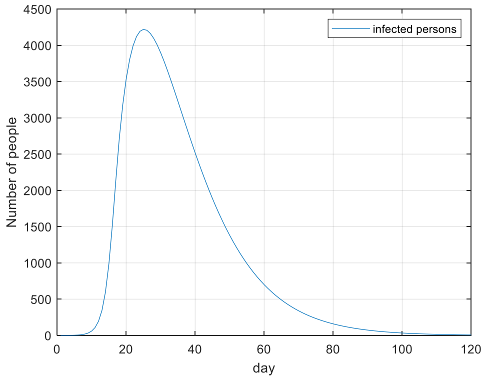

Fig 4: Change in the number of infected persons over time "at the first outbreak"

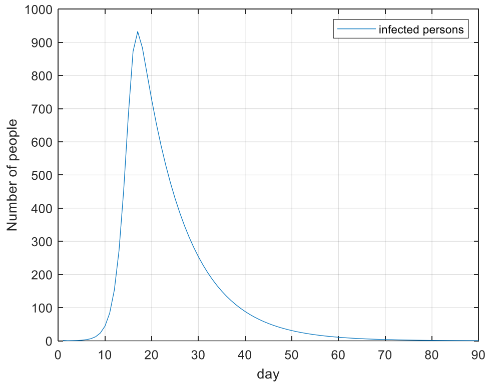

Fig 5: Change in the number of infected persons over time "when well prepared"

4.2 Order and Delivery Model Analysis

Based on the above trend of the number of infected persons over time, equation (2) is solved based on the cplex solver for the two scenarios of "first outbreak" and "when well prepared", where the values of the infrastructure parameters are set as shown in Table 3 below The values of the infrastructure parameters are shown in Table 3.

TABLE 3. Parameter settings

Number of Hospitals	Number of storage centers	Number of suppliers
3	6	6

During the first sudden outbreak, medical supplies were in short supply in the first and middle term, and a large amount of medical supplies were put into production every day, and the number of people in the epidemic peaked on day 25, so the first inflection point in the total cumulative cost occurred, and the cumulative cost started to grow at a high rate; due to the gradual putting a large amount of medical supplies into production and the good control of the epidemic, we can find that around day 50, the cumulative cost growth rate decreased The cost trend gradually flattens out (as shown in Figure 6). After the first round of the outbreak, all parties are well controlled and deployed, and it is clear that the total cumulative cost decreases significantly compared to the previous one and starts to flatten out around day 40 (as shown in Figure 7), which is a good representation of the cumulative cost trend.

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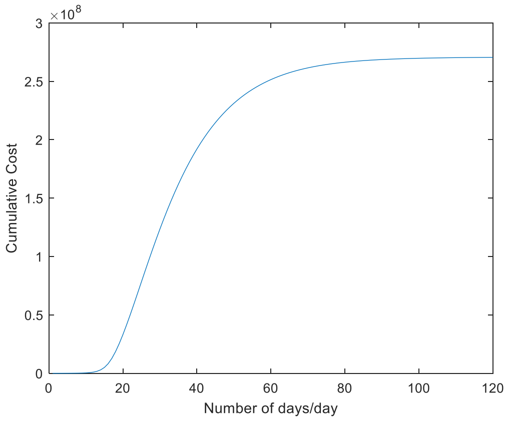

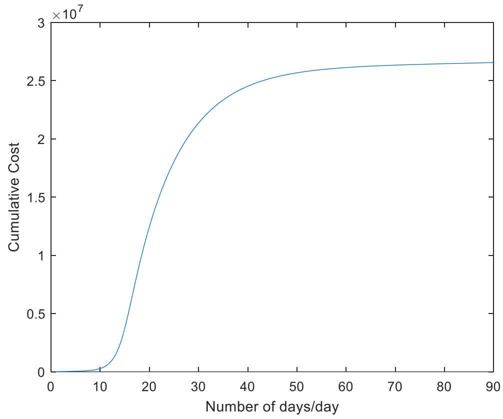

Fig 6: "At first outbreak" cumulative for total cost over time

Fig 7: Cumulative total cost over time for "when ready"

In the first outbreak of the epidemic, the changes in the quantity of medical supplies produced by suppliers S_1、S_2、S_3、S_4、S_5, and S_6 over time are shown in Figure 8 and Figure 9 below, from which it can be found that in the early stage, the production of medical supplies was at a low level due to the sudden outbreak of the epidemic, which did not immediately receive the attention of the public and society and the suppliers did not form a large-scale industrial chain. With the passage of time, the epidemic became more and more serious, the number of infected people rose sharply, and a large number of patients went to hospitals for medical treatment, urgently needing a lot of medical supplies to rescue. At this time, the national community issued news about various protective measures and deployed production lines for all parties, and major suppliers received assignments to mass-produce medical supplies to hospitals. Around the 20th, the outbreak reaches its peak and so does the production of medical supplies, which then changes over time depending on the number of patients and the specific situation. From around day 40-50, production gradually tends to decrease due to the control of the epidemic and inventory storage in the warehouse. Figures 8 and 9 well reflect the trend in the production of medical supplies by suppliers throughout the cycle, which corresponds to the trend in the number of infected patients.

When the epidemic is controlled and then there is another localized outbreak, the production of medical supplies is mainly carried out by supplier S_6 because there is still a certain accumulation of medical supplies in each hospital before, and the number of infected people is significantly reduced and the outbreak area is controlled in a localized area, so the change of production is shown in Figure 10 below. Since the production of medical supplies is mainly carried out by supplier S_6 only, we can find a significant decrease in the output of the supplier compared to the first outbreak of the epidemic. This phenomenon can indicate that the epidemic was controlled to some extent with experience, and the measures such as vaccination, establishment of various infrastructures, and enactment of laws and regulations were effective.

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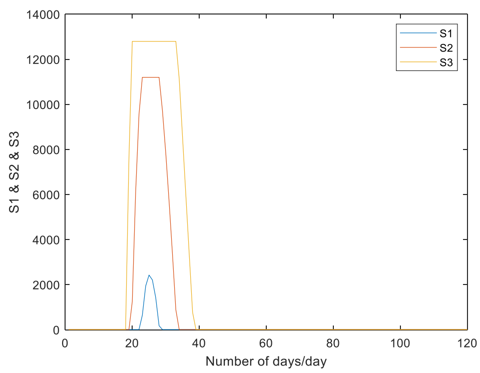

Fig 8: "First outbreak" supplier and production change graph

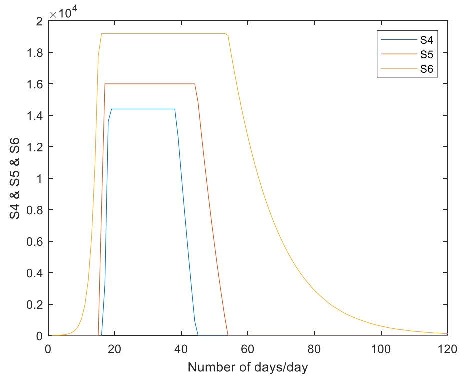

Fig 9: "First outbreak" supplier and production change graph

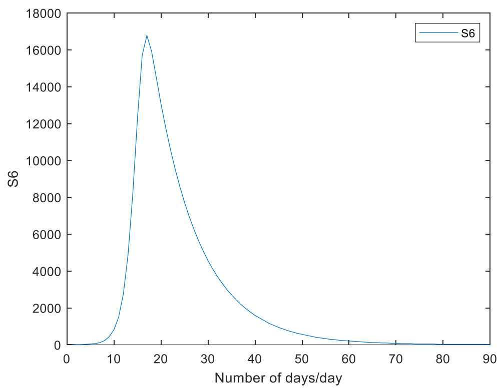

Fig 10: "When ready" supplier production change chart

In the epidemic cycle, "Scenario 1" and "Scenario 2" are discussed separately at day 27. Scenario 1 is the "first outbreak" and Scenario 2 is the "full preparedness" of the epidemic. The capacity of hospitals H_1 、H_2、H_3 are 500, 1000, and 3000, respectively, and the capacity of providers S_1、S_2、S_3、S_4、S_5、S_6 are 9600, 111200, 12800, 14400, 16000, and 19200, respectively.

In scenario 1, the number of infected patients is 4164, and the number of patients accepted at hospitals H_1、H_2、H_3 is 500, 1000, and 2664, respectively; the storage center orders a total of 75012, and DC_1、DC_2、DC_3、DC_4、DC_5、DC_6 orders from suppliers are 1420, 11200, 12796, 14398, 16000, 19198; the total number of medical supplies sent to the hospital is 12492, and the number of medical supplies sent to the hospital by DC_1、DC_2、DC_3、DC_4、DC_5、DC_6 are 235, 1865, 2131, 2398, 2665, 3198, respectively. at scenario 2, the total number of infected people is 348, and the hospitals H_1、H_2、H_3 receive 348, 0, and 0 patients, respectively; the storage center orders a total of 6324 from suppliers, and the number of medical supplies sent to the hospital is 1044 in total.

In order to visualize the results, the following graphs are made. Figure 11 shows the comparison between the number of patients accepted by each hospital and its capacity at day 27. It can be seen that after the implementation of various measures, the number of infections was significantly reduced in scenario 2 and was concentrated in one hospital for treatment. Figure 12 shows the comparison of the number of patients, the number of orders from the storage center and the number of medical supplies sent

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to the hospitals in scenario 1 and scenario 2 on day 27, which shows that when in the "scenario 2" mode, the numbers are significantly reduced, thus showing that the epidemic is under control and that the model is realistic, thanks to the continuous efforts of the community. Therefore, it can be seen that the epidemic can be controlled and the model is in line with the actual situation with the continuous efforts of the community.

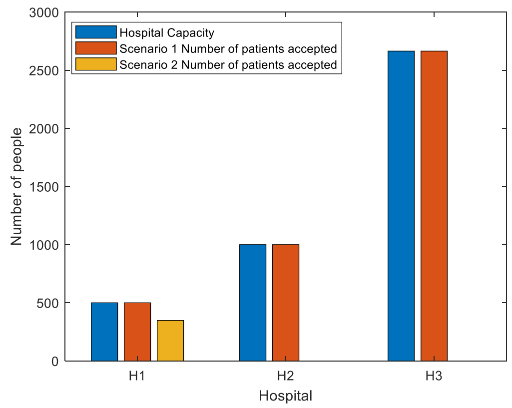

Fig 11: Number of patients accepted by hospitals on day 27 vs. capacity

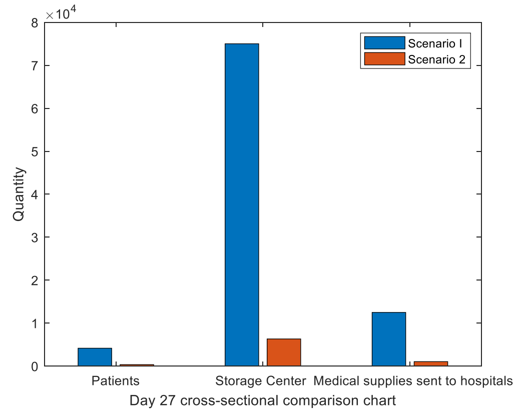

Fig 12: Cross-sectional comparison on day 27

V. COMPARATIVE ANALYSIS OF ALGORITHMS

In previous studies, such problems were mostly solved by genetic algorithms. In this problem, the population size is set to 300 and the maximum number of iterations is 6300, but the genetic algorithm can only find the approximate optimal solution but not the optimal solution directly, and in the case of a large number of variables, it is easy to find the local optimal solution for some of the variable values, and at the same time, the solution time is long and the cost value at each time point cannot be calculated (as shown in Table 4). In this paper, a cplex solver is used to solve the model based on matlab software, and the optimal solution can be found in a short time. Therefore, the cplex solver is the best choice in the computational solution of this type of model.

TABLE 4. Genetic Algorithm (for scenario one)

Maximum number of iterations	6300
Population size	300
Crossover probability	0.8
Variation probability	0.2
Running time	5.5h

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VI. CONCLUSION

In this paper, we analyze the trend prediction of the infected population (SEIR model) and the drug ordering and distribution model for the two scenarios of "first outbreak" and "adequate preparedness" in the context of the current epidemic situation. The SEIR population dynamics model was used to predict the trend of the infected population during the transmission cycle, and then a "many-to-many" ordering and distribution model was developed based on the SEIR model, focusing on the ordering and distribution model between hospitals, storage centers and suppliers——Any designated storage center can randomly deliver medical supplies to any designated hospital according to the specific situation, and similarly, the storage center can randomly order medical supplies to any designated supplier according to the actual situation. In the case study, the model is analyzed in terms of "overall periodicity" and "individual cases", and we can find that when the epidemic is in its first outbreak, the treatment period is long and the number of patients is large, so hospitals, storage centers and suppliers need to spend However, after the first outbreak, the number of people wearing masks, the community responding to the call to quickly establish a sound infrastructure, and the adoption of more advanced scientific screening and treatment methods, the number of patients, the infection cycle, and the costs were all significantly reduced. In addition, the establishment of good protective measures and a reasonable system, through legal means, i.e., legal control of infection in hospitals as well as in society, depending on the actual epidemic can be controlled only within two to three incubation periods. Thus, in summary, it can be seen that the changes in each data over time are reasonable, and the ordering and distribution are flexible and mobile, so the model has some value and significance for this health emergency.

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