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SIMULATION CASE STUDY: HOW ARCTIC SHIPPING SHARES THE FLOW OF CARGO FROM TRADITIONAL ROUTES

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ABSTRACT

The accelerated melting of the Arctic ice makes the opening of the Arctic shipping routes closer, bringing about a new pattern of shipping networks. To evaluate the effect of the opening of the Arctic route on the cargo flow of traditional routes, in this study, we will forecast the ice conditions for the opening of the Arctic route, then develop a minimum cost aimed cargo flow assignment model, taking the Arctic route into the world container shipping network and intuitive output results through simulation.

1 INTRODUCTION

Global warming has led to the melting of arctic ice on a large scale, making the Arctic a "place where every country competes" for marine resources. According to the Arctic Climate Impact Assessment Report released by the International Arctic Council in 2004, the Arctic has been accelerating its vocal changes in the past ten years in environmental, ecological, social, economic, and many other aspects. In 2009, the "Fraternity" and "Vision" of the German Brugger Shipping Company departed from South Korea and successfully arrived in Rotterdam, the Netherlands, through the Northern Sea Route (NSR), becoming the first non-Russian ship in history to pass through the NSR, kicking off the prelude to the international transportation of the NSR With further warming and the melting of Arctic ice, the opening of the Arctic shipping routes connecting Asia, Europe, and North America will greatly shorten the voyage of ocean shipping in Asia and Europe, and will also form a new structure of the Arctic transportation network, which may pose a major challenge to the Suez Canal Route (SCR) and the Panama Canal Route.

Future changes in arctic ice will determine whether the Arctic route can be fully opened. When the Arctic route is opened, a new transportation network is formed, and how shipping companies choose the appropriate transportation route and how to distribute cargo flow in the new shipping network, thereby creating greater revenue for themselves, requires effective calculation and simulation. This is not only directly related to the economic benefits of shipping enterprises but also provides a reference for the planning and development of ports and cities.

This study compares changes in the flow of goods on major global routes (sea and rail) before and after the opening of the Arctic route. Among the factors that determine the flow of goods on a route, transportation costs are key, so this study proposes a mathematical model of cargo flow assignment with the goal of the minimum total cost and simulates the model in combination with the prediction of future Arctic ice conditions.

The rest of the paper is organized as follows: a literature review is presented in Section 2. Section 3 introduces the methodology. Section 4 develops the case study and simulation. And section 5 provides the conclusion.

2 LITERATURE REVIEW

Due to scientific and technological constraints, research on the analysis and prediction of melting arctic ice was a late start. Lefebvre and Goosse (2008) analyzed changes in the sea ice area of the Antarctic and Arctic over the 21st century by using multiple Atmosphere-Ocean General Circulation Models(AOGCM), confirming the possibility of opening Arctic shipping routes. In the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5), Stocker et al.(2013) analyzed global sea ice cover in the 21st century and predicted changes in the Climate of the Arctic from 2020 to 2200 by forecasting data observed by satellites in several countries. Based on the Atmospheric Circulation Model of the Massachusetts Institute of Technology, and the ice-ocean coupled model, Yang et al. (2019) developed a sea ice data assimilation and prediction system to predict sea ice concentration and thickness by assimilating Special Sensor Microwave Imaging Detectors. Chai et al. (2021) counted the thickness and strength of ice in the first year along the NSR and estimated the ice thickness, ice strength, and other physical parameters of sea ice to provide information for ships to achieve Arctic navigation.

Based on the premise that the Arctic route can indeed be opened, there is still a lack of research on the distribution of cargo flow in the container shipping network, including the Arctic route, but many studies on multimodal transport issues that target single transport modes or do not consider Arctic route can bring a lot of inspiration to this study. For example, Soehodho and Nahry (2010) have set up various types of cargo flow distribution systems with the goal of minimizing cost. Li et al. (2014) use the rolling time-domain method to analyze the dynamic container flow assignment under multimodal transport. Lee et al. (2014) applied a coupled linear programming model to simulate the distribution of cargo flow in the global freight network. Sun and Zheng (2016) analyze the flow distribution of empty and laden containers in the global maritime network by solving the flow assignment model with the concave function as the target function. Wang et al. (2020) used a generalized Nash equilibrium model with shipping companies as leaders and shippers as followers to calculate container flows through NSR and SCR, respectively. Gao et al. (2022) consider carbon tax and cargo owners' choice preferences and establish a two-level programming model to optimize the container ocean shipping network.

Looking back at the previous research results, the contribution of this study will be to establish a cargo flow distribution model of the global container shipping network based on the ice melting situation in the Arctic, bring the Arctic route into it, and analyze the impact of the opening of the Arctic route on the traditional global container transport network by simulating the cargo flow distribution results of the global shipping network.

3 METHODOLOGY

The issue we discuss in this article is how the container flow of the global shipping network will be distributed after the opening of the Arctic route. Cargo flow distribution is calculated and analyzed from the perspective of shipping companies, who will consider the cost and time of transporting goods using different routes. Therefore, we believe that shipping companies want to decide on the type of ship, the container ship, and the route and container volume that these ships use when carrying out transport production. At the same time, the future melting and coverage of Arctic ice also need to be predicted to determine whether the Arctic route can be opened, and based on this result, a freight flow distribution model for the shipping network of empty and laden containers will be established.

Before moving on to the details of this section, we will present a framework diagram that assesses how Arctic ice melt affects container flows. The diagram consists of four parts: Arctic ice melt forecast, container shipping cost analysis, container shipping flow assignment model, and cargo flow assignment simulation.

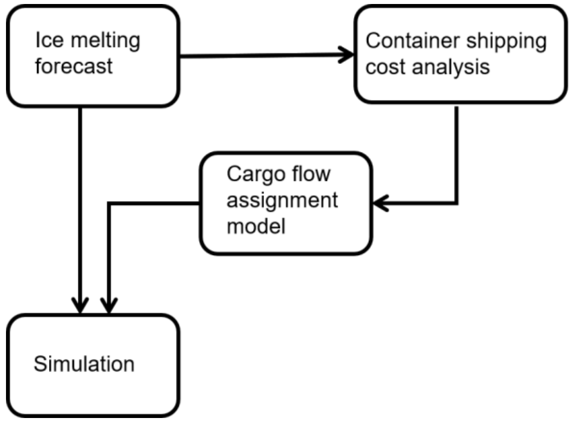

Figure 1: Framework of assessment of Arctic ice melting effect on container flow.

3.1 Ice Melting Forecast

The fifth phase of the current International Coupling Model Comparison Program (CMIP5) conducts climate analysis in different contexts through 63 global AOGCMs in 35 countries, including future short-term climate change projections (to 2035) and future long-term climate change projections (to 2100-2300). CMIP5 also provides the latest data to estimate future changes in sea ice cover at the poles, and the program model represents the most advanced international version of the model. Therefore, this study uses the global atmosphere-ocean coupling model mentioned in IPCC AR5 as a predictive model for Arctic ice melting.

According to the different characteristics of the simulation scenario, this paper selects the moderately gentle scenario under the typical concentration route situation with a large number of models and synthesizes multiple models in IPCC AR5 under the scenario. Each model's sea ice intensity data further determines the dividing line between Arctic seawater and sea ice. In order to reduce the error of the prediction model, this paper will finally determine the edge of sea ice cover based on the dividing line between seawater and sea ice determined by more than 50% of the models in the selected model.

In order to facilitate data processing, this paper chooses to process the density of Arctic sea ice in the form of grid data, and the model data that can be applied after precision screening are the Global Climate Model of the Meteorological Research Institute Version 3 (MRI-CGCM3), Australian Community Climate and Earth-System Simulator Version1-3 (ACCESS1-3) and CNRM-CM5, the CMIP5 version of the Earth System Model. All these model data are sourced from the IPCC Data Distribution Centre. The AOGCM of MRI-CGCM3, ACCESS1-3, and CNRM-CM5 allows for predictions of Arctic ice cover up to 2100. In this paper, 2020, 2030, and 2050 are selected as the forecast time periods for data comparison. At the same time, March and September were selected as observation periods for winter and summer to more clearly see the melting of ice in different seasons.

In this study, Microcity software was used to predict the MRI-CGCM3, ACCESS1-3, and CNRM-CM5 models based on the combined atmosphere-ocean coupling prediction data, and the results of the three models were comprehensively processed, and the results of more than 50% of the models were selected as the standard. The sea ice concentration of 15% is the boundary line with or without sea ice. The final result is shown in figure 2. The white area represents the ice-covered part.

It can be seen from the results that the extent of Arctic sea ice will gradually shrink in the future. Although the winter ice conditions represented by March have little change, the ice layers around Greenland and the northern waters of Russia have begun to disappear during the summer time represented by September. By 2050, the northern seas of Russia can already meet the full navigability of the Arctic route.

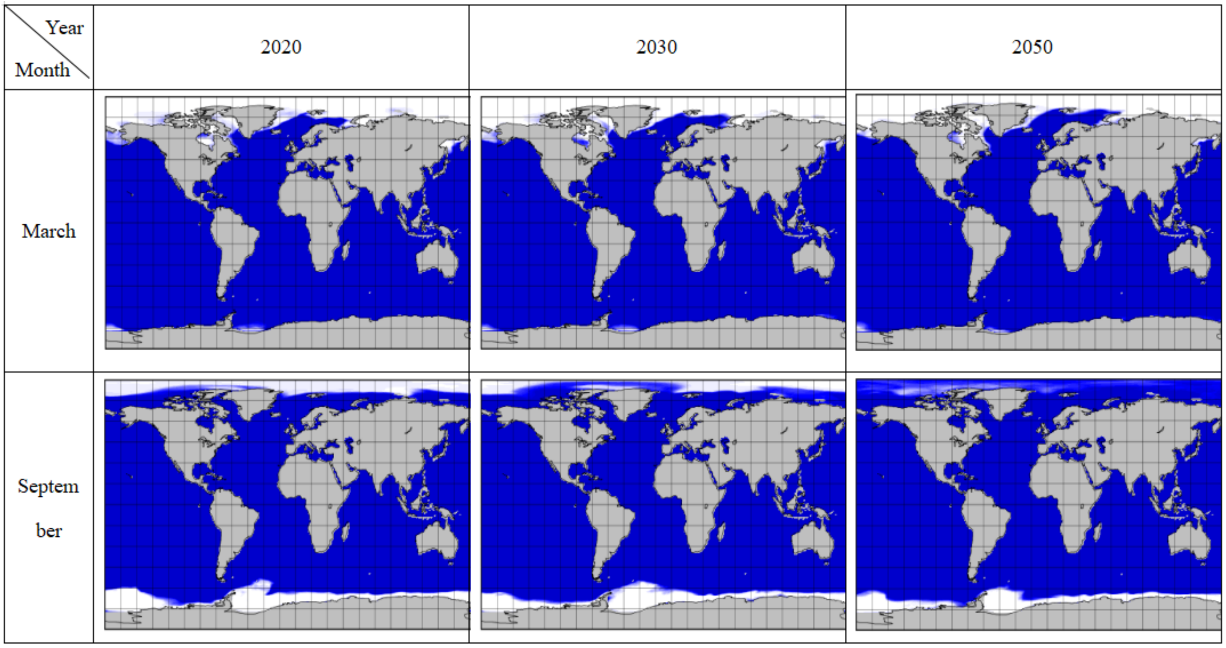

Figure 2: The comprehensive forecast results of arctic sea ice cover.

3.2 Container Shipping Cost

The cost of container shipping will take into account the cost of sea freight and rail transportation separately.

From the perspective of shipping companies, container shipping costs can be roughly divided into three categories: capital costs, operating costs and voyage costs.

Compared with shipping costs, the composition of railway transportation costs is simpler. The cost of container railway transportation is based on the main factors of production: labor cost, fuel cost, electricity cost, material cost and depreciation cost. Different from the shipping cost calculation method, the cost and calculation principles of railway transportation are relatively unified because the railway freight rates are generally formulated by the relevant state departments. Taking the " International Freight Association Specification for unified transit tariffs " and "Railway Freight Tariff Rules" as the billing basis for goods in global railway intermodal transport, the specific procedure for calculating transit freight is: first, according to the transport route recorded on the transport documents, in transit Find the corresponding transportation tariff mileage in the odometer. Usually, the transportation tariff mileage can be determined by the shortest route; The freight class and transit mileage can find out the specific rate; finally, the railway freight transportation cost is calculated according to the formula "total freight = container transportation rate × billable weight ×transit mileage".

3.3 Model

3.3.1 Assumptions

The following assumptions are made in this research model:

(1) Shipping companies do not own their own fleets, and all ships used for transportation are time-chartered from the chartering market.

(2) The types of goods are 20-foot or 40-foot ordinary containers (laden containers and empty containers), aiming at meeting the fixed needs of each port node and carrying out the deployment and transportation of laden containers and empty containers in the entire shipping network.

(3) When calculating the transportation cost, the shipping cost actually considered in this paper mainly includes: market rental cost, fuel cost, and container handling cost; railway transportation cost mainly includes basic transportation cost and additional cost; the cost of the virtual route is zero, not considered Transit costs for shipping network nodes.

(4) At the same time, considering the limited capacity of transportation routes, the passing capacity of the real port route is subject to the demand generated by the port, the passing capacity of other internal networks is assumed to be very large, and the passing capacity of the virtual route is based on its corresponding empty container remaining capacity and the missing amount.

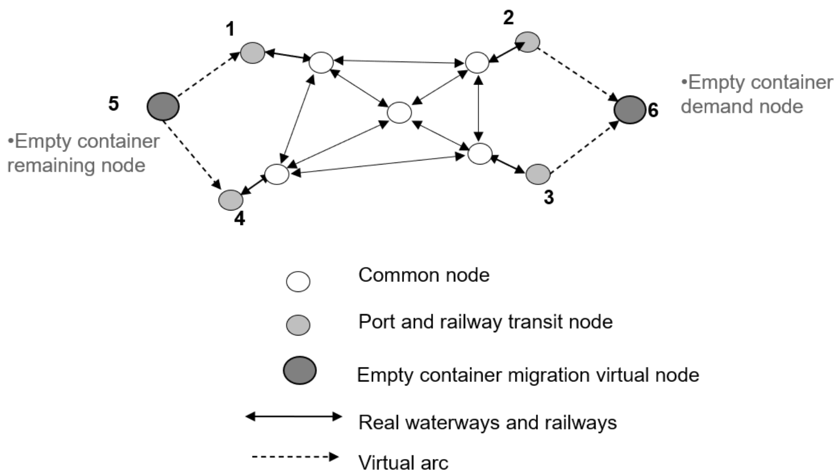

Figure 3: Network design for container shipping network.

As shown in Figure 3, taking from port 2 to 4 (cargo flow is 10) and from port 3 to 1 (cargo flow is 15) as an example, laden containers are transported from ports 2 and 3 to ports 4 and 1 through the shipping network respectively, At this time, ports 4 and 1 will generate a large number of empty containers, and ports 2 and 3 will lack empty containers, so empty containers need to be dispatched. Concentrate all empty box residuals to node 5 and all empty box demand to node 6 through a virtual arc (route cost 0), thereby establishing a normal Origin-Destination (OD) demand from 5 to 6, and setting virtual arc 5- 1 and 3-6 have a passing capacity of 15, and virtual arcs 5-4 and 2-6 have a passing capacity of 10.

3.3.2 Parameters

V : the set of all port nodes and railway nodes;

P : the set of all port nodes, including empty container remaining virtual nodes and empty container demand virtual nodes;

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P : the set of all port nodes, including empty container remaining virtual nodes and empty container demand virtual nodes, $P \subseteq V$;

$\underline{A}$: the set of all waterways ;

$\overline{A}$: the set of all railways ;

B : the set of all routes ;

K_f : type of laden container ;
K_e : type of empty container ;
O : the set of departure ports, $O \subseteq P$;
D : the set of destination ports, $D \subseteq P$;
y_f : volume sharing factor for laden containers k_f ;
y_e : volume sharing factor for empty containers k_e ;
h_{ij}^f : loading and unloading costs of laden containers k_f on route ij ;
h_{ij}^e : loading and unloading costs of empty containers k_e on route ij ;
d_i^f : net flow of laden containers k_f at node i ;
d_i^e : net flow of empty containers k_e at node i ;
u_{ij} : route capacity of ij ;
q_r^f : demand for laden containers k_f at node i ;
q_r^e : demand for laden containers k_e at node i ;
R_{ij}^f : shipping rates for laden containers k_f on route ij ;
R_{ij}^e : shipping rates for empty containers k_e on route ij
dis_{ij} : transport mileage on route ij ;
x_{ij}^f : the flow of laden containers k_f on route ij (decision variable) ;
x_{ij}^e : the flow of empty containers k_e on route ij (decision variable) ;

3.3.3 Mathematical Model

$$min = \sum_{(i,j)\in A} c_{ij}\left(\sum_{k_f\in K_f} y_f x_{ij}^f + \sum_{ke\in K_e} y_e x_{ij}^e\right) + \sum_{(i,j)\in A}\sum_{k_f\in K_f} h_{ij}^f x_{ij}^f + \sum_{(i,j)\in A}\sum_{k_e\in K_e} h_{ij}^e x_{ij}^e + \sum_{(i,j)\in A} v_{ij}\left(\sum_{k_f\in K_f} y_f x_{ij}^f + \sum_{ke\in K_e} y_e x_{ij}^e\right) + \sum_{(i,j)\in \bar{A}} R_{ij}^f x_{ij}^f dis_{ij} + \sum_{(i,j)\in \bar{A}} R_{ij}^e x_{ij}^e dis_{ij}. \tag{1}$$

$$\sum_j x_{ij}^f - x_{ji}^f = d_i^f, \forall i \in v, k_f \in K_f. \tag{2}$$

$$\sum_j x_{ij}^e - x_{ji}^e = d_i^e, \forall i \in v, k_e \in K_e. \tag{3}$$

$$\sum_{k_f\in K_f} y^f x_{ij}^f + \sum_{k_e\in K_e} y^e x_{ij}^e \le u_{ij}, \forall (\mathrm{i,j}) \in B. \tag{4}$$

$$\mathrm{x}_{\mathrm{ij}}^{\mathrm{f}} \ge 0, \forall (\mathrm{i,j}) \in \mathrm{B}. \tag{5}$$

$$\mathrm{x}_{\mathrm{ij}}^{\mathrm{e}} \ge 0, \forall (\mathrm{i,j}) \in \mathrm{B}. \tag{6}$$

$$d_i^f = \begin{cases} q_r^f, if\ i = r \in O \\ -q_r^f, if\ i = s \in O \\ 0, otherwise \end{cases} \tag{7}$$

$$d_i^e = \begin{cases} q_r^e, if\ i = r \in O \\ -q_r^e, if\ i = s \in O \\ 0, otherwise \end{cases} \tag{8}$$

The objective function (1) is the sum of the shipping cost and railway cost of container shipping, $c_{ij}(\cdot)$ and $v_{ij}(\cdot)$represent the cost function of ship chartering and voyage chartering cost function respectively, and the loading and unloading cost of laden and empty containers is represented by

$$\sum_{(i,j)\in A}\sum_{k_f\in K_f} h_{ij}^f x_{ij}^f + \sum_{(i,j)\in A}\sum_{k_e\in K_e} h_{ij}^e x_{ij}^e.$$

that is, the cost of shipping is the sum of the chartering cost, voyage cost and loading and unloading cost; the railway cost of laden and empty containers is represented by

$$\sum_{(i,j)\in \bar{A}} R_{ij}^f x_{ij}^f dis_{ij} + \sum_{(i,j)\in \bar{A}} R_{ij}^e x_{ij}^e dis_{ij}.$$

Equations (2) and (3) guarantee the residual flow at each node. Equation (4) limits each route to no more than the passing capacity of that route. Equations (5) and (6) restrict the decision variable from being negative, that is, the flow of goods on each route must be greater than or equal to zero. Equations (7) and (8) indicate that the node surplus at the port of origin and port of destination should meet the container demand at the port.

4 CASE STUDY AND SIMULATION

4.1 Container Transport Cost

In terms of shipping cost, this paper uses Panamax ships as the analysis basis in the research, assuming that the ship's economic speed is 20 knots and the maximum speed is 22 knots, and the calculation is based on full load. Shipping companies own ships in the form of market leasing, and use the charter market The price is regarded as the capital cost, excluding ship maintenance and insurance costs, only considering the operation and management cost of the route passing through the Panama Canal, which is 5,000 US dollars / day. In the voyage cost, this paper calculates the total fuel consumption based on the relationship between the fuel cost and the square of the speed, and then estimates the fuel cost per unit container; at the same time, it is assumed that the container handling fee is USD 50/TEU as the port operation fee.

The railway cost is calculated according to the formula "Total freight = container transportation rate\times billable weight\times transit mileage". The transit mileage is calculated based on the shortest route between two nodes of the global railway network; different transportation rates are set for each continent; according to the container size standard, the weight of a 20-foot container is converted to 22 tons, and the weight of a 40-foot container is 27 tons.

4.2 Container Transport Network Data

In order to realize the optimization and simulation of cargo flow distribution in the global container shipping network, it is first necessary to build a global container shipping network. In this paper, ports and railway transfer stations are used as nodes to establish a global container shipping network. At the same time, two major Arctic route, the Northeast route and the Northwest route, are added to the network. The results are shown in Figure 4.

Secondly, the entire network is topologically obtained to obtain the specific distance of the route between the nodes, and the radian formula is used for further processing to avoid the error between the calculation result and the actual sailing distance of the ship. Finally, data such as container demand, route distance, and route throughput capacity of major ports around the world are stored in the global container transportation network. In order to study the cargo flow distribution of empty containers at the same time, we establish a two-way container transportation network, and further analyze the flow distribution of cargo flow between two nodes through the east-bound and west-bound network.

4.3 Simulation Process

The simulation process is shown in Figure 5.

Step0: Clear the data and establish a global container shipping network based on the current global shipping network route and container demand between ports. In the initial step of the simulation, the Arctic sea ice coverage in March 2020 was used as the initial state, and the time interval was 6 months. Based on the temporal changes in Arctic ice melt, at each time step, the system generates Arctic sea ice cover based on forecast data.

Step 1: According to the location of the Arctic route and the sea ice coverage, determine whether the Arctic route is blocked by sea ice. If it is blocked, go to Step 2, otherwise it is proved that the Arctic route can be navigable normally, and go to Step 1 until all Arctic routes are judged, then go to Step 3.

Step2: Since this Arctic route is covered by sea ice and cannot be navigated normally, this route is deleted from the system and a new container transportation network is generated.

Step3: According to the established cargo flow distribution model, carry out the cargo flow distribution of empty containers and laden containers respectively. See the specific optimization process in the dotted box. Until the demand for empty containers and laden containers between all ports reaches an equilibrium state, output the cargo flow distribution results under the Arctic sea ice cover at this time, and go to Step 4.

Step4: Determine whether the system time has reached the forecast period (September 2050). If it does not reach the expected time node, go to Step 0. Otherwise, the distribution results of the cargo flow in all forecast periods of the system have been output.

4.4 Realization of Simulation

According to the above model, data and process, this paper uses Microcity to realize the optimization and simulation of the cargo flow distribution model. After writing the program to calculate the transportation cost and establish the cargo flow distribution model, by setting the relevant options, you can directly see the final cargo flow distribution result in the grid interface, or observe the output data from the Messages interface, shown in Figure 6. The data settings of the cargo flow assignment model can be operated on interfaces such as Workspace and Flow Assignment.

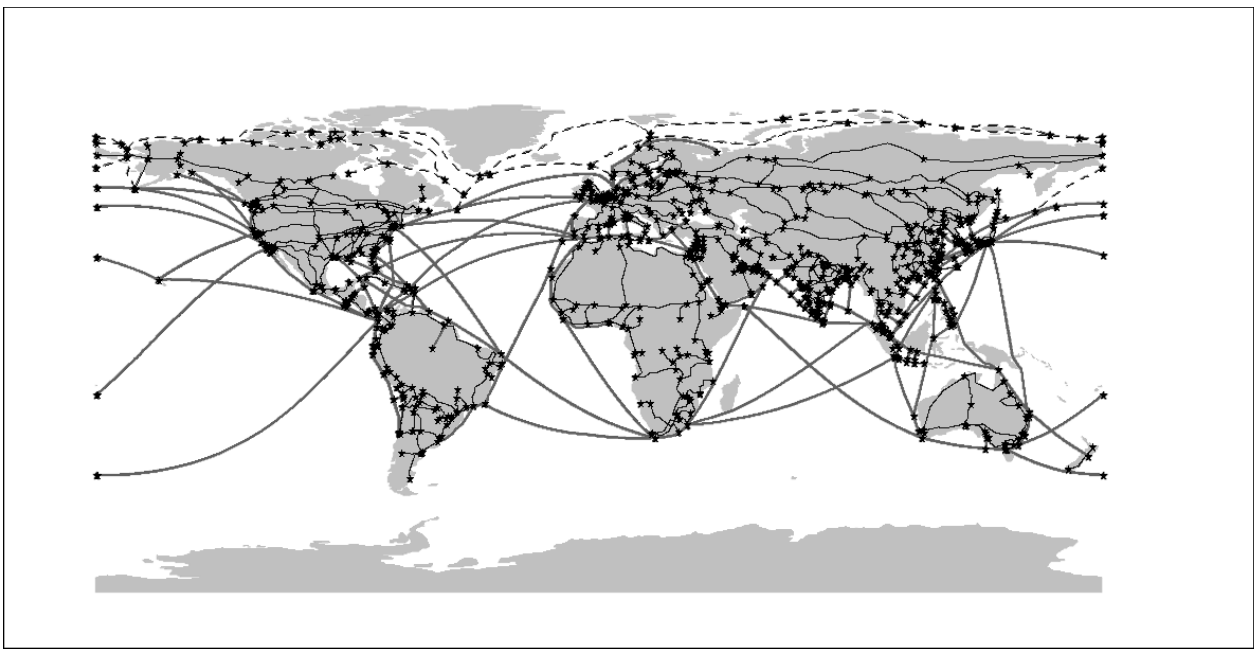

Figure 4: Global container shipping network.

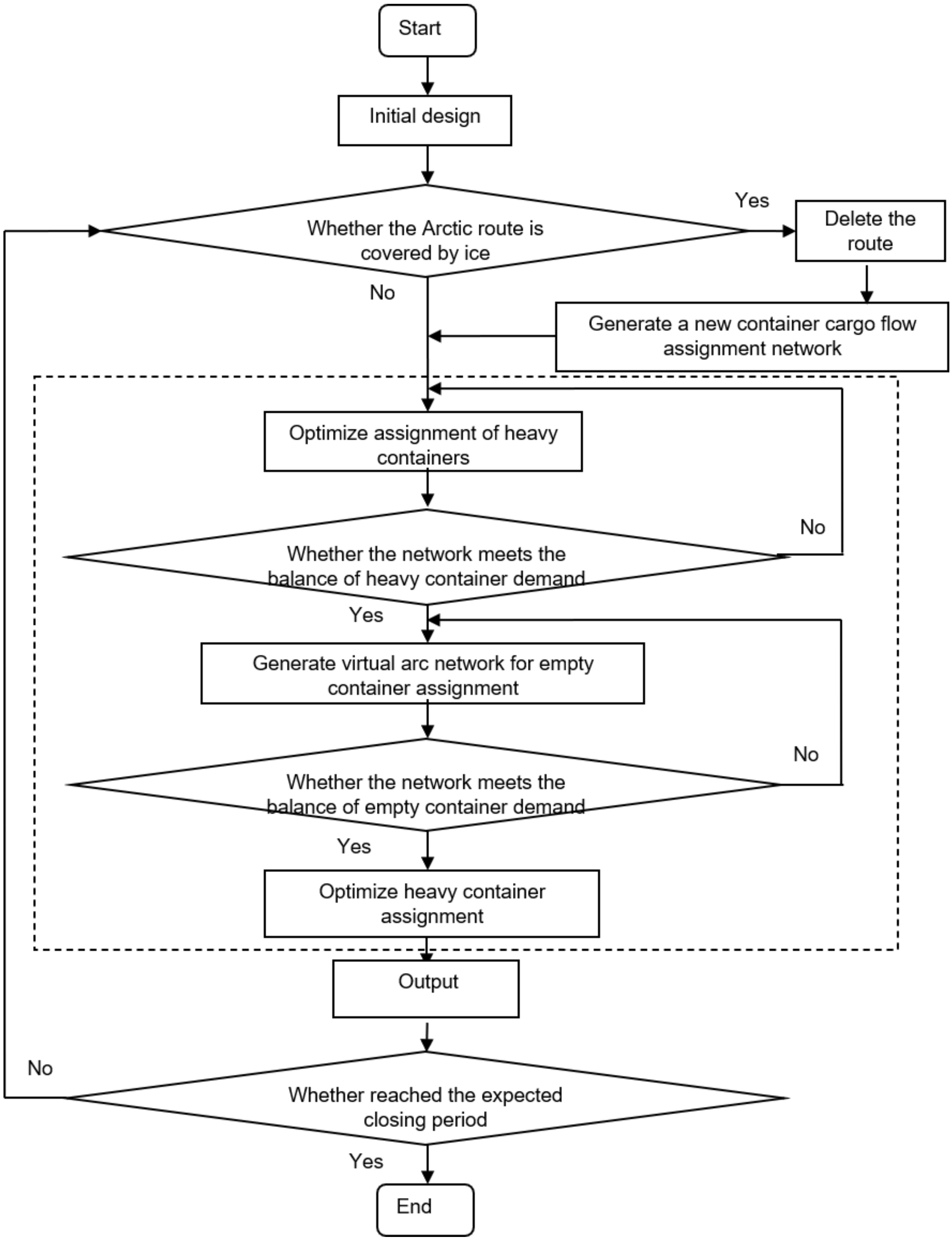

Figure 5: The simulation process flowchart.

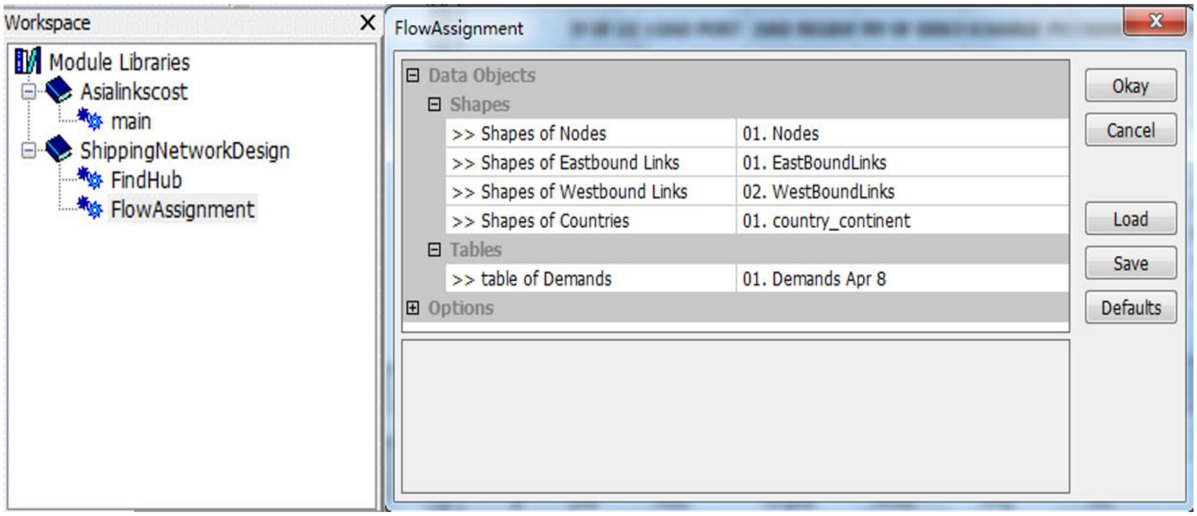

Figure 6 : The simulation interface.

4.5 Results

After optimizing and simulating the cargo flow distribution model, we obtained the cargo flow distribution results of the global container shipping network (Figure 7). The thickness of the purple lines indicates the volume of the cargo flow. According to the result data, after the Arctic route is fully navigable, the northeast route and the northwest route will share about 4% of the global container cargo flow. In addition, comparing the cargo flow distribution results without considering the Arctic route (Figure 7), it can be clearly observed that the Arctic route Its opening will affect the cargo flow distribution of traditional routes, especially the cargo flow distribution of East Asia-Europe routes and Asia-North America routes through the Strait of Malacca, the Strait of Bab and the Suez Canal will be greatly affected; in terms of railway transportation, the Arctic route will be greatly affected. The full opening has little impact on the distribution of freight flow of the railway transport network, but the container railway freight flow of the Eurasian Land-Bridge is still slightly weakened.

In the results, 34% of the routes in the global container transport network experienced a reduction in cargo flow following the opening of the Arctic route. Of these routes, 9% are those with a reduction of more than 90% in cargo flow, 10% are those with a 60%-90% reduction, 4% are those with a 40%-60% reduction, and 10%-40% are reduced 23%, and 54% were less than 10%, which is shown in Figure 8.

5 CONCLUSION

To sum up, this study quantitatively analyzes the melting of Arctic sea ice in the future, builds a cargo flow distribution model for the container shipping network, and studies the impact of the opening of Arctic shipping routes on the global container shipping cargo flow distribution through optimization and simulation of the model. Through the establishment of a virtual arc network, the dispatch of empty containers is taken into account, and the distribution of goods flow that meets the needs of laden containers and empty containers at the same time is realized. Our results clarify two main points: first, the opening of the Arctic route will have a relatively obvious impact on the cargo flow of the routes passing through the Strait of Malacca and the Suez Canal; There will also be a downward trend.

In addition, this study did not consider the passage capacity of waterways, such as the passage capacity of the Arctic route and the narrow waterways it passes through. Indeed, these factors are necessary for further research. For the calculation of container shipping cost, this study only considers the chartering cost, fuel cost, and loading and unloading cost of shipping, while railway convenience only considers the basic cost and additional cost, and further refinement of the classification of transportation cost can bring the final result closer In practice, there is greater persuasiveness, thereby solving practical problems.

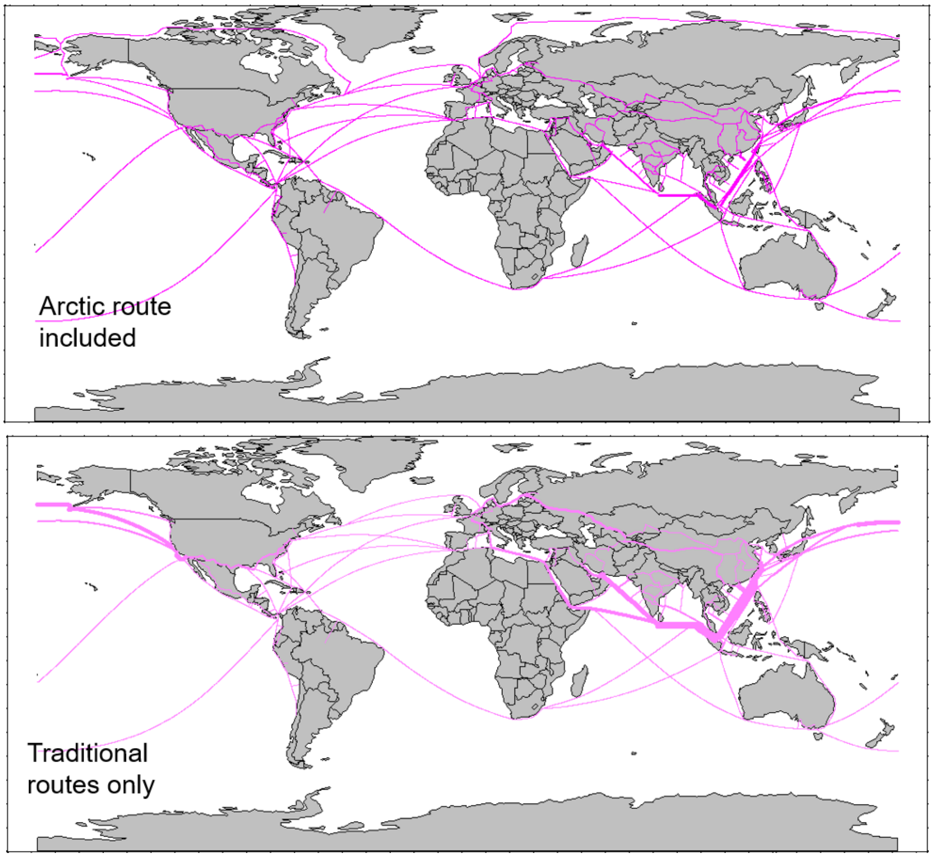

Figure 7: The simulation results of container cargo flow assignment.

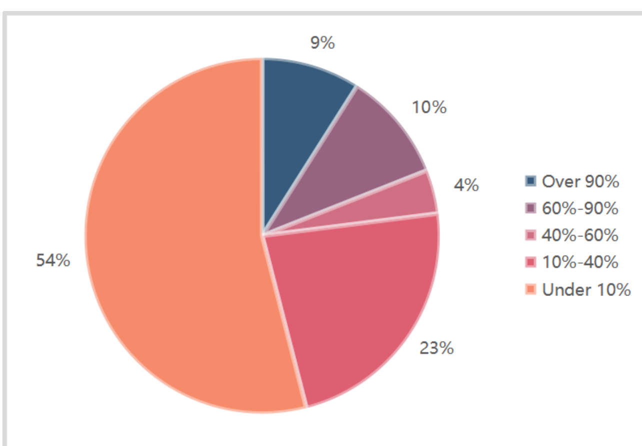

Figure 8: The percentage of traditional routes with different reduced cargo flow.

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REFERENCES

Chai, W. , B. J. Leira, K. V. Høyland, C. Sinsabvarodom, and Z. Yu. 2020. "Statistics of Thickness and Strength of First-year Ice along the Northern Sea Route". *Journal of Maritime Science and Technology* 26(2):331-343.

Gao, S., X. Xu, C. Li, Y. Liu, and K. Chen. 2022. "Container Ocean Shipping Network Design Considering Carbon Tax and Choice Inertia of Cargo Owners". *Ocean & Coastal Management* 216:105986.

Lee, E., P. G. Oduor, K. Farahmand, and D. Tolliver. 2014. "A Coupled Linear Programming Model with Geospatial Dynamic Trip Assignment for Global-scale Intermodal Transportation". *Maritime Economics & Logistics* 16(1): 33-54.

Lefebvre, W. and H. Goosse. 2008. "Analysis of the Projected Regional Sea-ice Changes in the Southern Ocean During the Twenty-first Century". *Climate Dynamics* 30:59-76.

Li, L., R. R. Negenborn and B. D. Schutter. 2014. "Receding Horizon Approach for Container Flow Assignment in Intermodal Freight Transport". *Transportation Research Record* 2014:132-140.

Soehodho, S. and Nahry. 2010. "Traffic Flow Consideration in Design of Freight Distribution System". *IATSS Research* 34:55-61.

Stocker, T., D. Qin, and G. Plattner. 2013. "Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change ". Climate Change 2013: The Physical Science Basis，Cambridge University Press, Cambridge, United Kingdom.

Sun, Z., and J. Zheng. 2016. "Finding Potential Hub Locations for Liner Shipping". *Transportation Research Part B* 1(12):1-12.

Wang, D., R. Ding, Y. Gong, R. Wang, J. Wang, and X. Huang. 2020. "Feasibility of the Northern Sea Route for Oil Shipping from the Economic and Environmental Perspective and Its Influence on China's Oil Imports". *Marine Policy* 118:104006.

Yang, Q., L. Mu, X. Wu, J. Liu, F. Zheng, J. Zhang, and C. Li. 2019. "Improving Arctic Sea Ice Seasonal Outlook by Ensemble Prediction Using An Ice-ocean Model". *Atmospheric Research* 227:14-23.

AUTHOR BIOGRAPHIES

ZHUO SUN has his beginnings in Dalian, which is known for its thriving port. Having finished a dual bachelor's degree in civil engineering and computer science from the Dalian University of Technology, he decided to travel East Asia in pursuit of knowledge. He went to South Korea for his master's course in the field of water resources and then went to Japan's Nagoya University to finish his PhD focusing on spatial analysis of urban systems. Early in his undergraduate studies it dawned on him to develop a software tool that would help analyze transport systems. The following years served as an incubation period for his idea and after almost ten years of contemplation and devotion to hard work, his idea was finally realized as 'Microcity'. He now carries with him the innovative spirit working as an adjunct research fellow in the National University of Singapore's (NUS) Centre for Maritime Studies doing research on shipping network design, port planning and port operation. His e-mail address is mixwind@gmail.com.

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