

## Research Article

# Cross-Border E-Commerce Logistics Transportation Alternative Selection: A Multiattribute Decision-Making Approach

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Received 19 January 2022; Revised 10 February 2022; Accepted 15 February 2022; Published 8 March 2022

Academic Editor: Gengxin Sun

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Cross-border e-commerce logistics and transportation system is important link in the cross-border e-commerce supply chain. How to choose a fast, safe, reliable, and low-cost logistics transportation mode is an urgent problem to be solved in cross-border e-commerce logistics. In view of this, this paper first analyzes the system characteristics of cross-border e-commerce logistics transportation systems and analyzes the factors affecting the choice of transportation mode from the perspective of reliability. Then, based on the ELECTRE method system, a multiattribute decision-making method for cross-border e-commerce logistics transportation mode selection is proposed. Finally, through a data example, it is verified that the model constructed in this paper and the proposed multiattribute decision-making method can effectively help cross-border e-commerce choose logistics transportation mode according to goods.

## 1. Introduction

The rapid development of cross-border e-commerce has not only changed the pattern of China's import and export trade but also rapidly improved the development of the national economy. In the process of cross-border e-commerce trade, a safe and reliable cross-border e-commerce logistics and transportation system is an important link to ensure the smooth progress of cross-border e-commerce trade [1, 2]. From 2016 to 2019, China's manufacturing industry continued to upgrade, domestic brands poured into overseas markets, B2C cross-border e-commerce flourished, and China's foreign trade industry also experienced structural improvement, with a significant increase in growth rate and a compound growth rate of more than 9%. The booming cross-border e-commerce industry has an increasing demand for its logistics and transportation modes. The requirements of reliability, controllability, security, stability, low cost, informatization, and intelligence have become important factors in cross-border logistics and transportation systems [3].

The rapid development of cross-border e-commerce has promoted China's economic transformation, employment, and consumption. At the same time, there are

many areas that need to be improved [4–6]. (1) The service capacity of international express enterprises is difficult to meet the development needs of cross-border e-commerce. The transaction volume of cross-border e-commerce is increasing year by year, but it lacks the service capacity of corresponding logistics enterprises. For example, at present, international express is the most used in cross-border logistics distribution, but relying only on international express will lead to goods extrusion, warehouse explosion, low distribution speed, and low service level. (2) The infrastructure of the logistics transportation system is not perfect. In the whole logistics transportation system, the basic settings of warehousing, transportation, distribution, and other links are not perfect. There are gaps in the connection between various modes of transportation, and the system is unscientific. (3) The connection between various links of cross-border logistics is a lack of professionalism. International logistics costs are high, the operation is difficult, the business module is complex, and the quantity and variety of goods are various. Therefore, the number of international logistics enterprises engaged in the whole cross-border logistics service is small, so it is difficult to control each logistics link. (4) Cross-border e-commerce logistics costs are high. Compared with domestic logistics,

cross-border e-commerce requires higher costs in warehousing, distribution, customs declaration, and other links. On the basis of ensuring the same logistics service level, cross-border logistics enterprises need to pay more costs. If there are returns and exchanges in the whole logistics link, the cost will be higher. (5) The accuracy and timeliness of logistics information are low. Due to the lack of professionalism in the connection between various links of cross-border e-commerce, the timeliness and accuracy of information between links are low. This deficiency will also make users lack trust in logistics and transportation enterprises. The above deficiencies exist in the cross-border logistics and transportation system, which not only hinders the development of cross-border logistics and transportation enterprises but also brings difficulties to users in choosing logistics and transportation methods.

To sum up, with the development of cross-border e-commerce, the problems of cross-border e-commerce logistics have become increasingly prominent. The reliability, controllability, security, stability, low cost, informatization, and intelligence of cross-border e-commerce logistics transportation are hot topics in the development of cross-border e-commerce logistics. However, how to choose an economic and reasonable logistics service provider is an urgent problem to be solved in the development of cross-border e-commerce logistics.

The remainder of this paper is organized as follows: In Section 2, the related works will be shown in detail. In Section 3, the cross-border e-commerce logistics and transportation system is analyzed. In Section 4, the cross-border e-commerce logistics transportation mode based on ELECTRE was proposed. An example is given in Section 5. Finally, some conclusions are drawn in Section 6.

## 2. Related Works

At present, the research mainly focuses on the logistics system of cross-border e-commerce, the development of cross-border e-commerce, the optimization of the cross-border e-commerce supply chain, the selection of cross-border e-commerce logistics methods, etc.

In terms of cross-border e-commerce research, Gomez et al. investigated the importance of distance to physical online trade and studied the positive role of policymakers in cross-border e-commerce choice in the EU digital single market [7]. Gomez et al. analyzed and compared the differences in influencing factors and challenges between online and offline cross-border trade [8]. Jiao et al. analyzed the e-commerce logistics system and its direct and indirect impact on its operation [9]. In order to improve the service level and competitiveness of cross-border e-commerce, Luo et al. proposed to promote the construction of overseas warehouses and border warehouses and reasonably select the cross-border logistics mode [10]. Cheng et al. put forward countermeasures to speed up the development of cross-border e-commerce in Fujian from the aspects of guidance and support of local governments, cultivating cross-border e-commerce industrial chain, promoting third-party cross-border payment, promoting the

construction of credit system, and strengthening precision marketing [11].

In terms of cross-border e-commerce supply chain optimization, Deng et al. put forward supply chain management coordination and optimization measures such as integrating China's supply chain procurement system, building cross-border export high-quality e-commerce, strengthening logistics management, improving response speed, relying on big data application, and improving supply chain management capacity in view of the problems of few commodity types, poor product quality, and upstream and downstream information asymmetry in cross-border export e-commerce [12]. Kaplan et al. proposed the concept of demand price elasticity, including production planning and scheduling, inventory management, transportation delay, transportation cost, and transportation restriction [13]. Ding et al. proposed a cross-border two-way logistics network survivability method in the e-commerce supply chain, which improves the security of cross-border two-way logistics networks in the e-commerce supply chain [14]. Liu et al. analyzed the influencing factors of cross-border e-commerce supply chain and constructed the CBSCR influencing factor system based on the ternary theory of supply chain elasticity to ensure the safe operation of cross-border e-commerce supply chain [15]. Godichaud et al. proposed a supply chain model based on simulation and multiobjective optimization to optimize the control strategy of multilevel return supply chain [16]. Sampat et al. proposed the optimization formula of a multiproduct supply chain network. These formulas use a general graphical representation to capture the dependencies between any number of products, technologies, and transportation routes [17].

In terms of supply chain partner selection evaluation system, Chen et al. proposed a fuzzy decision method for supplier selection in supply chain system [18]. Ernst et al. introduced a conceptual framework for evaluating different supply chain structures in the context of modularization and postponement [19]. Tsai et al. proposed a fuzzy objective programming method, which integrates activity-based costing and performance evaluation into the value chain structure to realize the optimal selection and process allocation of multinational logistics suppliers [20]. Lin et al. studied the reliability of a complex supply chain system [21]. Demand forecasting is an important aspect of supply chain enterprise planning. Sanders et al. predicted the cross-border e-commerce logistics demand after considering the expected anomalies during the planning period [22]. Based on the satisfaction of different stakeholders, Miao et al. applied the double-sided matching method to the export cross-border e-commerce environment, to better match overseas demand and domestic suppliers [23]. Yi et al. studied consumers' willingness to use cross-border e-commerce, collected global consumer data from the perspective of psychological distance and commitment trust, and analyzed relevant factors affecting online consumers' intention [24].

It can be seen from the above studies that most studies only study the overall development of the cross-border e-commerce industry and cross-border e-commerce logistics system, analyze the unreasonable phenomena in various

links of transportation, storage, and distribution in the logistics system, and optimize the cross-border e-commerce supply chain. However, the existing research still has the following problems: (1) There is no discussion on the connection and cost control of various links in the logistics system; (2) the cross-border e-commerce logistics and transportation systems of different products in different regions of China are distinguished; (3) there is no in-depth research on supply chain management under online and offline multichannel mode; (4) what are the influencing factors in the cross-border e-commerce logistics system; (5) how to choose safe, reliable, and low-cost cross-border e-commerce logistics transportation mode according to these influencing factors.

In view of this, starting from the current cross-border e-commerce logistics characteristics, this paper analyzes the advantages and disadvantages of the current cross-border e-commerce logistics transportation mode and analyzes the main and secondary influencing factors in the cross-border e-commerce logistics system. Then, based on the multi-attribute decision-making theory, a logistics transportation decision-making method based on ELECTRE theory is proposed.

### 3. Analysis of Cross-Border E-Commerce Logistics and Transportation System

*3.1. Logistics Model of Cross-Border e-Commerce.* With the development of cross-border e-commerce, the logistics mode is becoming more and more diversified. At present, the logistics modes of cross-border e-commerce mainly include third-party logistics, logistics alliances, overseas warehouses, goods collection logistics, and bonded area logistics.

Third-party logistics (3PL), also known as outsourcing logistics or contract logistics, refers to a professional logistics company with substantive assets that provide logistics-related services to other companies and can provide more complete services. Logistics alliance is an organizational form between independent enterprises and market transactions. It is a relatively stable and long-term contractual relationship between logistics demanders, that is, various production and manufacturing enterprises, commercial circulation enterprises, and logistics enterprises due to the needs of their own development. Overseas location refers to the storage facilities established overseas. It refers to those domestic enterprises that transport goods to the target market countries in the form of bulk transportation, establish warehouses, and store goods locally and then respond at the first time according to the local sales orders to sort, package, and distribute directly from the local warehouse in time. Collection logistics refers to the operation that enterprises collect scattered small quantities of goods for transportation and distribution. Bonded area logistics refers to the business of warehousing, distribution, transportation, circulation processing, loading and unloading, logistics information, scheme design, and other related businesses in the areas under the customs supervision, including bonded

areas, bonded location, customs supervised warehouses. The characteristics of these modes are shown in Table 1.

*3.2. Cross-Border E-Commerce Logistics and Transportation System.* A logistics system is an organic whole with specific functions in a certain time and space, which is composed of materials to be transported and several mutually restrictive dynamic elements, including relevant equipment, transportation tools, storage equipment, personnel, and communication. It is an organic aggregate composed of two or more logistics functional units for the purpose of completing logistics services. In cross-border power grid logistics, transportation is an important central link, which closely connects manufacturers, middlemen, and buyers. However, for different types of sellers, the choice of logistics channels is different. No matter which channel you choose, the purpose is to ensure that you provide excellent services to buyers. The process of logistics mode selection is affected by many aspects such as technology, economy, policy, and consumer preference. It is a multiattribute decision-making process.

*3.3. Logistics Transportation Mode Selection Factors.* Because various modes of transportation and means of transportation have their own characteristics, and the requirements of goods with different characteristics for transportation are different, it is difficult and unrealistic to formulate a standard for selecting modes of transportation. However, according to the overall goal of logistics and transportation, it is still possible to determine a basic principle.

Generally speaking, the choice of cross-border e-commerce logistics transportation mode is affected by many factors, such as the type of transported goods, transportation volume, transportation distance, transportation time, transportation cost, transportation safety, logistics service level. Of course, these factors are not independent of each other, but closely connected and determined by each other.

- (1) Commodity performance characteristics. It is an important factor affecting enterprises' choice of means of transportation. Generally speaking, bulk goods such as grain and coal are suitable for waterway transportation; fresh products such as fruits, vegetables, and flowers are suitable for air transportation; pipeline transportation is suitable for oil and natural gas.
- (2) Transportation speed and distance. The speed of transportation and the distance of transportation determine the length of goods transportation time. The goods transported in transit, like inventory goods, will form capital occupation. Generally speaking, the commodities with large volume, low value, and long haul distance are suitable for waterway or railway transportation; the commodities with small batch, high value, and long haul distance are suitable for air transportation; road transportation is suitable for small batch and short distance.

TABLE 1: Comparison of cross-border logistics modes.

Logistics mode	Advantage	Disadvantage
Third-party logistics	Meet the scattered logistics needs and save resources	Insufficient personalized demand
Logistics alliance	Effective monitoring of cargo	Negative response of enterprises
Oversea location	Improve customer satisfaction; improve service level	Inventory quantity is difficult to grasp
Collection logistics	High efficiency and low cost	Slow delivery
Bonded area logistics	Short delivery time	Short storage time

- (3) Consistency of transportation. It is the consistency between the time required to perform specific transportation in several shipments and the original time or the time required for the previous  $n$  transportation. It is a reflection of transportation reliability. If a given transportation service takes two days for the first time and six days for the second time, this unexpected change will cause serious logistics problems for production enterprises.
- (4) Transportation costs. It is the operating cost, management cost, tax, etc. incurred in the transportation process. Operating costs (such as operating vehicle fuel taxes, depreciation, maintenance fees, insurance premiums) and management costs mainly include labor costs (such as transportation personnel wages, benefits, bonuses, allowances, and subsidies).
- (5) Transportation safety. It is the safe arrival of goods in the hands of consumers without damage, loss, or shortage.
- (6) Logistics service level. It is used to evaluate the customer satisfaction of logistics enterprises in the process of customer service. It is generally reflected in the quality of goods received by customers and the timeliness of transportation. Sometimes, the service attitude of logistics collectors and senders will also be evaluated.

#### 4. Multiattribute Decision Analysis of Cross-Border E-Commerce Transportation Market

The core of multiattribute decision-making is to study a satisfactory scheme based on the comprehensive analysis of multiple attributes of multiple schemes to be selected. ELECTRE is an elimination and selection rotation algorithm based on the harmony test and disharmony test. The method is simple and convenient, which makes it widely used. The flow chart of the ELECTRE decision-making method is shown in Figure 1. Therefore, this paper proposes a method of logistics transportation mode decision-making based on ELECTRE theory.

**4.1. ELECTRE Theoretical Basis.** Suppose the decision-making scheme set  $C = (c_1, c_2, \dots, c_n)$ , each scheme has the same attributes. Assuming that the attribute set is  $F = (f_1, f_2, \dots, f_m)$ , and the original decision data matrix  $A = (a_{ij})_{n \times m}$  where  $a_{ij}$  refers to the attribute value of the scheme  $c_i$  on the attribute  $f_j$ . The level priority consistency index matrix  $CM(c_i, c_j)$  is defined as, which represents the

consistency degree of the scheme  $c_i$  over the scheme  $c_j$ , expressed as

$$CM(c_i, c_j) = \frac{\sum_{k=1}^m cm_k(c_i, c_j)}{m}, \quad (1)$$

where

$$cm_k(c_i, c_j) = \begin{cases} 1; & f_k(c_i) + \alpha_k \geq f_k(c_j), \\ 0; & f_k(c_i) + \beta_k \leq f_k(c_j), \\ \frac{[f_k(c_i) + \alpha_k - f_k(c_j)]}{(\alpha_k - \beta_k)}, & \text{Other.} \end{cases} \quad (2)$$

$\alpha_k$  and  $\beta_k$  represent the indifference threshold and strict preference threshold of attributes. At the same time, the definition level priority validity index is represented by  $sm(c_i, c_j)$ . The value range of  $sm(c_i, c_j)$  is 0–1, which indicates the good and bad relationship between schemes. The greater the value of  $sm(c_i, c_j)$ , the greater the degree of  $c_i$  being better than  $c_j$ , and the smaller the value of  $sm(c_i, c_j)$ , the less the degree of  $c_i$  being better than  $c_j$ .

**4.2. Decision-Making Method of Cross-Border E-Commerce Logistics Transportation Scheme Based on ELECTRE Theory.** The ELECTRE method was first proposed by Benayoun et al. in 1966. The main concept of ELECTRE is to deal with the transcendence relationship between schemes and the use of criteria as evaluation and establish the advantageous relationship between schemes and schemes to eliminate poor schemes. The advantage of the ELECTRE method is that the decision-maker is easy to understand and master, and the specific decision-making calculation process can be programmed.

As a multiattribute decision-making problem, many scholars have proposed improved ELECTRE methods, such as ELECTRE I method, ELECTRE II method, and ELECTRE III method, and have been applied to multiattribute decision-making problems. These methods are basically proposed to solve more complex decision-making problems, aiming at the multiattribute decision-making problem where the decision-making data are accurate. The ELECTRE method used in this paper is the most classical method proposed by Benayoun.

The choice of cross-border e-commerce logistics transportation mode is affected by many factors, such as the type of transported goods, transportation volume, transportation distance, transportation time, transportation cost, transportation safety, and logistics service level. In this

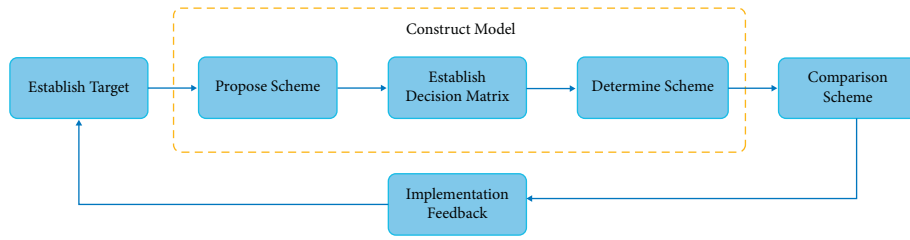


FIGURE 1: Decision flow chart.

paper, a questionnaire survey was conducted on the subjects of each link in the cross-border e-commerce supply chain. The survey results show that 99.72% of the survey objects regard transportation time, transportation cost, and transportation reliability as the main factors affecting the selection of transportation schemes. Therefore, in the decision-making process of cross-border e-commerce logistics transportation schemes, this paper takes transportation time, transportation cost, and transportation reliability as the attribute values of transportation scheme selection.

*Step 1.* Firstly, the decision attributes are quantified by using the qualitative grade quantization table. In order to ensure the accuracy of decision attribute quantification, this paper uses the expert scoring method to score different attributes from 0 to 10 and then counts the quantitative values of all experts for a decision attribute in a transportation scheme. However, because different experts have different rating standards, this paper introduces the membership function to quantify the quantitative value of decision attributes. The fuzzy set of each decision attribute is divided into five different fuzzy values (bad, slowly bad, medium, slowly good, and good). At the same time, this paper selects Gaussian function as the membership function of various fuzzy sets, expressed as

$$f(\mathcal{H}_j) = \exp\left[-\frac{(\mathcal{H}_j - b_j)^2}{\sigma_j^2}\right]. \quad (3)$$

Through the membership function, we can get the membership values of expert scoring values belonging to different fuzzy sets. In the process of expert scoring, we assume that the scores of experts in this field have the same weight value. Therefore, we can get the weighted average of the membership values of this attribute belonging to different fuzzy sets. Then, the center of gravity method is used to obtain the quantitative value of a decision attribute in the transportation scheme. The decision attribute matrix of all transportation schemes can be expressed as

$$X_{ij} = \begin{Bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & & & \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{Bmatrix}, \quad (4)$$

where  $x_{ij}$  represents the quantitative value of the attribute  $j$  in the transportation scheme  $i$ .

*Step 2.* Among multiple decision attributes, some decision attributes are more important than others. On the contrary, some decision attributes are less important than others. Therefore, through investigation, we analyze multiple attributes in the transportation scheme, such as item type, transportation volume, transportation distance, transportation time, transportation cost, transportation safety, and logistics service level, and use entropy information method to determine the weight values of different attributes.

$$h_j = -\frac{\sum_{i=1}^n (x_{ij} \cdot \ln x_{ij})}{\ln n}, \quad (5)$$

$$w_j = \frac{(1 - h_j)}{n - \sum_{j=1}^m h_j}. \quad (6)$$

After determining the weight value, the decision attribute matrix  $\tilde{X}_{ij}$  is modified, that is,  $\tilde{X} = w_j \cdot X_{ij}$ .

*Step 3.* ELECTRE method uses the concept that level is not inferior to relationship, determines the threshold value, compares two schemes, forms the good and bad relationship matrix of consistency and inconsistency, and then constructs the consistency matrix and inconsistency matrix. Therefore, after obtaining the decision attribute matrix  $\tilde{X}_{ij}$  and comparing the two schemes, we form a consistent set  $C_{kl}$  and a nonconsistent set  $D_{kl}$ , which is expressed as

$$C_{kl} = \{j | v_{kj} \geq v_{lj}\}, \quad j = 1, 2, \dots, n, \quad (7)$$

$$D_{kl} = \{j | v_{kj} < v_{lj}\} = j - c_{kl}, \quad j = 1, 2, \dots, n.$$

Through the intersection of consistent set  $C_{kl}$  and inconsistent set  $D_{kl}$ , the judgment matrix is obtained, and the optimal scheme is obtained.

## 5. Example Analysis

Suppose a merchant is mainly engaged in fresh agricultural products, and the average package weight is about 2.5 kg. Options include China Post (International), EMS, UPS, special line logistics, and SF international. For different transportation modes, this paper considers three attribute indexes: transportation time, transportation cost, and transportation reliability. The fuzzy sets of the three attribute indexes are divided into (long, slowly long, medium, slowly short, short), (high, slowly high, medium, slowly low, low), and (low, slowly low, medium, slowly high, high). In this

TABLE 2: Comparison of transportation modes.

Company	Transportation time	Transportation cost	Transportation reliability
China Post	0.936	0.887	0.993
EMS	0.865	0.823	0.965
UPS	0.898	0.891	0.791
Special line logistics	0.942	0.754	0.913
SF international express	0.975	0.853	0.978

paper, the Gaussian function is used as the membership function of various fuzzy sets, and finally, the quantitative value of a decision attribute in the transportation scheme is obtained by using the center of gravity method. The attribute value of the scheme is shown in Table 2. Simulation environment: Windows 10, Intel Xeon CPU E3, 32 GB RAM. Simulation platform: MATLAB R2020b.

The entropy of the attribute matrix  $H_j$  is calculated according to equation (5), and then, the weight of the matrix  $w_j$  is calculated according to equation (6).

$$\begin{aligned} H_j &= (0.412, 0.317, 0.303), \\ w_j &= (0.179, 0.193, 0.201). \end{aligned} \quad (8)$$

The decision attribute matrix  $\tilde{X}_{ij}$  is expressed as

$$\tilde{X}_{ij} = \begin{Bmatrix} 0.1675 & 0.1712 & 0.1996 \\ 0.1548 & 0.1588 & 0.1940 \\ 0.1607 & 0.1720 & 0.1590 \\ 0.1686 & 0.1455 & 0.1835 \\ 0.1745 & 0.1646 & 0.1966 \end{Bmatrix}. \quad (9)$$

Consistent sets  $C_{ij}$  and inconsistent sets  $D_{ij}$  are represented as

$$\begin{aligned} C_{ij} &= \begin{Bmatrix} - & 0.0975 & 0.1576 & 0.1419 & 0.6557 \\ 0.9058 & - & 0.9706 & 0.4218 & 0.0357 \\ 0.1270 & 0.5469 & - & 0.9157 & 0.8491 \\ 0.9134 & 0.9575 & 0.4854 & - & 0.9340 \\ 0.6324 & 0.9649 & 0.8003 & 0.9595 & - \end{Bmatrix}, \\ D_{ij} &= \begin{Bmatrix} - & 0.2824 & 0.3294 & 0.1755 & 0.1959 \\ 0.2973 & - & 0.2779 & 0.1526 & 0.1782 \\ 0.1569 & 0.1108 & - & 0.2622 & 0.2585 \\ 0.2622 & 0.0185 & 0.3801 & - & 0.2837 \\ 0.0685 & 0.0389 & 0.0138 & 0.0747 & - \end{Bmatrix}. \end{aligned} \quad (10)$$

According to the consistency set  $C_{ij}$  and nonconsistency set, the consistency and contradiction dominant matrix is constructed, and the intersection is obtained to obtain the judgment matrix, as shown in Table 3.

It can be guided by Table 3. Firstly, the schemes that have no advantages, that is, China Post and EMS, are deleted and selected, and UPS, special line logistics, and SF international logistics are retained, and then, the UPS and special line logistics with only one advantage are deleted, leaving only SF international logistics. The conclusion, in this case, is that SF

TABLE 3: Dominant matrix of contradiction set integration.

China post	—	0	0	0	0
EMS	0	—	0	0	0
UPS	0	0	—	1	0
Special line logistics	0	0	0	—	1
SF international express	1	1	0	1	—

international logistics is recommended. The experimental results show that SF international logistics has obvious advantages in transportation time, transportation cost, transportation safety, and logistics service level for fixed cargo types and transportation volume.

## 6. Conclusion

This paper analyzes the impact of transportation price and transportation timeliness on the reliability of cross-border e-commerce logistics transportation mode by using a structural equation model. Then, from the perspective of reliability, the subjective and objective factors affecting the choice of transportation mode are analyzed, the main process of multiattribute decision-making model based on ELECTRE method system is constructed, and an actual case operation is carried out to verify the operability of the model. By comparing with the actual logistics situation, the feasibility of the model is verified. The multiattribute decision-making method proposed in this paper can also help cross-border e-commerce sellers choose appropriate cross-border e-commerce logistics and transportation products for their goods.

## Data Availability

The data supporting the conclusion of the article are shown in the relevant figures and tables in the article.

## Conflicts of Interest

The author declares that there are no conflicts of interest.

## Acknowledgments

This work was supported by the Zibo Vocational Institute.

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