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Procurement Decision of Logistics Service Integrators in Logistics Service Supply Chain

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ABSTRACT

As the core of the LSSC, integrators procure logistics services from specialized providers, coordinating and bundling them into complete offerings. Relying mainly on external sourcing, their strategies include wholesale, full booking, and spot purchases. This paper develops procurement models under both constrained and unconstrained budgets, analyzing strategy shifts via mathematical modeling and validating them through simulation.

KEYWORDS

Logistics service supply chain; Logistics service integrators; Service capability sourcing

1 Introduction

Research on logistics service supply chains (LSSC) has attracted growing attention due to increasing logistics complexity and specialization [5,10]. Early studies classified logistics providers , whereas recent work focuses on integrative structures and operational dynamics[11-12]. Integrated logistics service providers (ILSPs) coordinate specialized services to minimize costs and meet service objectives through IT and alliances [1,3,7,15]. Growing personalized demands and e-commerce have accelerated resource integration and network expansion [4,6,9,14]. Manufacturers influence platform participation [2,8,13], enhancing logistics regardless of traditional retail strategies. Building on Yin et al. (2024) [16], this study models capital-constrained ILSP procurement using a three-period model to optimize pricing and ordering, offering empirical insights for cost reduction and profitability.

2 The procurement by logistics service integrators

2.1 Problem description

This study examines a single-cycle, two-tier LSSC where a logistics service integrator (LSI) relies on a functional provider (FLSP) for specific capabilities to meet customer demand, as illustrated in Figure 1.

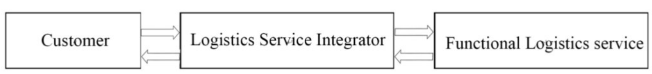

Figure 1 Structure of LSSC

The integrator's procurement decision is divided into three stages: t_0, t_1, and t_2. At t_0, initial and option order quantities are placed based on demand forecasts. At t_1, forecasts are updated, and the option execution volume is determined. At t_2, spot purchases are made based on actual demand.

2.2 Model Assumptions and Symbol Definitions

The following assumptions are made for the convenience of research.

(1) Logistics service demand is stochastic and market-priced.

(2) Each unit of demand requires one unit of capacity, fully sourced from external providers.

(3) Information is symmetric; both parties are finite-rational and risk-neutral.

(4) Logistics service integrators dominate the LSSC.

(5) In the integrator's procurement model, the wholesale price is lower than the option cost, which in turn is lower than the spot market price.

Key variables include initial order q, option quantities $m1$ and me, spot purchase $m2$, respective costs $\omega1$, $\omega2$, $\omega0$, ωe,

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selling price p, and budget Y.

D: The logistics requirements ($D \geq 0$, a random variable with an average value of $\mu = E(x) = \int_0^\infty xf(x)dx$, with distribution function $F(x)$ and density function $f(x)(x \geq 0)$,$F(x)$ which are continuous, differentiable, and strictly increasing functions , $F(0)=0$,$F^{-1}(x)$ is the inverse function of $F(x)$ that the integrator needs to provide.

C_i: Expected procurement cost of the integrator

q': Market demand quantity after information update by the integrator, satisfying the following relationship

$$0 < \omega_1 \leq \omega_0 + \omega_e \leq \omega_2 \leq p$$

The wholesale price is the lowest, spot price the highest, and the option price falls in between—all below the selling price, ensuring profitability. Symbols marked with an asterisk (*) denote optimal solutions.

The logistics service integrator makes procurement decisions in three stages: at t_0 , determining the initial order quantity q and option purchase quantity m_1 ;at t_1 , deciding the option execution quantity m_e ; and at t_2 , determining the spot purchase quantity m_2.

3 Supplier sourcing model

3.1 Procurement Strategy of LSI without Funding Constraints

3.1.1 Procurement decision of the integrator at time t_0

The expected procurement cost of the integrator is

$$C_i(q,m_1) = \int_q^{q+m_1} \omega_e (x-q)f(x)dx + \int_{q+m_1}^{\infty} [\omega_e m_1 + \omega_2(x-q-m_1)]f(x)dx + \omega_1 q + \omega_0 m_1 \quad (1)$$

Where option execution cost incurs when forecasted demand exceeds wholesale quantity but remains within total booked capacity.

The variables in this equation are as follows: $\int_q^{q+m_1} \omega_e (x-q)f(x)dx$ denotes option execution cost when forecast demand exceeds wholesale quantity but remains below total pre-booked capacity; $\int_{q+m_1}^{\infty} [\omega_e m_1 + \omega_2(x-q-m_1)]f(x)dx$, represents cost when forecast demand exceeds combined wholesale and option quantities; $\omega_1 q$, which represents the wholesale cost; and $\omega_0 m_1$, which represents the option booking cost.

Therefore, the objective function is

$$minC_i(q,m_1) = \int_q^{q+m_1} \omega_e(x-q)f(x)dx + \int_{q+m_1}^{\infty} [\omega_e m_1 + \omega_2(x-q-m_1)]f(x)dx + \omega_1 q + \omega_0 m_1 \quad (2)$$

Its first-order partial derivatives is

$$\frac{\partial C_i(q,m_1)}{\partial q} = \omega_e F(q) + (\omega_2 - \omega_1) \times F(q+m_1) + \omega_1 - \omega_2 \quad (3)$$

$$\frac{\partial C_i(q,m_1)}{\partial m_1} = (\omega_2 - \omega_e)F(q+m_1) + \omega_e + \omega_0 - \omega_2 \quad (4)$$

And its second-order partial derivatives is

$$\frac{\partial C_i^2(q+m_1)}{\partial {m_1}^2} = (\omega_2 - \omega_e)f(q+m_1) \quad (5)$$

$$\frac{\partial {C_i}^2(q+m_1)}{\partial {m_1}^2} = (\omega_2 - \omega_e)f(q+m_1) \quad (6)$$

Thus, the Hessian matrix of the function is

$$H = \begin{bmatrix} \omega_e f(q) + (\omega_2 - \omega_e)f(q+m_1) & (\omega_2 - \omega_e)f(q+m_1) \\ (\omega_2 - \omega_e)f(q+m_1) & (\omega_2 - \omega_e)f(q+m_1) \end{bmatrix} \quad (7)$$

Where $\omega_e > 0, \omega_2 - \omega_1 > 0$ when

$$\omega_e f(q) + (\omega_2 - \omega_e)f(q+m_1) > 0 \quad (8)$$

$$\begin{bmatrix} \omega_e f(q) + (\omega_2 - \omega_e)f(q+m_1) & (\omega_2 - \omega_e)f(q+m_1) \\ (\omega_2 - \omega_e)f(q+m_1) & (\omega_2 - \omega_e)f(q+m_1) \end{bmatrix} \quad (9)$$

Equations (8) and (9) show that the first- and second-order principal minors of matrix H are positive, proving H is positive definite. Thus, the objective function in equation (2) is convex with a minimum.

Let equation (3) = 0, equation (4) = 0, which means

$$\frac{\partial C_i(q,m_1)}{\partial q}=\omega_e F(q)+(\omega_2-\omega_1)\times F(q+m_1)+\omega_1-\omega_2=0 \tag{10}$$

$$\frac{\partial C_i(q,m_1)}{\partial m_1}=(\omega_2-\omega_e)F(q+m_1)+\omega_e+\omega_0-\omega_2=0 \tag{11}$$

Solving equations (10) and (11), we obtain

$$q^*=F^{-1}(\frac{\omega_0+\omega_e-\omega_1}{\omega_e}) \tag{12}$$

$$m_1{}^*=F^{-1}(\frac{\omega_2-\omega_0-\omega_e}{\omega_2-\omega_e})-q^* \tag{13}$$

3.1.2 Procurement decision of the integrator at time t_1

At time t_1, the logistics service integrator's main task is to determine the option quantity m_e by forecasting demand from t_0 to t_1, considering the initial purchase, and deciding the option's execution volume.Assuming that the probability density function of customer demand has been revised based on new market information (i), denoted as $f(x/i)$, and that all other market parameters remain constant, the logistics service integrator predicts a total market demand of q'.

The procurement decision of the logistics service integrator at this stage is

$$m_e^*=min\{[q'-q^*]^+,m_1^*\} \tag{14}$$

In equation (14), $[q'-q^*]^+$ is a non-negative integer. In the first stage, m_e^* takes the lower value between the predetermined quantity of options and the difference between the new forecasted quantity and the demand quantity. This can be explained as follows.

when $q'\leq q^*$,$[q'-q^*]^+=0$. This indicates that the demand forecast at t_1 is lower than the initial wholesale quantity set at t_0. As a result , the integrator has sufficient capacity and does not execute the option, making $m_e^*=0$.

When $q^*<q'<q^*+m_1$, the integrator partially exercises options, yielding an execution quantity of $m_e^*=q'-q^*$.

When $q'\geq q^*+m_1{}^*$, the integrator fully exercises all options and the most option-executed quantity $m_e{}^*=m_1{}^*$.

3.1.3 The purchasing decision of the integrator at time t_2

At time t_2, if initial and option purchases are insufficient, the integrator must procure additional capacity to meet actual demand.

Currently, the integrator's spot purchasing volume is

$$m_2{}^*=max\{D-q^*-m_e{}^*,0\} \tag{15}$$

3.2 Analysis of the impact of funding shortages on integrators' purchasing strategies

Capital constraints significantly influence the integrator's procurement strategy.The funding for this project is limited to

$$Y<\omega_1 q^*+(\omega_0+\omega_e)m_1{}^*+\omega_2 m_2{}^* \tag{16}$$

3.2.1 Analysis of time t_1 with fund constraint

The first-stage integrator decision under funding constraints forms a constrained nonlinear programming problem, solved via the K-T conditions and expressed through hypothetical propositions.

The fund constraint is given by

$$Y<\omega_1 q^*+(\omega_0+\omega_e)m_1{}^* \tag{17}$$

Given the function

$$L(q,m_1,\lambda)=C_i(q,m_1)-\lambda_1[\omega_1 q+(\omega_0+\omega_e)m_1-Y]-\lambda_2 q-\lambda_3 m_1 \tag{18}$$

Thus, the K-T conditions are:

$$\frac{\partial L}{\partial q}=\omega_e F(q)+(\omega_2-\omega_1)\times F(q+m_1)+\omega_1-\omega_2-\lambda_1\omega_1-\lambda_2=0 \tag{19}$$

$$\partial m_1=\left(\omega_2-\omega_e\right)F\left(q+m_1\right)+\omega_e+\omega_0-\omega_2-\lambda_1\omega_0-\lambda_1\omega_e-\lambda_3=0 \tag{20}$$

$$\omega_1 q+(\omega_0+\omega_e)m_1-Y\geq 0$$

$$q \geq 0$$
$$m_1 \geq 0$$
$$\lambda_1\left[\omega_1 q+\left(\omega_0+\omega_e\right)m_1-Y\right]=0$$
$$\lambda_2 q=0$$
$$\lambda_3 m_1=0$$
$$\lambda_1,\lambda_2,\lambda_3 \geq 0$$

$\lambda_1,\lambda_2,\lambda_3$ are the general Lagrange multiplier.

If $\omega_1 q+(\omega_0+\omega_e)m_1=Y$ holds true,

Assuming $q=0, m_1>0$, holds true, then $\lambda_3=0$ is obtained from equation (20), and can be derived from equation (19).

$$F(m_1)=\frac{\omega_2+\lambda_2-(1-\lambda_1)\omega_1}{\omega_2-\omega_e} \tag{21}$$

From equation (20) we have

$$F(m_1)=\frac{\omega_2-(1-\lambda_1)(\omega_0+\omega_e)}{\omega_2-\omega_e} \tag{22}$$

Associative equations (21) and (22) yield

$$1-\lambda_1=\frac{\lambda_2}{\omega_1-\omega_0-\omega_e} \tag{23}$$

Substituting (23) into (21), then

$$F(m_1)=\frac{\omega_2+\lambda_2-\dfrac{\omega_1\lambda_2}{\omega_1-\omega_0-\omega_e}}{\omega_2-\omega_e} \tag{24}$$

Because $F(m_1)\leq 1 F(m_1)\leq 1$, it follows that

$$F(m_1)=\frac{\omega_2+\lambda_2-\dfrac{\omega_1\lambda_2}{\omega_1-\omega_0-\omega_e}}{\omega_2-\omega_e}\leq 1 \tag{25}$$

From equation (25)

$$\lambda_2 \leq \frac{\omega_e(\omega_1-\omega_0-\omega_e)}{\omega_0+\omega_e} \tag{26}$$

Because $0<\omega_0, 0<\omega_e, 0<\omega_1<\omega_0+\omega_e$, it satisfies

$$\lambda_2 \leq \frac{\omega_e(\omega_1-\omega_0-\omega_e)}{\omega_0+\omega_e}<0 \tag{27}$$

The contradiction between $\lambda_2<0$ and $\lambda_2 \geq 0$ in the K-T conditional of equation (20) means that Assumption 2.4.1 is invalid.

Therefore, we can conclude with Proposition 1.

Proposition 1 If $\omega_1 q+\left(\omega_0+\omega_e\right)m_1=Y$,then $q=0, m_1=0$ cannot be the optimal solution.

Proposition 1 Imposes a constraint on the integrator ' s procurement solution under limited funding.It is indicated that when the integrated supplier's purchasing decision is constrained by fund $\omega_1 q+(\omega_0+\omega_e)m_1=Y$ (where $Y<\omega_1 q^*+(\omega_0+\omega_e)m_1{}^*$), the initial order quantity q must be greater than 0.

Proposition 2 If $\omega_1 q+(\omega_0+\omega_e)m_1=Y$, then the relationship between $F(q)\leq 1-\dfrac{\omega_1\omega_e}{\omega_2(\omega_0+\omega_e)-\omega_1(\omega_2-\omega_e)}$ holds, and $q=\dfrac{Y}{\omega_1}, m_1=0$ is the optimal solution.

From equation (18), when $q>0$, $\lambda_2=0$. Also, because of $m_1=0$,. from equation (19) we have

$$F(q)=\frac{\omega_2-(1-\lambda_1)\omega_1}{\omega_2} \tag{28}$$

From (20), we have

$$F(q)=\frac{\omega_2+\lambda_3-(1-\lambda_1)(\omega_0+\omega_e)}{\omega_2-\omega_e} \tag{29}$$

By solving (28) and (29) together, we can obtain the solution.

$$1-\lambda_1=\frac{\omega_2(\lambda_3+\omega_e)}{\omega_2(\omega_0+\omega_e)-\omega_1(\omega_2-\omega_e)} \tag{30}$$

Substituting equation (30) into equation (29) yields

$$F(q)=1-\frac{\omega_1(\lambda_3+\omega_e)}{\omega_2(\omega_0+\omega_e)-\omega_1(\omega_2-\omega_e)} \tag{31}$$

From equation (31),we have

$$F(q) \leq 1 - \frac{\omega_1 \omega_e}{\omega_2(\omega_0 + \omega_e) - \omega_1(\omega_2 - \omega_e)} \tag{32}$$

In conclusion, hypothesis 2 holds.

Under tight budgets, the integrator favors wholesale procurement and drops options when funds are limited. Hypothetical Proposition 3 identifies when both methods are applied.

Proposition 3 If the relationship between $\omega_1 q + \left(\omega_0 + \omega_e\right) m_1 = Y, F(q) > 1 - \frac{\omega_1 \omega_e}{\omega_2(\omega_0 + \omega_e) - \omega_1(\omega_2 - \omega_e)}$ holds, then the optimal solution $q, m_1 q, m_1$ of the problem is greater than zero, and D satisfies

$$F(q) = \frac{(\omega_0 + \omega_e - \omega_1)(1 + \lambda_1)}{\omega_e} \tag{33}$$

$$F(q + m_1) = \frac{\omega_{2-}(\omega_0 + \omega_e)(1 + \lambda_1)}{\omega_2 - \omega_e} \tag{34}$$

When $\lambda_1 \geq 0$.

Proof According to Proposition 1, $q > 0$ must hold. Additionally, from assumption 2, when $F(q) \leq 1 - \frac{\omega_1 \omega_e}{\omega_2(\omega_0 + \omega_e) - \omega_1(\omega_2 - \omega_e)}$, $q = \frac{Y}{\omega_1}$, $m_1 = 0$. Therefore, when $F(q) \leq 1 - \frac{\omega_1 \omega_e}{\omega_2(\omega_0 + \omega_e) - \omega_1(\omega_2 - \omega_e)}$, $F(q)$ is a strictly increasing function. To meet demand, purchasing all items at wholesale prices would exceed the budget Y. However, option booking prices are lower than wholesale prices and help hedge against demand uncertainty. Solving equations (33), (34), and $\omega_1 q + (\omega_0 + \omega_e) m_1 = Y$ yields specific values for q, m_1 and λ_1.Therefore, the optimal solution for this problem, $q, m_1 q, m_1$ must be greater than zero. By applying the K-T condition after substituting $q > 0, m_1 > 0$ we can obtain $\lambda_2 = 0, \lambda_3 = 0$, then

$$F\left(q\right) = \frac{\left(\omega_0 + \omega_e - \omega_1\right)\left(1 + \lambda_1\right)}{\omega_e}$$

$$F\left(q + m_1\right) = \frac{\omega_{2-}\left(\omega_0 + \omega_e\right)\left(1 + \lambda_1\right)}{\omega_2 - \omega_e}$$

In summary, Proposition 3 holds.

Proposition 3 indicates that under sufficient funding, the optimal procurement strategy integrates both initial and option orders, with solutions at t_0 varying according to budget constraints.

3.2.2 Analysis at time t_1 with financial constraints

When there is a funding constraint, it can be expressed as

$$\omega_e m_e{}^* \leq Y - \omega_1 q^* - \omega_0 m_1{}^* \tag{35}$$

When $q' \leq q$, which refers to $m_e{}^* = 0$, equation (35) holds. At this point, the logistics service integrator does not add any orders, and the optimal execution quantity of the logistics service integrator's option is 0.

When $q^* < q' < q' + m_1{}^*$, which refers to $m_e{}^* = q' - q^*$, equation (35) holds, the logistics service integrator adds orders, and the optimal execution quantity of the logistics service integrator's option is $q' - q^*$.

When $q' \geq q^* + m_1{}^*$, which refers to $m_e{}^* = m_1{}^*$,equation (35) does not hold. At this point, the logistics service integrator adds orders in this stage. The optimal execution quantity of the logistics service integrator's option is equal to the option reservation quantity, which is $m_1{}^*$.

3.2.3 Analysis of moment t_2 with financial constraints

When procurement funding is limited, the integrator will use the remaining funds to purchase logistics services that may not be sufficient. This is referred to as

$$m_2{}^* = min\,\{[D - q^* - m_e{}^*]^+, \frac{Y - \omega_1 q^* - (\omega_0 m_1{}^* + \omega_e m_e{}^*)}{\omega_2}\} \tag{36}$$

In equation (36), q, $m_1{}^*$, and $m_e{}^*$ are determined by equations (12), (13), and (14) respectively. $m_2{}^*$, In addition to market demand and prior purchases, spot procurement is also constrained by available funds, which determine the maximum purchasable quantity.

3.2.4 The impact of funding shortages on integrators' sourcing strategies

Based on the previous analysis, the following conclusions can be drawn.

Corollary 1 When there is a purchasing fund constraint, the sum of the integrator's initial purchase quantity and option purchase quantity is smaller than when there is no purchasing fund constraint.

Proof When there is no purchasing fund constraint, according to equation (13), the sum of the integrator's optimal initial purchase quantity and option purchase quantity satisfies

$$F(q^*+m_1^*)=\frac{\omega_2-\omega_e-\omega_0}{\omega_2-\omega_e} \tag{37}$$

Under fund constraints, Proposition 3 (Eq. 34) states that the integrator's optimal initial and option purchase quantities must satisfy the given condition.

$$F(q+m_1)=\frac{\omega_2-(\omega_0+\omega_e)(1+\lambda_1)}{\omega_2-\omega_e}$$

Because of $\lambda_1 \geq 0$, $F(q^*+m_1^*) \geq F(q+m_1)$, and because $F(x)$ is an increasing function of x, thus corollary 1 holds

Corollary 2 Under budget constraints, integrators prioritize initial over option procurement.

Proof When there is no constraint on procurement funds, according to equation (12), the optimal initial procurement quantity of integrators satisfies

$$F(q^*)=\frac{\omega_0+\omega_e-\omega_1}{\omega_e} \tag{38}$$

However, when there is a fund constraint, the initial purchase quantity for the integrator satisfies equation (38) as shown in hypothesis proposition 2.4.3

$$F(q)=\frac{(\omega_0+\omega_e-\omega_1)(1+\lambda_1)}{\omega_e}$$

Because $\lambda_1 \geq 0$, $F(q^*) \leq F(q)$, and because $F(x)$ is an increasing function of x

$q^* \leq q, m_1^* \geq m_1$, corollary 2 is proved.

Corollary 1 and Corollary 2 reflect the impact of purchasing fund shortage on the initial purchase and option purchase of the integrator.

4 Case analysis

To validate the study's conclusions, a numerical simulation is conducted. Assuming demand follows a uniform distribution over [0, 300], with parameters $p=90, \omega_1=60, \omega_0=10, \omega_e=60, \omega_2=80$, the impact of procurement funds on integrator decisions is analyzed. Without budget constraints, equations (12) and (13) yield the optimal initial purchase q^* and option quantity $m_1^*=100$, requiring a budget of $Y=10000$. If $Y<10000$, the integrator cannot follow the optimal strategy. Table 1 presents decisions under different funding levels.

Table 1 Different procurement strategies of LSI under different budget funds

Purchase Quantity Financial Constraints/ thousand dollars	0	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000
Wholesale Volume	0	16	32	50	62	65	62	60	58	56	50
Option Booking Volume	0	0	0	0	4	16	33	49	65	81	100
Total Amount Booked	0	16	32	50	66	81	95	109	123	137	150
Profit/thousand dollars	0	480	960	1500	1940	2290	2550	2810	3070	3330	3500

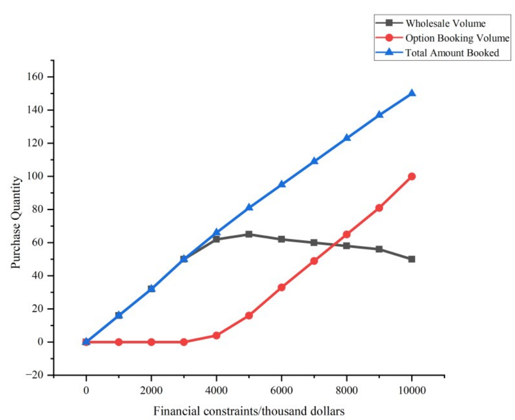

Figure 2 Procurement strategy of LSI under different budget funds

Table 1 and Figure 2 confirm that initial procurement is always used when demand exists, supporting Conclusion 1. As funds reach 10,000, total purchases peak at 150, matching the unconstrained optimum. Increased budget shortages shift reliance toward initial purchases, verifying Conclusion 2. Potential profit also rises with funding, though exact values require further data and analysis.

5 Conclusions

This study investigates the procurement strategies of logistics service integrators (LSIs) in the LSSC across three stages, under both constrained and unconstrained financial conditions. The main findings are:

(1) Financial constraints reduce the total quantity of initial and option procurement compared to the unconstrained case. (2) Under constraints, LSIs increase initial procurement while reducing option purchases. (3) In the second and third stages, option execution and spot purchases are influenced by both demand and available funds.

These conclusions are based on simplified assumptions and a model involving a single integrator and provider. In practice, LSSCs often involve multiple integrators and providers, which presents a direction for future research.

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References

[1] Brewer B, Ashenbaum B, Ogden J A. Connecting strategy-linked outsourcing approaches and expected performance[J]. International Journal of Physical Distribution & Logistics Management, 2013, 43(3): 176-204.

[2] Chen N, Cai J, Kannan D, et al. Optimal channel selection considering price competition and information sharing under demand uncertainty [J]. Industrial Management & Data Systems, 2024, 124(4): 1329-1355.

[3] Ellram L M, Tate W L, Billington C. Understanding and managing the services supply chain[J]. Journal of Supply Chain Management, 2004, 40 (3): 17-32.

[4] Fabbe-Costes, Nathalie & Jahre, Marianne & Roussat, Christine. Towards a typology of the roles of logistics service providers as 'supply chain integrators'[C]. Supply Chain Forum: an International Journal.2008, 9. 28-43.

[5] Gkanatsas E, Krikke H. Towards a pro-silience framework: a literature review on quantitative modelling of resilient 3PL supply chain network designs[J]. Sustainability, 2020, 12(10): 4323.

[6] He C, Liu W. Coordinating contracts for a three-lever logistics service supply chain[J]. Journal of Industrial and Production Engineering, 2015, 32(5): 331-339.

[7] Li L, Li G. Integrating logistics service or not? The role of platform entry strategy in an online marketplace[J]. Transportation Research Part E: Logistics and Transportation Review, 2023, 170: 102991.

[8] Mageto J. Current and future trends of information technology and sustainability in logistics outsourcing[J]. Sustainability, 2022, 14(13): 7641.

[9] Muller EJ. The top guns of third-party logistics[J]. Distribution, 1993, (3): 30-38.

[10] Persson G, Virum H. Growth strategies for logistics service providers: a case study[J]. The International Journal of Logistics Management, 2001, 12(1): 53-64.

[11] Premkumar P, Gopinath S, Mateen A. Trends in third party logistics – the past, the present & the future[J]. International Journal of Logistics Research and Applications, 2021, 24(6): 551-580.

[12] Qin X, Liu Z, Tian L. The optimal combination between selling mode and logistics service strategy in an e-commerce market[J]. European Journal of Operational Research, 2021, 289(2): 639-651.

[13] Rahman S, Ahsan K, Yang L, et al. An investigation into critical challenges for multinational third-party logistics providers operating in China [J]. Journal of Business Research, 2019, 103: 607-619.

[14] Razzaque, C. Sheng. Outsourcing of logistics functions: a literature survey [J]. International Journal of Physical Distribution&Logistics Management,1998, 28(2):89-108.

[15] Sum C C, Teo C B. Strategic posture of logistics service providers in Singapore[J]. International Journal of Physical Distribution & Logistics Management, 1999, 29(9): 588-605.

[16] Yin M, Huang M, Wang D, et al. Multi-period fourth-party logistics network design with the temporary outsourcing service under demand uncertainty[J]. Computers & Operations Research, 2024, 164: 106564.