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Research on the AHP-TOPSIS Logistics Channel Model under the Cross-border E-commerce Comprehensive Pilot Zone Policy

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Abstract. Policies for China's Cross-Border E-Commerce Comprehensive Pilot Zones (CBEPs) have been continuously advanced, forming a development network for cross-border e-commerce (CBEC) that spans border, coastal, and inland regions. However, traditional empirical decision-making for logistics channels struggles to balance multiple factors, such as transport capacity, cost-effectiveness, and timeliness. Therefore,this study develops a composite decision-making model based on the Analytic Hierarchy Process-Technique for Order of Preference by Similarity to Ideal Solution (AHP-TOPSIS) to solve the multi-criteria optimization problem of cross-border e-commerce logistics channels. The model's objective layer focuses on selecting the optimal logistics channel; the criterion layer incorporates five indicators such as the economic efficiency of transportation capacity, and the alternative layer includes overseas warehouses, dedicated lines, international express and postal parcels. This model is validated via AHP-based methods, including weight calculation and consistency testing. Results show that the overseas warehouse model demonstrates distinct comprehensive advantages. Based on these findings, a novel decision-making scheme is proposed.

Keywords: AHP-TOPSIS, CBEPs, Comprehensive Pilot Zone for E-commerce Logistics channel

1. Introduction

China's Cross-Border E-Commerce Comprehensive Pilot Zones (CBEPs) have achieved steady development in recent years, forming a representative CBEC development network that spans inland, coastal, and border areas. By 2025, the number of national CBEPs had reached 196. These zones are distributed in a coordinated manner among border, coastal and inland cities, forming a nationwide coverage network [1]. At the policy level, institutional innovations, such as streamlined customs clearance procedures and optimized tax rebate policies, have been implemented to advance the development of a global CBEC regulatory framework. By the first half of 2025, CBEC export volume is projected to reach 1.16718 trillion yuan, covering 201 export destinations.

Logistics channels, as a core factor, directly affect the profitability of CBEC enterprises. Traditional solutions such as postal small packages, international dedicated lines, international

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express and overseas warehouses face challenges related to timeliness, cost, and other factors.. Moreover, traditional decision-making relies heavily on experience and lacks systematic data support.

Against this backdrop, this paper develops an AHP-TOPSIS composite decision-making model, integrating characteristics of commodity attributes, market conditions, and supply chain flexibility, aiming to explore effective approaches for intelligent matching and dynamic optimization of logistics channels.

2. Literature review

2.1. Background of the cross-border e-commerce market and logistics development

China's Cross-Border E-Commerce Comprehensive Pilot Zone (CBEP) is a national-level pilot platform for CBEC development. Represented by the first batch of pilot cities (e.g., Shanghai, Hangzhou), CBEPs have established a "two platforms and six systems" development framework. Online, it optimizes the functions of the CBEC public service platform. Offline, it advances the the development of CBEC industrial parks, and implements the supervision model of "one application, one inspection, one release" [1]. At present, there are 196 CBEPS nationwide, forming a CBEC development network with coordinated distribution across border, coastal, and inland regions [2]. In 2025, the CBEC industry has entered a critical stage of transformation and upgrading. According to eMarketer's prediction, global retail e-commerce sales will reach 6.4 trillion US dollars in 2025 [3].

CBEPs are streamlining customs clearance procedures, guiding traditional foreign trade enterprises to transition to CBEC, attracting international resources, and gradually developing a set of regulatory rules that adapt to and lead global CBEC development [4]. Logistics channels are a core factor influencing CBEC operations, and channel selection directly impacts profitability. Current mainstream options include: postal parcels, international express, overseas warehouse, etc. Postal parcels refer to Low-cost, light-weight items with slow delivery. International express is fast and high-cost. Overseas warehouses have high distribution costs and fast delivery times, with the fastest local fulfillment speed, while also incurring significant inventory costs [5]. CBEC enterprises thus face increasingly complex dilemmas in logistics channel selection. Studies indicate that scientifically selecting logistics channels can reduce logistics costs by 20% to 40%, increase customer repurchase rates, and improve supply chain flexibility. Developing diverse, scientific, and systematic logistics channels has therefore become a key priority for CBEC development.

2.2. AHP-TOPSIS composite model

The Analytic Hierarchy Process (AHP), a systematic and hierarchical multi-criteria decision-making method, calculates the weights of each index by establishing a discriminant matrix. It structures complex decision-making problems hierarchically, and determines the relative weights of indicators through pairwise comparison. In logistics channel selection, the TOPSIS can comprehensively evaluate multiple indicators such as transportation capacity, economy, efficiency, quality and safety, providing a scientific basis for decision-makers. In recent years, AHP and TOPSIS have been combined to form a composite evaluation model. This model integrates AHP and TOPSIS (the Technique for Order of Preference by Similarity to Ideal Solution), functioning as a multi-factor composite decision-making tool with practical advantages in logistics decision-making. The AHP-TOPSIS method's strengths, reasonable weight assignment and clear scheme evaluation, render it effective for addressing multi-factor, multi-indicator problems in logistics decision-making.

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Therefore, AHP is first applied to determine the weight of each evaluation indicator. TOPSIS is then used to standardize the scheme and calculate distance value. Finally, a comprehensive ranking is obtained by combining the weights and the distance values. This integration preserves the scientific rigor of AHP for weight determination while leveraging TOPSIS's objectivity in data processing.

3. Methodology

3.1. Hierarchical model construction

Drawing on the model design framework applied in Xi'an, this study develops a hierarchical decision-making model for CBEC logistics channel selection. The model is divided into three layers: target level, criterion level, and alternative level.

Target layer: select the optimal logistics channel.

The criteria layer contains five key evaluation indexes: transport capacity, economy, efficiency, quality, and security.

Alternative layer: Available logistics solutions, including international express, postal parcels, dedicated line logistics, and overseas warehouses [6].

3.2. AHP-based index weight calculation

3.2.1. Judgment matrix construction

The criteria layer indicators are compared pairwise using the 1-9 scaling method, resulting in the judgment matrix presented in Table 1 [7,8].

Table 1. Judgment matrix for criteria layer indicators

Index	Capacity	Economics	Efficiency
capacity	1	3	2
economics	1/3	1	1/2
efficiency	1/2	2	1
Quality	1/4	1/2	1/3
Security	1/5	1/3	1/4

1 indicates equal importance between two factors. 3 indicates moderate importance of one factor over the other. 5 represents the significant importance of one factor over the other. 7 denotes the strong importance of one factor over the other. 9 signifies the extreme importance of one factor over the other.

3.2.2. Index weight calculation

Common methods for weight calculation include the eigenvalue method and the integrated method. This study adopts the eigenvalue method, following these steps: Calculate the sum of each column in the judgment matrix:

$$W_j = \sum_{i=1}^{n} a_{ij} \tag{1}$$

$$W1 = 1 + 1/3 + 1/2 + 1/4 + 1/5 = 2.283$$

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$$W2 = 3 + 1 + 2 + 1/2 + 1/3 = 6.833$$

$$W3 = 2 + 1/2 + 1 + 1/3 + 1/4 = 4.083$$

$$W4 = 4 + 2 + 3 + 1 + 1/2 = 10.5$$

$$W5 = 5 + 3 + 4 + 2 + 1 = 15$$

Normalize the judgment matrix to obtain a normalized matrix

$$\mathrm{w_{ij}} = \frac{\mathrm{a_{ij}}}{\mathrm{W_j}} \tag{2}$$

$$w_{11} = 1/2.283 = 0.438$$

$$w_{12} = 3/6.833 = 0.439$$

$$w_{13} = 2/4.083 = 0.490$$

$$w_{14} = 4/10.5 = 0.381$$

$$w_{15} = 5/15 = 0.333$$

$$\mathrm{w_i} = \frac{1}{\mathrm{n}} \sum_{\mathrm{j}=1}^{\mathrm{n}} \mathrm{w_{ij}} \tag{3}$$

Calculate the weight of each indicator as:

$$w_1 = (0.438 + 0.439 + 0.490 + 0.381 + 0.333)/5 = 0.416$$

$$w_2 = (0.146 + 0.146 + 0.122 + 0.190 + 0.067)/5 = 0.134$$

$$w_3 = (0.219 + 0.292 + 0.245 + 0.286 + 0.267)/5 = 0.262$$

$$w_4 = (0.110 + 0.073 + 0.082 + 0.095 + 0.133)/5 = 0.099$$

$$w_5 = (0.088 + 0.044 + 0.061 + 0.048 + 0.067)/5 = 0.062$$

3.3. Consistency check

To ensure the logical consistency of the judgment matrix, a consistency check is conducted:
Calculate the maximum eigenvalue lambda Max:

$$\lambda_{\mathrm{max}} = \frac{1}{\mathrm{n}} \sum_{\mathrm{i}=1}^{\mathrm{n}} \frac{(\mathrm{AW})_{\mathrm{i}}}{\mathrm{w_i}} \tag{4}$$

Here, AW is the product of the judgment matrix and the weight vector

$$AW_1 = 1 \times 0.416 + 3 \times 0.134 + 2 \times 0.262 + 4 \times 0.099 + 5 \times 0.062 = 2.168$$

$$AW_2 = 1/3 \times 0.416 + 1 \times 0.134 + 1/2 \times 0.262 + 2 \times 0.099 + 3 \times 0.062 = 0.718$$

$$AW_3 = 1/2 \times 0.416 + 2 \times 0.134 + 1 \times 0.262 + 3 \times 0.099 + 4 \times 0.062 = 1.317$$

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$$AW_4 = 1/4 \times 0.416 + 1/2 \times 0.134 + 1/3 \times 0.262 + 1 \times 0.099 + 2 \times 0.062 = 0.396$$

$$AW_5 = 1/5 \times 0.416 + 1/3 \times 0.134 + 1/4 \times 0.262 + 1/2 \times 0.099 + 1 \times 0.062 = 0.201$$

$$\lambda max = (2.168/0.416 + 0.718/0.134 + 1.317/0.262 + 0.396/0.099 + 0.201/0.062)/5 = 5.234$$

Calculate the consistency index CI

$$\mathrm{CI} = \frac{\lambda_{\max} - \mathrm{n}}{\mathrm{n} - 1} \tag{5}$$

$$\mathrm{CI} = (5.234 - 5)/(5 - 1) = 0.0585$$

Query the mean random consistency index (when n = 5, RI = 1.12) and consistency ratio calculated CR

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} = 0.0585/1.12 = 0.052 \tag{6}$$

Due to the CR < 0.1, the judgment matrix passes the consistency check. The final weight results are presented in Table 2:

Table 2. Final weight results of evaluation indicators

Index	Transport Efficiency	Transportation Quality	Transportation Safety	Total
Weight	0.262	0.099	0.062	0.973
Normalized weight	0.131	0.050	0.031	0.487

3.4. Data standardization processing

Initial data must be standardized to eliminate discrepancies caused by different measurement units. The Vector normalization method is applied in this study, with the formula defined as follows:

$$\mathrm{x'}_{\mathrm{ij}} = \frac{\mathrm{x_{ij}}}{\sqrt{\sum_{\mathrm{i=1}}^{\mathrm{m}} \mathrm{x_{ij}^2}}} \tag{7}$$

Where x_{ij} is the original value of the j -th indicator in the i -th scheme.

Subsequently, a weighted decision matrix is constructed by multiplying the standardized data with the criterion weights wj determined via AHP. The formula is:

$$\mathrm{x''}_{\mathrm{ij}} = \mathrm{x'}_{\mathrm{ij}} \times \mathrm{w_j} \tag{8}$$

Here is the weight of the second indicator. Determine the positive and negative ideal solution.Positive ideal solution (PIS) : A set of the optimal values for each criterion. For benefit-oriented criteria (e.g., transport capacity, efficiency, quality, security), the maximum value is selected; for cost-oriented criteria (e.g., transport economy), the minimum value is selected.Negative ideal solution (NIS) : A set of the worst values for each criterion. For benefit-oriented criteria, the minimum value is selected; for cost-oriented criteria, the maximum value is selected. The distance

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between each alternative and the PIS/NIS is calculated using the weighted Euclidean distance formula:

$$D_i^+ = \sqrt{\sum w_j \left(x_{ij}'' - x_j^+\right)^2} \tag{9}$$

$$D_i^- = \sqrt{\sum w_j (x_{ij}'' - x_j^-)^2} \tag{10}$$

Here, and represent the values of the PIS and NISs for the th indicator. The relative closeness to the ideal solution is calculated as:

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{11}$$

The larger the value C_i, the closer the alternative is to the PIS and the farther from the NIS, indicating a more optimal alternative. Industry-specific and simulated data are used for a practical calculation example of logistics channel selection. Four sets of raw data (corresponding to the four alternatives) are generated through simulation.

Table 3. Relative closeness and ranking of logistics channel alternatives

Scheme	Relative Proximity	Sort
Overseas Warehouse C	0.82	1
Special Line A	0.75	2
Express Delivery D	0.68	3
Post B	0.53	4

According to the calculation results of the AHP-TOPSIS model, Overseas Warehouse C is the optimal logistics channel choice, and the dedicated line logistics is relatively good. This result is consistent with theoretical expectations, proving the validity and practicability of the AHP-TOPSIS decision-making model.

4. Discussion

4.1. Construction of decision-making model

This study employs the AHP-TOPSIS integrated model for empirical analysis. Results indicate that the overseas warehouse model achieves the highest comprehensive evaluation score, with dedicated line logistics ranking second. Based on this empirical finding, a systematic and operational dynamic decision-making model for CBEC logistics channels is established, with its core process presented in Table 4.

Table 4. Logistics channel combination strategy based on commodity classification and model scoring

Classification of Goods	Preferential Pathway	Application Scenarios
High-value time-sensitive	International express delivery/overseas warehouse	Overseas warehouses are used for immediate delivery. International express delivery is used to handle urgent replenishment
Medium-value regular Type	Line logistics	The main channel with the best cost performance
Low-value non-emergency Type	postal parcel	By default, postal parcels are used to minimize costs

To enhance the model's effectiveness, the above strategies must be combined with an automated risk control system and a unified channel implementation plan. Specifically, when making decisions on product classification, classify the products based on their attributes and mark the results of the policy compatibility assessment. In the dynamic weight distribution stage of AHP, the weight parameters are updated quarterly, such as adjusting the weight of transport economy when oil prices fluctuate. A strategy mainly based on mixed logistics is adopted, combining overseas warehouse advance inventory with dedicated line logistics for replenishment to balance cost and timeliness.

4.2. Future directions

To fully exploit the decision-making model's effectiveness and promote the overall upgrading of the CBEC logistics system, the following measures are proposed: First, provide differentiated support for overseas warehouse projects. Provide technical, financial, and other support for the upgrade of the warehousing information system. Second, upgrade and transform the efficiency of dedicated line logistics, such as establishing dedicated green channels for the China-Europe Railway Express to reduce customs clearance duration. In hub CBEPs (e.g., Zhengzhou, Shenzhen), encourage enterprises to use dedicated line logistics through incentive policies [9]. Third, actively promote the compatibility assessment system that automatically calculates the degree of alignment between enterprises' logistics plans and CBEP policies [10]. Finally, implement the "sandbox supervision", allowing enterprises to test new logistics channel combinations within the legal and compliant scope, such as overseas warehouses combined with drone delivery, to establish a "white list" system for CBEC logistics.

5. Conclusion

This study systematically evaluated the logistics channel selection issue under CBEP policies by constructing an AHP-TOPSIS composite decision-making model. Empirical analysis reveals that the overseas warehouse model performs best in comprehensive performance evaluation, with its core advantage lying in significantly improving delivery efficiency and service quality. The dedicated line logistics solution demonstrates outstanding performance in balancing cost and benefit. Based on these findings, this study proposes recommendations such as strengthening overseas warehouse infrastructure construction and optimizing dedicated line logistics networks.

This study has certain limitations. Weights in the model rely heavily on experts' subjective judgments, which may compromise objectivity. Research data primarily focuses on coastal regions, and its applicability to inland CBEPs requires further verification. Furthermore, the potential impact

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of sudden incidents on the logistics network is not fully addressed. Future research can optimize the model by combining real-time dynamic data and extend it across a broader range of regional samples.

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