Research on Response Elastic Simulation and Optimization of Natural Disaster Emergency Supply Chain

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Abstract. China has a vast territory and a large population density. The frequent occurrence of natural disasters has caused enormous losses to the lives and property of our people. With the expansion of the connotation of rescue organizations, a cooperative relationship between rescue organizations and rescue organizations and commercial organizations to improve rescue efficiency and minimize losses caused by natural disasters has become a research in emergency supply chain research. New perspective. Through the construction of the natural disaster emergency supply chain elastic simulation model, the paper optimizes and analyzes the two strategies of fortification inventory and emergency procurement to obtain the optimal solution and proposes the elastic optimization strategy. With the dynamics of simulation, the simulation model of natural disaster emergency supply chain is established, and the elasticity is optimized as the optimization goal.

1. Introduction
China is one of the country’s most seriously endangered by natural disasters, and the types and frequency of disasters are higher than the world average. Frequent disasters, if not rescued in time, will not only cause huge damage to production and casualties, but also affect social stability and even cause backwardness in productivity. Therefore, how to mobilize all aspects of strength and improve the coverage and rescue efficiency of rescue has become an important issue that China needs to solve.

Judging from the large-scale natural disasters that have occurred in China in recent years, although disasters occur, the Chinese government and all sectors of society will adopt various corresponding emergency measures to carry out rescue activities, but the effect is still not optimistic. For example, in the 512 Wenchuang Earthquake that occurred in 2008 and this year's southwest drought relief, although the government has tried its best to carry out various relief activities, the whole society and various civil organizations are actively donating money and even a large number of Volunteers were directly involved in the disaster relief operation, but during the rescue process, a large number of relief materials could not be delivered to the victims in time. Especially in the vast rural areas, some of the victims still suffered from avoidance because they could not get timely assistance. Loss. The reason is that the bottleneck is the emergency supply chain system after the disaster [1-2]. In response to this problem, from the international experience, the form of logistics organization in the process of innovation and rescue is also an important means to effectively improve rescue efficiency and rescue coverage.
2. Emergency supply chain concept and characteristics

Emergency supply chain management is a specific management strategy behavior, which refers to various losses caused by evading or reducing natural disasters, various emergencies, and public safety, and through emergency stock management system and emergency management funds. The coordination of emergency service rescue personnel and relief supplies is optimized to minimize the impact of emergencies and natural disasters, as well as time and transportation costs. The emergency supply chain consists of three nodes: the upstream, middle, and lower reaches, respectively, the upstream emergency supplies supplier, the midstream emergency command center, and the downstream disaster site [3].

Upstream node enterprises: The segment enterprises in this part can be divided into the following two parts, some of which refer to the material reserve pool established by various levels of government. At present, the state has established a second-level material reserve. The other part is the government or private enterprise groups. The state has cooperated with some enterprises to reach a specific cooperative supply relationship. After the disaster, the material reserves and cooperative enterprises jointly produce and supply emergency materials. The mid-stream node emergency command center refers to a government-centered organization that includes multiple functional departments. The government uses the command center to coordinate and direct the various social forces involved, and to carry out the entire emergency rescue work. The role of organization and coordination plays a central role in the operation of the entire supply chain. The downstream node refers to the disaster point, that is, the on-site command center connected to the emergency command center in the disaster area. After the disaster occurs, the downstream supply points will drive the operation of the entire supply chain, and information, logistics, and capital flow will run throughout the chain. In different supply chain systems, the core enterprises have different roles. The emergency command center is the core enterprise of the emergency supply chain. It consists of a number of different government functions, and implements centralized and dynamic management of the entire chain [4]. From the perspective of the location of the emergency command center, it is the coordination, organization, and liaison of its upstream and downstream nodes. The operation of the supply chain needs to be connected, and the operational efficiency is directly determined. The emergency supply chain system can realize the efficient flow of materials. From the perspective of the operation process of the supply chain, the disaster relief command center in the disaster area needs to obtain local disaster information in time, so that the emergency command center can determine the emergency plan as soon as possible, provide order information to the upstream supplier enterprises, and urge the enterprise to carry out emergency production of emergency materials and accelerate. The flow of materials to the disaster area. From the above analysis, only when the enterprises or participants of each node achieve effective collaboration can effectively improve the operational efficiency of the emergency supply chain. Therefore, in the modeling of the structural equations of the emergency supply chain, in order to improve the ability of coordinated operation between nodes on the chain, all the nodes in the middle and lower reaches of the supply chain are included in the model, and the importance of any one of them is not overemphasized. Finally, structural equation modeling is used to realize the overall optimization of the emergency supply chain. Emergency supply chain inventory is characterized by unconventionality, uncertainty, time urgency and weak economy.

3. Construction of Elastic Simulation Model for Natural Disaster Emergency Supply Chain

3.1. Model construction

Firstly, suppose that in the rescue operation under natural disaster conditions, three different emergency logistics schemes can be adopted: independent mode (under government supervision, each rescue organization independently completes emergency logistics tasks); public mode (rescue activities by government) Control, invest in the establishment of a standing emergency supply chain system, which is shared by various rescue organizations when disasters occur; cooperation mode (under the supervision and guidance of the government, through government agencies or private relief organizations to conclude cooperation agreements with core enterprises to utilize the enterprise supply chain The system
has both social resources). For these three models, it can be analyzed from the three dimensions of cooperation structure, mutual cooperation and cooperation strength. The factors of these dimensions will have a direct impact on the mode selection and operation effect of cooperation strategy. Among them, the structure of cooperation includes partners, direction (horizontal, vertical), mutual relationship between partners (competition, non-competition), entry and exit, and number of partners; characteristics of cooperation include: attributes, functional scope, coordination ability, and Region; cooperation strength includes attributes (temporary or permanent), functional scope and participation in action. The author divides the theory of emergency logistics cooperation into two aspects, one is the research of cooperation motivation, and the other is the analysis of influencing factors. On this basis, the research framework is proposed as shown in Figure 1.

Figure 1. Emergency supply chain cooperative decision model

Suppose \( \eta_i \) represents the endogenous latent variable of the model, \( Y_1, Y_2, Y_3 \) is called the observed variable corresponding to the latent variable \( \eta_i \), and \( \lambda_{Y_i} \) is called the weighting coefficient between the latent variable and the observed variable [5]. Then there is a difference between the explicit variable and the dependent variable in the measured model 3 weighting factors. There are supply chain response elastic equations as follows:

\[
\eta = \beta \eta + \Gamma \xi + \zeta
\]  
\[
X = \chi \xi + \delta
\]  
\[
Y = \gamma \eta + \epsilon
\]

The expected values of the error terms \( \delta, \epsilon \) and the residual term \( \zeta \) in the structural equation model are all zero. The error terms \( \delta, \epsilon \) are not related to the latent variables \( \xi, \eta \), and the error term \( \epsilon \) is not related to the error term \( \delta \).

Among the three formulas given above, the first formula explains the effect relationship between latent variables, the latter two formulas are measurement equations, and the measurement equations characterize the relationship between explicit variables and latent variables. The specific meanings of the symbols in the above formulas are given in Table 1.
Table 1. Symbolic meanings in the elastic equation model of supply chain response

| Variable | Definition                                      | Dimension |
|----------|------------------------------------------------|-----------|
| \( \eta \) | Endogenous latent variable                      | \( m \times l \) |
| \( \xi \) | Exogenous latent variable                       | \( n \times l \) |
| \( \zeta \) | Disturbance term in the equation                | \( m \times l \) |
| \( y \) | Endogenous marker (endogenous observation variable) | \( p \times l \) |
| \( x \) | Exogenous marker (exogenous observation variable) | \( q \times l \) |
| \( \varepsilon \) | Y measurement error                             | \( p \times l \) |
| \( \delta \) | X measurement error                             | \( q \times l \) |

The emergency supply chain emergency capability is named \( \eta_1 \), and the quantity flexibility, time flexibility, and variety softening are respectively named as \( y_1, y_2, y_3 \); The emergency supplier's emergency supply capability, emergency command center command and coordination capability, and disaster response information feedback capability are named as \( \xi_1, \xi_2, \xi_3 \). The production capacity, delivery date and distribution capacity are respectively named as \( x_1, x_2, x_3 \); the road traffic recovery capability, material financing ability and emergency response time are named as \( x_4, x_5, x_6 \); the disaster area information collection capability, information communication recovery capability, and emergency communication facility equipment configuration level are named as \( x_7, x_8, x_9 \).

From the above structural model diagram, the following structural equation expression can be written:

\[
\eta_1 = \lambda_1 \xi_1 + \lambda_2 \xi_2 + \lambda_3 \xi_3 + \zeta
\]

The above \( \lambda \) coefficient is a parameter in the structural equation model diagram, and the above equations and groups are solved by software to obtain the analytical solution of the equation. According to scholars' research, a structural model needs to be identified as a whole. The following conditions must be met: if there is no correlation between the factors, then at least three indicators should be set for each factor. If there is a correlation between the factors, then each factor should be set to a minimum [6]. Two indicators are defined. In the emergency supply chain structural equation model established in this paper, each factor corresponds to three indicators, so the conditions that the model can be identified are met. In addition, experts and scholars have proposed a \( t \)-test rule that can test whether the model can be identified:

\[
t \leq \frac{(p+q)(p+q+1)}{2} = DP
\]

In the above formula, \( p \) represents the number of indicators corresponding to the endogenous latent variable, \( q \) represents the number of indicators corresponding to the exogenous latent variable, and \( t \) represents the number of parameters that need to be estimated in the model. In this model, \( p=3, q=9, t=18, DP=78 \), so the model established in this paper conforms to the recognition rule, that is, the model can be identified.

3.2. Maximum Likelihood Estimation Model

AMOS software performs parameter estimation by the algorithm principle of maximum likelihood method. The maximum likelihood method first obtains a set of sampled data from the sample, and sets
the density function of the sample to \( f(x_1, x_2, x_3, \ldots, x_n; \theta) \), where \( \theta \) is the parameter to be estimated, then the function \( L(\theta) = f(x_1, x_2, x_3, \ldots, x_n; \theta) \) is called the function to be estimated. The algorithm logic of the most human likelihood estimation parameter is based on the analytical solution or numerical solution of the existing sample finding function. That is, when the estimated value of the parameter 0 is estimated to maximize the probability of the sample, the estimated value should be considered as a parameter. The value is appropriate. However, apart from some simple sample distributions, it is difficult to obtain the analytical solution of the function when estimating the parameters by the maximum likelihood method. The second-best solution is to obtain the numerical solution.

Since there is only one endogenous latent variable in the structural equation of the emergency supply chain established in this thesis, there are a total of seven parameter matrices that need to be solved in this paper, which are respectively \( \Delta, \Lambda, \Gamma, \Phi, \Psi, \theta, \epsilon \). In the structural equation model of the emergency supply chain established in this paper, there is only one endogenous variable \( \eta_1 \), so it is not necessary to solve the \( \beta \) matrix. In this thesis, the factor load and path coefficient of the emergency supply chain structural equation model are solved by the iterative operation of parameters. Solve the above weight coefficient, that is, solve three \( \Delta, \Lambda, \Gamma \) matrices, \( n=3, m=l, p=3, q=9 \) in the model. There are expressions as follows:

\[
\begin{align*}
|\theta_{m+1} - \theta_m| &\leq \varepsilon_1 \\
\ln \frac{L(\theta_{m+1})}{L(\theta_n)} &\leq \varepsilon_2 \\
d \ln \left[ \ln (\theta_{m+1}) \right] &\leq \varepsilon_3
\end{align*}
\] (6)

Where \( A \) is the minimum value specified by the group. If the individual parameters are not estimated, but the group vector parameters, the above derivative needs to be converted to the partial derivative. The method is similar. In this paper, the data obtained from the questionnaire is substituted into the AMOS software based on the maximum likelihood algorithm, and the factor load and path coefficient of the structural equation model are obtained.

3.3. Case Analysis

\( \varepsilon_1, \varepsilon_2, \varepsilon_3 \) Disaster relief material production enterprise has adopted a horizontal allocation strategy for the disasters in the face of disasters. The specific flexible strategies include an increase in the number of suppliers, cooperation among suppliers, virtual supply chains, and social transportation. The company adopted a vertical allocation strategy of the primitive body. The specific robust strategies include capacity expansion, advance processing, increased shifts, additional flexible lines, and vertical configuration of the primitives. The contribution of each measure to the vertical and horizontal allocation strategy is shown in Table 2.
Table 2. Horizontal configuration strategy and its specific strategy data

| Measure | Increase in the number of suppliers | Cooperation between suppliers | Virtual supply chain | Social transportation | Primitive configuration |
|---------|-------------------------------------|-------------------------------|----------------------|----------------------|------------------------|
| contribution | 0.5                          | 0.7                           | 0.2                  | 0.9                  | 0.9                    |

Measure | Capacity expansion | Processing in advance | Increase the number of shifts | Add flexible line | Primitive body longitudinal configuration |
|---------|-------------------|-----------------------|-------------------------------|------------------|------------------------------------------|
| contribution | 0.7                          | 1                      | 0.3                           | 0.8              | 0.9                                    |

4. Suggestion and advice
The emergency supply chain material management process has strong portability, and has certain guidance for the disaster relief and reconstruction work of the entire disaster area. It will be promoted and used in the disaster area, and it is likely to achieve results and achieve greater social benefits. In addition, because the emergency supply chain has certain commonalities, its material management work also has certain commonalities. The corresponding flexible work of the natural disaster emergency supply chain can also be extended to the material management of other emergency supply chains. Especially in a country with frequent natural disasters in China, the material management process of the emergency supply chain has certain reference significance in the material management of natural disasters such as floods, snowstorms and typhoons.

Acknowledgements
This work was financially supported by Soft Science Project of Shaanxi Science and Technology Department in 2019 (2019KRM052) fund.

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