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Optimization of Emergency Epidemic Prevention Material Reserve and Supply System of Shanxi Province in China: Based on Anylogic Simulation

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ABSTRACT

Due to the randomness and uncertainty of epidemic occurrence, there are insufficient emergency supplies and low efficiency of transportation equipment in Shanxi Province. In order to meet the needs of materials in Shanxi Province, it is urgently necessary to establish a reserve and supply system with perfect facilities and equipment. According to the geographical location of 11 prefecture-level cities in Shanxi Province and the actual situation of transportation equipment, this paper simulates the location of warehouse construction in each city. Through simulation modeling, the emergency epidemic prevention materials reserve and supply system of prefecture-level cities in Shanxi Province was simulated under the epidemic situation. The research idea of "simulation-analysis-optimization-summary" was defined, and the AnyLogic software was used to simulate and analyze the emergency epidemic prevention materials reserve and supply system of the whole Shanxi Province. Through the simulation of different scenarios, the optimization direction of transportation equipment is obtained. Based on the optimization effect of each plan of transportation equipment loading on the emergency epidemic prevention materials reserve and supply system in Shanxi Province, the best optimization plan was obtained. The results show that the efficiency of transportation equipment allocation is improved and the loading capacity of transportation equipment is reasonable and effective. After optimization, the order backlog of each prefecture-level city storage warehouse is reduced, and the order processing time is reduced. The optimization ideas proposed in this paper provide the optimization direction for the emergency epidemic prevention materials reserve and supply system in Shanxi Province, and also have certain guiding significance for how to deal with major public health emergencies.

KEYWORDS: Emergency logistics; Reserve and supply systems; Epidemic prevention materials; Agent modeling; AnyLogic simulation optimization

1. INTRODUCTION AND LITERATURE REVIEW

The 14th Five Year Plan period is a crucial period for promoting the modernization of emergency management systems and capabilities. The emergency material support work is facing a new situation and challenges. General Secretary Xi Jinping clearly proposes to establish a sound and unified emergency material support system, making emergency material support an important part of the construction of the national emergency management system. How to improve emergency logistics has become a top priority. At present, the layout of China's emergency material support system is not balanced and the level of technology is relatively low. In terms of local reserves, there are many shortcomings in terms of capacity and transportation capacity. In recent years, public health emergencies have occurred frequently. From SARS in 2003 to COVID-19 in 2020,all kinds of public health emergencies pose a great threat to people's life safety. In this situation, efficiently and orderly carrying out emergency material support work has become an important issue facing the world. The 14th Five Year Plan proposes a development strategy of establishing an emergency logistics system with rapid response and strong impact resistance. Emergency logistics refers to a special logistics activity that provides emergency support for the needs of materials, personnel, and funds in response to serious natural disasters, sudden public health incidents, public safety incidents, and military conflicts. It is composed of elements such as fluid, carrier, flow direction, process, and flow rate, and has spatial utility, temporal utility, and physical utility. In most cases, emergency logistics achieves its logistics benefits through logistics efficiency, which is an important link in ensuring people's life safety and social stability. In the face of problems such as insufficient reserves and untimely supply of epidemic prevention materials, it is crucial to improve the reserve and supply system of emergency epidemic prevention materials in Shanxi Province.

Improve the emergency material support system and effectively improve the response speed of emergency materials. By improving the emergency epidemic prevention material reserve and supply system in Shanxi Province, we aim to enhance material utilization efficiency, resource integration capabilities, and maintain social stability. We should conduct research on emergency material dispatch that is in line with the national conditions and focus on establishing a sound emergency epidemic prevention material support system. This is of great significance for ensuring the safety of people's lives and property, maintaining social stability and national security in our country.

This article combines GIS technology with intelligent agent modeling using AnyLogic simulation technology. Simulate the emergency epidemic prevention material reserve and supply system in Shanxi Province through AnyLogic and Excel interaction, external parameter control input, and intelligent group interaction. Realize timely distribution of epidemic prevention materials throughout the province. To address the current issues in material distribution in Shanxi Province, this study investigates the impact of transportation equipment configuration and full load on order backlog and processing time. Simulate multiple times by changing the full load rate and configuration of transportation equipment to find optimization directions.

This article simulates the distribution of epidemic prevention materials using AnyLogic software, which has high practical value. Firstly, improve the efficiency of epidemic prevention material distribution by optimizing the configuration of transportation equipment and the full load rate of transportation equipment. A reasonable allocation of transportation equipment and the full load rate of transportation equipment can reduce the empty load rate of vehicles, reduce order backlog, and meet the needs of material distribution. Secondly, based on the analysis of simulation results, it can provide decision-making reference for government departments in emergency material distribution in major public health events. To cope with different epidemic developments and demand situations. In addition, this simulation study is not only applicable to the distribution of epidemic prevention materials, but also provides reference for emergency logistics in various emergency situations or disaster events and has universal value.

Through multiple research and analysis of the sudden outbreak of the epidemic nationwide, it has largely exposed the shortcomings of insufficient reserves of emergency epidemic prevention materials in various regions of China. Sun Yi (2020) and others pointed out the specific situation and problems of the shortage of emergency supplies at the initial stage of the COVID-19.The stock of medical protective clothing and other materials is in short supply, and the potential for emergency production is lacking. The phenomenon of some materials being "should be stored but not stored" is prominent[Error! Reference source not found.].At present, the issue of emergency material reserves and allocation mainly focuses on determining[2] reserve levels or inventory strategies[3].Some scholars have started and conducted research on material storage. Luyan Wang(2023)conducted a study on the storage of community emergency supplies[4].Lijo John(2009) Lijo John(2009) and others combined quantity elasticity contracts and discount incentives with humanitarian supply chains for emergency material procurement[5].Fuyu Wang(2023) and others have conducted a study on the fast and fair allocation of emergency supplies after large-scale sudden disasters based on the improved NSGA-II algorithm. Benita[6]Benita M. Beamon (2006) and others developed a stochastic inventory control model to determine optimal order quantities and reorder points for long-term emergency relief response [7].Eren Erman Ozguven (2012) and others demonstrated the utility of the stochastic humanitarian inventory control model and the estimation of minimum safety stock levels for emergency stockpiles [8].Some scholars have conducted research on the site selection of epi demic prevention distribution centers. Shilong Li (2018) and Nyimbili P H (2020) studied the emergency material location model using an improved Analytic Hierarchy Process[9-10]. Yan X (2021) determined the optimal site selection scheme for hierarchical supply by maximizing rescue satisfaction and minimizing the number of warehouses**Error! Reference source not found.**. Yandong He (2017) proposed a mixed fuzzy multi criteria decision-making method to select the location of sustainable joint distribution centers**Error! Reference source not found.**.Seelbach(2015) and others have used stochastic modeling and related indicators to inform the development of a framework for applying these indicators to assess the disaster response capacity of logistics networks [**Error! Reference source not found.**.Feng J (2020) optimized site selection based on variable weighting algorithm**Error! Reference source not found.**.Mu X (2016) comprehensively considered multiple factors for the location selection of emergency material reserve points[15].Scholars at home and abroad have conducted research on the distribution of emergency supplies from multiple perspectives. For example, Bernardo Villarreal(2018)and others expand Lean Transportation Approach and Improve Emergency Medical Process (EMP) Performance **Error! Reference source not found.**.Ying Qiu(2023)and others constructed a tripartite evolutionary game (ETG) model and a system dynamics (SD) model with higher-level emergency management agencies (HAE),local emergency management agencies (LAE), and emergency logistics enterprises (ELE) as the main stakeholders**Error! Reference source not found.**.Bouchra (2018) established a model based on the shortest delivery time and explored the distribution of emergency supplies**Error! Reference source not found.**.Shaolong Hu(2019) used a progressive hedging algorithm to solve a multi-stage stochastic programming model for large-scale disaster relief distribution**Error! Reference source not found.**.Chengming Qi (2020) used heuristic algorithms to schedule and optimize epidemic prevention materials[11].Yanyan Wang(2018)proposed a multi-objective allocation model for emergency supplies that balances efficiency and fairness[21].Liu H (2022) optimized the distribution path of emergency supplies by establishing a multi-objective mathematical model[22] Ferrer (2018) explored the last mile delivery of post disaster relief supplies and considered multiple measurement indicators such as fairness and coverage[23].Yiwen J (2018) considered the uncertainty of material distribution and used robust optimization methods to study material distribution[24].Xianfeng Y (2018) proposed using a two-stage approach to solve the problem of vehicle routing and relief allocation[25].Some scholars[26-28] have constructed two-stage stochastic programming and transportation models. Mengran Wan (2023) and Ren Xide (2012) established a multi cycle dynamic transportation model for the distribution of various emergency supplies under uncertain demand[29-30].Chen Liu (2021) studied the decision-making model for emergency material distribution based on fuzzy objective programming[31].Jianjun Dong(2023) and others have concluded that ULS can significantly improve urban transportation and logistics[32].

At present, there is relatively little research on using Anylogic technology to simulate emergency material distribution. In China, Anylogic simulation technology is commonly used for simulation research in bank queuing models or spatial design of subway stations. In this regard, this article uses Anylogic simulation modeling software to conduct systematic simulation research on the emergency epidemic prevention material reserve and supply system in Shanxi Province. In summary, we will actively use big data and simulation software technologies to build a reserve and supply system for emergency epidemic prevention materials in Shanxi Province, in order to transfer and transport emergency materials. Analyze how to effectively reserve and supply epidemic prevention materials to cope with the sudden spread of the epidemic, meet the province's demand for epidemic prevention materials, and provide timely supply.

2. CURRENT STATUS OF EMERGENCY EPIDEMIC PREVENTION MATERIAL RESERVE AND SUPPLY SYSTEM IN SHANXI PROVINCE

Basic information

The scope of emergency epidemic prevention materials mainly focuses on the following three aspects:

1. Emergency epidemic prevention materials, including emergency medical materials, medicines, sanitary disinfection and sterilization supplies, medical equipment, epidemic prevention protection supplies, etc.

2. Raw and auxiliary materials, components, and electronic components required for the production of emergency epidemic prevention materials.

3. Other emergency epidemic prevention transit materials determined by superiors and command centers. Excluding materials with special storage and transportation requirements, as well as those transported in bulk through filling.

The demand for epidemic prevention materials in various regions of Shanxi Province is high, and transportation and distribution operations are complex and difficult. There are numerous sources of emergency supplies. In addition to the national unified plan for allocation, the sources of emergency supplies donated by society are scattered. Usually, it arrives frequently and irregularly, and the demand for epidemic prevention materials involves a wide range. The order volume of epidemic prevention materials has grown rapidly and lasted for a long time during the epidemic, making it difficult to control the quantity and timing of incoming goods.

After a series of investigations, and for the convenience and scientificity of modeling, this article selected 11 addresses from 11 prefecture level cities in Shanxi Province as reserve warehouses and 32 counties and districts as demand points to receive and distribute materials.

Problem analysis

Shanxi Province is located in the interior of Chinese Mainland, close to Hebei, Shaanxi and Inner Mongolia. Shanxi Province has a large population and close economic ties with neighboring provinces. When the epidemic broke out in neighboring provinces, Shanxi Province was inevitably affected. This has led to more sudden outbreaks and rapid spread of the epidemic in Shanxi Province, resulting in insufficient reserves of epidemic prevention materials and a shortage of supply and demand.

In areas with a shortage of emergency epidemic prevention materials in Shanxi Province, there are problems such as poor supply of medical protection materials and insufficient supply of goods. In the emergency measures taken in various regions of Shanxi Province to cope with epidemic prevention and control, there are problems with insufficient transportation equipment and personnel for medical protective equipment.

Through analysis of the existing emergency epidemic prevention material reserve and supply system in Shanxi Province, there are mainly two problems.

(1) There is a large backlog of orders. Due to insufficient material distribution, a large amount of emergency epidemic prevention materials have accumulated in the reserve warehouse. This leads to problems such as low delivery efficiency, and the demand points cannot be met in a timely manner.

(2) The order processing time is long. In the scheduling process of epidemic prevention materials, when the materials are insufficient to meet the order requirements, the order will be suspended and enter the next processing cycle. Therefore, there is a problem of long processing time in the processing process. Long order processing cycles can delay the scheduling and distribution of materials, affecting the timely supply of epidemic prevention materials.

3. BUILD SYSTEM SCENARIOS AND SIMULATION MODELING

Selection of modeling methods

At present, AnyLogic simulation software mainly supports three modeling methods: multi-agent, discrete event systems, and system dynamics. This model uses AnyLogic simulation to simulate the emergency epidemic prevention material reserve and supply system in Shanxi Province.

Table 1. Comparison of Three Simulation Modeling Methods

Modeling methods	Characteristic	Applicability
Discrete event	Centered on business processes, most can be described as a series of discrete independent time series	Describe the system as a process
Agent-based simulation	Behavioral interactions between intelligences lead to changes in system dynamics	Multiple independent objects exist in the system
System dynamics simulation	An abstract system dynamics approach	Only global dependencies exist for the system

Source: Chen Yongfan(2022)[32]

Due to the existence of different things with different parameters in real life, the interrelationships between things are dynamically changing. This article selects intelligent agent simulation modeling. By performing functional control on it, capture the behavior of intelligent agents and the flow of information between them. Geographic Information System (GIS) refers to natural, social, and cultural landscape data that refers to the spatial location of the Earth's surface. GIS The real world expressed by GIS is the substantive content abstracted by models. The types and accuracy of geospatial data in GIS for different purposes vary. Through the interaction between AnyLogic and GIS technology, Simulate and predict the evolution of geographic spatial processes. Using GIS data as a living environment agent can effectively overcome the limitations of general distribution problems. There are significant differences between agents in GIS environments and general agents. GIS data has rich geographic information and certain carrying functions. By creating GIS components, Agent agents can perform "activities" in GIS space. This enables each agent in intelligent agent modeling to facilitate the flow of internal Data information, and the intelligent agent is dynamic in the GIS environment. By dynamically controlling specific agents, specific agents can be recorded and monitored in real-time during the simulation process.

Environmental modeling and generation of intelligent agents

Location selection of reserve warehouses and demand points in prefecture level cities

Firstly, study the location selection of reserve warehouses and demand points in Shanxi Province. Based on the regional structure of Shanxi Province and the historical experience of epidemic outbreaks in various cities, one reserve warehouse is set up in each prefecture level city of Shanxi. These 11 reserve warehouses are located in Xiaodian District of Taiyuan City, Shuocheng District of Shuozhou City, Yuci District of Jinzhong City, Xiaoyi City of Lvliang City, Xinfu District of Xinzhou City, Pingcheng District of Datong City, Yaodu District of Linfen City, Yanhu District of Yuncheng City, Luzhou District of Changzhi City, urban area of Jincheng City, and urban area of Yangquan City. The specific site selection information is as follows:

Table 2. Site selection and latitude and longitude of emergency epidemic prevention material storage warehouses in prefecture level cities

Type	Name of total warehouse	City of jurisdiction	Latitude	Longitude
1	JD Logistics Park	Taiyuan City	37.7379446	112.6163641
2	Zicheng Commercial Logistics Park	Shuozhou City	39.3109589	112.4248255
3	Zhongding Logistics Park	Jinzhong City	37.6999617	112.6468581
4	Dadi Shunxiang Logistics Park	Lvliang City	37.1810433	111.7613903
5	Iinzhou Passenger Transport Center	Xinzhou City	38.4356107	112.7070659
6	Xintianhe Logistics Park	Datong City	40.0519389	113.2760547
7	Airpot Warehouse Logistics Park	Linfen City	36.1137133	111.5119326
8	JD Logistics Yuncheng Transit	Yuncheng City	35.0929281	110.9660185
9	Deyixing Logistics Park	Changzhi City	36.1843432	113.0892387
10	Beidou Logistics Park	Jincheng City	35.4841836	112.8565027
11	National Pharmaceutical Shanxi Yangquan Pharmaceutical Co., Ltd	Yangquan City	37.8595348	113.6323819

Source: Compiled by the author

Based on various factors such as the area, population, infrastructure, and transportation of each city,32 demand points will be set up throughout the province. Located in Yuci District, Jinzhong City, Jiexiu City, and Zuoquan County. Yangqu County, Yingze District, and Gujiao City in Taiyuan City. Yangquan City District, Mining Area. Qinshui County, Jincheng City, urban area. Pingcheng District, Yunzhou District, and Guangling County in Datong City.

Xinfu District, Yuanping City, Kelan County, Xinzhou City. Ying County, Shuocheng District, Youyu County, Shuozhou City. Xiaoyi City, Xingxian County, Lishi District, Lvliang City. Yaodu District, Xiangning County, and Hongdong County in Linfen City. Salt Lake District of Yuncheng City, Yongji City, Jishan County, and Jiang County. Luzhou District, Xiangyuan County, and Qin County in Changzhi City. The selection of epidemic prevention material demand points is shown in Table 2.

All site selection will be organized into Excel format and stored in a folder under the model for future reference.

The main basis for selecting demand points is:

1. Try to be as close as possible to the end market in order to improve the delivery efficiency of epidemic prevention materials in the city and reduce delivery costs.

2. Focus on target areas with high demand for epidemic prevention materials.

3. It has scalability and can expand the area of the reserve warehouse on site in the event of a surge in material demand.

4.It is separated from the office space and has the characteristics of independent operation and storage type warehouse.

5. Close to transportation hubs or main roads in various regions, with good transportation conditions.

6. Based on the demand for materials in urban and suburban areas, differences in land prices across regions, and government directives.

7. Based on the level of storage capacity of medical supplies in nearby hospitals. Focus on selecting places close to infectious disease hospitals and isolation hospitals.

Table 3. Selection of demand points for emergency epidemic prevention materials

City where the demand point is located	Name of demand point	City where the demand point is located	Name of demand point
Jinzhong City	Yuci District Disease Control Center	Taiyuan City	Yingze District Disease Control Center
	Jiexiu City Disease Control Center		Yangqu County Jindebang Pharmaceutical Logistics Park
	Zuoquan County Disease Control Center		Gujiao Disease Control Center
Yangquan City	Mining Area Disease Control Center	Jincheng City	Urban Disease Control Center
	Urban Disease Control Center		Qinshui County Fangcang Hospital
Datong City	Datong City Disease Control Center	Xinzhou City	Xinzhou City Disease Control Center
	Yunzhou District Center for Disease Prevention and Control		Yuanping City Disease Control Center
	Guangling County Disease Control Center		Kelan County Center for Disease Prevention and Control
Shuozhou City	Shuocheng District Disease Control Center	Linfen City	Yaodu District Disease Control Center
	Youyu County Disease Control Center		Xiangning County Disease Control Center
	Yingxian Disease Control Center		Hongdong County Disease Control Center
Lvliang City	Xiaoyi City Disease Control Center	Changzhi City	Luzhou District Center for Disease Prevention and Control
	Lishi District Disease Control Center		Xiangyuan County People's Hospital
	Xingxian Disease Control Center		Qinxian People's Hospital
Yuncheng	Yuncheng City		

City	Disease Control Center		
	Yongji City Disease Control Center		
	Jishan County People's Hospital		
	Jiangxian People's Hospital		

Source: Organized by the author

The Logistics Park and disease control center serve as professional guarantees for the cold chain transportation of pharmaceuticals, and refrigerated trucks and cold storage are used to transport and reserve drugs with strict storage conditions. The reserve warehouses and supply points selected in this article are selected from the existing situation in Shanxi Province, as well as logistics parks and disease control centers with backup medical reserve conditions.

2.2.2environment modeling

Under the state of epidemic prevention and control, there is a high demand for emergency epidemic prevention materials in Shanxi Province, and the demand for materials in various regions is difficult to determine. Therefore, improving the emergency material reserve and supply system in Shanxi Province has become a top priority, and building a scenario modeling of the actual outbreak of the epidemic in Shanxi Province is the foundation of the entire modeling.

Firstly, it is the main process involved in the material distribution chain, which is the main part of the simulation model. The demand points in the epidemic area place orders for material needs and place orders with the nearest prefecture level city reserve warehouse. The reserve warehouse receives the order and determines whether the current reserve warehouse can meet the material requirements on the order, as well as whether there are suitable idle vehicles available for transportation. There will be four situations:

1. The materials in the current reserve warehouse can meet the order requirements and there are idle vehicles available for transportation. At this point, load the materials onto the vehicle.
2. The materials in the current reserve warehouse can meet the order requirements and there are no idle vehicles for transportation. At this time, the order is suspended and waiting for idle vehicles.
3. The materials in the current reserve warehouse cannot meet the order requirements and there are idle vehicles for transportation. Split the current order into two sub orders A and B based on the parts that can be met and the parts that cannot be met. Execute sub order A that meets the conditions and load the materials onto the vehicle. The unsatisfactory sub order B enters the replenishment process.
4. The materials in the current reserve warehouse cannot meet the order requirements and there are no idle vehicles for transportation. Split the current order into two sub orders A and B based on the parts that can be met and the parts that cannot be met. Execute sub order A that meets the conditions, at which point the order is suspended and waiting for idle vehicles. The unsatisfactory sub order B enters the replenishment process.

Secondly, the model determines whether the idle vehicles currently loaded with materials have reached the capacity for departure, or if there are order tasks approaching their deadline. If yes, proceed with the shipment. If no, continue to wait. The vehicle transports the materials to the destination, and the transportation process ends. The specific process is shown in Figure 1.

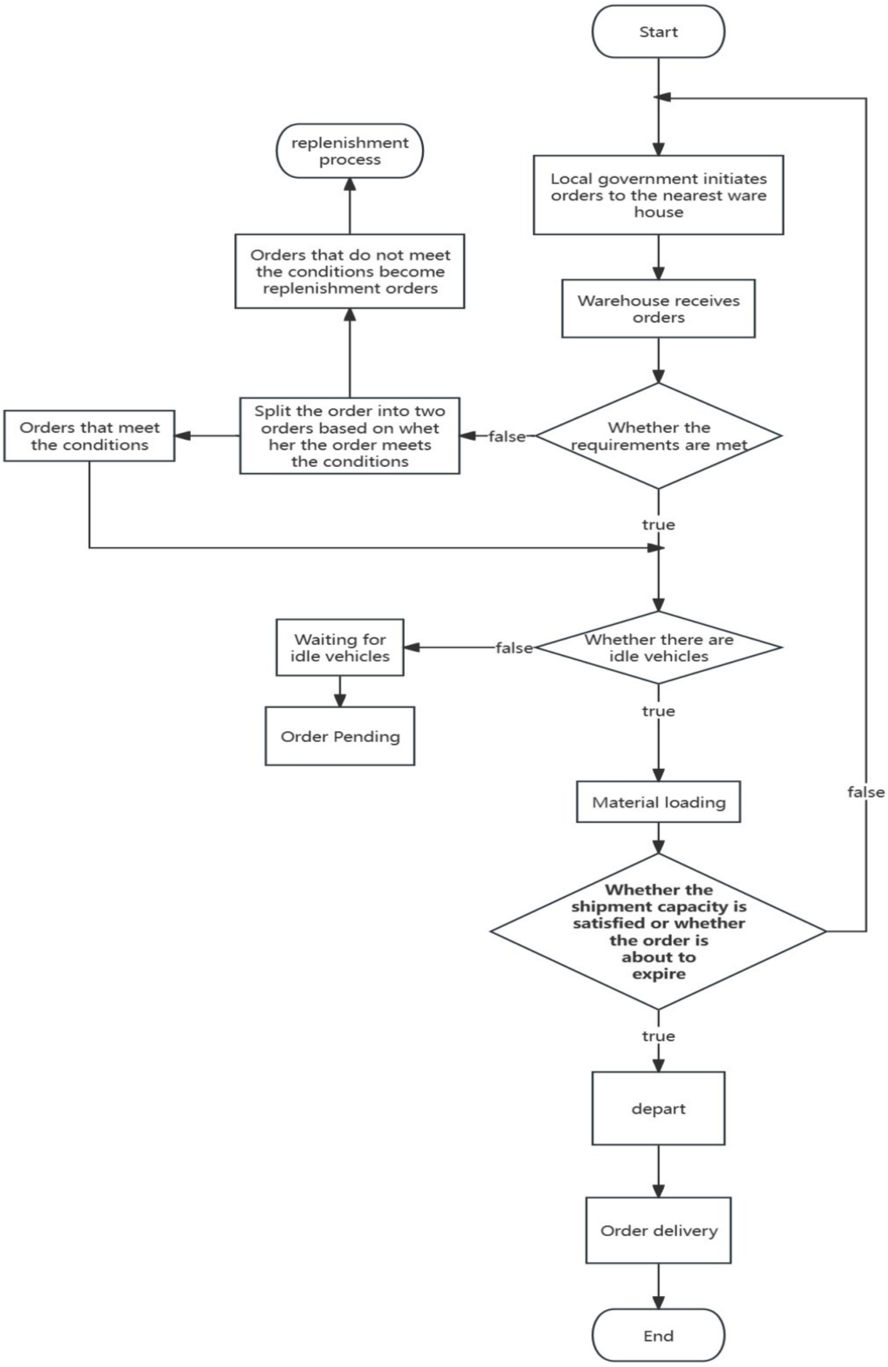


Figure 1. Order Transportation Logic Flowchart

In addition, the replenishment logic follows the quantitative ordering method. After investigation, it was found that the epidemic prevention materials reserve in Shanxi Province is located in the reserve warehouse of China National Pharmaceutical Group Shanxi Company or the reserve warehouse of pharmaceutical enterprises. When the emergency epidemic prevention material reserves of each prefecture level city are insufficient, a replenishment order demand is initiated. The logic of completing replenishment orders is the quantitative ordering method. Pre determine an order point and order quantity, and the system checks inventory at any time. Start ordering when inventory drops to the ordering point. The order quantity is the economic order quantity, which then enters the lead time LT for ordering. When the lead time LT ends, a portion of the inventory is consumed, causing the inventory to drop to a lower level. At this point, the ordered goods in bulk Q arrive, and the inventory quickly rises to a higher level, entering the second cycle. This keeps circulating. Reserve warehouses in prefecture level cities request materials and place orders with the nearest higher-level warehouse in their geographical location. Replenishment orders triggered by the detection mechanism of the reserve warehouse. Check if there are any idle vehicles, and if not, suspend the order and wait. If available, load the materials onto the vehicle and depart. The vehicle transports the materials to the destination and the process ends. The replenishment process is shown in Figure 2

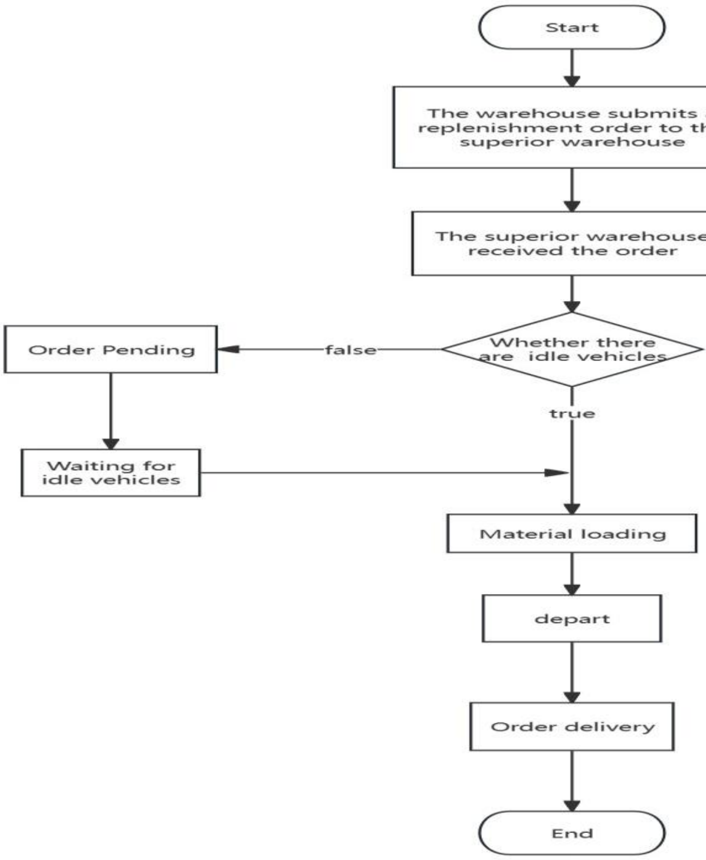


Figure 2 Logistics flowchart of replenishment process

In order to obtain a clear road network and good visualization effect, this model was scaled down to Taiyuan, the provincial capital of Shanxi Province, as an example, as shown in Figure 3.The location selection basis for the distribution model is the same as above, extending radially from the center to the surrounding areas to maximize the transportation of emergency epidemic prevention materials.

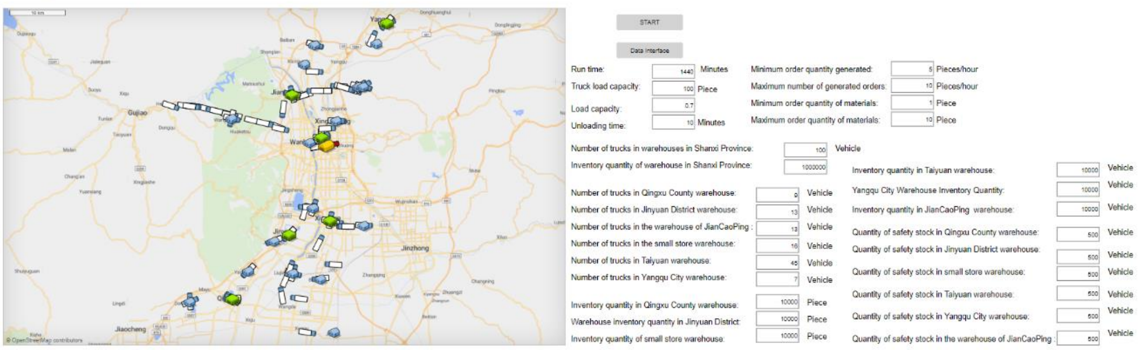


Figure 3. Emergency Material Distribution Path Model in Taiyuan City

Simulation model based on Anylogic software

Intelligent agent parameter settings

Environmental modeling for building an epidemic prevention material reserve and supply system in Shanxi Province, with initial modeling parameters and definitions shown in Table 4.

Table 4. Intelligent Agent Parameter Settings

Agent	Meaning	Parameter	Assignment

Truck	Transportation Equipments	volume
		stowage ratio
		nearOrder
			volume=20;
			stowage ratio=0.6;
			order location for priority delivery；

Retailer	Supply Points	rateOrder maximum quantity per order minimum quantity per order	rateOrder= (10,100); maximum quantity per order=3; minimum quantity per order=1；
Distribution	Main Warehouse	Truck ulilization ratenumOfTruck Truck speed	Truck ulilization rate=workTime / time； Truck speed=16.6；

Source: Compiled by the author

Intelligent agent behavior logic settings

While conducting model simulation, cross use system dynamics methods to define the behavior of transportation equipment intelligent agent groups. The dynamic changes of the system are manifested as the result of the interaction between individual behaviors of intelligent agents. Using Java language to logically set up important intelligent agents such as storage warehouses, demand points, orders, and transportation equipment.

（1）Demand points

As an important component of the supply system, demand points are one of the important links in the supply chain of epidemic prevention materials. County demand points initiate order requests to the reserve warehouse based on the demand situation, waiting for the reserve warehouse to dispatch Trucks to deliver materials.

（2）Order

An order is a type of intelligent agent that is sent in the form of an MSG from demand points in epidemic areas to reserve warehouses in prefecture level cities. It serves as a bridge connecting the reserve warehouse and supply points. As one of the intangible elements of the system, timely processing of orders can better meet the needs of epidemic prevention and control.

（3）Reserve warehouses in prefecture level cities

After receiving the order requirements, the reserve warehouse coordinates the outbound and loading of materials. The reserve warehouse randomly selects idle transportation equipment to deliver orders, ensuring that each county and district demand point can receive timely supply of epidemic prevention materials. When the storage capacity is insufficient, issue a replenishment order request to the superior warehouse.

（4）Transportation equipment

Transportation equipment plays a crucial role in delivering materials from reserve warehouses to demand points. The transportation equipment will immediately deliver upon receiving instructions from the reserve warehouse and unload the materials upon arrival at the destination. If there is an unprocessed order demand, it is necessary to go to the nearest demand point to process the order.

The above are the behavioral logic settings of several key intelligent agents in the emergency epidemic prevention material reserve and supply system of Shanxi Province. They can achieve timely supply of materials and reduce the occurrence of supply-demand imbalance through mutual coordination and cooperation among all parties.

Important initial data settings

Quantity of transportation equipment configuration

Through software simulation modeling, further research will be conducted on the two most important indicators of epidemic prevention material transportation equipment configuration and transportation equipment full load rate within the system. Box trucks are the most commonly used ordinary transportation equipment for logistics transportation companies, and these types of transportation equipment are also commonly used for transportation and distribution. Can be used for transporting personal protective equipment. A refrigerated truck is a specialized transportation vehicle equipped with a refrigeration unit and a polyurethane insulated compartment for refrigeration. It is used to transport disinfection and sterilization supplies and medical equipment. Based on the particularity of epidemic prevention materials, we simulate the transportation equipment configured as ordinary trucks and refrigerated trucks. The model time is the simulated real time, randomly selected from September 1,2022 to December 1, 2022.Simulate a simulation lasting three months as realistically as possible. Through various simulations, select the time stage with the most obvious and representative fluctuations for simulation analysis.

By analyzing various factors comprehensively, the backlog of orders and order processing time are used as evaluation indicators to evaluate the effectiveness of the optimization plan from these two aspects. Based on the research on population density, spatial distance, and economic development level of various cities in Shanxi Province, the preliminary allocation of transportation equipment is determined in the following table:

Table 5. Preliminary simulation of transportation equipment configuration (unit: vehicle)

City of location	Taiyuan Warehouse	Shuozhou Warehouse	Jinzhong Warehouse	Lvliang Warehouse	Xinzhou Warehouse	Datong Warehouse	Linfen Warehouse	Yuncheng Warehouse	Changzhi Warehouse	Jincheng Warehouse	Yangquan Warehouse
Configuration Quantity of Transportation Equipment	100	50	80	100	60	72	87	90	110	90	40

Data source: Based on Shanxi Statistical Yearbook and simulation.

Full load rate of transportation equipment

The full load rate of transportation equipment refers to the relative value of the degree of full load of truck cargo that is in a transportation state for a certain period of time. In principle, transportation can only be carried out when the loading volume of the transportation equipment reaches more than half of the overall unit volume. Through continuous data iteration experiments, we selected 0.6 as the initial value of the full load rate when the evaluation indicators began to show significant changes, and simulated the full load rate of transportation equipment.

Model operation and simulation results

（1）Model operation status

According to the simulation model, external parameters control inputs and interact with the intelligent agent population. Interact and output simulation data through OutDate external links, and visually display its increase and decrease in the form of a bar chart. Then export the data in the form of a data table and draw a line chart to analyze the trend of evaluation indicators.

Real time display of inventory, truck utilization, order processing time, and order backlog through statistical charts facilitates our analysis and adjustment to better improve the delivery efficiency of epidemic prevention materials. As shown in Figure4.

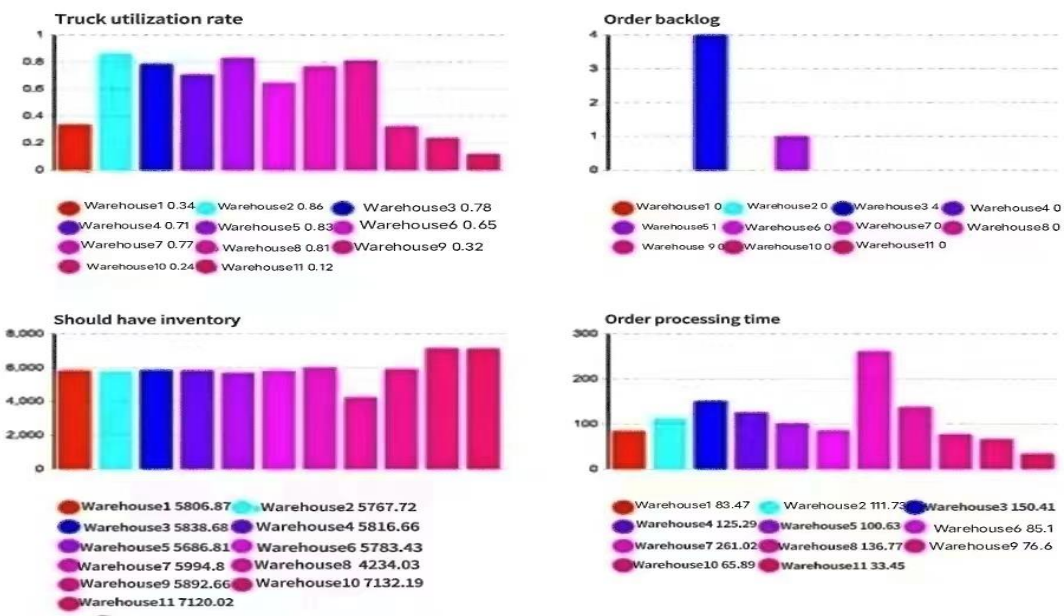


Figure 4: Cross section of important intelligent agent data for different reserve warehouses under random time

（2）Model simulation results

The initial simulation results are consistent with the problems encountered in the emergency epidemic prevention reserve and supply system of Shanxi Province mentioned above. This initial data will be used as the original control group (i.e. Scenario 1) data to analyze the changes in order backlog and order processing time under different scenarios.

4. OPTIMIZATION PLAN

Based on the analysis of the above issues, it can be concluded that the loading plan of transportation equipment has the most critical impact on the emergency material reserve and supply system. This article will analyze the data changes in different scenarios by changing the full load rate and Configuration of transportation equipment to find optimization directions.

On the basis of the effectiveness of the model, keep other constants unchanged. Change the full load rate and configuration of transportation equipment separately. Scenarios 1,2, and 3 use transportation equipment with full load rates of 0.6,0.75,and 0.9,and scenarios 4 and 5 use 1.25 and 1.5 times the initial vehicle configuration.

Compare and analyze the changes in order backlog and order processing time in different scenarios. In different scenarios, the parameter settings of the model are shown in Table 6.Taking Shuozhou City, which first experienced backlog, Xinzhou City with the highest backlog, and Linfen City, which had the longest order processing time, as examples.

Table 6. Simulation of Different Reserve Warehouse Parameters in Different Scenarios

Warehouse name	Full Load Rate of Transportation Equipment	transportation equipment configuration in Shuozhou warehouse	transportation equipment configuration in Xinzhou warehouse	transportation equipment configuration in Linfen warehouse
Scenario 1	0.6			
Scenario 2	0.75	50	60	87
Scenario 3	0.9			
Scenario 4	0.6	63	75	109
Scenario 5		75	90	131

5. EVALUATION OF OPTIMIZATION PLAN EFFECTIVENESS

Evaluation indicators

Evaluation indicators are standards or quantitative indicators used to measure, evaluate, and compare a certain goal or performance.

After analysis, research, and multiple experiments, the following evaluation indicators have been determined:

（1）The length of order processing time

（2）What is the backlog of orders

Order processing time is an important indicator for measuring the efficiency of material delivery. It reflects the time required for an order to be generated and processed. A shorter order processing time indicates a more efficient delivery process, allowing orders to be processed and delivered faster.

Order backlog refers to the number of orders that have not yet been fully processed and delivered. A higher backlog of orders may indicate delayed or congested delivery processes, which may lead to delayed delivery of epidemic prevention materials.

Using these two indicators as evaluation criteria, it is used to observe whether material distribution is optimized when changing the models of transportation equipment loading rate and transportation equipment configuration quantity respectively. When the processing time of orders is reduced and the backlog of orders is reduced, both effects are met simultaneously, and optimization direction is obtained.

The impact of transportation equipment load factor on evaluation indicators

The impact on order backlog

Simulate the changing trends of different reserve warehouses in scenarios 1,2, and 3, and observe the changes in order backlog.

Due to the large amount of data, it is not suitable to observe the experimental simulation operation of different transportation equipment with full load rates. By using a line graph to compare the data of three scenarios, a more intuitive data change can be obtained. As shown in Figures 5,6, and 7.

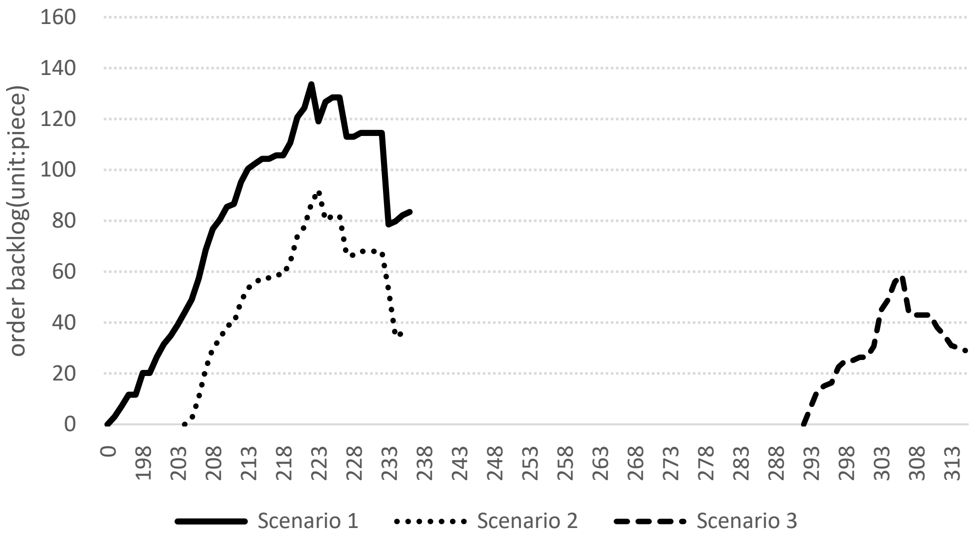


Figure 5. Experimental situation of the backlog of reserve warehouse orders in Shuozhou City as a function of the full load rate of transportation equipment

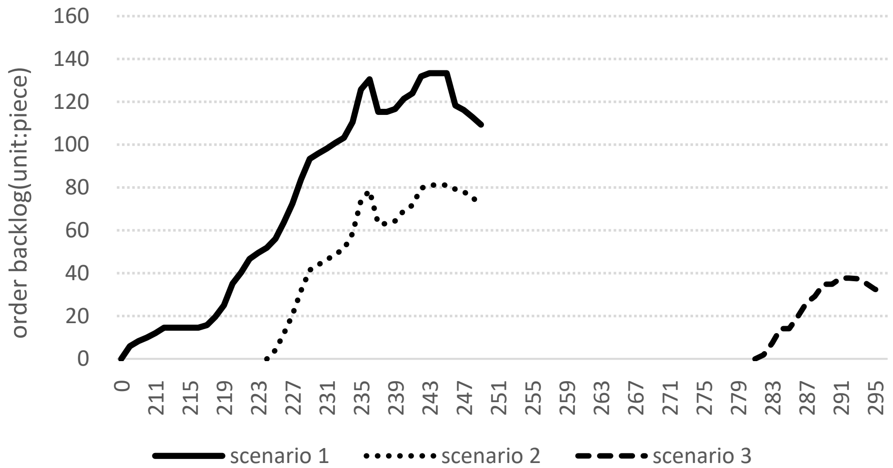


Figure 6. Experimental situation of the backlog of reserve warehouse orders in Xinzhou City changing with the full load rate of transportation equipment

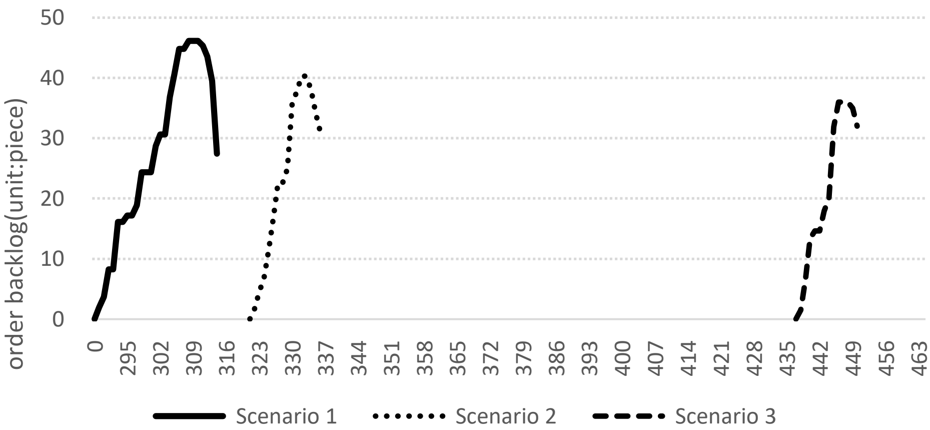


Figure 7. Experimental situation of the backlog of reserve warehouse orders in Linfen City changing with the full load rate of transportation equipment

According to the analysis in the above figure, it can be concluded that:

（1）With the increase in the full load rate of transportation equipment, the same reserve warehouse has begun to experience delayed order backlog time. As shown in Table 7

Table 7. Comparison of the time when the backlog of reserve warehouses began to occur before and after changing the full load rate of transportation equipment

Order backlog start time/hour	Shuozhou Warehouse	Xinzhou Warehouse	Linfen Warehouse
Scenario 1	194	208	289
Scenario 2	205	225	322
Scenario 3	293	282	438

（2）As the full load rate of transportation equipment increases, the peak backlog of orders in the same reserve warehouse decreases. As shown in Table 8.

Table 8. Comparison of peak order backlog before and after changing the full load rate of transportation equipment

Order backlog/piece	Shuozhou Warehouse	Xinzhou Warehouse	Linfen Warehouse
Scenario 1	128	133	46
Scenario 2	92	81	40
Scenario 3	58	38	36

（3）After multiple experiments, simulation cross-sectional data was obtained and further verified. The situation of each reserve warehouse is generally similar to the two types of reserve warehouses analyzed above. Yuncheng, Lvliang, and Jincheng have a low backlog of orders, and the peak changes are relatively small after each optimization. However, due to the large backlog of orders in Datong, Xinzhou, Shuozhou, and other cities, the fluctuation range of each peak after optimization is relatively large. But overall, all reserve warehouses in Shanxi Province reflect the above trend of data changes.

（4）A preliminary conclusion can be drawn from this. The different full load rates of transportation equipment will lead to a reverse trend in the backlog of orders. When the full load rate of transportation equipment is higher, the time when the backlog of orders starts to appear is later and the peak backlog volume is smaller. The number of data captures for order backlog has decreased, and the time interval from the beginning of backlog to the peak of backlog has become shorter.

（5）In real-life situations, strive to increase the full load capacity of transportation equipment as much as possible. Fully leverage the positive effect of high transportation equipment load on order volume within a reasonable range to improve the transportation speed of epidemic prevention materials. Reduce capital waste and meet the demand for medical supplies from demand points.

The impact on order processing time

Due to the large amount of data in simulation software experiments and the necessity of studying not all data. This article selects a three-day time period on an hourly basis to calculate the processing time of orders. The experimental data results are shown in the following figure. As shown in Figures 8, 9, and 10.

Figure 8. Experimental situation of the change in order processing time of the reserve warehouse in Shuozhou City with the full load rate of transportation equipment

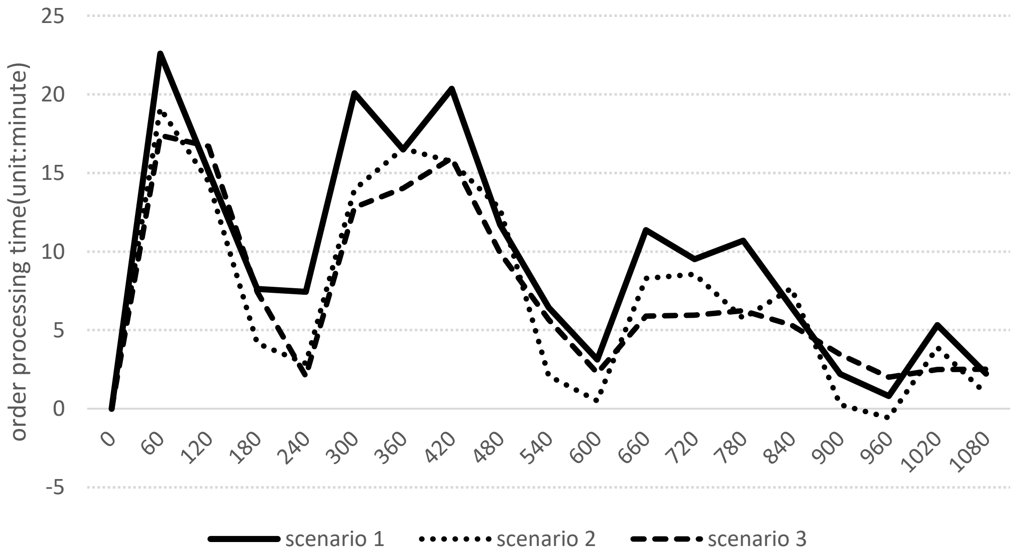


Figure 9. Experimental situation of the change in order processing time of reserve warehouses in Linfen City with the full load rate of transportation equipment

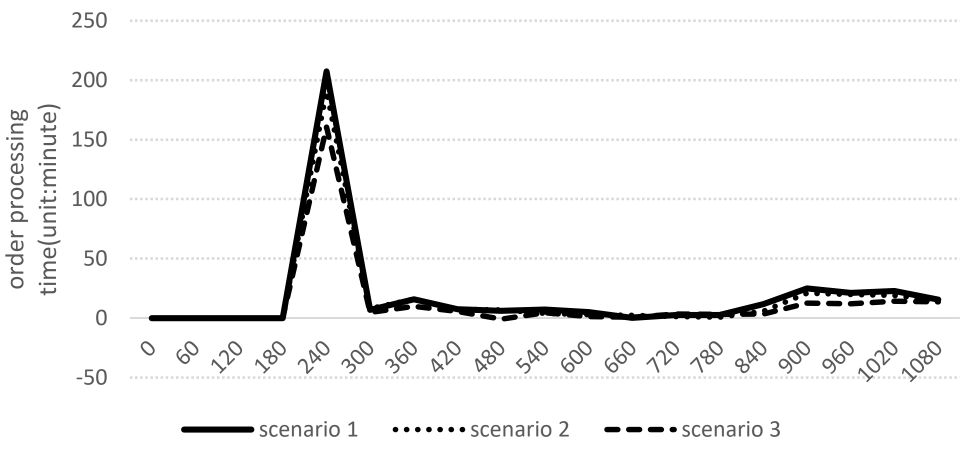


Figure 10. Experimental situation of the change in order processing time of reserve warehouses in Xinzhou City with the full load rate of transportation equipment

According to the analysis in the above figure, it can be concluded that:

(1) As the loading rate of transportation equipment increases, the peak processing time of orders in the same reserve warehouse decreases. As shown in Table 9.

Table 9. Comparison of peak order processing time before and after changing the full load rate of transportation equipment

Order processing time/minute	Shuozhou Warehouse	Xinzhou Warehouse	Linfen Warehouse
Scenario1	29.8	22.6	207.4
Scenario2	25.8	19.1	190.7
Scenario 3	23.2	17.4	160.4

(2) After multiple experiments to obtain simulation cross-sectional data and further verification, the situation of each reserve warehouse is generally the same as the two types of reserve warehouses analyzed above. After optimization and comparison of reserve warehouses in Taiyuan, Shuozhou, Jinzhong, Xinzhou, Changzhi, Jincheng, etc, it was found that the optimized order processing time showed negative values. After optimizing reserve warehouses such as Lvliang, Datong, Linfen, Yuncheng, and Yangquan, they all approach 0 minutes infinitely. This indicates that increasing the full load rate of transportation equipment significantly reduces order processing time. And handle the backlog of orders in the early stage, reducing time.

(3) The preliminary conclusion is that as the full load rate of transportation equipment increases, the order processing time decreases. By optimizing various factors in reality to improve the full load rate of transportation equipment, the time for processing orders is compressed to ensure timely delivery of materials.

CONCLUSION

When the full load rate of transportation equipment increases, the backlog of orders and order processing time both decrease and show a reverse trend. This meets the evaluation criteria and is also beneficial for exploring the direction of model optimization.

The impact of transportation equipment configuration on evaluation indicators

The impact on order backlog

Due to the large amount of data that is not suitable for observation, this article adopts a line chart to compare the three experimental data. Obtain more intuitive data representation changes. As shown in Figures 11,12,and 13.

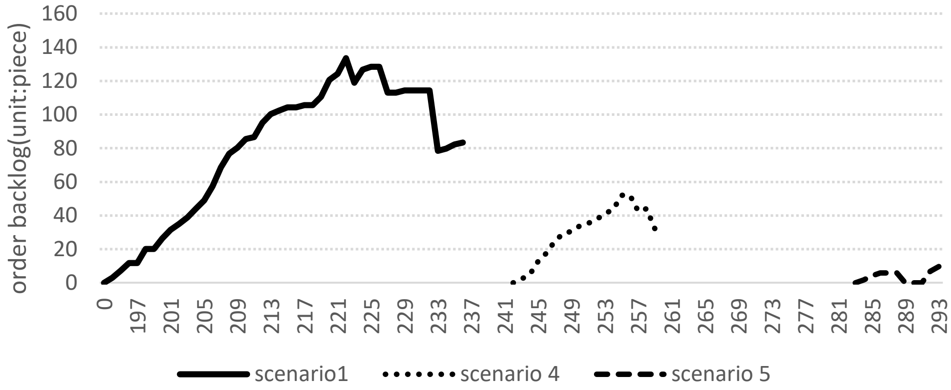


Figure 11. Experimental situation of order backlog in reserve warehouses in Shuozhou City as a function of transportation equipment configuration

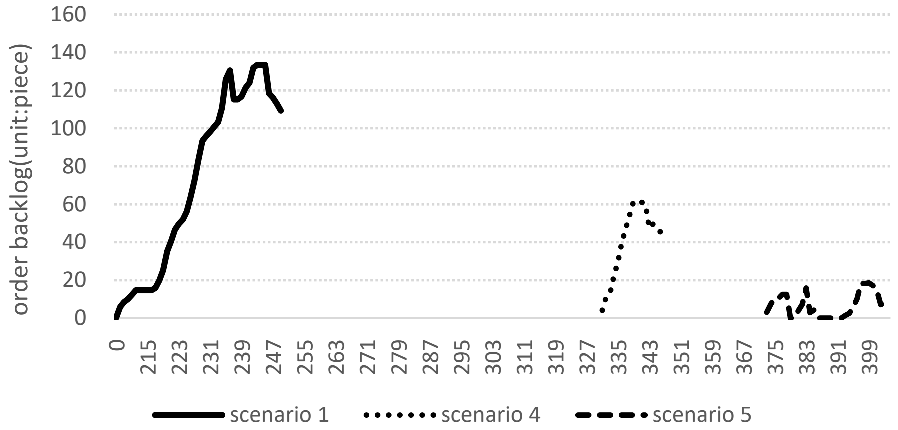
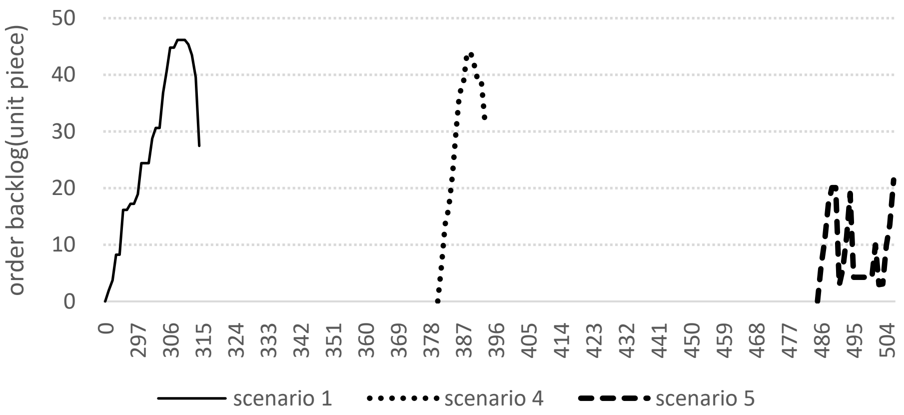


Figure 12. Experimental Situation of Order Backlog in Reserve Warehouse of Xinzhou City as a Function of Transportation Equipment Configuration



transportation equipment configuration

According to the analysis in the above figure, it can be concluded that:

（1）With the increase in transportation equipment configuration, The backlog of orders in the same reserve warehouse has been delayed. As shown in Table 10

Table 10. Comparison of the Time for Backlogging in Reserve Warehouses Before and After Changing the Configuration of Transportation Equipment

Order backlog start time/hour	Shuozhou Warehouse	Xinzhou Warehouse	Linfen Warehouse
Scenario 1	194	208	289
Scenario 2	243	331	381
Scenario 3	284	373	486

(2) With the increase of transportation equipment configuration, the peak backlog of orders in the same reserve warehouse has decreased. As shown in Table 11

Table 11. Comparison of peak order backlog before and after changing the configuration of transportation equipment

Order backlog/piece	Shuozhou Warehouse	Xinzhou Warehouse	Linfen Warehouse
Scenario 1	134	133	46
Scenario 2	52	62	44
Scenario 3	10	18	21

(3) After inspection, the situation of the remaining reserve warehouses is the same as that of the Shuozhou and Linfen reserve warehouses analyzed above. The reserve warehouses in Yuncheng, Shuozhou, Datong, and Xinzhou have been optimized to minimize the backlog of orders to zero and continue to fluctuate. The backlog of orders in the reserve warehouses of Linfen and Jinzhong is infinitely close to zero and fluctuates up and down. Among them, the Lvliang Reserve Warehouse has experienced a long-term zero backlog phenomenon after optimization. The inventory backlog has decreased, and the model has been further optimized.

(4) Changing the configuration of transportation equipment to increase the number of single transportation equipment delivery orders can effectively reduce the backlog of orders. Ensure timely delivery of epidemic prevention materials and solve the problem of epidemic prevention material reserves and supply. Assist in dynamically clearing the backlog of orders, ensuring timely supply and guarantee of people's demand for epidemic prevention materials.

The impact on order processing time

The line graphs representing the order processing time of Shuozhou Reserve Warehouse and Linfen Reserve Warehouse in scenarios 1,4, and 5 are shown in Figures 14, 15,and 16

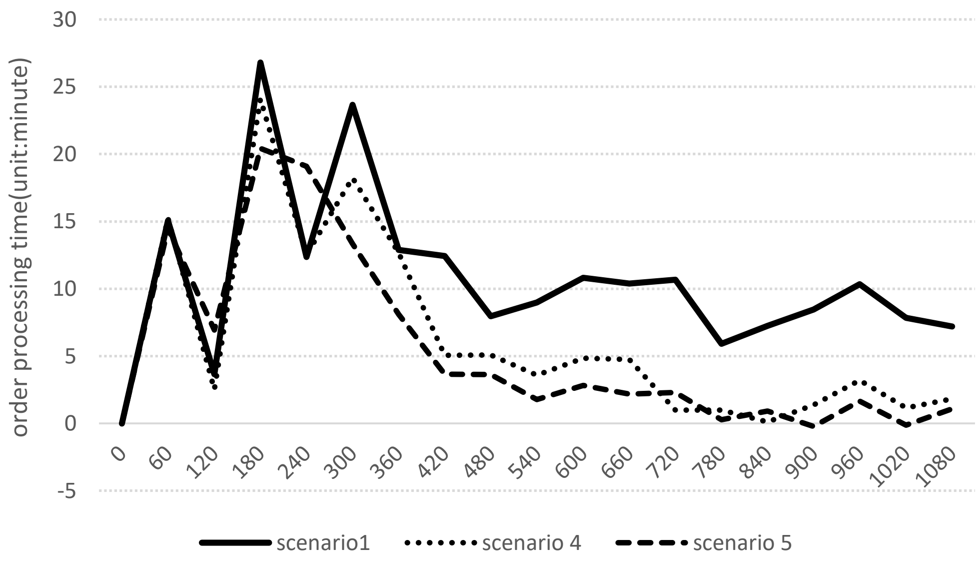


Figure 14. Experimental situation of the change in order processing time of the reserve warehouse in Shuozhou City with the configuration of transportation equipment

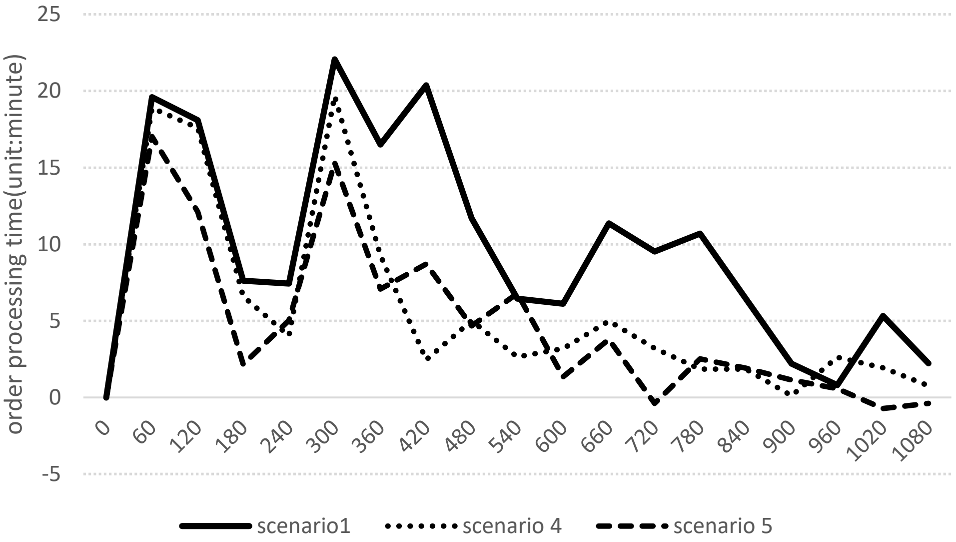


Figure 15. Experimental situation of changes in order processing time of reserve warehouses in Xinzhou City with the configuration of transportation equipment

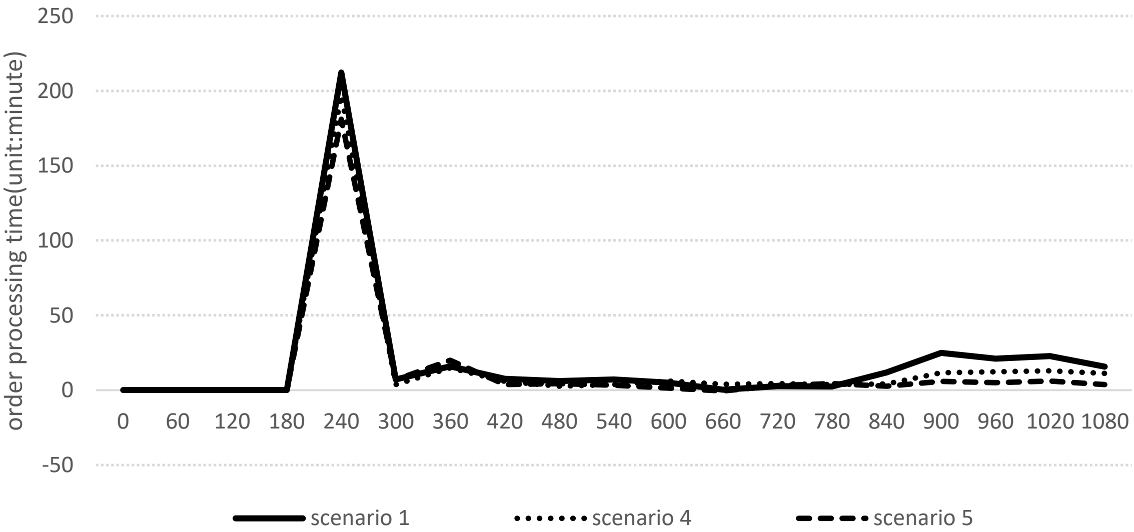


Figure 16. Experimental situation of the change in order processing time of reserve warehouses in Linfen City with the configuration of transportation equipment

According to the analysis in the above figure, it can be concluded that:

(1) With the increase of transportation equipment configuration, the peak processing time of orders in the same reserve warehouse decreases.As shown in Table 12

Table 12.Comparison of peak order processing time before and after changing the configuration of transportation equipment

Order processing time/minute	Shuozhou Warehouse	Xinzhou Warehouse	Linfen Warehouse
Scenario 1	26.8	22.1	212.4
Scenario 2	24.1	19.7	197.1
Scenario 3	20.4	17.0	181.2

(2) After multiple data tests through simulation experiments, the situation of the remaining reserve warehouses is the same as the two types of reserve warehouses analyzed above. After optimizing the reserve warehouses in Taiyuan,

Datong, Linfen, and Yangquan, the peak decline trend is relatively small. The peak decline trend of reserve warehouses in seven cities, namely Shuozhou, Jinzhong, Lvliang, Xinzhou, Yuncheng, Changzhi, and Jincheng, is obvious, and the graph curve fluctuates greatly.

（3）The preliminary conclusion is that with an increase in transportation equipment configuration, order processing time will decrease. Therefore, it is possible to reduce the time from order generation to processing completion to improve the supply capacity of epidemic prevention materials in Shanxi Province and ensure timely delivery of materials.

CONCLUSION

When the configuration of transportation equipment changes, both the backlog of orders and the processing time of orders change and show a reverse trend. The larger the configuration of transportation equipment, the better its impact on evaluation indicators. The more effective the optimization of Shanxi Province's epidemic prevention material reserve and supply system is.

6. DISCUSSION AND OUTLOOK

The Anylogic simulation model can effectively reproduce the distribution of emergency epidemic prevention materials in Shanxi Province. Using Anylogic to dynamically simulate the emergency epidemic prevention material reserve and supply system in Shanxi Province, a large amount of simulation data was compared. By changing the full load rate and configuration of transportation equipment, simulate the simulation data changes of the evaluation indicators of the emergency epidemic prevention material reserve and supply system in Shanxi Province in the real situation. Comparing the simulation data of order backlog and order processing time under different conditions, the following conclusions and prospects can be drawn.

1.In the context of major public health events, there is a high demand for emergency epidemic prevention materials in various urban areas of Shanxi Province. By increasing the configuration of transportation equipment and the loading rate of transportation equipment, it is possible to effectively shorten order processing time and reduce order backlog. In the real situation, increase the fixed assets investment and scientific and technological innovation of transportation equipment, increase the base number of transportation equipment, and strive to improve the full load rate of transportation equipment. This helps to enhance the supply capacity of medical reserves and reduce the backlog of orders.

2.In real life, there are numerous system design parameters. The changes in some key parameters of the actual influencing factors will greatly affect the operation of the system. The simulation model can use system dynamics methods and interaction with system dynamics modules within the software to create a system flowchart for further analysis of real-world impact factors.

3.The impact of different delivery strategies will affect the model, resulting in different simulation logic and actual performance simulation scenarios. In future research, different delivery strategies such as nearest delivery, delivery in order of order, and centralized delivery can be attempted for comprehensive optimization in multiple aspects.

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