# Simulation of Supply Chain Disruption in Community Group-buying Based on System Dynamics

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**Abstract.** Supply chain disruption is an unavoidable problem for enterprises, and community group-buying enterprises must face up to the risk of supply chain disruption. This paper takes a four-level supply chain composed of shared warehouse, central warehouse, grid warehouse and self-pickup point as the research object, selects three indicators of "inventory", "profit" and "order delivery volume" to measure the damage degree of the supply chain caused by the disruption, and constructs a four-level supply chain disruption model by system dynamics method for simulation analysis. The results of system dynamics simulation show that: (1) the disruption in the downstream of the supply chain causes more damage to the supply chain than the disruption in the upstream of the supply chain. The sales disruption has the greatest impact on the overall supply chain, and any disruption will affect the overall performance of the supply chain; (2) The logistics standby warehouse strategy can alleviate the impact of disruption, and the mitigation effect is related to the substitution effect of standby logistics warehouse on retailers.

**Keywords:** supply chain of community group buying, supply chain disruption, system dynamic

## 1 Introduction

As a new circulation mode of fresh goods, community group buying began to enter residents' life in 2016. This online and offline combined shopping activity centered on community residents has obvious regional characteristics, uniqueness and convenience, and can be said to be a new, comprehensive and networked group buying model. The development of community group buying lies in its direct connection with local agricultural business entities, shortening the circulation of agricultural products, and reducing commodity costs and logistics costs. Community group buying has a short time and a fast development speed, and it also faces many problems. For example, fierce price war among community group buying platforms often causes losses of enterprises [1].

In terms of existing research, a few scholars explored and analyzed from the perspective of supply chain operation mode and logistics. Yi investigated the supply chain model of community group buying and established a mixed integer location selection model of freshness loss [2]. Yong Wang and Wei Qiu established a VRP model for the

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logistics distribution of community group-buying enterprises, and used genetic algorithm to solve the model to optimize the distribution path [3]. Fang Qian et al. used SOR model to explore users' willingness of value co-creation in the context of community platform economy [4]. These studies mainly focus on the composition and distribution of community group-buying supply chain. Katsoras and Georgiadis[5] studied the impact of production disruption caused by COVID-19 on closed-loop supply chain, and used system dynamics method to simulate the results that the impact of disruption depends on manufacturer output, product demand and the duration of recovery period. Wilson[6] simulated and studied the impact of transportation interruption on supply chain performance in a five-level supply chain system, considered four transportation interruption scenarios, and pointed out that transportation interruption between suppliers and manufacturers had the greatest impact. Hishamuddin et al.[7] considered supply interruption and transportation interruption, A simulation study of a three-level supply chain system with multiple suppliers is conducted to compare the impact of disruptions on the total system recovery cost and other performance metrics, and it is pointed out that transportation disruptions have a more destructive impact on the entire supply chain compared to supply disruptions. Ivanov[8] studied the impact of disruption risk on production and distribution network design, which would lead to delivery delay and failure to recover supply chain performance, and pointed out that recovery policy should not be limited to the disruption period, but should consider the post-disruption period. Kamalahmadi and Parast[9] pointed out that pre-positioning inventory and setting up standby suppliers can help enterprises effectively mitigate the impact of supply chain disruption. Ndivhuwo and Clarles[10] deeply discussed how inventory management responds to complex and uncertain demand, and analyzed in detail how such demand affects inventory management. Paul et al. [11] believed that the risk factors involved in the supply chain system include imperfect production process, risks and disruptions in production, supply, demand and transportation.

Based on the above research, the research mainly focuses on the composition and distribution of community group-buying supply chain. There is little research on supply chain disruption of community group-buying. Based on the existing research, this paper will take the community group-buying supply chain as the research object, analyze the characteristics of group-buying product supply chain, use VENSIM PLE software to establish the dynamics model of community supply chain system, and conduct simulation analysis on the model.

## 2 Model Construction

### 2.1 Boundary of the Model

Based on the analysis of the operation process of the supply chain of community group buying, the scope of the system boundary is determined as follows: (1) The supplier adopts the stock-by-stock mode. The supplier replenishment is carried out according to the difference between the shared warehouse stock and the target stock (the target stock is a fixed value). When the shared warehouse stock is lower than the target stock, the replenishment notice is issued, and when the shared warehouse stock is higher than the target stock, there is no replenishment notice. (2) There are time delays in each transportation process in the supply chain. (3) The supplier's production of agricultural products is outside the system boundary.

## 2.2 Basic Assumptions

According to the characteristics of the research objects and the different research contents, the following basic assumptions are made: (1) The goods in the whole supply chain are a kind of products; (2) The sales unit is pieces, and the weight of one piece is 500g; (3)Products will arrive in the shared warehouse within the arrival time after the replenishment notice is issued in the shared warehouse, regardless of the production cycle; (4) Without considering the limitation of warehouse capacity on inventory; (5) Supplier cost accounting only considers supplier ordering cost, shared warehouse storage cost, shared warehouse fresh loss cost, out-of-stock cost and supplier transportation cost; The cost accounting of community group purchase platform only considers the ordering cost, inventory cost, transportation cost and out-of-stock cost of community group purchase platform; (6) The supply of upstream firms to downstream firms drops to zero after the interruption begins.

## 2.3 Basic Equation

**Table 1.** Description of system variable names.

| Variable Names | Abbreviations | Units | Equation |
|---|---|---|---|
| Inventory in transit | $ZTKC_i$ | pieces | $ZTKC_i = \begin{cases} \int_0^t (DHLi - SHLi) * dt,\ i = 1 \\ \int_0^t (FHLi = SHLi) * dt,\ i = 2\ \ 3\ \ 4 \end{cases}$ |
| Stock | $KC_i$ | pieces | $KC_i = \int_0^t SHLi - FHLi) * dt,\ i = 1\ \ 2\ \ 3\ \ 4$ |
| Orders | $DD_i$ | Pieces/day | $DD_i = MAX(0, XQYCL_i + \frac{QWKCLi-KCi}{KCTZTSi}),\ i = 1,\ 2,\ 3,\ 4$ |
| Shipments | $FHL_i$ | Pieces/day | $FHL_i = MIN(KC_i, DD_i) * ZDMS_i,\ i = 1,\ 2,\ 3$ |
| Quantity received | $SHL_i$ | Pieces/day | $SHL_i = DELAY1(DHL_i, DHYCTS_i)$ |
| Order quantity | $DHL_i$ | Pieces/day | $DHL_i = DELAY1(DD_i, DHSJ)$ |
| Sales volume | $XSL_i$ | Pieces/day | $XSLi = MIN(KCi, SCXQL) * ZDi,\ i = 4$ |
| Desired inventory | $QWKCL_i$ | pieces | $QWKCL_i = KCTZTS_i * XQYCL_i,\ i = 1,\ 2,\ 3,\ 4$ |
| Demand forecast quantity | $XQYCL_i$ | Pieces/day | $XQYCL_i = \begin{cases} SMOOTH(FHLi, YDPHSJi),\ i = 1\ \ 2\ \ 3 \\ SMOOTH(FHLi,\ XSLi),\ i = 4 \end{cases}$ |
| Cumulative order quantity | $LJDDL_i$ | pieces | $LJDDL_i = \int_0^t SDDDLi - JFDDLi) * dt,\ i = 1,\ 2,\ 3,\ 4$ |
| Quantity of orders delivered | $JFDDL_i$ | Pieces/day | |

| | | | |
|---|---|---|---|
| Quantity of orders received | $SDDDL_i$ | Pieces/day | $SDDDL_i = \begin{cases} DDi+1, & i=1, 2, 3 \\ SCXQLi, & i=4 \end{cases}$ |
| Order time | $DHSJ$ | day | |
| Moving smooth time | $YDPHSJ_i$ | day | |
| Days of inventory coverage | $KCFGTS_i$ | day | |
| Days of late arrival | $DHYCTS_i$ | day | |
| Days of inventory adjustment | $KCTZTS_i$ | day | |
| Ordering cost | $DHCB_i$ | Yuan /day | $DHCB_i = \begin{cases} DWDHCBi * DHLi, & i=1 \\ DWDHCBi * SHLi, & i=2\ 3\ 4 \end{cases}$ |
| Inventory cost | $KCCB_i$ | Yuan /day | $KCCB_i = KC_i * DWKCCB_i, \ i = 1, 2, 3, 4$ |
| Out of stock cost | $QHCB_i$ | Yuan /day | $YSCB_i = FHL_i * DWYSCB_i, \ i = 1, 2, 3, 4$ |
| Shipping cost | $YSCB_i$ | Yuan /day | |
| Cost of fresh wastage | $SXSHCB$ | Yuan /day | |
| Unit order cost | $DWDHCB_i$ | Yuan /piece | |
| Unit inventory cost | $DWKCCB_i$ | Yuan /piece | |
| Cost per unit out of stock | $DWQHCB_i$ | Yuan /piece | |
| Unit shipping cost | $DWYSCB_i$ | Yuan /piece | |
| Total cost | $ZCB_i$ | Yuan /day | |
| Income | $SR_i$ | Yuan /day | $SR_i = \begin{cases} CPJGi * FHLi, & i=1\ 2\ 3 \\ CPJGi * FHLi, & i=4 \end{cases}$ |
| Profit | $LR_i$ | Yuan /day | |
| Product price | $CPJG_i$ | Yuan /piece | |
| Cumulative total profit | $LJZLR_i$ | Yuan | $LJZLR_i = \int_0^t LRi * dt, \ i = 1, 2, 3, 4$ |
| Market demand | $SCXQL$ | Pieces/day | |
| Interrupt mode | $ZDMS_i$ | / | |

After the system dynamics model is established, Vensim software is used to edit the equations between variables. The formulas in the software are the transformation of mathematical formulas, the logic is clearer and easier to adjust. The names of variables involved in editing equations in the model are shown in Table 1, i is 1,2,3, 4 represents G (shared bin), Z (central bin), W (grid bin) and T (self-lifting point) respectively.

At the beginning of simulation, the values of auxiliary variables and constants need to be set for the model, combined with the setting of supply chain coefficient parameters by reading relevant literature and the actual operation of the supply chain, combined with the research report of fresh electricity supplier industry, the relevant parameter Settings of the model in this paper are shown in Table 2.

**Table 2.** Decision, demand and profit of different cooperation models.

| Parameters | Numerical values | Units | Parameters | Numerical values | Units |
|---|---|---|---|---|---|
| G Inventory adjustment days | 1.5 | day | W Inventory adjustment days | 0.7 | day |
| G Days of inventory coverage | 2 | day | W days of inventory coverage | 1.5 | day |
| G Arrival delay days | 0.315 | day | W Arrival delay days | 0.375 | day |
| G Smoothing time | 3 | day | W Smoothing time | 2 | day |
| G cost per order | 1 | Yuan/piece | W unit order cost | 2.8 | Yuan/piece |
| G cost per unit out of stock | 0.05 | Yuan/piece | W cost per unit out of stock | 0.15 | Yuan /piece |
| G cost per unit of inventory | 0.02 | Yuan/piece | W unit inventory cost | 0.075 | Yuan /piece |
| G unit shipping cost | 0.01 | Yuan/piece | W unit shipping cost | 0.03 | Yuan /piece |
| G Product price | 2.2 | Yuan/piece | W Product price | 4.2 | Yuan /piece |
| Z Inventory adjustment days | 0.67 | day | T inventory adjustment days | 0.7 | day |
| Z days of inventory coverage | 1.5 | day | T days of inventory coverage | 1.5 | day |
| Z Arrival delay days | 0.225 | day | T days of arrival delay | 0.375 | day |
| Z Smoothing time | 2 | day | T smoothing time | 2 | day |
| Z cost per order | 2.2 | Yuan/piece | T cost per order | 3.4 | Yuan /piece |
| Z cost per unit out of stock | 0.1 | Yuan/piece | T cost per unit out of stock | 0.2 | Yuan /piece |
| Z cost per unit of inventory | 0.04 | Yuan/piece | T unit inventory cost | 0.1 | Yuan /piece |
| Z Unit transportation cost | 0.02 | Yuan/piece | W Product price | 6.4 | Yuan /piece |
| Z Product price | 3.2 | Yuan/piece | | | |

The supply chain system constructed in this paper consists of four subsystems: shared warehouse subsystem, central warehouse subsystem, grid warehouse subsystem and self-generated idea system. The factors and variables that affect the supply chain system include inventory, order, expected inventory, days of inventory adjustment, days of inventory coverage, days of arrival delay, forecast demand, transportation cost, procurement cost, inventory cost, etc. Inventory and order affect each other, the size of the order volume is restricted by inventory, expected inventory and inventory adjustment days, and inventory is affected by the order volume, the large order volume leads to the increase of inventory. Profit is determined by costs and revenue, and revenue is determined by shipments and product prices. The cumulative order size is determined by the number of orders received and the number of orders delivered. The larger the number of orders received, the more likely the order is to accumulate, and the larger the number of orders delivered, the less likely the order is to accumulate. The four subsystems restrict each other and affect the behavior pattern of the whole system. In order to facilitate the construction of the model, G represents the shared bin, Z represents the central bin, W represents the grid bin, and T represents the self-picking point.

In this paper, Vensim PLE software is used to build a community group-buying supply chain system dynamics model, as shown in Figure 1.

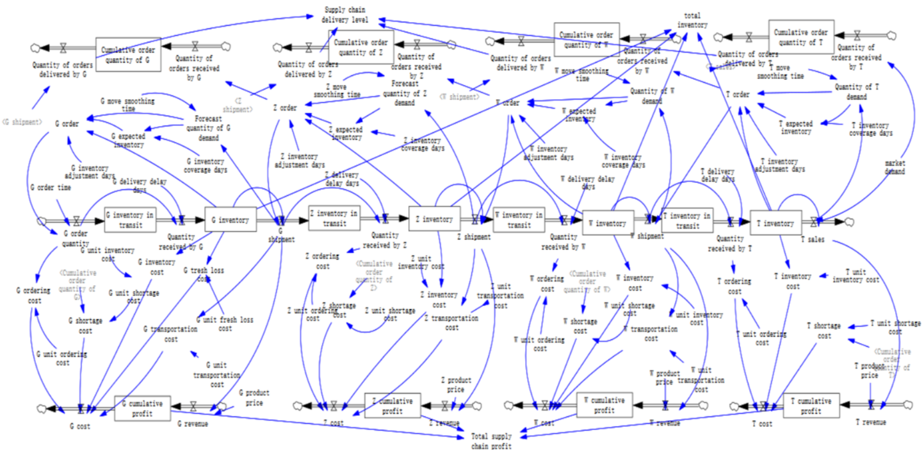

**Fig. 1.** supply chain system dynamics model.

## 3 Interruption Recovery Simulation Analysis

### 3.1 Supply Chain Interruption Simulation

In the model constructed in this paper, supply chain interruption occurs between each node of the supply chain, and the interruption does not occur at the same time. The simulation analyzes the impact of four kinds of interruption on supply chain operation: supply interruption of shared warehouse, delivery interruption of central warehouse, transportation interruption of grid warehouse and sales interruption of pick-up point.

The simulation TIME of the model was set as INITIALTIME=0, FINAL TIME=200, and TIME STEP=1, indicating that the simulation started from the 0th day and ended on the 200th day. The step length was 1, a total of 200 days.

Three variables, "interrupt time point", "interrupt duration" and "interrupt mode", are set in SD model to reflect the interrupt occurrence process. PULSE function in system dynamics is introduced to set the interrupt situation. Pulse function means that the value of the function suddenly rises from 0 to 1 at a certain point in time, and then decreases to 0 after a certain period of time. Take the supply interruption scenario as an example, set "supply interruption time point =18", "supply interruption duration =10", "supply interruption mode =1-PULSE (supply interruption time point, supply interruption duration)", "G shipment =MIN(G inventory, Z order)* supply interruption mode", indicating that the supply interruption time starts from the 18th day. Lasts for 10 days and ends on day 28, with zero shipments during the interruption. The same is true for the other three interrupt Settings. Since the research focuses on the effect of interruption on inventory, profit and cumulative order volume, the market demand is set to a constant value, "Market demand =6000".


**Fig. 2.** Simulation diagram of total supply chain inventory under different disruption scenarios.

Figure 2 shows the changes of total supply chain inventory under different interruption scenarios. During the period of interruption, the supply chain inventory fluctuation caused by sales interruption is the largest, and the inventory decline is the largest within 20 days after the interruption, indicating that the total inventory level of the supply chain is the most affected when sales interruption occurs. Sales interruption means that the sales volume drops to zero, which means that the downstream of the supply chain is interrupted. Therefore, the disruption that occurs downstream has the greatest impact on the total inventory level of the supply chain and takes the longest time to recover. The disruption effect spreads from downstream to upstream.

The changes of the total delivery level of the supply chain when four kinds of disruption occur are summarized, as shown in Figure 3. During the disruption, the total delivery order volume of the supply chain drops to zero at the earliest in the case of sales disruption, and the delivery level of the supply chain recovers the fastest after the disruption ends. In the case of shared warehouse supply, the total order delivery volume of the supply chain decreases to zero at the latest, and the order delivery volume is significantly higher than that of the other three disruptions. This is because when the upstream supply stops shipping, the downstream nodes still have a certain amount of inventory to meet the downstream orders. When the interruption occurs in the downstream, the downstream node will immediately stop ordering to the upstream node, and the upstream node will stop shipping.

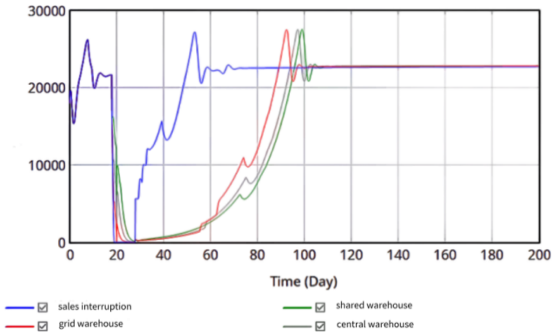


**Fig. 3.** Simulation diagram of order delivery status under different interrupt scenarios.

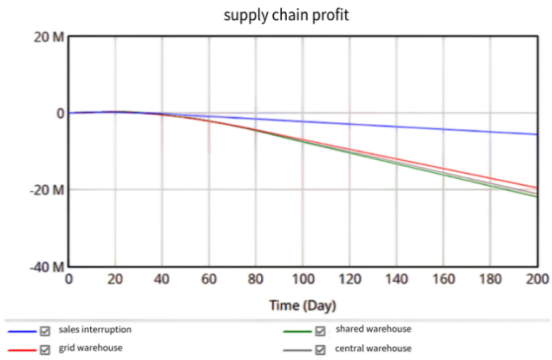


**Fig. 4.** Simulation diagram of total profit state of supply chain under different interruption scenarios.

Figure 4 shows the changes of the total profit of the supply chain when the four kinds of disruptions occur. It can be seen from the figure that when the sales interruption occurs, the total profit of the supply chain decreases the fastest. When the sales interruption occurs, the sales volume is zero, and the inventory cost and shortage cost increase first. Backlogs of orders before the disruption have also been rising, hurting overall supply chain profits.

### 3.2 Standby Logistics Warehouse Strategy

This paper focuses on reducing the negative impact of sales interruption on supply chain, puts forward the strategy of spare logistics warehouse, and analyzes the effectiveness and feasibility of this strategy by simulation.

In order to test the effectiveness of the recovery strategy and make the simulation process close to the real situation, the random distribution function is used RANDOM UNIFORM. The market demand is set as RANDOM UNIFORM (4000,6000,0), indicating that the market demand is evenly distributed between 4000 and 6000 pieces. The simulation time is set to start on day 0 and end on day 200 with a step size of one day, and the interruption time is consistent with the Settings above, with the interruption starting on day 18, the interruption lasting for 10 days, and the interruption ending on day 28. In this paper, percentage is used to represent the substitution effect of the standby logistics warehouse for the self-pickup point, and the strategy of the standby logistics warehouse is simulated by setting the sales equation. During the interruption period, the sales volume is set to 60%, 70% and 80% of that without interruption respectively, indicating that the standby logistics warehouse has 60%, 70% and 80% substitution effect for the self-pickup point.

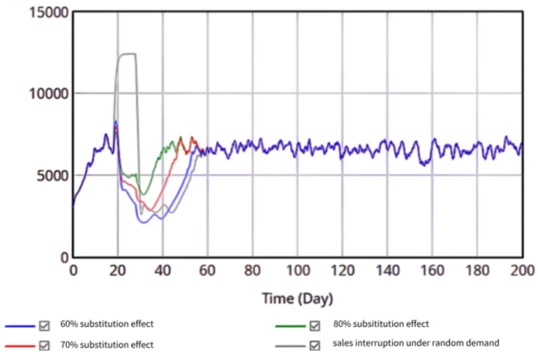


**Fig. 5.** Inventory change chart at the retail end after the standby logistics warehouse strategy is adopted.

Figure 5 shows the change of self-pickup point inventory under different replacement effects of standby logistics warehouse. As can be seen from the figure, under the replacement effect of 60% of the standby logistics warehouse, the inventory of the self-pick point began to decline on the 19th day, and still maintained a downward trend after the 28th day, and began to recover on the 31st day. The decline speed of the inventory is not much different from the sales interruption situation under random demand. It can be seen that under the replacement effect of 60%, the mitigation effect of the standby logistics warehouse strategy on the recovery of interruption is not obvious. Under the substitution effect of 70%, the inventory of the self-picking point decreases on the 19th day and the change value of the inventory is lower than the substitution effect of 60%. The inventory decreases slightly within 6 days after the interruption, and begins to recover on the 34th day. At this time, the inventory is slightly better than the logistics standby warehouse strategy without strategy and under the substitution effect of 60%, thus, under the substitution effect of 70%, The setting of logistics warehouse has a certain recovery effect on sales interruption. Under the 80% replacement effect, the inventory at the pick-up point fluctuated slightly during the interruption period, and began to recover on the 31st day, and the inventory level was basically close to the normal level on the 37th day. Therefore, the logistics warehouse setting with 80% replacement effect has a good easing effect on sales interruption. It can be seen that the logistics warehouse with 60% substitution effect has little effect on interruption recovery and the higher the degree of substitution of logistics warehouse to self-picking point, the better the interruption recovery effect.

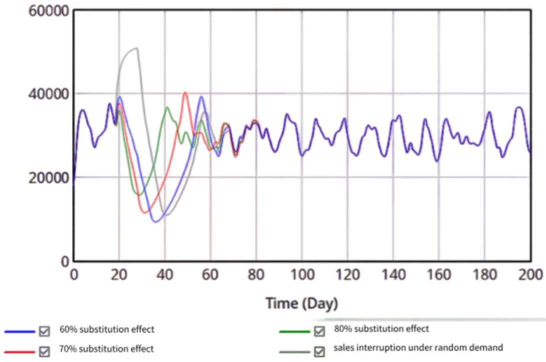


**Fig. 6.** Total inventory status diagram of supply chain under the standby logistics warehouse strategy.

As shown in Figure6, under the 60% replacement effect of the standby logistics warehouse, the fluctuation range of the total supply chain inventory is still large during the interruption period and is in an unstable state; Under the 70% substitution effect, the fluctuation of the total supply chain inventory during the interruption is small, which indicates that it can alleviate the sales interruption to some extent. Under the substitution effect of 80%, it can be seen from the figure that the decline from day 20 to day 28 is basically consistent with the rise from day 29 to day 41, indicating that the total inventory of the supply chain begins to fluctuate normally and tends to operate normally. Therefore, under the 80% substitution effect, the logistics standby warehouse has played a good role in restoring the sales interruption.

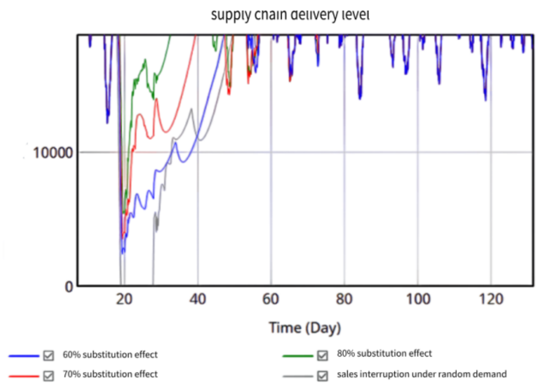


**Fig. 7.** State diagram of supply chain delivery level under the standby logistics warehouse strategy.

As can be seen from the comparison of Figure7, among the above three logistics warehouse strategies, the logistics warehouse strategy with 80% replacement effect makes the supply chain delivery level fluctuate least and recover fastest when sales are interrupted. The delivery level of supply chain can be effectively restored. Therefore, the backup logistics warehouse with 80% replacement effect can effectively alleviate the impact of sales interruption, and the backup logistics warehouse strategy is effective. It can be seen that the higher the substitution effect of logistics warehouse strategy, the more significant the mitigation effect on supply chain delivery level.

# 4 Conclusion and Prospect

## 4.1 Conclusion:

The research conclusions of this paper are as follows:

(1) Disruptions occurring at downstream nodes, namely sales disruptions, have the greatest impact on the overall supply chain performance, while disruptions occurring at upstream nodes have a gradually decreasing impact on the supply chain performance. Enterprise decision makers should strengthen the control of nodes close to the consumer end to prevent disruptions from damaging the supply chain.

(2) The standby logistics warehouse strategy is effective for supply chain interruption recovery. The mitigation effect of the spare logistics warehouse on the disruption is related to the substitution effect on the retailer, and the higher the substitution effect, the better the mitigation effect. In the model of this paper, when the replacement effect of spare logistics warehouse reaches 80%, it can play a good recovery role in interruption. Therefore, the standby logistics warehouse strategy can be used as an effective strategy for enterprises to mitigate the interruption, and provides a reference for enterprises to deal with the interruption risk.

## 4.2 Outlook

There are still limitations in this paper, and future research can be carried out from the following aspects:

(1) In this study, we only consider the situation that different types of interruptions occur separately, and do not add the interruption probability to the model.

(2) This paper only studies one interrupt recovery strategy. In the future, the recovery effects of different interruption recovery strategies can be compared and the combined effects of multiple recovery strategies can be studied.

(3) This paper mainly uses the system dynamics method to simulate and analyze the supply chain interruption. The system dynamics model is a simplification of the real system, and the simulation results are restricted by many assumptions of the model. In the future, other methods can be combined to study the impact of interruption on the supply chain and the mitigation effect of recovery strategies in a more diversified way.

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