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Research on Optimizing Transportation along the Belt and Road under Multi-modal Transportation Model

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Abstract: *The development of logistics is the need of social reproduction and the arterial system of national economy. The overall goal of cross-border logistics is to serve international trade and transnational operations, that is, to find the best path and the best combination of transport modes through scientific design with the lowest logistics cost and the least transportation risk, and to transport goods to the delivery destination. To sum up, this paper takes the economic cost of multimodal transport as the optimization objective from the actual situation, designs the optimization of the system path of multimodal transport, and accelerates the evolution of the great changes that the world has never seen in a century along the Belt and Road. The distinctive banner of contemporary Chinese-style modernization is openness. With the development of the "Belt and Road" policy, China has further improved its level of opening up to the outside world, and strengthened the integration of economic and trade development with countries along the route. Firstly, the optimization objective of routing is determined. By taking the cross-border logistics routes of countries along the Belt and Road as the research object, this paper introduces the related concepts and theories such as multimodal transport and the Belt and Road. Secondly, by analyzing various factors that affect route selection, it is finally determined that the logistics cost in route selection is the optimization target, and road transportation, railway transportation, water transportation and air transportation are the transportation modes. Based on this, the objective function is constructed and the logistics cost is analyzed quantitatively. Finally, the improved intelligent optimization algorithm is used to solve the problem. Finally, citing the "Belt and Road" example, the case algorithm is solved to provide a reference scheme for China's "Belt and Road" economic and trade cooperation.*

Keywords: *multimodal transport; Belt and Road; transportation optimization*

1. Introduction

In recent years, China has been experiencing a rapid development of various modes of transportation, and the construction of an integrated transportation system has become a key direction for the development of modern logistics and an important link in the smooth circulation of the national economy. Intermodal transportation has grown in tandem with the development of containerized transportation and is the best choice for cross-border logistics transportation. Intermodal transportation is an efficient combination of transportation modes that can achieve complementary advantages and minimize shortcomings by coordinating different modes of transportation. By simplifying transportation processes, it can reduce energy consumption, lower greenhouse gas emissions, accelerate cargo turnover, and lower transportation costs, achieving economic, technical, and carbon emission optimization.

Currently, the optimization of intermodal transportation routes is mainly concentrated on theoretical research and theoretical significance. The industry is affected by real-world factors, and actual use is relatively rare. Firstly, there are defects in the development of intermodal transportation, such as insufficient infrastructure capacity, uncoordinated mechanisms, insufficient elements, low organizational efficiency, and low competitiveness of intermodal transportation products. Secondly, affected by geographical economic factors, some nodes have saturated capacity or low utilization rates in both directions, while the inland resources are scarce and cannot establish effective coordination mechanisms with port and border areas, and many logistics parks lack comprehensive cargo and intermodal transportation services, which have become obstacles in the actual logistics activities.

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The development of logistics is the need of social reproduction and the arterial system of national economy. The overall goal of cross-border logistics is to serve international trade and transnational operations, that is, to find the best path and the best combination of transport modes through scientific design with the lowest logistics cost and the least transportation risk, and to transport goods to the delivery destination. Multimodal transport has unparalleled advantages in cross-border logistics, linking different modes of transport, several transport enterprises, or production, supply, transport, marketing departments organically, coordinating the whole journey, so that the goods can handle one consignment procedure from the place of origin or departure quickly, simply, economically and safely to the place of receipt. To sum up, this paper takes the economic cost of multimodal transport as the optimization objective from the actual situation, and designs the optimization of the system path of multimodal transport to provide a reference for the transport along the Belt and Road.

2. Concepts related to multimodal transport

2.1 Industry research status

Liu Bingfang and Lin Tan[1] analyzed the development trend and form characteristics of international multimodal transport, and better applied them to the development of multimodal transport in China. The development of multimodal transport should pay attention to actively training multimodal transport operators, and build mature international multimodal transport network; Build a sound management system and remove institutional obstacles to development; Take sea-rail combined transport as a breakthrough to promote the development of sea-land combined transport network; Accelerate the application of advanced information technology in international multimodal transport services. By studying the development status and characteristics of China's container multimodal transport, Yang Lei[2] found its existing problems and conducted analysis and research, so as to propose countermeasures such as accelerating the construction of technical standard system, constructing cooperation mechanism of multimodal transport and open and shared information platform. Pallme[3] said that multimodal transport stimulated the American economy and changed the international trade and transportation system, especially the widespread use of containers became a support point for rapid economic growth. Through research and analysis, this paper provided application framework and guidance for the development, planning and governance of multimodal transport facilities. Zhang Ning [4] established the multimodal transport equipment system through comprehensive research and analysis of the American multimodal transport equipment standard system. This is an effective measure to promote the whole industry to save logistics costs, save transportation time, improve transportation efficiency, and respond to policies to promote the structural reform of the supply side of logistics. Su Hang and Li Haijun [5] analyzed the path optimization of low-carbon multimodal transport of refrigerated containers under uncertain demand and applied solvers to achieve model solving. Realizing the multimodal transport of refrigerated containers can reduce the transportation cost of fresh agricultural products, improve transportation efficiency, and reasonably improve the carbon tax rate can effectively promote the transit rail and achieve low-carbon transport. The improvement of confidence level is conducive to meeting customer needs. However, due to the limitations of transportation capacity and transit capacity, it is often necessary to change the transportation scheme, which will lead to a non-linear increase in the total transportation cost.Janic M[6] conducted a specific study on the economic cost of multimodal transport, built the optimization of multimodal transport routes with the lowest economic cost, and put forward research views on the sustainable development of the transport system of the European Union. From the perspective of logistics enterprises, Li Kuimei and Zheng Bo[7] comprehensively considered the losses caused by various uncertain factors in the course of multimodal transportation, combined with the costs of the three transportation modes of truck, truck and ship, and built a route optimization model, which mainly aimed at the lowest logistics cost.

2.2 Multimodal transport

Multimodal transport is usually defined as a composite transport through the container transport as the carrier, through two or more means of transport complement each other and complete the transport process. The United Nations Convention on International Multimodal Transport of Goods is defined as the transport of goods in accordance with an international multimodal transport contract, in at least two different modes of transport, by the multimodal transport operator from the origin of the goods in one country to the designated destination place of delivery in another country.

The development of container transport is the basis for the development of multimodal transport,

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which is the mode of intermodal transport that can achieve the optimal combination in cross-border logistics activities. Operators and carriers and operators of transit nodes can help complete the whole process of cross-border multimodal transport of goods through one-time consignment, billing, documentation and insurance operations. The whole multimodal transport process should be regarded as a continuous and uninterrupted whole, through the arrangement and combination of various modes of transport and routes, to achieve continuous transport, the best route and the lowest cost comprehensive transport of goods.

Multimodal transport features (1)The improvement of transportation organization level. Multimodal transport network is a type of logistics network, whose organizational structure is composed of "points" and "edges". Different modes of transport have their different characteristics. Multimodal transport can effectively connect different modes of transport, improve the level of transport organization, and effectively make good use of different modes of transport to achieve modern logistics "door-to-door" transport.(2)Improvement of transportation efficiency and freight quality. Multimodal route optimization greatly saves transit time and reduces the loss of goods. Because in this mode of transport, the container as the main transport carrier, in the entire route circulation process, no disassembly handling, multimodal transport to the maximum extent to ensure the continuous transport of goods, reduce the transfer and waiting time, and effectively reduce the rate of goods loss. (3)The procedure is simple and the cost is reduced. The entire process of multimodal transportation only needs to complete a single shipment, sign a multimodal transportation contract, pay a single freight, purchase an insurance, and obtain a waybill to complete the entire transportation process. Therefore, it simplifies the shipping process procedures, documentation procedures and multi-party settlement procedures, etc., which greatly facilitates the transportation and use of the shipper and the consignee. (4)The realization of rationalized modes of transportation. Multimodal transport can make use of the advantages and disadvantages of various modes of transport for reasonable collocation, so as to seek the best combination point, such as sea transport, rail transport low price, long time, less environmental pollution, and road transport and air transport short time, high cost, high energy consumption, more pollution. Therefore, public rail combined transport, sea rail combined transport, sea and air combined transport can not only make up for each other's shortcomings, but also play a higher advantage role, achieve the effect of 1+1>2, while reducing logistics costs, and receive good economic benefits.

Multimodal transport operation process. In multimodal transport, the operator is the whole organizer, and the process mainly has the following links:(1)The operator receives the customer's transport application, concludes an intermodal transport contract with the multimodal transport parties, and then organizes multimodal transport logistics activities.(2) Release, pick-up and transport of containers.(3) Export declaration.(4) Packing and receiving goods.(5) Booking and arranging cargo delivery.(6) To insure the logistics and transportation of goods.(7) Sign the multimodal bill of lading, organize and complete the whole process of transportation of goods.(8) Customs business during transportation.(9) Delivery of goods.(10) Handling of freight accidents.

2.3 Multimodal transport along the Belt and Road

In the past ten years, the total import and export volume of China and the countries jointly built by the Belt and Road has increased by 6.4% annually, and has accumulated to 19.1 trillion yuan. China's outbound direct investment exceeded $240 billion. By June last year, China had signed more than 230 documents on joint construction and cooperation with more than 150 countries and 30 international organizations. 2023 marks the 10th anniversary of the Belt and Road Initiative. The Belt and Road Forum for International Cooperation held in Beijing has pointed out the direction for China to build the Belt and Road in the next decade.

Among them, as a flagship project of the Belt and Road Initiative, the China-Europe Railway Express has opened up a new land transport corridor between Asia and Europe, from the China-Laos Railway to the Jakarta-Bandung high-speed railway, with the continuous development of high-quality cooperation under the Belt and Road Initiative over the past decade. The "Belt and Road" multimodal transport is a way to seamlessly connect and interconnect different modes of transport (such as rail, road, sea, air, etc.) to achieve efficient cargo transportation and logistics distribution under the framework of the "Belt and Road" initiative. Multimodal transport has not only enabled more countries to realize connectivity, but also injected new momentum into the construction of the Belt and Road.

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3. Logistics cost analysis of multimodal transport

The logistics cost of multimodal transport mainly refers to the total cost of the entire transportation process. Usually includes the sum of transportation costs, transit costs, storage costs, insurance and other costs, of which transportation costs and transit costs occupy the main cost space.

In this study, first of all, the transit cost refers to the transit cost of the goods through different ports at home and abroad according to the selected multimodal transport mode (for example, container disassembly, loading, warehousing, secondary transportation, etc.). The transit cost of different types of ports or ports is also different due to the number of goods, weight, service providers and other factors. Secondly, transportation costs should be produced according to the different prices of different means of transport, and the total cost of different modes of transport is compared: water transport < rail transport < road transport < air transport. Therefore, multimodal transport operators usually give priority to lower cost water transport and rail transport in actual logistics activities.

4. Objective function

4.1 Objective function condition assumption

(1) The whole transport process as a whole transport, there is no division of the goods.

(2) The same node or transport path can only be transferred once at most, and the transport path is non-cyclic.

(3) The entire logistics process does not consider the adverse weather, equipment failure and other external factors.

4.2 Parameters and variables

Total cost F1 includes minimum transportation cost C1, transit cost C2, waiting cost C3, cargo damage cost C4, and the cost item is defined in detail as follows:

$$F_1 = C_1 + C_2 + C_3 + C_4 \tag{1}$$

① Transportation cost C1: reflects the transportation cost generated by choosing different transportation modes on each route. Transportation costs vary with distance and mode of transportation. Where, $c_{(h,i)}^{k}$ is the unit transportation cost of the k mode of transportation on the path (h,i). Be defined as:

$$C_1 = \sum_{(h,i)\in A} \sum_{k\in M} q \cdot c_{(h,i)}^{k} \cdot d_{(h,i)}^{k} \cdot x_{(h,i)}^{k} \tag{2}$$

②Transit cost C2: The transit cost of goods when the mode of transport is changed at a certain node. Where, c_i^k is the transfer cost of the k mode of transport at the node i. Be defined as:

$$C_2 = \sum_{i\in K} \sum_{k\in M} q \cdot c_i^k \cdot y_i^k \tag{3}$$

③Waiting cost C3: the waiting cost of goods at the transit node. Where, c_w^k is the waiting cost per unit time of the k mode of transport, and w_i^k is the waiting time of the node i. Be defined as:

$$C_3 = \sum_{i\in N} \sum_{k\in M} q \cdot w_i^k \cdot c_w^k \cdot y_i^k \tag{4}$$

④Damage cost C4: The cost of compensation for damage to goods during transportation and transit. Be defined as:

$$C_4 = \sum_{(h,i)\in A} \sum_{k\in M} q \cdot U \cdot \theta_n^k \cdot (d_{(h,i)}^k / 100) \cdot x_{(h,i)}^k + \sum_{i\in K} q \cdot U \cdot \theta_z \cdot y_i^k \tag{5}$$

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5. Study on optimization of multimodal transport along the Belt and Road

5.1 Path overview

In this paper, 14 regions or countries are selected in the study of the "Belt and Road" path, including five domestic starting points (two inland areas, three port areas) and seven overseas destination points. Transport mode selected rail transport, water transport, air transport, road transport, four common modes of transport. The 14 regions or ports and four modes of transportation are combined and arranged, and the transportation network layout diagram of the region is formed by intelligent algorithm.

The specific layout of the multimodal transport network is shown in Figure 1

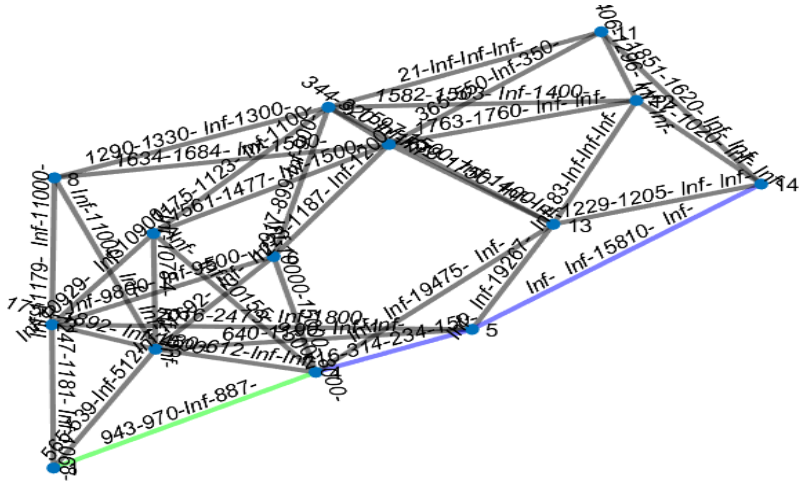

Figure 1: Transport Network Map of Regions along the Belt and Road

5.2 Routes and modes of transport

In the scheme with the lowest logistics cost, the algorithm chooses the path 1-4-5-14, and the logistics cost is ￥1824200.00.The specific transport routes and modes are shown in the following Tab.1.

Table 1: Routing and mode of transport selection form

Route selection	1		4		5		14
Mode of transport		railway		waterway		waterway	

When choosing a lower cost mode of transport, priority should be given to rail and water, which are not only more suitable for the geographical conditions of the regions along the Belt and Road, but also can take into account the needs of the lowest cost. This option shows that by choosing more economical modes of transport, such as water or road transport, transport costs can be effectively reduced without significantly affecting the total transport time. Therefore, the lowest cost solution is suitable for scenarios where budgets are limited or cost control is sensitive, especially in the case of bulk commodity shipping or large volume orders. The scheme not only effectively controls transportation costs, but also maintains a relatively short time and moderate carbon emissions. Rail transport and water transport are also suitable for bulk cargo and container transport, ensuring the volume of bulk cargo transport while reducing costs. This model is used in most of the current scenarios of cross-border goods flow along the Belt and Road.

6. Conclusion

The multimodal transport discussed in this paper is mainly concerned with cross-border long-distance cargo transport. In the process of long-distance transportation, there are many unpredictable variables, such as frequent changes in transportation links and great changes in transportation environment. In this study, a variety of common uncertainties in actual transportation activities are optimized, which is more in line with the actual situation, so that the route optimization structure can actually and effectively provide more reasonable suggestions for industry-related

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enterprises and government agencies. This study aims to understand and solve the current challenges faced by cross-border multimodal transport in terms of economic benefits, and then build the path optimization of cross-border multimodal transport with the optimization goal of logistics cost, so as to promote the development and progress in the field of multimodal transport. Provide theoretical guidance for cross-border logistics in the aspects of low carbon energy saving and cost reduction; Taking the cross-border logistics routes of the "One Belt, One Road" trade routes as an example, the optimization scheme of multimodal transport routes is provided.

By constructing the objective function, this paper considers the lowest logistics cost, and emphasizes railway transportation and water transportation in multimodal transportation. In the case study, it is found that the choice and combination of transportation modes and the choice of different routes will affect variables such as cost, time and carbon emissions. In future applications, operators or logistics enterprises should consider their own preferences to choose the appropriate routes and transportation modes. The route optimization of multimodal transportation ultimately helps the industry weigh logistics costs in cross-border logistics transportation, especially transportation along the Belt and Road, to maximize comprehensive benefits. The designed efficient transportation scheme helps enterprises to achieve a balance between economic benefits and environmental benefits in the global supply chain. The development of scientific intermodal transport helps the prosperity of the intermodal transport market and also contributes to the implementation of the Belt and Road strategy in China.

To sum up, the development of logistics is the need of social reproduction and the arterial system of the national economy. According to the "China Trade Logistics Development Report (2023)", the total amount of China's trade logistics in 2023 reached 126.1 trillion yuan, an increase of 5%. It can be seen from the data that the theme of today's world economic development is common development. With the close exchanges of trade cooperation among countries and the strengthening of the trend of economic globalization, countries are interrelated and dependent on each other on the basis of international division of labor. The overall goal of cross-border logistics is international trade and cross-border business services, that is, with the lowest logistics costs and minimal transportation risks, through scientific design to find the best path and the best combination of transportation modes, the goods to the delivery destination. Multimodal transport has unparalleled advantages in cross-border logistics, linking different modes of transport, several transport enterprises, or production, supply, transport, marketing departments organically, coordinating the whole journey, so that the goods can handle one consignment procedure from the place of origin or departure quickly, simply, economically and safely to the place of receipt. Based on the above, this paper takes the economic benefit as the optimization goal from the actual situation, and designs the system path optimization of multimodal transport.

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