Research on order allocation of single-cycle multi-type logistics service

Yanyong HU, Zhiqiang FAN*
School of business administration, Henan Polytechnic University, Jiaozuo, Henan 454000, China
*Corresponding author’s e-mail: 211713020004@home.hpu.edu.cn

Abstract. Based on the logistics service supply chain, there are many fuzzy factors in the real market competition environment, and the relationship between them is complicated, in order to make the research more in line with the actual situation. In this paper, the supply capacity of logistics service providers and the demand for logistics service capacity are set as fuzzy variables, and the problem of order allocation of logistics service supply chain under fuzzy environment is studied. Firstly, the problem is described, and the multi-objective logistics service order allocation model with fuzzy parameters is established. Secondly, the credibility theory is used to fuzzed. Finally, the feasibility of the calculation model is verified by a specific example, and the logistics service integrator is used. The order allocation decision provides a theoretical basis.

1. Introduction
With the rising service economy and the diversified, novel and personalized development trend of customer demand, traditional self-operated logistics and third-party logistics have been unable to meet the needs of social development. The logistics service supply chain emerged as the times required. An emerging logistics development model is playing an increasingly important role. Compared with foreign countries, the research on the development of logistics service supply chain in China is relatively late. Compared with the product supply chain, the theoretical aspects are relatively unsound, and it is of great significance to study and enrich relevant theories. In the research of logistics service supply chain, logistics service order allocation research is particularly important. Order allocation restricts response speed, completion time, service quality, etc., and directly affects whether the order task is handed over to the right supplier at the right time. The right order allocation has a pivotal position in supply chain management. A correct understanding of the importance, operation mode and method of the logistics service supply chain is a basic guarantee for the survival of enterprises in the globalization and information market competition. It is also an inevitable requirement for modern enterprises to seek development and growth. The goal of logistics service supply chain management is to purchase a certain number of services from logistics service providers at the right price and at the right time, while pursuing high quality and low cost, while ensuring that the order tasks are completed. According to the statistics of the National Bureau of Statistics, in 2012-2018, the added value of China's service industry increased from 2,488.5 billion yuan to 469.75 billion yuan, with an average annual growth rate of 7.9%, 0.9 percentage points higher than the actual annual growth rate of GDP; The proportion continued to rise, reaching 52.2% in 2018; in the first half of 2019, the added value was 2,477.4 billion yuan, a year-on-year increase of 7.0%. As the scale of the service industry continued to expand and its strength continued to increase, China began to enter a new service-oriented economy era [1].

In the research of logistics service supply chain, Zhang Guangsheng et al [2] believe that the logistics
service supply chain structure follows the model of “functional logistics service provider → logistics service integrator → customer enterprise”, and is based on logistics service integrators. Assign the collected customer business orders to the logistics service provider. Ge Rainbow et al. [3] believe that the basic operational structure of the logistics service supply chain is “a single logistics service function provider → logistics service integrator → terminal logistics service demand side”, due to the increasing complexity and diversity of modern logistics service outsourcing. The logistics traditional enterprise with different functions starts from the end customer logistics demand, forms the enterprise alliance, completes the intensive logistics service supply, and the multi-level supply and demand relationship formed by the cooperation of different logistics organizations and mutual benefit the logistics service supply chain. In addition, many scholars have studied the distribution of logistics service orders. For example, Moghaddam [4] studied supplier selection and order allocation in retrograde logistics systems with uncertain supply and demand, based on factors such as total profit, total defect, late delivery, and relevant economic risks of candidate suppliers. A fuzzy multi-objective optimization mathematical model under uncertain environment, and a Monte-Carlo simulation method combined with fuzzy target programming is developed to determine the complete Pareto optimal solution of the proposed model. Selection and order allocation. On the basis of the three-level logistics service supply chain, Li Kaihang [5] built a coordinated operation model between logistics service integrators, logistics service providers and subcontractors with the goal of overall coordination and optimization of logistics service supply chain. How to construct a logistics service supply chain order allocation model provides a feasible reference.

More and more scholars are beginning to pay attention to the impact of operational ambiguity on order allocation. For example, Chen Haodong et al. [6] studied the demand and supply capacity as fuzzy uncertain variables, how to carry out supplier selection and order allocation, and established a mixed integer dynamic nonlinear programming model with the goal of minimizing cost, and proposed corresponding The defuzzification method is used to solve the model by using the branch and bound method. Gupta et al. [7] focused on the weighted possibility planning method for sustainable supplier selection and order allocation under fuzzy environment. The price is inaccurate information, and an optimization model integrating fuzzy diversification was constructed, and a weighted possibility programming method was proposed to solve the constructed optimization model.

Through careful reading of related literatures at home and abroad, it is found that most of the research is on the order allocation of traditional basic secondary structure logistics service supply chain, the order quantity is fixed, and it is mostly limited to a single type of logistics capacity allocation research. Based on the previous research, this paper will expand the logistics capability type into multiple types, and its order quantity is dynamically updated.

2. Problem description and modeling

2.1 Problem description
In a three-tier supply chain consisting of a single logistics service integrator, multiple logistics service providers and a logistics capability demand customer group, the logistics service integrator is in a dominant position, responsible for collecting logistics capacity demand customer orders and processing them. The post-conversion to logistics capability purchase order is assigned to the appropriate logistics service provider for the operation of the logistics service task. Based on the fuzzy environment, the supply quantity of logistics service providers and the logistics capacity demand of logistics service integrators are regarded as fuzzy uncertain variables. Through historical data, you can know the value range of logistics service provider supply and logistics service integrator demand. In this context, logistics service integrators make allocation decisions for single-cycle multiple logistics capacity demand orders, and procure logistics capabilities from two or more functional logistics service providers to fuzzy and distribute them.
2.2 Symbol description and assumptions

$I$: Collection of logistics service providers and $i \in I$.

$J$: Collection of order tasks and $j \in J$.

$Z$: For the overall goal and $\{Z_1, Z_2, \ldots, Z_n\}$ is the target.

$p_{ij}$: Logistics service provider $i$ completes the unit service price of order task $j$.

$\tilde{f}_{ij}$: Logistics service provider $i$ has the fuzzy supply of the required logistics capacity for the order task $j$.

$\delta$: Proportion of transaction expense expenses that logistics service integrators need to pay with the cost of logistics capacity procurement.

$\beta$: The ratio of the compensation caused by the loss of orders caused by the logistics service provider's delayed service to the original order service price.

$m_{ij}$: Logistics service provider $i$ has the logistics function and logistics task $j$ the matching degree of logistics function required.

$a_{ij}$: The logistics service provider $i$ provides the average quality of service level of the same logistics service capability required by the order task $j$, which is obtained by the logistics service integrator through historical cooperation related data statistics and is fixed for a long period of time.

$l_{ij}$: The service defect rate of the logistics service provider when completing the order task refers to the percentage of the number of defective products (caused by damage, serial, odor, etc.) in the total service product when the logistics service provider serves the terminal customer in a single service process.

$k_{ij}$: The logistics service provider $i$ completes the order churn rate of the order task $j$, that is, the logistics service provider due to insufficient logistics service capacity. Part of the order quantity is lost due to the failure of completion, and the proportion of the lost order quantity to the allocated order quantity.

$\tilde{D}_j$: Fuzzy demand for logistics service integrators for logistics tasks $j$.

$L_j$: Maximum service defect rate acceptable for order task $j$.

$K_j$: The maximum order churn rate that can be accepted by order task $j$.

$x_{ij}$: The specific task amount assigned by the logistics service integrator to the logistics service provider $i$ order task $j$.

$y_{ij}$: For the 0-1 variable, 1 when the logistics service provider provides logistics services for order task $j$, otherwise 0.

To make the problem easier to describe and close to reality, the following assumptions are made:

1. Each fuzzy variable is independent of each other.
2. The logistics service integrators themselves do not have or can not meet the customer's logistics needs, and all the logistics demand orders of the customers need to be allocated to the logistics service providers, and they do not provide the logistics service capacity supply.
3. For the same type of logistics service demand, the logistics service integrator can open the order and be completed by multiple logistics service providers.
4. Since logistics service integrators can work with multiple logistics service providers, the supply of various types of logistics service capabilities is unlimited.
5. Logistics service integrators can accurately obtain customer logistics capacity demand and logistics service provider logistics capacity availability through information platform and historical data.
2.2 Model construction

According to the above description of the symbols, it is easy to find out. In the fuzzy environment, the single-cycle logistics service supply chain order allocation problem is modeled as follows:

\[
\begin{align*}
\min Z_1 &= \sum_{i=1}^{l} \sum_{j=1}^{J} \delta p_{ij} x_{ij} y_{ij} \\
\min Z_2 &= \sum_{i=1}^{l} \sum_{j=1}^{J} p_{ij} x_{ij} \\
\min Z_3 &= \sum_{i=1}^{l} \sum_{j=1}^{J} k_{ij} x_{ij} \\
\min Z_4 &= \sum_{i=1}^{l} \sum_{j=1}^{J} \beta k_{ij} x_{ij} p_{ij} \\
\max Z_5 &= \sum_{i=1}^{l} \sum_{j=1}^{J} m_{ij} x_{ij} \\
\max Z_6 &= \sum_{i=1}^{l} \sum_{j=1}^{J} a_{ij} x_{ij}
\end{align*}
\]

Equation (1) minimizes the total transaction cost; Equation (2) minimizes the total procurement cost of purchasing logistics service capabilities from logistics service providers; and Equation (3) minimizes the number of order losses, that is, maximizes customer satisfaction. Service demand; formula (4) is to minimize the cost of order loss compensation; formula (5) is to maximize the matching degree between logistics service providers and order tasks; formula (6) is to maximize the overall level of logistics service quality. Obviously, for the six objective functions can not achieve the optimal at the same time, and for the convenience of algorithm design, this section uses the multi-objective weighting method to coordinate between the targets to make the overall optimal. Set the weight coefficient \(\lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5, \lambda_6\) to get the objective function (7):

\[
\begin{align*}
\min Z &= \lambda_1 \sum_{i=1}^{l} \sum_{j=1}^{J} \delta p_{ij} x_{ij} y_{ij} + \lambda_2 \sum_{i=1}^{l} \sum_{j=1}^{J} p_{ij} x_{ij} + \lambda_3 \sum_{i=1}^{l} \sum_{j=1}^{J} k_{ij} x_{ij} \\
&\quad + \lambda_4 \sum_{i=1}^{l} \sum_{j=1}^{J} \beta k_{ij} x_{ij} p_{ij} - \lambda_5 \sum_{i=1}^{l} \sum_{j=1}^{J} m_{ij} x_{ij} - \lambda_6 \sum_{i=1}^{l} \sum_{j=1}^{J} a_{ij} x_{ij}
\end{align*}
\]

Restrictions:

\[
\begin{align*}
\sum_{i=1}^{l} x_{ij} y_{ij} &\geq \bar{D}_j \quad \forall j \\
\sum_{i=1}^{l} l_{ij} x_{ij} &\leq L_j \bar{D}_j \quad \forall j \\
\sum_{i=1}^{l} k_{ij} x_{ij} &\leq K_j \bar{D}_j \quad \forall j \\
x_{ij} &\leq \bar{f}_{ij} y_{ij} \quad \forall i, j \\
x_{ij} &\geq 0, y_{ij} = 0\text{ or }1
\end{align*}
\]

Constraint (8) limits the supply of logistics service providers' logistics service capacity to be greater than or equal to the logistics service integrator's logistics service capacity requirements, ensuring that all logistics tasks are completed; constraints (9) limit the logistics service defects Less than the maximum acceptable service defect to ensure the quality of service; constraint (10) limits the order loss
of the selected logistics service provider to less than the maximum order loss that the logistics service integrator can accept; constraint (11) limits the amount of order service allocated to the logistics service provider to be no more than the fuzzy supply of its maximum logistics service capacity; Equation (12) limits the value range of the decision variable.

2.3 Model transformation

Since the model constraints contain fuzzy variables, in this case, if the deterministic model is used for solving, the problem can only be simplified by setting some assumptions, which will cause the research model to be out of touch with the reality. The objective function formula (1) cannot be directly solved by the conventional deterministic method, and the target optimization method in the fuzzy environment needs to be further studied. In order to solve the model, this paper assumes that all uncertain parameters are triangular fuzzy numbers. For this problem, based on the research basis of the literature [8-10], introduce the credibility theory, set the confidence level parameters, and combine the actual situation of the problem with the confidence level. The greater the decision maker’s logistics service integrator's satisfaction, the higher the confidence level parameter is set to greater than 0.5. In this way, the credibility theory is used to clearly convert the objective function and constraints with triangular fuzzy numbers.

**Lemma 1** Let $\varphi$ be a triangular fuzzy variable $(u_1, u_2, u_3)$ $(u_1 < u_2 < u_3)$, then for a given confidence level $\xi$ (0.5 $\leq \xi \leq 1$), there is:

$$
Cr\{\varphi \leq u_i\} \geq \xi \iff u \geq 2(1 - \xi)\varphi_2 + (2\xi - 1)\varphi_3
$$

(13)

**Lemma 2** Let $\varphi$ be a triangular fuzzy variable $(u_1, u_2, u_3)$ $(u_1 < u_2 < u_3)$, then for a given confidence level $\eta$ (0.5 $\leq \eta \leq 1$), there is:

$$
Cr\{\varphi \geq u_i\} \geq \eta \iff u \leq 2(\eta - 1)\varphi_1 + 2(1 - \eta)\varphi_2
$$

(14)

Based on Lemma 1 constraint (8) can be transformed into a clear equivalence (15); similarly, based on Lemma 2 constraints (9), (10) and (11) can be transformed into a clear equivalence (16) , (17) and (18).

$$
\sum_{i=1}^{I} x_{ij}y_{ij} \geq 2(1 - \xi)D_{j2} + (2\xi - 1)D_{j3} \quad \forall j
$$

(15)

$$
\sum_{i=1}^{I} l_{ij}x_{ij} \leq (2\eta - 1)L_{j1}D_{j1} + 2(1 - \eta)L_{j2}D_{j2} \quad \forall j
$$

(16)

$$
\sum_{i=1}^{I} k_{ij}x_{ij} \leq (2\eta - 1)K_{j1}D_{j1} + 2(1 - \eta)K_{j2}D_{j2} \quad \forall j
$$

(17)

$$
x_{ij} \leq (2\eta - 1)f_{ij1}y_{ij} + 2(1 - \eta)f_{ij2}y_{ij} \quad \forall i, j
$$

(18)

Using the above method, the logistics service supply chain order allocation model in a fuzzy environment can be transformed into the following clear equivalent form:

$$
\min Z = \lambda_1 \sum_{i=1}^{I} \sum_{j=1}^{J} \delta_{ij}x_{ij}y_{ij} + \lambda_2 \sum_{i=1}^{I} \sum_{j=1}^{J} p_{ij}x_{ij}y_{ij} + \lambda_3 \sum_{i=1}^{I} \sum_{j=1}^{J} k_{ij}x_{ij}
$$

$$
+ \lambda_4 \sum_{i=1}^{I} \sum_{j=1}^{J} \beta_{ij}k_{ij}x_{ij}y_{ij} - \lambda_5 \sum_{i=1}^{I} \sum_{j=1}^{J} m_{ij}x_{ij} - \lambda_6 \sum_{i=1}^{I} \sum_{j=1}^{J} a_{ij}x_{ij}
$$

(19)

Restrictions:

$$
\sum_{i=1}^{I} x_{ij}y_{ij} \geq 2(1 - \xi)D_{j2} + (2\xi - 1)D_{j3} \quad \forall j
$$

(20)
\[ \sum_{i=1}^{4} l_i x_{ij} \leq (2\eta - 1)L_j D_{j1} + 2(1-\eta)L_j D_{j2} \quad \forall j \quad (21) \]
\[ \sum_{i=1}^{4} k_i x_{ij} \leq (2\eta - 1)K_j D_{j1} + 2(1-\eta)K_j D_{j2} \quad \forall j \quad (22) \]
\[ x_{ij} \leq (2\eta - 1)f_{ij} y_{ij} + 2(1-\eta)f_{ij} y_{ij} \quad \forall i, j \quad (23) \]
\[ x_{ij} \geq 0, y_{ij} = 0 \text{ or } 1 \quad (24) \]

3. Case analysis

In order to verify the analysis of the constructed model, this section designs a case and solves it with Lingo11.0 software. Assume that a logistics service supply chain consists of one logistics service integrator and four logistics service providers, and distributes three logistics tasks in a single cycle. Since the order is allocated in an uncertain environment where the supply capacity of logistics service providers and the demand for customer logistics capacity are fuzzy variables, logistics service integrators need to analyze historical data and perform fuzzy equivalent conversion in order to use deterministic methods. Solve. In order to avoid the risk of logistics service integrators in the fuzzy environment, in order to improve the satisfaction of logistics service integrators on the distribution plan, the confidence level in the text should be set to not less than 0.5, and the false setting level \( \xi \) and \( \eta \) should be taken is 0.8. The defect rate of each order task service allowed by the logistics service integrator is \( L_1 = 0.04 \), \( L_2 = 0.05 \), \( L_3 = 0.06 \). The maximum order churn rate of each order task allowed is \( K_1 = 0.007 \), \( K_2 = 0.009 \), \( K_3 = 0.008 \). The proportion of logistics service order transaction expense is \( \delta = 0.2\% \). Order loss compensation rate \( \beta = 50\% \). Set goals The weight of the function is \( \lambda_1=\lambda_2=\lambda_3=\lambda_4=0.2 \), \( \lambda_5=\lambda_6=0.1 \). Table 1 shows the fuzzy supply quantity and logistics capacity fuzzy demand quantity of the logistics service provider and the unit service price; the matching degree and the service quality value are shown in Table 2; the service defect rate and the order churn rate are shown in Table 3. The model was solved using Lingo11.0 software. The results are shown in Table 4. The objective function is 3939.889.

| \( i \) | \( j \) | \( f_{ij} \) | \( p_{ij} \) | \( D_{j} \) |
|---|---|---|---|---|
| 1 | 1 | (80,90,100) | 50 | (200,220,240) |
| 2 | 2 | (70,80,90) | 52 | (90,110,130) |
| 3 | 3 | (80,90,100) | 45 | (60,80,100) |
| 4 | 4 | (50,60,70) | 40 | (90,100,110) |

| \( m_{ij} \) | \( j \) | \( j \) | \( j \) | \( a_{ij} \) | \( j \) | \( j \) | \( j \) |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 0.40 | 0.30 | 0.25 | 0.75 | 0.80 | 0.85 |
| 2 | 0.35 | 0.40 | 0.25 | 0.85 | 0.70 | 0.75 |
| 3 | 0.30 | 0.40 | 0.30 | 0.80 | 0.85 | 0.90 |
| 4 | 0.45 | 0.35 | 0.30 | 0.90 | 0.95 | 0.80 |
Table 3. Service defect rate and order churn rate

| i = 1  | j = 1 | j = 2 | j = 3 | k = 1 | j = 2 | j = 3 |
|--------|-------|-------|-------|-------|-------|-------|
| 0.04   | 0.03  | 0.03  | 0.005 | 0.004 | 0.006 |
| 0.02   | 0.04  | 0.03  | 0.007 | 0.009 | 0.008 |
| 0.03   | 0.05  | 0.04  | 0.004 | 0.0006| 0.005 |
| 0.04   | 0.03  | 0.05  | 0.006 | 0.005 | 0.007 |

Table 4. Model solution result

| i = 1  | j = 1 | j = 2 | j = 3 |
|--------|-------|-------|-------|
| 94     | 54    | 48    |
| 74     | 14    | 0     |
| 64     | 54    | 94    |

As can be seen from Table 4, the order quantity assigned by the logistics service provider 1 is 50 for task 3. The order quantity assigned by logistics service provider 2 is task 1 is 94, task 2 is 54, task 3 48. The logistics service provider 3 assigned the order quantity is task 1 is 74, task 2 is 14. Logistics service provider 4 is assigned the task amount is task 1 is 64, task 2 is 54, task 3 Is 94.

4. Conclusion

This paper considers the impact of fuzzy factors on service order allocation, and regards logistics service capability supply and demand as fuzzy variables, and comprehensively considers the objectives of transaction cost, purchase cost, order loss quantity and logistics service quality level, and establishes fuzzy multi-objective logistics. The service order allocation model is adopted, and the feasibility theory is used to make the fuzzy constraint conditions clear. Finally, the validity and feasibility of the model are verified by using lingo software for specific examples.

Reference

[1] National Bureau of Statistics. The service industry has been in the midst of a storm of seventy years. The new era of the wave of tides and heads—the report of the series of economic and social development achievements of the 70th anniversary of the founding of New China [R], 2019.

[2] ZHANG Guangsheng, LIU Wei. Emergency task assignment of logistics service supply chain considering service timeliness[J]. Journal of Computer Applications, 2016(08):2335-2339.

[3] Ge Caihong, Ji Bifa. Research on Multi-task Cooperation Mechanism of Logistics Service Supply Chain[J]. Journal of Zhejiang Shuren University (Humanities and Social Sciences), 2018, 18(01): 53-59.

[4] Moghaddam K S. Fuzzy multi-objective model for supplier selection and order allocation in reverse logistics systems under supply and demand uncertainty[J]. Expert Systems with Applications, 2015, 42(15-16):6237-6254.

[5] Li Kaihang. Research on the coordination mechanism of three-level logistics service supply chain under the new normal [D]. Tianjin University of Technology, 2018.

[6] CHEN Haodong, WANG Zhiping, CHEN Yan. Mixed Integer Nonlinear Programming Model for Dynamic Supplier Selection in Fuzzy Environment[J]. Operations Research and Management Science, 2015, 24(04): 128-136.

[7] Gupta P, Govindan K, Mehlawat M K, et al. A weighted possibilistic programming approach for sustainable vendor selection and order allocation in fuzzy environment[J]. The International Journal of Advanced Manufacturing Technology, 2016, 86(5-8):1785-1804.

[8] Zhang Guangsheng, Liu Wei. Logistics service supply chain capability combination purchasing decision considering price risk[J]. Computer Integrated Manufacturing System: 1-17 [2019-09-09].http://kns.cnki.net/kcms/detail /11.5946.TP.20180809.1543.036.html.
[9] Parthiban P, Punniyamoorthy M, Ganesh K, et al. A hybrid model for sourcing selection with order quantity allocation with multiple objectives under fuzzy environment[J]. International Journal of Applied Decision Sciences, 2009, 2(3):275-298.

[10] Qu Meng, Zhu Bin, Hui Jizhuang, et al. Production planning of closed-loop supply chain based on credibility theory [J]. Industrial Engineering and Management, 2018, 23(04): 36-44.