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Research Article

Joint Optimization of a Dry Port with Multilevel Location and Container Transportation: The Case of Northeast China

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Dry port construction can reduce the cost of container transportation, and its location is the focus of existing research. Considering dry port capacity limitations and scale advantages, this study calculates the costs associated with dry port construction and operations, transportation, time, and the environment and constructs a joint optimization model of the dry port location and transportation scheme to minimize the total cost. Taking 35 prefecture-level cities in Northeast China as the source of container goods and Dalian port as the destination, this study conducts an empirical analysis using the Gurobi 9.0.2 optimizer of the AMPL software to solve the problem and takes the minimum total cost as the goal to select the best dry port and container transshipment scheme. The research draws the following conclusions. Seven dry ports also need to be built in the road-rail (RD-RL) mode, which shares 82.76% of the container transshipment volume, to reduce the total transportation cost by approximately 21.67%. Although multimodal transport through dry ports increases the time cost slightly, it can significantly reduce the economic and environmental costs of container transportation.

1. Introduction

In the process of economic and social development, the deployment and optimization of Cyber-Physical Systems play an increasingly important role. Power system, pipeline network, and transportation network are important components of Cyber-Physical Systems. Some achievements of energy system and pipeline network [1–3] provide a new idea for the study of connectivity reliability of urban transportation network. The joint optimization model proposed in this study solves the optimization problem of transportation network, which can be used as reference for other physical network optimization such as power system or pipe network. Similar to other networks, inland container transportation network has the structural characteristics of a complex network. However, the spatial entity of transportation network makes it different from an abstract network such as the social network, which is especially apparent in inland container transportation network. Due to the uncertainty of construction conditions, grade of dry port, freight demand, and transshipment scheme, the joint optimization of dry port selection and container transshipment presents additional complexity.

Dry ports can optimize the inland transportation system by reducing container transportation costs, alleviating port congestion, expanding the hinterland of the seaport, and providing convenient services for shippers (such as customs declaration) [4, 5]. Moreover, some studies have confirmed that dry ports have significant effects in reducing carbon dioxide emissions, transportation costs, and waiting time for container trucks [6–8]. Dry ports can also effectively integrate various inland transportation methods and nodes, improve the efficiency and benefits of inland cargo transportation, and promote the rapid development of inland container multimodal transportation [9]. With rapid globalization and developments in international trade, the container throughput of China's coastal ports has greatly expanded, reaching 261.07 million TEU in 2019 [10]. Reductions of cost, energy consumption, and carbon emissions of inland container transportation contribute to the sustainable development of the Chinese economy, especially to the logistics industry [11]. In addition, there is a negative decoupling between China's economic development and freight demand, and there is a limit to the growth of freight demand [12]. With the growth of gross domestic product (GDP), freight demand remains stable or even declines [12], and China's seaports are bound to face increasing competition for supply in the future.

As a hub in the transportation network, the role and value of the dry port depend on its location advantages. A reasonably located dry port can attract enough goods in the inland areas and achieve economies of scale through a combination of rail and road transport. On the contrary, problems such as overcapacity, waste of resources, low efficiency and utilization, and low rate of return on investment may occur in poorly planned dry ports. Moreover, the construction of a dry port requires a large amount of capital investment; once it is completed, it can hardly be relocated, and the sunk cost is high [13]. More than 150 dry ports were built in China by December 2019 (according to the data collected from Statistics). Most of them are not connected by railways, and some even lack the function of customs clearance. The throughput of goods is not consistent with the input of resources, and the efficiency of these dry ports is low [14]. As an important logistics node in the inland container transportation network, the location layout, scale, quantity, and service area of the dry port have important contributions to the efficiency of the entire transportation chain. This study measures the economic and environmental benefits of developing a dry port, considers the dry port's carrying capacity, sets up its construction and operational costs at different scale levels, quantifies the time and carbon emission costs, builds the location model of the dry port, seeks the optimal scheme of inland container transportation, and takes Northeast China as an example. Based on the freight distribution of the foreign trade container volume, the optimal number of dry ports, location layout, service scope, and transportation scheme of the region are obtained to prove the effectiveness of the model.

2. Literature Review

2.1. Optimization of Container Transportation

2.1.1. Optimization of Transportation Mode, Route, and Node. The main goal of related research is cost minimization, and the research methods mainly include (multiple) goal, mixed integer, and bi-level programming models. Jeong et al. [15] established a linear integer programming model with objective functions, including operation and transportation time costs, to reveal the potential hub location, and Wang and Yun [16] studied the container transportation problem with time windows under truck and train transportation modes. Demir et al. [17] proposed a green multimodal transport service network design problem with uncertain freight transport time window and demand and, using the sample average approximation method, provided a flexible, reliable, and environmentally friendly alternative for long-distance transportation of large quantities of goods. Wang et al. [18] studied the modeling and optimization of a combined highway-railway transportation system embedded in a hub spoke network under uncertainty and proposed a fuzzy biobjective optimization method that minimizes the expected value of the total cost and the maximum time demand on the critical value, so as to optimize the combined highway-railway transportation mode. Zhao et al. [19] established a two-stage model of combined positioning and path planning to locate a river hub port and dry port with the objective of minimizing total transportation cost.

2.1.2. Optimization of a Dry Port-Seaport Network. Most of the related research considers carriers, seaports, dry port operators, and cargo owners and integrates economic, social, and environmental factors to maximize the interests of all parties, so as to optimize the dry port-seaport network. Wang et al. [20] studied the location of a dry port considering the interaction between the port and hinterland, comprehensively considered the relationship among the dry port, seaport, and regional logistics system, and optimized the configuration of the dry port system. Chang et al. [21] considered the carrying capacity limitation of the dry port, constructed a two-stage multicapacity-level dry port location model with the objective of minimizing construction and transportation costs, and optimized the layout and freight demand distribution of the dry port in Northeast China. The game theory method is also introduced into the optimization of dry port–seaport network [22–25]. Wei and Dong [26] applied the biobjective, mixed integer programming model to study a new type of cross-border logistics network connecting the marine logistics network with the inland cross-border logistics network through the dry port, and discussed the organization optimization of inland import and export goods under different network scenarios. Tsao and Thanh [27] used a multiobjective hybrid robust possibilistic flexible programming method to determine the optimal number, location, and capacity of dry ports. Van Nguyen et al. [13] combined data mining and complex network theory and used a two-stage optimization method to determine the location and service area of a dry port in a large-scale inland transportation system.

2.2. Cost Accounting of Container Inland Transportation. In recent years, the concept of sustainable development has been deeply rooted in the hearts of people, and transportation demand has become increasingly diversified. Environment, time, and social costs are becoming increasingly important in the optimization of inland container transportation [28]. As the dry port becomes the key hub of the inland container transportation network, the construction and operation costs of the dry port get included in the comprehensive cost of inland container transportation. O'Kelly [29] proposed a hub location model considering the fixed cost of infrastructure, added the fixed cost to the single allocation hub location problem, and optimized the p-hub location model with the number of hubs as the decision variable. Janic [30] proposed a comparable internal and external comprehensive cost model, and discussed the influence of the policy of internalizing external transport costs on the future competition between intermodal transport and road freight networks. Zhang et al. [31] internalized CO_2 emission cost and optimized the network configuration for different CO_2 prices. Chang [32] established a total cost optimization model including fixed and transportation costs. Pekin et al. [33] considered the impact of cargo types on time value, established a total cost function including multimodal transport market price and container time value, and improved the multimodal transport terminal location analysis model. Rahimi et al. [34] developed a multiobjective, multimodal queuing system considering traffic congestion and the maximum carrying capacity of the hub to analyze the waiting time of flow units in a transportation hub; this system was used to solve the multiobjective hub location problem of hub congestion. Wei and Dong [26] used comprehensive costs, including economic, environmental, and social costs, to study the long-term sustainable development of the dry port network.

Previous studies on the locations of dry ports have many achievements (Table 1). Based on previous studies, this study uses a technical and economic method to convert the construction cost of the dry port by year, brings the operation and time costs of the dry port into the comprehensive cost, optimizes the calculation of container road transportation cost, and considers the scale effect of railway transportation, as well as the capacity level of the dry port and the conditions of urban construction of the dry port, so as to make the joint optimization model of the dry port location and transportation scheme closer to the actual problems. Then, taking China's northeast region as the empirical object, the empirical calculation is carried out, and the solution is solved using the AMPL software Gurobi 9.0.2 optimizer. The cargo flow distribution of container cargo is examined with regard to when it can be split or not under three transport modes: road transport, intermodal road-rail-road transport, and intermodal road-rail transport; the total cost of container transport under different transport scenarios are discussed, and the scale, location layout, and service scope of dry port construction when the total cost is optimal are determined, so as to realize the optimization of dry port location and inland container transport.

3. Problem Description

The joint optimization problem of the dry port location and transportation scheme studied in this paper is a two-stage and three-level inland container transportation network (Figure 1) optimization problem, which is composed of shippers, dry ports, and seaports. In this network, there are three modes of transportation: the first mode is intermodal road-rail transport (RD-RL mode), in which containers are transported from the shipper to the dry port by road, and then transported from the dry port to the seaport by rail. The second mode is intermodal road-rail-road transport (RD-RL-RD mode). In reality, some dry ports lack railway facilities that are directly connected with the seaport and thus need road trucks to transport containers from the seaport city railway station to the seaport wharf. The third mode is road transport (RD mode), in which the containers are directly transported from the shipper to the seaport.

For the inland container transportation network, $\mathrm{Net} = (\mathrm{Nd}, E)$, where Netrefers to the inland container transportation network and $\mathrm{Nd} = \left\{\mathrm{Nd}^1, \mathrm{Nd}^2, \mathrm{Nd}^3\right\}$ represents the transportation node. There are three types of nodes in the network: $\mathrm{Nd}^1 = \left\{\mathrm{Nd}_i^1, i = 1, 2, 3, \ldots, I\right\}$ refers to the node of the shipper city$I$; $\mathrm{Nd}^2 \subseteq \mathrm{Nd}^1 = \left\{\mathrm{Nd}_j^2, j = 1, 2, \ldots, J\right\}$ refers to the node of the dry port city J; and the dry port node is generated in the shipper city node. $\mathrm{Nd}^3 = \left\{\mathrm{Nd}_k^3, k = 1\right\}$ represents the only seaport node, and $E$is the arc between the nodes $\mathrm{Nd}^1, \mathrm{Nd}^2$, and Nd^3, which are different modes of transportation. $E_{ijk} = \left\{\mathrm{Nd}_i^1, \mathrm{Nd}_j^2, \mathrm{Nd}_k^3\right\}$ is the arc that refers to road rail transportation through the dry port. $E_{ik} = \left\{\mathrm{Nd}_i^1, \mathrm{Nd}_k^3\right\}$ is the arc that means the road is directly transported.

4. Formulation

4.1. Model Assumptions

(1) The total cost of the inland container transportation network includes the construction, operation, and logistics (transportation economic, time, and carbon emission) costs of the dry port.

(2) Under the corresponding construction level, the container transfer capacity limits, fixed construction cost, annual operation cost, recommended scale range, storage waiting time, and discount coefficient of the scale effect of rail tariff are known.

(3) The foreign trade volume of containers in node cities, namely, freight demand, is known (dry ports are generated in shipper city nodes).

(4) The containers are transferred once through a single dry port.

(5) Without considering the transport capacity constraints in the freight transportation process, sufficient road passing capacity and sufficient railway trains are assumed.

(6) During container transport, trucks and trains travel at a known average speed.

(7) The container transport in the inland container transport network is a one-way transport, and only the process of transporting containers from the shipper to the seaport is studied; reverse transportation is not considered.

(8) A 20-foot box is the object of study, and the total weight of the container is set at 24 tons according to the standard set by ISO/TC104.

(9) The maximum level limit of dry ports that can be built in different cities is known.

4.2. Model Formulation. The parameters and variables in cost accounting and model construction and their meanings are listed in Table 2.

Taking the minimum total cost of inland container transportation as the objective function, this study

Table 1: Summary of the literature on dry port location problem.

	Global perspective	Grade constraint	Factors to be considered				Construction cost	Road cost function		Problem size		Method
			Economy	Environment	Social	Time		Linear	Subsection	Medium	Large	
Feng et al.(2013)			√				√	√		√		Greedy algorithm; genetic algorithm
Chang Zheng et al (2017)		√	√				√	√		√		MCHLP; genetic algorithm
Zhang et al.(2018)			√			√	√	√		√		Game-theoretical; logit discrete selection
Tsao and Linh (2018)	√		√	√	√		√	√		√		Continuous approximation; game theory
Xu et al.(2018)			√	√		√		√		√		Game-theoretical; logit discrete selection
Tsao and Thanh (2019)		√	√	√	√		√	√		√		MOMRPFP
Zhao et al.(2019)	√		√			√		√		√		Two-stage planning model
Van Nguyen et al.(2020)	√										√	Data mining; complex network
This paper	√	√	√	√		√	√		√	√		MCHLP; AMPL

"Global perspective" does not specify the alternative dry port cities, but directly determines the location of dry port from the city nodes. "Problem size" refers to the size of the studied dry port network, which is classified as medium-scale if the study focuses on regional-level network and as large-scale if the focus is on the nationwide network.

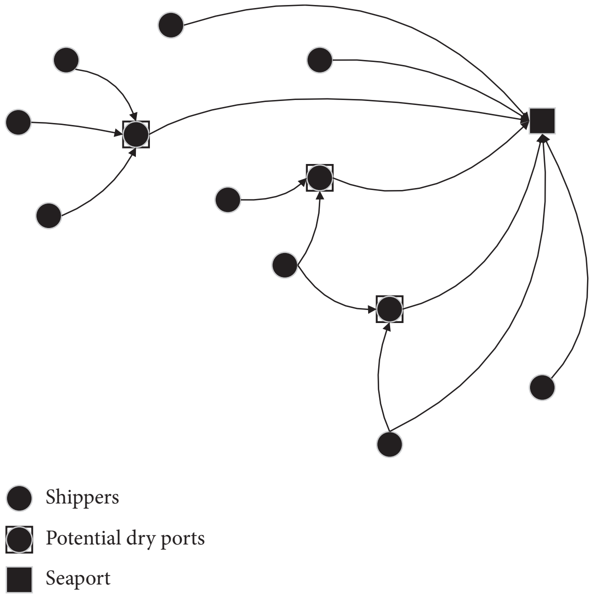

Figure 1: A simple diagram of an inland container transportation network.

Table 2: The parameters and variables and their meanings.

Symbol	Category	Meaning
I	Indices	Set of shippers
J	Indices	Set of candidate locations of dry ports
G	Indices	Set of capacity levels for dry ports
f_b	Parameters	The total cost of opening a dry port with capacity level b (USD)
s	Parameters	Investment payoff period for dry port construction (year)
u	Parameters	Capital discount rate (percentage)
r_g	Parameters	The cost of operating a dry port with capacity level g per year (USD)
C_{ij}^{rd}	Parameters	Economic cost of container transport from shipper i to dry port j by road (USD)
C_{jk}^{rl}	Parameters	Economic cost of container transport from dry port j to seaport k by railway (USD)
C_{kk}^{rd}	Parameters	Economic cost of container transportation from the rail station in the seaport city to seaport k by road (USD)
L_{ij}^{rd}	Parameters	Distance of transport from shipper i to dry port j by road (km)
L_{jk}^{rl}	Parameters	Distance of transport from dry port j to seaport k by rail (km)
L_{kk}^{rd}	Parameters	Distance of container transport from the railway station in the seaport city to seaport k by road (km)
P^1	Parameters	Base price of railway delivery (USD)
P^2	Parameters	Base price of railway operation (USD)
P^3	Parameters	Container usage fee (USD)
P^4	Parameters	Container cleaning fee (USD)
P^5	Parameters	Container handling charges (USD)
P^6	Parameters	Unloading charges of containers in the yard (USD)
disc_g	Parameters	Discount coefficient of the dry port with capacity level g
W	Parameters	The price of transport per container from the rail station in the seaport city to seaport s by road (USD per TEU)
L_{ik}^{rd}	Parameters	Distance of transport from shipper g to seaport s by road (km)
C_{ij}^{rdt}	Parameters	Time cost of container transport from shipper i to dry port j by road (USD)
C_{jk}^{rlt}	Parameters	Time cost of container transport from dry port j to seaport k by rail (USD)
C_{kk}^{rdt}	Parameters	Time cost of container transport from the rail station in the seaport city to seaport k by road (USD)
t_g	Parameters	Cargo storage time at the dry port with capacity level g (day)
V	Parameters	Average value of the cargo per container (USD)
R	Parameters	Current deposit interest rate (percentage)
v^{rl}	Parameters	Average speed of container transport by rail (km per hour)
v^{rd}	Parameters	Average speed of container transport by road (km per hour)
DN	Parameters	365, the number of days in a year
HN	Parameters	24, the number of hours in a day
C_{ij}^{rdc}	Parameters	Carbon dioxide emission cost of container transport from shipper i to dry port j by road (USD)
C_{jk}^{rlc}	Parameters	Carbon dioxide emission cost of container transportation from dry port j to seaport k by railway (USD)

Table 2: Continued.

Symbol	Category	Meaning
$C_{kk}^{r\,dc}$	Parameters	Carbon dioxide emission cost of container transport from the railway station in the seaport city to seaport s by road (USD)
E^{rl}	Parameters	Carbon dioxide emissions per container per distance by rail (kg eq per container per km)
$E^{r\,d}$	Parameters	Carbon dioxide emissions per container per distance by road (kg eq per container per km)
E^{rr}	Parameters	Carbon dioxide emissions per container of road and rail transshipment handling (kg eq per TEU)
T^c	Parameters	Unit cost of carbon dioxide emissions handling in the outside market (USD per kg eq)
n	Parameters	$\begin{cases} 2, & \text{RD}-\text{RL}-\text{RD mode}, \\ 1, & \text{RD}-\text{RL mode}. \end{cases}$
Cap_g	Parameters	Capacity of the dry port with capacity g (TEU)
H_j	Parameters	The highest level of the dry port that the candidate dry port city j can build
M	Parameters	1,000,000,000, a large enough number
Q_i	Parameters	Volume of containers transported from shippers $i \in I$
y_{jg}	Decision variables	$\begin{cases} 1, & \text{if dry port } j \text{ with capacity level } g \text{ is opened}, \\ 0, & \text{otherwise}. \end{cases}$
x_{ij}	Decision variables	Whether containers are transported from shippers $i \in I$to candidate dry ports $j \in J$
q_{ij}	Decision variables	Volume of containers transported from shippers $i \in I$to candidate dry ports $j \in J$

establishes a model of a dry port location with multiple capacity levels. The total transportation cost, C, is composed of the annual dry port construction cost C^c, dry port operating cost per year C^o, and comprehensive transportation cost C^{lc}, which can be expressed as

$$C = C^c + C^o + C^{lc}. \tag{1}$$

4.2.1. Annual Construction Cost of Dry Port C^c. Assuming that the present value of investment is f, the benchmark rate of return on investment is$u$, and the construction calculation period of the project is $s$years, then the capital recovery annuity is$f \times u/[1 - (1+u)^{-s}]$, and $f \times u/[1 - (1+u)^{-s}]$is the annual capital recovery coefficient [35], from which the annual construction cost of grade g dry port can be obtained:

$$C^c = \sum_{j\in J} \sum_{g\in G} f_g y_{jg} \frac{u(1+u)^s}{(1+u)^s - 1}. \tag{2}$$

4.2.2. Operating Cost of Dry Port C^o. The operating cost of the dry port refers to the costs directly related to the operation of the dry port or related to the labor services provided by the dry port, including direct material expenses, direct labor costs, and indirect costs of operation and management. Transshipment is the main service provided by dry ports. In this study, the cost of transshipment between road and rail transport that occurs in dry port transshipment is classified as part of the operating cost of dry ports.

$$C^o = \sum_{j\in J} \sum_{g\in G} r_g y_{jg}. \tag{3}$$

4.2.3. Comprehensive Transportation Costs of Inland Containers C^{lc}. The comprehensive transportation cost of inland containers comprises transportation, time, and environmental costs.

This study assumes that the scale effect of a dry port is reflected in the economic cost of railway transportation. The larger the level of the dry port, the smaller is the discount coefficient of the scale effect. The market-oriented degree of container road transportation is high; thus, there is no clear formula to determine its price. Assuming that the container freight from the railway station to the seaport in the seaport city is constant (W), and the rest of the road freight is a function of the road transportation distance $f(L)$, the specific functional relationship needs to be calculated by collecting the actual data. The economic cost of container transport through dry port transshipment is

$$\begin{aligned} C^{dp} &= \sum_{i\in I} \sum_{j\in J} C_{ij}^{rd} + \sum_{j\in J} \sum_{i\in I} \sum_{g\in G} C_{ij}^{rl} + (n-1) \sum_{i\in I} \sum_{j\in J} C_{kk}^{rd} \\ &= \sum_{i\in I} \sum_{j\in J} f\left(L_{ij}^{rd}\right) q_{ij} + \sum_{j\in J} \sum_{i\in I} \sum_{g\in G} \left[\left(P^1 + P^2 L_{jk}^{rl} + P^3 + P^4 + P^5 + P^6\right) q_{ij}\right] \text{disc}_g + (n-1) \sum_{i\in I} \sum_{j\in J} W q_{ij}. \end{aligned} \tag{4}$$

The economic cost of container transportation for direct road transport is

$$C^{r\,d} = \sum_{i\in I} \sum_{j\in J} f\left(L_{ik}^{rd}\right)\left(Q_i - q_{ij}\right). \tag{5}$$

In this study, the time cost of transportation is expressed using the current interest that can be generated by the value of the freight in the container during transportation for the corresponding time. The time cost of container transport through dry port transit is calculated as

$$\begin{aligned} C^{dpt} &= \sum_{i\in I}\sum_{j\in J} C_{ij}^{rdt} + \sum_{j\in J}\sum_{i\in I}\sum_{g\in G} C_{jk}^{rlt} + \sum_{i\in I}\sum_{j\in J} C_{kk}^{rdt} \\ &= \sum_{i\in I}\sum_{j\in J} \frac{L_{ij}^{rd}}{\mathrm{DN}\cdot v^{rd}\cdot \mathrm{HN}} \mathrm{VR}\, q_{ij} + \sum_{j\in J}\sum_{i\in I}\sum_{g\in G} \frac{1}{\mathrm{DN}}\left(\frac{L_{jk}^{rl}}{v^{rl}\cdot \mathrm{HN}} + t_g\right)\mathrm{VR}\, q_{ij} + \sum_{i\in I}\sum_{j\in J} \frac{L_{kk}^{rd}}{\mathrm{DN}\cdot v_{rd}\cdot \mathrm{HN}} \mathrm{VR}\, q_{ij}. \end{aligned} \tag{6}$$

The container transportation time cost of direct road transportation is

$$C^{rdt} = \sum_{i\in I}\sum_{j\in J} \frac{L_{ik}^{rd}}{\mathrm{DN}\cdot v^{rd}\cdot \mathrm{HN}} VR\left(Q_i - q_{ij}\right). \tag{7}$$

In this study, the carbon tax to be paid for CO_2 emissions is used to express the environmental cost, which depends on the amount of CO_2 emissions during the transportation, loading, and unloading of containers. The carbon emission cost of container transportation by dry port transshipment is

$$\begin{aligned} C^{dpc} &= \sum_{i\in I}\sum_{j\in J} C_{ij}^{rdc} + \sum_{j\in J}\sum_{i\in I} C_{jk}^{rlc} + C_{rdc}^{ss} \\ &= \sum_{i\in I}\sum_{j\in J} E^{rd} L_{ij}^{rd} q_{ij} T^c + \sum_{j\in J}\sum_{i\in I}\left(E^{rl} L_{jk}^{rl} + nmq_{ij} T^c\right) + \sum_{i\in I}\sum_{j\in J} E^{rd} L_{kk}^{rd} q_{ij} T^c. \end{aligned} \tag{8}$$

Cost accounting of the carbon emissions of container transportation for direct road transportation is

$$C^{rdc} = \sum_{i\in I}\sum_{j\in J} E^{rd} L_{ik}^{rd}\left(Q_i - q_{ij}\right) T^c. \tag{9}$$

In summary, the logistics-related costs of inland container transport are accounted for as

$$C^{lc} = C^{dp} + C^{rd} + C^{dpt} + C^{rdt} + C^{dpc} + C^{rdc}. \tag{10}$$

The model is as follows:

$$\begin{aligned} &\min C = C^c + C^o + C^{lc}, \\ &\text{s.t.} \\ &Q_i, q_{ij} \in N, \quad \forall i \in I, \forall j \in J, \\ &\sum_{j\in J} q_{ij} \le Q_i, \quad \forall i \in I, \\ &x_{ij} M \ge q_{ij}, \quad \forall i \in I, \forall j \in J, \\ &x_{ij} \le q_{ij} M, \quad \forall i \in I, \forall j \in J, \\ &\sum_{g\in G} y_{jg} \le \sum_{i\in I} x_{ij}, \quad \forall j \in J, \\ &M \sum_{g\in G} y_{jg} \ge \sum_{i\in I} x_{ij}, \quad \forall j \in J, \\ &\sum_{g\in G} y_{jg} \le 1, \quad \forall j \in J, \\ &\sum_{i\in I} q_{ij} \le \sum_{g\in G} y_{jg} \mathrm{Cap}_g, \quad \forall j \in J, \\ &\sum_{g\in G} y_{jg} g \le H_j, \quad \forall j \in J, \\ &y_{jg} \in \{0, 1\}, \quad \forall j \in J, \forall g \in G. \end{aligned} \tag{11}$$

5. Case Study of Northeast China

In 2017, Dalian Port undertook 98.5% of the volume of foreign trade containers in Northeast China. The sea-rail intermodal transport channel, with Dalian port as the main sea-rail intermodal hub, has a large-scale operation, which delivers the sea-rail intermodal transport volume throughout Northeast China. The foreign trade container hinterland of Dalian port includes three provinces in Northeast China and four leagues in Inner Mongolia. Due to the particularity of geographical location, the hinterland has strong independence. In addition, in 2016, among the major ports in China, Dalian Port's sea-rail combined transportation volume reached 406,000 TEU, accounting for 19.16% of the country's total volume. To sum up, it is representative and typical to select the northeast region to carry out the joint optimization research of dry port planning and container transportation.

5.1. Research Scope. There are 41 prefecture-level cities in Northeast China, including six coastal port cities. The container transportation modes of these cities are more diverse than those of inland cities. They are not included in the scope of this study. Therefore, the scope of shippers and alternative dry port cities in this study covers 35 prefecture-level cities in the inland of Northeast China (Table 3), and the destination port is Dalian Port.

5.2. Data Sources and Processing. The core of the joint optimization problem of dry port with multilevel location and container transportation is to determine the number, location, and grade of land ports, so as to achieve the goal of reducing inland container transportation cost. The total transportation cost is selected as the objective function. The basis of joint optimization is to determine the cost of road

Table 3: Thirty-five cities in Northeast China.

Research scope	City name
Heilongjiang province	Harbin, Qiqihar, Jixi, Hegang, Shuangyashan, Daqing, Yichun, Jiamusi, Qitaihe, Mudanjiang, Heihe, Suihua and Daxinganling
Jilin province	Changchun, Jilin, Siping, Liaoyuan, Tonghua, Baishan, Songyuan, Baicheng, and Yanbian
Liaoning province	Shenyang, Anshan, Fushun, Benxi, Fuxin, Liaoyang, Tieling, and Chaoyang
Inner mongolia autonomous region	Chifeng, Tongliao, Hulunbuir, Xing'an league, and Xilin Gol League

and rail transportation. The demand and spatial distribution of container freight also have an important influence on joint optimization. In addition, cities with developed economy and convenient transportation should be chosen for the construction of dry ports. On one hand, it is conducive to the support of goods and human resources; on the other hand, it can facilitate the distribution of goods and enhance the attraction of goods by dry port. Therefore, this study collects data regarding the container transportation volume of each city, the road distance and railway distance between cities, and according to the existing research, the average speed of road and rail transportation, and other related parameters are set.

5.2.1. Mileage Data. The railway distance and the highway distance (Table 4) were taken from the "Train ticket network" and the "Gaode map," respectively (the data for "Train ticket network" is updated up to 2020).

5.2.2. Foreign Trade Container Weights. From custom data statistics, this study obtained the volume of the foreign trade containers of 35 cities (Table 4) in Northeast China in 2017.

5.2.3. Transportation Cost-Related Data. Reflecting the actual situation in Northeast China, this study sets the average speed of highway operation as 70 km/h, and the average speed of railway operation as 100 km/h. The relevant charging standards of rail transport (Table 5) come from the railway freight tariff rules of the Ministry of Railways of the People's Republic of China and the notice of the National Development and Reform Commission on issues related to the adjustment of railway freight tariffs (2014).

The relevant fee standard for road transport is regressed from the cost data of 83 road containers (20-ft. containers) transported by 29 freight forwarders in China (Table 6) [36]. The price function of the container road transport is

$$f\left(L_R\right) = \begin{cases} 1204.31, & L_R \leq 50, \\ 0.0007L_R^2 + 5.7532L_R + 914.9, & L_R > 50. \end{cases} \tag{12}$$

Among them, $L_R$is the road transport distance.

Regarding the economic cost of road transport from the railway station to the port in the seaport city when the seaport city lacks railway facilities that are directly connected to the port, the container goods must be transported to the port through the container truck. Generally, the distance between the railway station of the port city and the port is short, and it is easy to distribute goods back and forth; this is classified as short-haul transportation. Through investigation, it is concluded that the price (W) of short-distance transshipment of containers in the seaport city is 29.61 USD/TEU.

5.2.4. Time Cost-Related Data. According to the average value of export containers in Dalian port, $V = 29{,}609.01$ USD/TEU; the interest rate is the current deposit interest rate in 2020; and $R = 0.35\%$.

5.2.5. Carbon Cost Data. According to Li and Su [37], carbon emissions from road transport are quantified as 0.796 kg/(ton· km); that from rail transport, 0.028 kg/(ton· km); and that from rail transit, 1.56 kg/ton. According to the standard of the Ministry of Environmental Protection, the carbon tax is set at 7.40 USD/ton. According to the ISO Standard for Container, the weight of the 20-foot container is 24 tons.

5.2.6. Calculation Parameters of Land Port Construction Cost. In this study, the capital discount rate is 8%, and the capital recovery period for dry port construction cost is 15 years.

5.2.7. Relevant Data of Dry Port Grade. Referring to the relevant literature [38] and the investment and operation of similar dry ports in China, this study estimates the construction level and annual operation cost of the dry port, recommended scale range, general storage waiting time, and the discount coefficient of the scale effect and divides the dry port into four levels. The scale of the first-level dry port is the smallest, and the scale of the fourth-level dry port is the largest. The specific divisions are listed in Table 7.

5.3. The Capacity of Cities to Build Dry Ports. The construction of a dry port is closely related to the city's economic development level, investment capacity, foreign trade development level, transportation conditions, and railway infrastructure conditions. Therefore, this study selects nine indicators related to the construction and development of dry ports: GDP, actual foreign investment, total retail sales of social consumer goods, local government revenue, investment in fixed assets, total post and telecommunications business, foreign trade import, foreign trade export, and the score of railway station grade (the data corresponding to the index is from the city statistical bulletin in 2018). The factor analysis method is used to evaluate 35 inland cities in

Table 4: Foreign trade container volume and related mileage data of cities.

	Foreign trade container weight in 2017/TEU	Road distance to Dalian port/km	Railway distance to Dalian station/km
Anshan	54799	302.2	308
Liaoyang	25145	332.3	333
Shenyang	467953	382.1	397
Fushun	31920	445.9	444
Benxi	20486	381.2	457
Tieling	8408	452.7	467
Chaoyang	30800	481.3	473
Fuxin	6793	408.4	535
Liaoyuan	7254	611.0	559
Siping	9763	582.4	585
Tongliao	17664	633.8	634
Changchun	395951	680.8	700
Jilin	36360	782.7	821
Baishan	14326	637.3	833
Songyuan	9654	812.5	849
Tonghua	3960	557.4	870
Baicheng	15547	902.5	938
Harbin	45141	948.6	946
Chifeng	20761	633.5	968
Suihua	12569	1051.9	1071
Yanbian Korean autonomous prefecture	49019	1016.7	1073
Xing'an league	293	963.5	1116
Daqing	81033	985.3	1120
Qiqihar	5300	1138.3	1156
Jiamusi	8178	1289.9	1271
Mudanjiang	38755	1055.4	1315
Yichun	2860	1262.5	1387
Qitaihe	290	1283	1460
Jixi	2740	1223	1509
Xilinguole league	11208	1026.1	1513
Hegang	467	1354	1521
Shuangyashan	2344	1358.1	1544
Heihe	5241	1510.1	1582
Daxinganling	230	1699.1	1587
Hulunbeir	32944	1474.6	1663

Northeast China, and the highest dry port grade that each city can build is obtained. Using SPSS for dimension reduction factor analysis, the result of the KMO test is 0.868, and the probability of Bartlett's sphericity test statistical value is less than $0.001\,(P \leq 0.001)$, which shows that the selected variables have high correlation and are suitable for factor analysis. In accordance with the principle of eigenvalues greater than 1, two common factors are extracted by principal component analysis, and the cumulative contribution rate of the principal component is 87.457%. Table 8 shows the scores and grade limits of the construction capacity of the dry ports in each city.

5.4. Model Solution Results. In this study, we use the AMPL software, select the optimizer Gurobi 9.0.2 to solve the model, and obtain the cost of different transportation modes and the construction scale level, quantity, and hinterland range of the dry port. Moreover, this study analyzes the model results from two aspects: transportation cost change and the dry port construction scheme.

5.4.1. Changes in Transportation Costs. From the perspective of total cost, the total cost of direct transportation of containers by road is the highest, at about 1,202.23 million USD, and the total cost of the RD-RL mode is the lowest, at approximately 941.68 million USD (Table 9). Compared with the RD mode, the total costs of the RD–RD-RL mode (container cannot be split), RD-RL–RD mode, and RD-RL mode are lower by 17.85%, 18.92%, and 21.67%, respectively. The results reveal that the container multimodal transport mode of dry port transshipment can effectively reduce the total transportation cost. The RD-RL mode is the best transport mode with the optimal total transport cost. This indicates that whether the railway can reach the seaport directly has a significant impact on reducing the cost of container transportation.

Regarding transportation economic cost, the proportion of economic cost under different transportation modes in the total transportation cost can reach more than 88%, and the economic cost of the RD mode is the highest. Compared with the RD mode, the economic costs of the RD-RL-RD (container cannot be split), RD-RL-RD, and RD-RL modes are lower by 18.03%, 19.82%, and 22.98%, respectively.

Table 5: Railway transport related charging standards.

Pay service	Charge standard (20-foot box)	Charging basis
Base price of railway delivery (P^1)	65.14 USD/TEU	China railway Corporation: Notice on the adjustment of railway container freight rate (2018)
Base price of railway operation (P^2)	0.47 USD (TEU·km)	
Container usage fee (P^3)	If it is less than 500 km, it's 19.25 USD/TEU; if it is less than 2000 km, it in 1.92 USD per 100 km	Notice on adjusting container usage fee and freight tarpaulin usage fee (tyy (2008) No. 144)
Container cleaning fee (P^4)	0.74 USD/TEU	Notice on adjusting the rates of some passenger and freight miscellaneous charges and announcing the rates of railway coal dust suppression transportation and items (T. Y. (2009) No. 224)
Container handling charge (P^5)	28.87 USD/TEU	Article 16 of the notice of the Ministry of railways on revising and re promulgating the charging method for railway cargo handling operations
Unloading fee of container in yard (P^6)	26.65 USD/TEU	

Table 6: Quadratic function regression results of road transportation economic cost.

Dependent variable: Y

Method: least squares

Date: 01/26/21 time: 16 : 19

Sample: 1 83

Included observations: 83

$Y = C(1)*X2 + C(2)*X + C(3)$

Coefficient	Std. Error	t-statistic	Prob.	
$C(1)$	0.000733	0.000132	5.542924	0
$C(2)$	5.753184	0.430664	13.35888	0
$C(3)$	914.8968	175.7349	5.206118	0
R-squared	0.960057	Mean dependent var		4063.855
Adjusted R-squared	0.959059	S.D. dependent var		4921.867
S.E. of regression	995.8865	Akaike info criterion		16.68062
Sum squared resid	79343192	Schwarz criterion		16.76805
Log likelihood	-689.2457	Hannan-Quinn criter.		16.71574
F-statistic	961.4377	Durbin-Watson stat		1.765773
Prob (F-statistic)	0			

In terms of time cost, the impact of the time cost of the different transportation modes on the total transportation cost is almost negligible (Table 10). The time cost of the RD mode is the lowest. Compared with the RD mode, the time cost of the RD-RL-RD (container cannot be split), RD-RL-RD, and RD-RL modes are higher by 4.63%, 7.12%, and 8.02%, respectively. This indicates that the direct road transportation mode has greater competitive advantage in terms of transportation time.

With regard to carbon emission cost, the carbon emission cost of the RD mode accounts for 10.82% of the total cost, while that of the multimodal transportation mode accounts for less than 5%. Compared with the RD mode, the carbon emission costs of the RD-RL-RD (container cannot be split), RD-RL-RD, and RD-RL modes are lower by 63.06%, 76.34%, and 78.37%, respectively. This indicates that multimodal transport can effectively reduce carbon emissions and the associated costs.

5.4.2. Dry Port Construction. Tables 8 and 9 show the scale grade, construction quantity, location layout, and hinterland distribution of the dry port under the multimodal transport mode of dry port transshipment. Under the RD-RL-RD mode, seven dry ports need to be built in Northeast China, including two fourth-level dry ports: Shenyang and Changchun, with a utilization rate of 100%; one third-level dry port: Harbin, with a utilization rate of 100%; one second-level dry port: Yanbian Korean Autonomous Prefecture, with a utilization rate of 54.17%; and three first-level dry ports: Chaoyang, Liaoyuan, and Hulunbuir, with an average utilization rate of 83.30%, all of which carry 79.88% of the container transshipment volume. Under the RD-RL mode with the optimal total transportation cost, the utilization rate of the four-level dry ports is 100% in Shenyang and Changchun, 100% in Harbin, 73.33% in Siping and Yanbian Korean Autonomous Prefecture, and 74.95% in Chaoyang and Hulunbuir. In this case, the dry ports carry 82.76% of the container transshipment volume. If the railway can reach the seaport directly, the proportion of the containers transshipped through the dry port in Shenyang will increase by 13.39%. The newly built second-level dry port Siping will replace Liaoyuan, the first-level dry port transshipping all the local containers and sharing part of the containers

Table 7: Classification of dry port scale.

Level of dry port	Construction cost (million USD)	Operating cost (million USD)	Designed carrying capacity (10,000 TEU)	Storage waiting time (day)	Discount coefficient of the scale effect
1	19.25	1.11	5	2	1
2	38.49	2.22	10	1.8	0.9
3	76.98	4.44	20	1.5	0.8
4	153.97	8.88	40	1	0.7

Table 8: Score and grade limit of dry port construction capacity of each city.

City	Score	Maximum level of dry port
Shenyang	2.51	4
Harbin	2.11	4
Changchun	1.84	4
Jilin	0.37	3
Daqing	0.36	3
Anshan	0.17	3
Mudanjiang	0.11	3
Chifeng	0.02	3
Qiqihar	−0.02	2
Benxi	−0.04	2
Hulunbuir	−0.07	2
Songyuan	−0.11	2
Tonghua	−0.11	2
Yanbian	−0.14	2
Jiamusi	−0.14	2
Tongliao	−0.16	2
Chaoyang	−0.19	2
Siping	−0.22	2
Suihua	−0.22	2
Xilin Gol League	−0.22	2
Fuxin	−0.28	1
Baicheng	−0.29	1
Liaoyang	−0.33	1
Liaoyuan	−0.33	1
Jixi	−0.35	1
Fushun	−0.36	1
Baishan	−0.38	1
Tieling	−0.38	1
Heihe	−0.41	1
Xing’an League	−0.42	1
Shuangyashan	−0.43	1
Hegang	−0.44	1
Daxinganling	−0.47	1
Qitaihe	−0.47	1
Yichun	−0.50	1

transshipped through Shenyang dry port in RD-RL-RD mode. This shows that the “last kilometer” problem has a great impact on the distribution of cargo demand, and to a certain extent, it also affects the location and layout of the dry port.

The locations of the dry ports and the spatial layout of the hinterland in the RD-RL-RD and RD-RL modes are shown in Figures 2 and 3. In the two transportation modes, the hinterland scope of the dry port is basically the same, and the location layout of the dry port is relatively decentralized and balanced, covering more than 85% of the inland cities in Northeast China. The hinterland cities of the dry ports are all located away from the harbor, except for the city itself. This indicates that there is no circuitous transportation away from the seaport when containers are transferred through the dry port. The competition between some dry ports is fierce, in the RD-RL-RD mode. Mudanjiang city is the competitive hinterland of Yanbian dry port and Harbin dry port; Changchun City is the competitive hinterland of Changchun dry port and Liaoyuan dry port; and Siping City is the competitive hinterland of Shenyang dry port and Liaoyuan dry port. In the RD-RL-RD mode, Changchun City is the competitive hinterland of Changchun dry port and Siping dry port Tables 10–12.

Table 9: Cost changes under the different transportation modes (unit: USD).

Cost type	RD mode	RD-RL-RD mode (container cannot be split)	RD-RL-RD mode	RD-RL mode
C	1,202,232,613.78	987,667,488.93	974,822,985.02	941,684,421.50
$C^{r\,d}$	1,070,569,856.88 (89.048%)	317,694,704.07 (32.166%)	145,297,084.94 (14.905%)	125,104,018.01 (13.285%)
$C^{r\,dt}$	1,581,666.09 (0.132%)	434,051.05 (0.044%)	198,740.18 (0.020%)	171,304.69 (0.018%)
$C^{r\,dc}$	130,081,090.81 (10.82%)	34,035,122.82 (3.446%)	14,337,233.56 (1.471%)	12,040,588.60 (1.279%)
$\sum_{i\in I}\sum_{j\in J}C_{ij}^{r\,d}$	—	194,490,393.74 (19.692%)	259,444,699.67 (26.615%)	263,679,554.78 (28.001%)
$\sum_{i\in I}\sum_{j\in J}C_{ij}^{r\,dt}$	—	122,188.21 (0.012%)	140,500.30 (0.014%)	135,410.69 (0.014%)
$\sum_{i\in I}\sum_{j\in J}C_{ij}^{r\,dt}$	—	10,451,861.70 (1.058%)	12,083,217.50 (1.240%)	11,669,116.14 (1.239%)
$\sum_{i\in I}\sum_{j\in J}\sum_{m\in M}C_{ij}^{rl}$	—	340,994,766.19 (34.525%)	418,724,637.15 (42.954%)	435,727,797.95 (46.271%)
$\sum_{i\in I}\sum_{j\in J}\sum_{m\in M}C_{ij}^{rlt}$	—	1,091,091.95 (0.111%)	1,344,020.64 (0.138%)	1,401,783.50 (0.149%)
$\sum_{i\in I}\sum_{j\in J}\sum_{m\in M}C_{ij}^{rlc}$	—	3,484,266.52 (0.353%)	4,250,156.61 (0.436%)	4,425,452.51 (0.47%)
$\sum_{i\in I}\sum_{j\in J}C_{kk}^{r\,d}$	—	24,326,913.11 (2.463%)	34,912,549.78 (3.581%)	—
$\sum_{i\in I}\sum_{j\in J}C_{kk}^{r\,dt}$	—	7,636.87 (0.001%)	10,959.99 (0.001%)	—
$\sum_{i\in I}\sum_{j\in J}C_{kk}^{r\,dc}$	—	75,681.03 (0.008%)	108,612.94 (0.011%)	—
$C_c + C_o$	—	60,458,811.66 (6.121%)	83,970,571.75 (8.614%)	87,329,394.62 (9.274%)

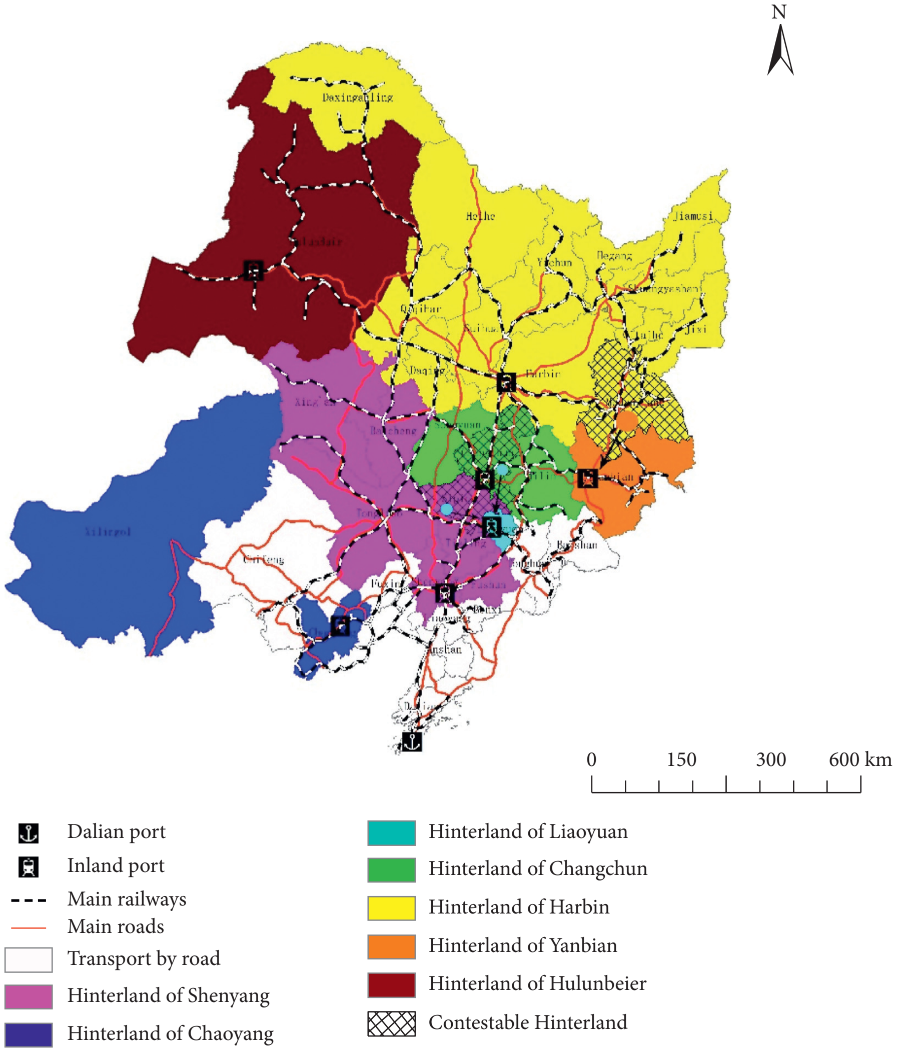

Figure 2: Hinterland area of the dry port under the road-rail-road mode.

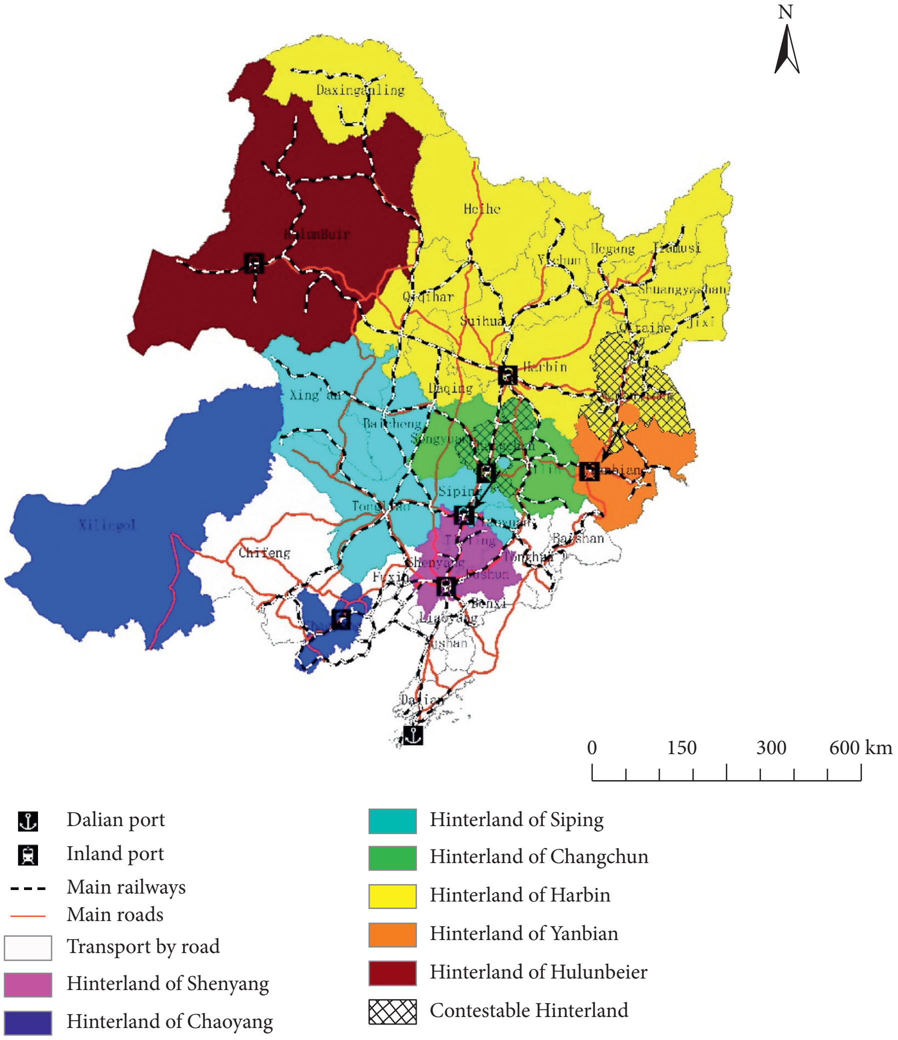

FIGURE 3: Hinterland area of the dry port under the road-rail mode.

TABLE 10: Cost of the different transportation modes and their proportion in total cost (unit: USD).

	RD mode	RD-RL-RD mode (container cannot be split)	RD-RL-RD mode	RD-RL mode
Economic cost	1,070,569,856.88 (89.048%)	877,506,777.12 (88.846%)	858,378,971.54 (88.055%)	824,511,370.74 (84.581%)
Time cost	1,581,666.09 (0.132%)	1,654,968.08 (0.168%)	1,694,221.12 (0.174%)	1,708,498.89 (0.175%)
Carbon emission cost	130,081,090.81 (10.82%)	48,046,932.06 (4.865%)	30,779,220.61 (3.157%)	28,135,157.24 (2.886%)
Construction and operation cost of dry port	—	60,458,811.66 (6.121%)	83,970,571.75 (8.614%)	87,329,394.62 (8.958%)

Table 11: Construction of the dry port under the RD-RL-RD mode.

Serial number	City name	Level of dry port	Transshipment volume (TEU)	Number of hinterland cities	Hinterland cities and transshipment volume (TEU)
1	Shenyang	4	400,000	7	Shenyang (317,186), Fushun (31,920), Tieling (8,408), Siping (8,982), Tongliao (17,664), Baicheng (15,547), and Xing'an (293)
2	Chaoyang	1	42,008	2	Chaoyang (30,800) and Xilin Gol (11,208)
3	Liaoyuan	1	50,000	3	Liaoyuan (7,254), Siping (781), and Changchun (41,965)
4	Changchun	4	400,000	3	Changchun (353,986), Jilin (36,360), and Songyuan (9,654)
5	Harbin	3	200,000	13	Harbin (45,141), Suihua (12,569), Daqing (81,033), Qiqihar (5,300), Jiamusi (8,178), Mudanjiang (33,607), Yichun (2,860), Qitaihe (290), Jixi (2,740), Hegang (467), Shuangyashan (2,344), Heihe (5241), and Daxinganling (230)
6	Yanbian	2	54,167	2	Yanbian (49,019) and Mudanjiang (5,148)
7	Hulun Buir	1	32,944	1	Hulun Buir (32,944)

Table 12: Construction of the dry port under the road-rail mode.

Serial number	City name	Level of dry port	Transshipment volume (TEU)	Number of hinterland cities	Hinterland cities and transshipment volume (TEU)
1	Shenyang	4	400,000	3	Shenyang (359,672), Fushun (31,920), and Tieling (8,408)
2	Chaoyang	1	42,008	2	Chaoyang (30,800) and Xilin Gol (11,208)
3	Siping	2	92,486	6	Liaoyuan (7,254), Siping (9,763), Tongliao (17,664), Changchun (41,965), Baicheng (15,547), and Xing'an (293)
4	Changchun	4	400,000	3	Changchun (353,986), Jilin (36,360), and Songyuan (9,654)
5	Harbin	3	200,000	13	Harbin (45,141), Suihua (12,569), Daqing (81,033), Qiqihar (5,300), Jiamusi (8,178), Mudanjiang (33,607), Yichun (2,860), Qitaihe (290), Jixi (2,740), Hegang (467), Shuangyashan (2,344), Heihe (5,241), and Daxinganling (230)
6	Yanbian	2	54,167	2	Yanbian (49,019) and Mudanjiang (5,148)
7	Hulun Buir	1	32,944	1	Hulun Buir (32,944)

6. Conclusion and Discussion

This study uses a technical economic method to calculate the construction cost of a dry port by year and takes the operation and time costs of the dry port into the comprehensive cost. Considering the scale effect of railway transportation, the capacity level of the dry port and the conditions of urban construction of the dry port, this study constructs a multicapacity-level model for the location of the dry port. From an empirical analysis of the situation in Northeast China using the AMPL software solution, the following conclusions are made.

(1) In the context of rapid economic development and stabilization of transport demand, dry port services can effectively reduce transport costs and carbon emission costs, lower the total cost, realize economies of scale in transport, and promote the transformation of the RD mode to a cleaner mode of transport.

(2) The RD-RL mode is the optimal method of container transportation. In this case, seven dry ports need to be built in Northeast China—two fourth-grade dry ports: in Shenyang and Changchun, with a utilization rate of 100%; one third-grade dry port: in Harbin, with a utilization rate of 100%; two second-grade dry ports: in Siping and Yanbian, with an average utilization rate of 73.33%; and two first-grade dry ports: in Chaoyang and Hulunbuir, with an average utilization rate of 74.95%, carrying 82.76% of the container transshipment volume. Compared with the RD mode, the total, economic, and carbon emission costs of the RD-RL mode are lower by 21.67%, 22.98%, and 78.37%, respectively, and the time cost is higher by 8.02%.

(3) Considering that the container cargo can be split, it has a great impact on the distribution of freight flow and transportation cost, and if only the container in the shipper city can be split at will in the transportation process, the total transportation costs can be optimized.

(4) In the RD-RL-RD mode, the road transportation cost between the shipper and the dry port accounts for 27.869% of the total transportation cost, and the road transportation cost between the seaport railway station and the seaport accounts for 3.593% of the total cost. The road transportation cost accounts for 31.462% of the total transportation cost. In the RD-RL mode, the road transport cost between the shipper and the dry ports accounts for 29.254% of the total transport cost. This indicates that the road

transportation cost between the shipper and the dry port has a significant impact on the total transportation cost, freight demand distribution, and dry port selection. Compared with the RD-RL-RD mode, the total annual transport cost of the RD-RL mode is lower by approximately 3.340%, CO_2 emissions are lower by approximately 8.590%, and the dry port selection scheme does not change significantly. This indicates that although the direct rail connection to the seaport does not have a significant impact on the dry port selection scheme, it helps in reducing the total transportation cost, especially the negative impact on the environment.

The market-oriented reform of China's railway operations has been intensifying, and the development of multimodal transport has been accelerating. This study considers the scale effect (discount coefficient) of railway transportation to make the study of dry port locations more consistent with the actual development. In addition, the location selection process in this study considers both the capacity level of the dry ports and the conditions for cities to build dry ports, which is an improvement of the two-stage dry port location method. It ensures that the number, level, and layout of dry ports are in line with the actual situation.

Future research may explore the following four aspects: First, the problem of dry port location is a complex system project involving many influential factors. More factors (such as weight coefficient of different costs) can be considered while setting optimization objectives, and the limitation of railway capacity can be considered while setting constraints. Second, this study has solved the joint optimization problem of land port planning and container transportation for a specific port, and the land port location problem may need to be extended to multiple ports. Third, this study focuses on regional-level network and intends to solve the optimization problem of the nationwide network. Fourth, this study focuses on the macro spatial layout of land port planning, and future research may be extended to the microlayout of the land port in the urban planning of the land port city.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

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