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Smart & Resilient Logistics Corridors Future Gateway to the Green Trade

Research on the Role of China Railway Express in Sino-European Trade Transportation

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ABSTRACT

To clarify the role and position of China Railway Express (CR-Express) as an innovative intercontinental transport service, we analyze transit time, loading/unloading time, and waiting time, while considering transport costs including freight charges, inventory carrying cost during transportation, opportunity cost of capital, and commodity depreciation over time. Using a multinomial logit-based modal split model together with Sino-European trade commodity and transport data, we calibrate the value of time (VoT) for nine categories of commodities. A sensitivity analysis is then conducted to examine how VoT and CR-Express service frequency influence the modal shares among sea, rail, and air for these commodities. The results indicate that increasing service frequency significantly enhances the attractiveness of CR-Express for paper products, textile products, precious metals/jewelry, and machinery/electrical products. Additionally, higher VoT for plant products, precious metals/jewelry, and machinery/electrical products leads to greater utilization of rail transport. These findings provide quantitative guidance for optimizing service frequency and targeting commodity classes to improve the competitiveness of intercontinental rail freight.

1. INTRODUCTION

Trade goods between China and Europe have traditionally been transported primarily by sea and air. Among these, air transport is the fastest but also the most expensive; thus, bulk trade goods have mainly been transported by sea so far [1]. Generally, in intercontinental trade transport, railways only serve as a feeder for sea transport.

Consequently, research on intercontinental trade transport has mostly focused on maritime shipping, with occasional studies touching upon sea-rail intermodal transport. However, with the proposal of the 'Belt and Road Initiative', the routes and number of China-Europe freight train services have exploded, and their coverage has rapidly expanded. The number of train trips increased from 17 in 2011 to 1,703 in 2016. By 2016, domestic origin cities for China-Europe freight trains had reached 16, overseas destination cities 12, operating lines 39, achieving a total import and export trade value of approximately USD 17 billion. The variety of goods transported by CR Express has gradually expanded, service quality has significantly improved, the service scope has broadened, and end-to-end service capabilities have steadily enhanced [1]. According to the "China Railway Express Construction and Development Plan (2016-2020)", the number of CR Express trips is planned to increase to 5,000 by 2020 [2].

Due to its long distance, high frequency, and moderate capacity, the developing CR Express is becoming an important independent mode of trade transportation between China and Europe. It can be said that CR Express has enriched the means and methods of China-Europe trade transport and is bound to play a significant role. Therefore, it is necessary to study the value of time for different types of goods based on the development of CR Express and the characteristics of China-Europe trade goods, and to analyze the competition and cooperation among various trade transport modes between China and Europe as the China-Europe railway service develops.

Yang Zhongzhen et al. [3] analyzed the transport accessibility for foreign trade from various regions in China and evaluated the port collection and distribution levels of various cities, but only considered the convenience and freight rates of sea transport in the intercontinental transport section. Yang Zhongzhen et al. [4] used SP surveys to construct a Logit model to analyze the market shares of various transport modes on high-speed passenger corridors in China and conducted sensitivity analysis on travel time, fare, and frequency. The results showed that travelers are more sensitive to changes in fare and travel time. Liu Huiyuan et al. [5] used VRTS to qualitatively analyze the impact of the proposed Kra Canal opening on the surrounding areas, conducting a comprehensive analysis from four aspects: strategic value, strategic risks, timing of development, and development strategy. The analysis indicated that the timing was not yet ripe for China to promote the development of the Kra Canal. Ding Jinxue et al. [6] used a Logit model from a spatial effects perspective to analyze the competitiveness of the Beijing-Shanghai High-Speed Rail and civil aviation. The results showed that the impact of high-speed rail on small city airports was greater than on large city airports, and the impact on terminal city airports was higher than on intermediate city airports. Liu Shuai et al. [7] constructed a bi-matrix game model of the relationship between market share and transport price for high-speed rail and express buses. The analysis results showed that as the value of time increases, the average profit and average market share of high-speed rail both increase. Fang Qigen et al. [8] used aggregate data to construct a Logit model to calculate and conduct elasticity analysis on five factors for coal transport by road and rail: punctuality, speed, economy, convenience, and safety. The results indicated that reducing the freight rate for road transport is significant for expanding its competitive advantage. Feo-Valero et al. [9] used a two-stage SP survey to analyze shippers' choice behavior between road and rail in Spain under conditions of remaining spare capacity in the rail transport market. Studying the modal share based on door-to-door transport time, freight cost, frequency, and delay time, they found that frequency is particularly important for freight mode choice. Rich et al. [10] studied the impact of the fixed link across the Øresund Strait on freight transport. Based on RP survey data, they used a Nested Logit model to calibrate coefficients for congestion time, transfer time, and freight cost, then analyzed the value of time for goods and calculated the modal splits for different transport modes by commodity type.

Arencibia et al. [11] conducted what is currently the only paper on modal share at the international level. The paper analyzed the impact of factors such as punctuality, damage rate, flexibility, and traceability on freight modal share through SP surveys, and used a game model with sensitivity analysis for solution, clarifying that these factors affect respective market shares by influencing freight rates. Yang et al. [12] calculated the value and weight coefficients of various commodities on four trade routes, including China-US and US-Europe, based on aggregate data. By refining the types of trade goods, they studied the impact of commodity value and weight on trade transport modal share, finding that commodity weight had a greater influence on modal share. Sun Xin et al. [13] used a competitive analysis model to compare the economics of China-Europe sea-rail intermodal transport and all-rail transport from the perspectives of transport distance, time, and cost. Nicole et al. [14] used an input-output model and a multinomial logit model to analyze the competitive splits of high-speed rail, air, and sea transport in 27 EU countries. The results suggested that the high-speed rail network should be vigorously developed to maximize social welfare. Chen et al. [15] used panel data to comprehensively analyze the impact of Chinese high-speed rail on Chinese aviation from both supply and demand perspectives. The analysis showed that Chinese high-speed rail has a significant substitution effect on Chinese air transport.

Currently, the mainstream model for research on competition and cooperation in intercontinental trade transport modes is the Logit model, where the utility function is often constructed based on publicly available freight rates and transport times from a macro-level carrier perspective, without considering the impacts of commodity depreciation cost, inventory cost, and value of time for different commodity types. However, from a practical standpoint, neglecting these factors is clearly unreasonable, as shippers care not only about the freight cost but also about the loss of value suffered by goods due to time spent in transit. Therefore, rail transport is also a very efficient and competitive mode. In addition, traditional generalized-cost models specify a linear combination of freight charges and transit time, by assuming shippers' disutility from time in transit and representing it through a single time coefficient that does not depend on the commodity shipped or on the value tied up in inventories. In contrast, this paper explicitly splits shipper cost into three components: (i) freight charges, (ii) inventory carrying costs that accumulate over time in transit, and (iii) time-dependent depreciation of commodity value. This structure allows transit time to be translated into monetary losses that differ systematically across commodity classes.

The contribution of this paper lies in collecting a large amount of data on China-Europe trade goods and trade transport, calibrating a modal share model for the three transport modes (sea, rail, air) in China-Europe trade transport based on the utility function and Logit model, and deriving the value of time for 9 categories of goods. In particular, based on sensitivity analysis, it studies the impact of changes in the value of time and the frequency of CR Express services on the modal splits of the three transport modes, revealing the main future marketing directions and methods for CR Express.

2. PROBLEM DESCRIPTION

In the era without CR Express, due to the vast difference in transport time and cost, the functional division between air and sea transport in the China-Europe intercontinental trade transport system had almost no overlap. Their market targets were distinctly different, and their respective market segments and roles in China-Europe trade transport could be distinguished without in-depth analysis. However, except for the huge difference in the capacity of individual transport units, China-Europe rail container transport and maritime container transport each have their own advantages and disadvantages in terms of transport time and cost. The difference in the comprehensive transport utility between the two modes has become smaller and possesses hidden characteristics. Therefore, to analyze the role of CR Express in China-Europe trade transport and its impact on sea transport between China and Europe, it is necessary to meticulously analyze the time and cost of rail transport versus maritime transport, and to study the sensitivity of different goods to transport time and cost. This is a shipper's discrete choice problem based on commodity value characteristics. The process of shippers choosing a transport mode is described as follows.

As intercontinental trade goods transport involves many links and factors, shippers need to consider the following when selecting a transport mode: 1) The freight paid in monetary terms; 2) The inventory cost of goods during transportation. Sea transport has large single-shipment volumes but long transit times, so compared to rail transport, the inventory cost for goods increases with sea transport; 3) The degree of depreciation of commodity value over time. Due to shortened product development and market launch cycles, shippers always want their products to reach the market as soon as possible after leaving the factory. The longer the transport time, the greater the possibility of product depreciation in the terminal market. Therefore, shippers need to consider the impact of transport time on product depreciation; 4) The accessibility of the first and last mile of the intercontinental trunk transport. Shippers need to measure the utility of different transport modes based on these four aspects and determine the chosen transport mode and route according to the principle of random utility maximization.

This paper first categorizes the attributes of the utility function for China-Europe trade goods into transport time and transport cost, dividing the total transport time into in-transit time, loading/unloading time, and waiting time. Secondly, based on the utility of various transport modes and the current market shares, the modal split model is calibrated to estimate the value of time for China-Europe trade goods. Finally, we analyze how changes in transport time and cost affect the market share of CR Express, thereby clarifying its competitive advantages in China-Europe trade and its influence on maritime transport. The key to this problem lies in constructing the utility function for goods transport based on the mode choice factors. The difficulties of this paper include calculating the value of time for goods and predicting the modal splits for different commodity types under various scenarios.

3. CONSTRUCTION OF THE TRANSPORT MODE UTILITY FUNCTION

According to random utility theory, a transport mode with higher utility has a greater probability of being chosen, and the utility of each transport mode is determined by factors such as transport cost and transport time. Let U_{rs}^{qm} denote the utility of transporting commodity q from origin r to destination s using mode m. Let V_{rs}^{qm} represent the deterministic part of the utility corresponding to the observable factor vector (transport time T_{rs}^{m}, total transport cost C_{rs}^{m}), and let ε_{rs}^{qm} be the random component representing unobservable factors. When ε_{rs}^{qm} follows independent Gumbel distributions, the Logit model can be used to calculate the modal split of each transport mode, as shown in equations (1) to (3) below.

The utility of various goods choosing different transport modes from origin r to destination s can be expressed by equation (1), and the modal split of each transport mode can be calculated using equation (3) [16].

$$U_{rs}^{qm} = V_{rs}^{qm} + \varepsilon_{rs}^{qm} \tag{1}$$

$$V_{rs}^{qm} = -b_t^q T_{rs}^m - b_c^q C_{rs}^m \tag{2}$$

$$P_{rs}^{qm} = \frac{Exp(V_{rs}^{qm})}{\sum_{m' \in M} Exp(V_{rs}^{qm'})} \tag{3}$$

Here, U_{rs}^{qm} represents the utility of transporting commodity q from origin r to destination s using mode m; V_{rs}^{qm} is the direct utility, i.e., the measurable part of U_{rs}^{qm}; P_{rs}^{qm} denotes the corresponding modal split of transport mode m; ε_{rs}^{qm} is the random term following a Gumbel distribution, representing factors other than those considered in this paper (transport time and cost); m is the transport mode, and M is the set of available transport modes; b_t^q is the time coefficient for commodity q (the preceding "-" indicates the shipper's aversion to transport time), b_c^q is the cost coefficient for commodity q (the preceding "-" indicates the shipper's aversion to transport cost); T_{rs}^m is the transport time, including the in-transit time TT_{rs}^m, the loading/unloading time at ports/stations LT_{rs}^m, and the waiting time WT_{rs}^m. Its calculation method is shown in equation (4), with the unit being hours (h). The in-transit time TT_{rs}^m primarily refers to the container handling time at the origin and destination of the intercontinental trunk line, and it is used to measure the accessibility of first and last mile of the intercontinental trunk transport. The waiting time WT_{rs}^m is calculated as shown in equation (5). The unit of transport time is hours (h). f_{rs}^m is the service frequency of transport mode m from origin r to destination s. Since the unit of frequency f_{rs}^m is trips/week, and there are 168 hours in a week, the interval between consecutive services is $168/f_{rs}^m$. Assuming goods arrive uniformly, the average waiting time for each shipment is $168/f_{rs}^m/2$.

$$T_{rs}^m = TT_{rs}^m + LT_{rs}^m + WT_{rs}^m \tag{4}$$

$$WT_{rs}^m = 168 / f_{rs}^m / 2 \tag{5}$$

C_{rs}^m is the total transport cost, including operating costs (fuel, equipment operation, etc.) Co_{rs}^m, inventory costs Ci_{rs}^m and depreciation costs Cd_{rs}^m. Its calculation method is as shown:

$$C_{rs}^m = Co_{rs}^m + Ci_{rs}^m + Cd_{rs}^m \tag{6}$$

$$Ci_{rs}^m = V^q \cdot r^q \cdot WT_{rs}^m \tag{7}$$

$$Cd_{rs}^m = V^q \cdot d^q \cdot T_{rs}^m \tag{8}$$

Here, V^q is the unit value of commodity type q, measured in USD/ container; r^q is the unit storage cost; and d^q is the daily depreciation rate.

3.1 Value of time calculation

The value of time for a commodity refers to the amount of money the shipper (the decision-maker in transport mode selection) is willing to pay for the time saved in transporting that commodity. That is, the shipper trades off time against cost to determine the transport mode [16]. To calculate the value of time, equation (3) is transformed into equation (6). Based on sample data, the maximum likelihood estimation method and the Newton-Raphson method are used to solve equation (6), obtaining the time coefficient b_t^q and the cost coefficient b_c^q. Then, equation (7) can be used for calculation. Actually, the value of time VOT^q is the trade-off rate between time and money for commodity q. In the existing literature, most studies either assume a single, common value of time for all commodities, or estimate mode-specific time coefficients only at an aggregate level, which makes it difficult to analyze differences in transport preferences across commodity classes [17]. Based on the above complete shipper-cost specification, VOT^q can not only explain the overall proportions of the three transport modes (sea, rail and air), but also their heterogeneity across different commodity categories, and clarify which commodity categories are structurally more inclined toward rail transport.

$$Ln(\frac{P_{rs}^{qm}}{P_{rs}^{qm'}}) = V_{rs}^{qm} - V_{rs}^{qm'} = b_t^q \frac{T_{rs}^{m'}}{T_{rs}^{m}} + b_c^q \frac{C_{rs}^{m'}}{C_{rs}^{m}} \tag{6}$$

$$VOT^q = \frac{b_t^q}{b_c^q} \tag{7}$$

4. NUMERICAL ANALYSIS

4.1 Data description

Matching the 10 main categories of trade goods between China and Europe with the 22 broad categories of trade goods from China Customs results in Table 1. These 9 commodity types are the subjects of analysis.

This paper collects data on sea, rail, and air transport for specific commodity types (9 types) exported from China to five countries (Belgium, Germany, France, Netherlands, Spain) from 2011 to 2015. Air and rail transport data are from UN Comtrade, and sea transport data are from Clarkson. The transport volume data for the three modes in 2015 are shown in Table 2. Table 3 shows the specific values of other collected parameters. Due to different destinations, transport costs vary; therefore, Table 3 only provides the minimum and maximum freight values.

Table 1 Commodity Classification in the Model

Commodity ID	Specific Content of the 22 Customs Trade Commodity Categories	HS Code Range
1	Vegetable products	2-3
2	Food; beverages, spirits and vinegar; tobacco and manufactured substitutes	4
3	Mineral products	5
4	Products of the chemical or allied industries	6
5	Plastics and articles thereof; rubber and articles thereof / Raw hides and skins, leather, fur skins and articles thereof; saddlery and harness; travel goods, handbags and similar containers; articles of animal gut / Wood and articles of wood; wood charcoal; cork and articles of cork; manufactures of straw, of esparto or of other plaiting materials; basket ware and wickerwork / Pulp of wood or of other fibrous cellulosic material; recovered (waste and scrap) paper or paperboard; paper and paperboard and articles thereof	7-10
6	Textiles and textile articles / Footwear, headgear, umbrellas, sun umbrellas, walking-sticks, seat-sticks, whips, riding-crops and parts thereof; prepared feathers and articles made therewith; artificial flowers; articles of human hair	11-12
7	Natural or cultured pearls, precious or semi-precious stones, precious	14-15

	metals, metals clad with precious metal and articles thereof; imitation jewelry; coin / Base metals and articles of base metal	
8	Machinery and mechanical appliances; electrical equipment; parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles / Vehicles, aircraft, vessels and associated transport equipment / Optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and apparatus; clocks and watches; musical instruments; parts and accessories thereof	16-19
9	Miscellaneous manufactured articles	20-22

Table 2 Cargo Volumes by Commodity and Transport Mode (10,000 tons)

Commodity (ID)	*Sea*	*Rail*	*Air*	*Commodity (ID)*	*Sea*	*Rail*	*Air*
1	2.95	0.16	0.26	6	86.10	8.80	13.20
2	0.45	0.11	0.03	7	0.05	0.00	0.01
3	22.26	0.00	1.53	8	20.99	4.05	1.26
4	53.03	0.00	1.59	9	1.31	0.23	0.19
5	17.15	2.40	2.53				

Table 3 Parameters per TEU

Parameter	*Sea*	*Rail*	*Air*	*Parameter*	*Sea*	*Rail*	*Air*
TTmin (h)	696	360	11.5	Cmin (CNY)	5439.5	12460	115767
TTmax (h)	720	456	16	Cmax (CNY)	6374	14570	118514
f(trips/week)	3.5	1	3.5				
LT (h/TEU)	0.05	0.6	0.05	Inventory cost: 1CNY/h; k:0.003 δ :0.00001			
i (/year)	4.25%	4.25%	4.25%				

4.2 Utility model calibration

Based on the data mentioned above, the transport mode utility models are calibrated for these 9 categories of China-Europe trade goods. The multinomial logit model was estimated by maximum likelihood using NLOGIT software. The standard model-fit statistics to ensure reproducibility are shown in Table 4.

Table 4 Calibration of the Transport Mode Choice Model

Statistic	*Symbol*	*Value*
Log-likelihood (null model)	LL(0)	-3,820.50
Log-likelihood (final)	LL(β^)	-2,415.20
McFadden's pseudo-R^2	1- LL(β^)/ LL(β^)	0.367

In the discrete-choice literature, McFadden's pseudo-R^2 values between 0.2 and 0.4 are typically interpreted as indicating good model fit. The estimated model in this study falls within this range, suggesting that the included cost–time components and commodity-specific variables provide strong explanatory power for modal choice.

Table 5 Calibration of the Transport Mode Choice Model

Commodity (ID)	bc (P-value)	bt (P-value)	Commodity (ID)	bc (P-value)	bt (P-value)
1	0.034 (0.001)	1.685 (0.020)	6	0.779 (0.009)	2.864 (0.004)
2	0.360 (0.000)	1.475 (0.000)	7	0.392 (0.017)	2.374 (0.015)
3	0.807 (0.000)	4.752 (0.000)	8	0.809 (0.002)	2.477 (0.002)
4	0.033 (0.000)	3.178 (0.000)	9	1.439 (0.000)	0.764 (0.000)
5	0.309 (0.000)	2.045 (0.000)			

Table 5 shows the calibration of the transport mode choice model. The P-value is a parameter used to determine the result of hypothesis testing. It is a decreasing indicator of the reliability of the result; the larger the P-value, the less reliable the variable is considered. Generally, $P<0.05$ is considered significant, and $P<0.01$ is considered highly significant, meaning that the probability that the difference between samples is due to sampling error is less than 0.05 or 0.01.

Judging from the P-values, the time coefficient b_t^q and cost coefficient b_c^q for Food (Commodity 2), Mineral products (Commodity 3), Chemical products (Commodity 4), Paper products (Commodity 5), Textile products (Commodity 6), Machinery/Electrical products (Commodity 8), and Miscellaneous manufactured articles (Commodity 9) are highly significant; the cost coefficient b_c^q for Vegetable products (Commodity 1) is highly significant, and the time coefficient b_t^q is significant; the time coefficient b_t^q and cost coefficient b_c^q for Precious metals/Jewelry (Commodity 7) are significant.

Overall, at a 95% confidence level, all test indicators meet the accuracy requirements. Since equation (2) itself carries a negative sign and the calibrated coefficients are standardized, the calibration results show that both the time and cost coefficients are positive, indicating that as time or cost increases, the modal split of a transport mode chosen by shippers' decreases. Among them, time has the greatest impact on the transport utility of Machinery/Electrical products (Commodity 8), while cost has the greatest impact on the transport utility of Mineral products (Commodity 3) and Chemical products (Commodity 4). As Machinery/Electrical products are time-sensitive [17] and have high added value, their optimal transport time is around 20 days. Therefore, transport time has a greater impact on their modal splits. Chemical and Mineral products are price-priority products, whose value does not depreciate significantly over time. Therefore, transport cost has a greater influence than transport time for Chemical and Mineral products.

Using equation (5), the value of time for different commodities can be calculated, as shown in Figure 1. The average value of time for all commodities is 48.9 CNY/(TEU*hour). Among them, Vegetable products (Commodity 1) and Chemical products (Commodity 4) have the highest values of time, at 49.56 CNY/(TEU*hour) and 96.3 CNY/(TEU*hour) respectively, while Miscellaneous manufactured articles (Commodity 9) has the lowest value of time, only 0.47 CNY/(TEU*hour).

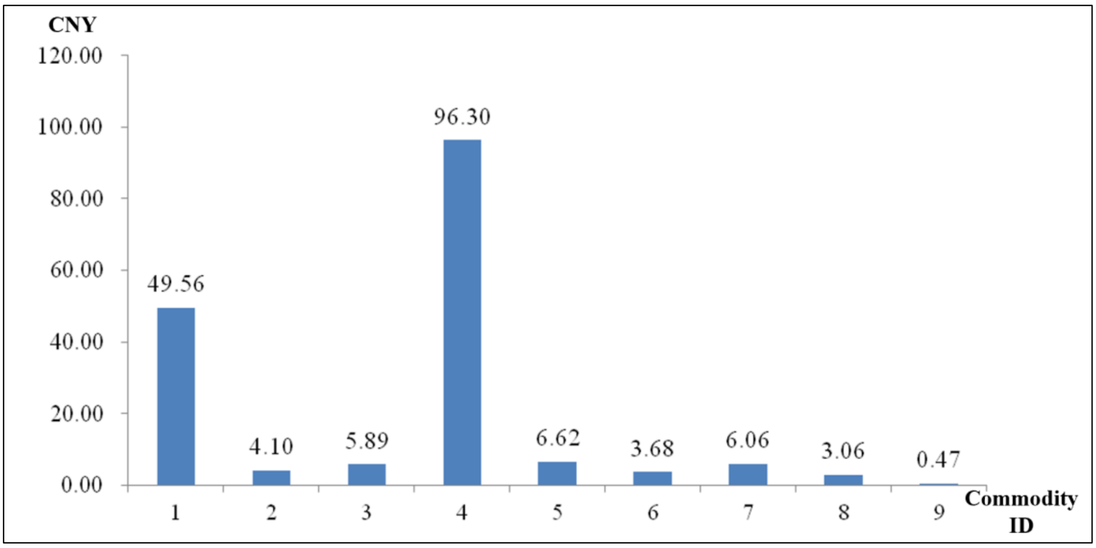


Figure 1 Values of Time for per TEU of Different Commodities

4.3 Analysis of current modal splits

Based on the current value of time, transport time, and cost, the calculated current modal splits are shown in Table 6. It can be seen that currently, the sea transport share for Mineral products (Commodity 3) and Chemical products (Commodity 4) is 100%; rail and air transport do not serve these two categories of goods at all. The sea transport share for Vegetable products (Commodity 1) is also as high as 98.86%. The top three commodities with the highest rail transport splits are Food (Commodity 2), Machinery/Electrical products (Commodity 8), and Miscellaneous manufactured articles (Commodity 9). Their rail transport splits reach 14.00%, 13.19%, and 11.93% respectively. The top three commodities with the highest air transport splits are Paper products (Commodity 5), Precious metals/Jewelry (Commodity 7), and Machinery/Electrical products (Commodity 8). Their air transport splits are 10.98%, 10.69%, and 12.61% respectively.

Table 6 Modal Splits of the Three Transport Modes (%)

Commodity (ID)	Sea	Rail	Air
1	98.86	0.59	0.54
2	84.29	14.00	1.71
3	100.00	0.00	0.00
4	100.00	0.00	0.00
5	84.43	4.58	10.98
6	88.69	7.14	4.17
7	81.43	7.88	10.69
8	74.20	13.19	12.61
9	80.10	11.93	7.97

4.4 Analysis of changes in mode share of CR-Express

It is foreseeable that the nature of trade goods between China and Europe will change in the future, and some changes will inevitably affect the position of CR Express in China-Europe trade transport. Additionally, changes in the attributes of CR Express itself will also affect its role and status in trade transport. The following analyzes the changes in the transport share of CR Express corresponding to variations in two attributes: the value of time of China-Europe trade goods and the frequency of CR Express services.

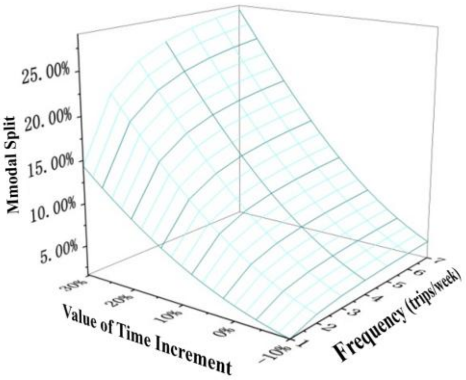
For the calculation, it is assumed that the value of time fluctuates between -10% and +30% of the current state, and the train frequency increases from 1 trip/week to 7 trips/week, while the attributes of air and sea transport remain unchanged. Equation (7) is used to convert the change in value of time into a change in bt/bc, and the service frequency is substituted into equation (4) to calculate the transport time. Then, equation (2) is used to calculate the utility of each transport mode. Finally, equations (1) and (3) are used to calculate the modal splits. From the calculation results, it can be intuitively observed that the rail share for Mineral products (Commodity 3) and Chemical products (Commodity 4) hardly changes with the variation of the two attributes (value of time and frequency). Additionally, Miscellaneous manufactured articles (Commodity 9) includes all other goods except Commodities 1 to 8 and is not representative. Therefore, these three commodity types are excluded from the following analysis, focusing only on the other 6 commodities.

Figure 2 shows the changes in the modal split of CR Express in trade transport as the two attributes mentioned above change. It can be seen that as the value of time increases, the changes in rail transport share vary significantly among the six commodities. When the value of time for goods increases from their respective -10% to +30%, the rail transport share for Vegetable products (Commodity 1), Precious metals/Jewelry (Commodity 7), and Machinery/Electrical products (Commodity 8) increases substantially. Among them, Precious metals/Jewelry (Commodity 7) shows the largest increase rate. When the frequency is 1 trip/week and its value of time increases from -10% to +30%, its rail transport share increases from 4.37% to 45.40%, a 9.38-fold increase. When the frequency is 7 trips/week, the rail transport share increases from 7.75% to 78.00%, a rise of 9.06 times. Therefore, it can be said that for such high time-value goods, the frequency of CR Express services should be increased to further enhance the timeliness of rail transport, increase its advantages, and widen the utility gap between rail and sea transport.

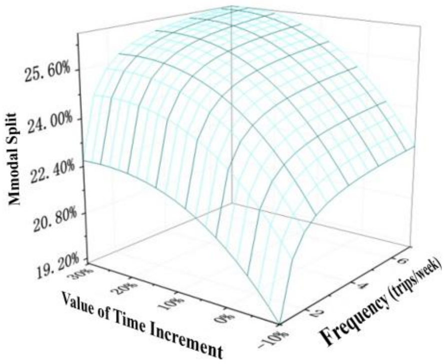
The rail transport share for Food products (Commodity 2) changes relatively little with variations in its value of time and rail service frequency. When the frequency is 1 trip/week and its value of time increases from -10% to +30%, its rail transport share only increases from 4.76% to 5.65%, a growth rate of 18.77%. Even when the frequency increases to 7 trips/week, its rail transport share only increases from 5.59% to 6.6%, with a growth rate of only about 18%. This shows that for this type of goods, it is not possible to increase the rail transport market share by improving the timeliness of rail transport; instead, only by reducing freight rates can its rail transport share be enhanced. It is particularly worth noting that the rail share for Paper products (Commodity 5) and Textile products (Commodity 6) is completely insensitive to the value of time, and even shows a decrease in rail transport share as the value of time increases. This might be a defect of the model itself; considering the rationality of actual China-Europe trade and rail transport capacity, this situation generally would not occur. Therefore, even in the future, shippers of "Paper products" and "Textile products" should not be the target of CR Express marketing.

When the value of time for goods increases from -10% to +30% of their current state, and the service frequency increases from 1 trip/week to 7 trips/week, the average increase in rail transport share for the aforementioned six commodities is 62.30%. Among them, the rail share for Vegetable products (Commodity 1) increases most significantly, by 118%. When the value of time for Vegetable products is 10% lower than the current level, as the frequency increases from 1 trip/week to 7 trips/week, its rail transport share increases from 1.53% to 3.55%. When its value of time is 30% higher, as the frequency increases from 1 trip/week to 7 trips/week, its rail transport share increases from 14.36% to 28.45%, with the latter effect being more obvious.

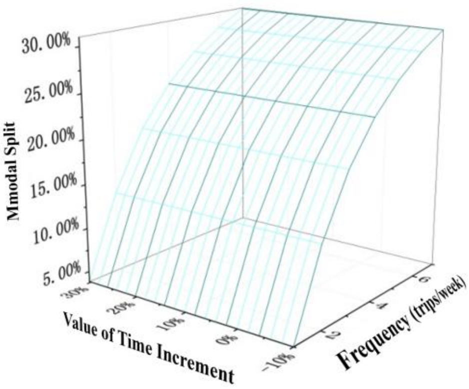
Therefore, it can be said that the higher the value of time of the goods, the more the frequency of CR Express services should be increased.



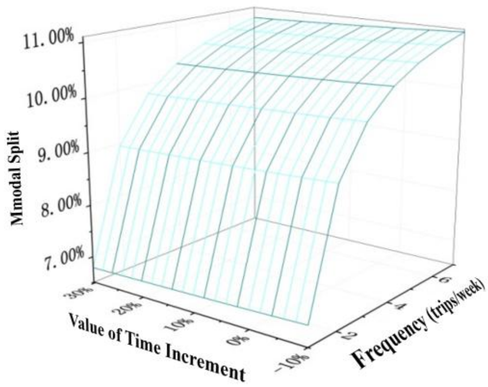
(a) Vegetables (Commodity 1)



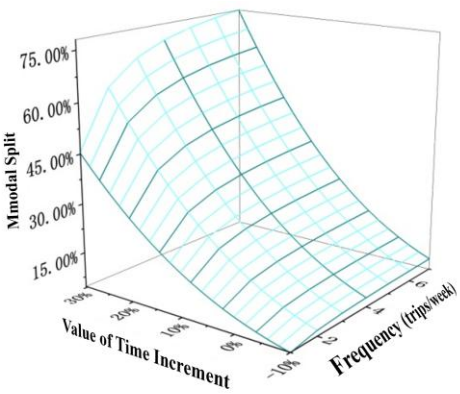
(b) Foods (Commodity 2)



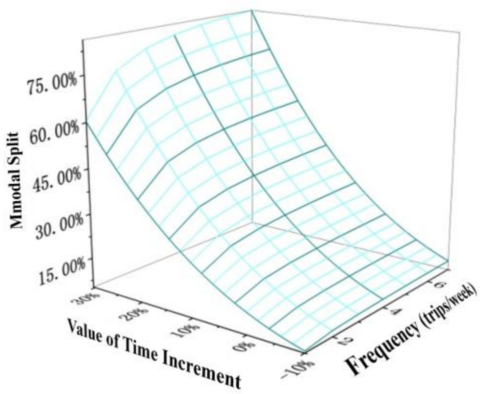
(d) Papers (Commodity 5)



(e) Textiles (Commodity 6)



(f) Precious Metals/Jewelry (Commodity 7)



(g) Machinery/Electrical Products (Commodity 8)

Figure 2 Mode Shares of CR-Express

The change in the rail share for Food (Commodity 2) is the smallest with changes in value of time and frequency. When the value of time for Food is 10% lower than the current level, as the frequency increases from 1 trip/week to 7 trips/week, its rail transport share only increases from 4.76% to 5.59%, an increase of only 17.45%. When the value of time for Food is 30% higher than the current level, as the frequency increases from 1 trip/week to 7 trips/week, its rail transport share increases from 5.65% to 6.605%, also increasing by only 17.73%. Therefore, CR Express does not play a significant role for food transport.

5. CONCLUSIONS

Based on the Logit model for transport mode choice and the generalized transport cost including freight charges, inventory cost during transportation, opportunity cost of capital, and commodity depreciation cost over time, this paper proposes a method for calculating the modal split of CR Express in China-Europe trade transport. Using collected data, the Logit model is calibrated, and the value of time for various goods is calculated. Sensitivity analysis is conducted on the modal splits of China-Europe trade transport with respect to the attributes of the value of time of goods and the frequency of train services.

From the above calculation and analysis, it can be concluded that to develop CR Express, multiple channels should be explored to develop its source of goods in the future. Vegetable products, Precious metals/Jewelry, and Machinery/Electrical products are suitable for CR Express. Therefore, the market for these goods should be developed, precision marketing should be carried out, cargo sources should be organized more targeted, cooperation with domestic production units related to Vegetable products, Precious metals/Jewelry, Machinery/Electrical products, etc., and overseas related commercial and trade enterprises should be strengthened, enterprises should be encouraged to choose CR Express logistics services, and brand loyalty for CR Express should be increased.

Secondly, it is necessary to reduce the price of CR Express. The calculation results show that reducing the freight cost of CR Express can effectively increase the market share of Machinery/Electrical products. Therefore, cargo source information from various channels should be integrated, the price mechanism should be improved, the government-guided pricing mechanism for domestic transport should be fully utilized, full-process price competition should be carried out, and the overall pricing competitiveness of CR Express should be enhanced. Simultaneously, routes should be optimized to reduce the transport cost of CR Express. Additionally, local government subsidy policies should be standardized, promoting localities to base their development positioning on their status and actual potential in foreign trade and economic development. Local governments can implement special subsidies for high-value or time-sensitive goods in local cargo sources, while gradually phasing out other financial subsidies to promote the marketization process of the block trains.

Finally, it is also necessary to increase the frequency of services. The calculation results show that increasing the frequency can greatly enhance the attractiveness of CR Express for Paper products, Textile products, Precious metals/Jewelry, and Machinery/Electrical products. Therefore, the frequency of train services from the source areas to Europe can be increased for these commodity types to enhance the role and status of rail transport.

The opening of CR Express has indeed provided a new platform for Asia-Europe trade goods transport. However, for cross-border and transcontinental CR Express, issues such as different railway gauges in various countries and the inherent capacity limitations of rail transport itself mean that CR Express can only serve as a supplementary transport mode to sea and air transport and cannot replace sea transport.

6. DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES:

The authors declare that no generative AI or AI-assisted tools were used during the preparation of this work.

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