Hindawi Publishing Corporation
Discrete Dynamics in Nature and Society
Volume 2013, Article ID 309585, 9 pages
http://dx.doi.org/10.1155/2013/309585

Research Article

A Location-Allocation Model for Seaport-Dry Port System Optimization

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Received 28 June 2013; Revised 26 October 2013; Accepted 3 November 2013

Academic Editor: Zhigang Jiang

Seaports participate in hinterland economic development through partnerships with dry ports, and the combined seaport-dry port network serves as the backbone of regional logistics. This paper constructs a location-allocation model for the regional seaport-dry port network optimization problem and develops a greedy algorithm and a genetic algorithm to obtain its solution. This model is applicable to situations under which the geographic distribution of demand is known. A case study involving configuration of dry ports near the west bank of the Taiwan Strait is conducted, and the model is successfully applied.

1. Introduction

Rapid development of seaports and intermodal transportation systems under integrated planning has made it necessary for seaports to dynamically assess what constitutes their hinterlands, and the scramble for hinterlands by seaports is heating up. On the other hand, it is increasingly recognized by hinterlands that seaports guide and support regional economic development, and there is a growing need to perform in hinterland locations seaports' functions except ship loading and unloading. The interactions of these two driving forces have induced rapid development of dry ports as both a means by which seaports vie for hinterland access and a means by which hinterlands stimulate economic growth. Logistics networks, each including a group of seaports and some dry ports, are becoming backbones of regional goods movement. At the end of 2011, there were over 100 dry ports built or being built in China, with the Port of Tianjin leading the development of more than 20 of them. There were also a large number of road and rail transportation hubs which were in many aspects similar to dry ports. The development of dry ports can mitigate problems caused by constraints related to land and others that limit seaports' growth. Dry ports can also coordinate the operation of the port supply chain and support regional economic development. Consequently, dry ports are changing the dynamics of interaction between seaports and hinterlands. This paper studies the location of dry ports from the perspective of seaport-hinterland interaction and optimizes the configuration of the seaport-dry port system, taking into consideration the relationships between dry ports, seaports, and the regional logistics system.

On the evolution of a port, Bird [1] developed the Anyport model describing how port infrastructures develop over time and space and how the relationship between ports and their host cities evolves. Three major steps of port development were identified: setting, expansion, and specialization. Based on his study of East African ports, Hoyle [2] amended the original Anyport model and proposed a six-stage model of port development. Notteboom and Rodrigue [3] proposed that adding to the three stages in Bird's model is the stage of regionalization, during which seaports achieve development mainly through inland expansion. Rodrigue and Notteboom [4] further extended the concept of inland to include both hinterland and foreland. CEMT [5] recognized that hinterland resources would inevitably become indispensable for seaports engaging in intense market competition.

The rapid development of multimodal transportation has driven the movement of containers within inland regions.

Since the early 1980s, operators of containerized transport have built sophisticated networks of inland container transport, and major nodes in these networks become the prototype of dry ports. Roso et al. [6] pointed out that on the backdrop of increased size of container vessels, dry ports play a key role in connecting seaports to the hinterland as they help relieve congestion at seaports while providing the hinterland with improved access to containerized ocean transport. As such, the location of dry ports became an import issue of research. Heaver et al. [7, 8], van Arjen Klink and van den Berg [9], Notteboom [10], Notteboom and Winkelmans [11], and Robinson [12] studied the relationship between ports and dry ports and further proposed different spatial configuration of dry ports. Yang [13] applied the method of multicriteria decision making to the problem of locating dry ports in the state of Texas, USA. Xu [14] developed a discrete choice model for locating an inland container depot, with the objective of profit maximization. In China, Xi et al. [15] proposed developing a dry port in the midwestern city of Xi'an. Guan [16] analyzed problems facing the development of dry ports in China. Cai and Chen [17] proposed 5 codevelopment patterns for seaports and dry ports. Wang [18] compared dry ports with container yards and constructed a discrete choice model for locating dry ports. Ma [19] developed a cellular automata program for locating dry ports that serve the Port of Tianjin. However, none of the existing research took into consideration the complex interaction between the government, the seaports, and the shippers when studying the problem of locating dry ports.

Key factors of a seaport group include port location, capacity, origin of shipments, and the cooperative and competitive relationships. If these factors are known, the task of optimizing the regional seaport-dry port system is to determine for the dynamic hinterland the number of dry ports, their locations and capacities, and the relationships among themselves as well as between them and the seaports. The regional configuration of dry ports is constrained by available candidate locations, transport access to these locations, and the shipping demand within the zone of influence of each location. The demand-supply relationship and the choice behavior of agents (seaports, dry ports, shippers, and carriers) need to be reasonably modeled. This research develops a location-allocation model for seaport-dry port system optimization, characterized by a probabilistic choice for shippers' use of dry ports and a partnership between seaports and dry ports. The research provides both a methodological approach for decision making and new insights on the relationship between seaports and the hinterland.

2. The Location-Allocation Model for Seaport-Dry Port System Optimization

For a regional seaport-dry port system focusing on exporting freight generated in the hinterland through seaports to the outside, there are two essential types of elements: nodes and links. Nodes include seaports, existing and planned dry ports, and hinterland origins of freight. Links connect the origins of freight to seaports, either directly or through dry-ports. This is shown in Figure 1.

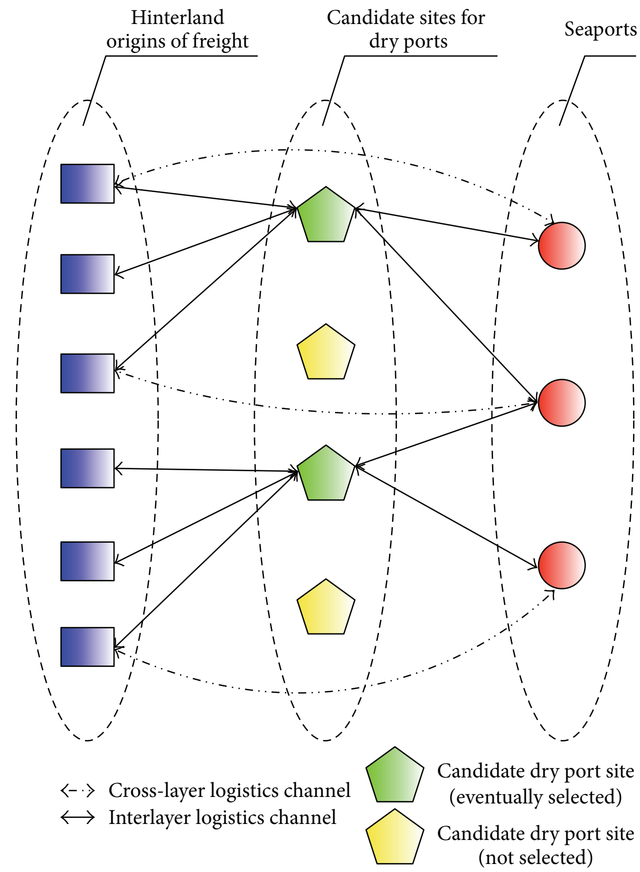


Figure 1: Network flow on a regional seaport-dry port system.

2.1. Model Assumptions. For the abovementioned export-oriented regional seaport-dry port system with a single type of freight, the process of location-allocation is as follows: (1) the government constructs of dry ports and designates for each dry port the seaports it collaborates with; (2) shippers choose to route freight to a seaport, either directly or through a dry port. The government's action in step (1) must anticipate the choice of shippers in step (2), in order to minimize the overall regional logistics cost. Thus we have a location-allocation model, in which the government determines the number and the locations of dry ports, taking into consideration freight allocation by shippers. The objective is to minimize the regional logistics cost.

With regard to the relationship between dry ports and seaports, two scenarios are considered: (1) a dry port can partner with and send freight to any number of seaports and (2) a dry port can send freight to only one seaport. In both cases, a seaport can receive freight from multiple dry ports.

In addition, the following assumptions are made.

(a) The locations of the nodes (freight origins, seaports, and candidate sites for dry ports) are predetermined and known.

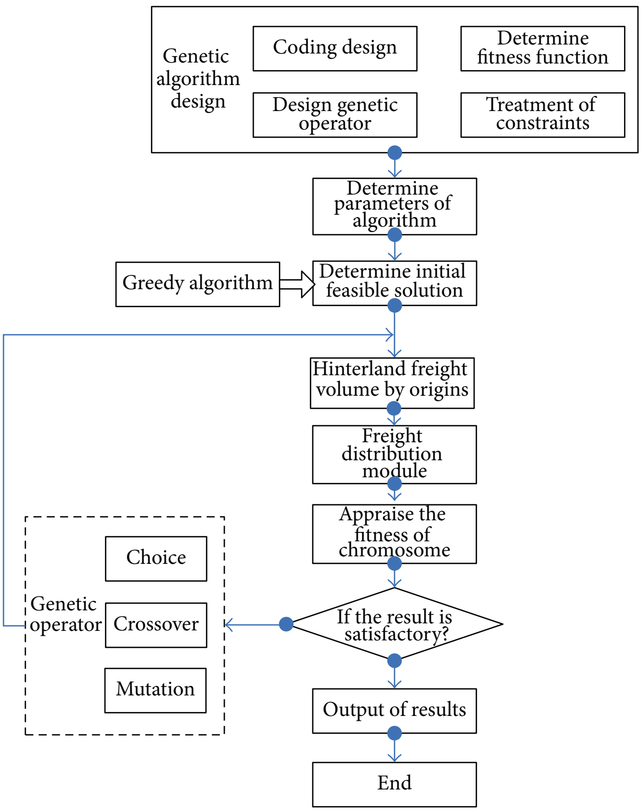


Figure 2: Process of the genetic algorithm.

(b) The transport links between the above nodes are predetermined and known.

(c) The freight volume originating from each hinterland origin is known, and freight must be exported through one of the seaports.

(d) The overall regional logistics cost includes the annual cost of transport, the amortized cost of setting up the dry ports, the cost of maintaining the transport links between dry ports and seaports, and the cost of maintaining the infrastructure at seaports.

(e) The unit transport cost on a link and the cost of setting up a dry port are not dependent on the freight volume, but the cost of maintaining a link or maintaining seaport infrastructure is dependent on the freight volume on the link or through the seaport.

(f) Any freight passes through at most one dry port.

2.2. Model Formulation

2.2.1. When a Dry Port Can Be Shared by Seaports. The programming model we develop consists of a model of system logistics cost minimization though determining from candidate dry port sites a subset to use, picking the collaborating seaports for each dry port, and allocating freight to different routes.

The model is as follows:

$$\min Z\left(\psi_k, \varphi_{jk}\right), \tag{1}$$

where

$$\begin{aligned} Z = {} & \sum_{i,j} \left\{ \left[\sum_{k \geq 1} \psi_k \varphi_{jk} Q_{ijk} \left(C_{i*k} l_{i*k} + \frac{C_{*jk} l_{*jk}}{m_j} \right) \right] \right. \\ & \left. + \frac{Q_{ij0} C_{ij0} l_{ij0}}{m_j} \right\} \\ & + \sum_k \psi_k b_k + \sum_{j,k} \varphi_{jk} \left(b_{jk} + a_1 Q_{jk}^{\theta_1} \right) + \sum_j a_2 S_j^{\theta_2}, \end{aligned} \tag{2}$$

s.t.

$$\psi_k \in \{0, 1\}, \quad \forall k \geq 1, \tag{3}$$

$$\varphi_{jk} \in \{0, 1\}, \quad \forall j, \forall k \geq 1, \tag{4}$$

$$Q_{jk} = \sum_i Q_{ijk}, \tag{5}$$

$$Q_k = \sum_j Q_{jk}, \tag{6}$$

$$S_j = \sum_k Q_{jk}, \tag{7}$$

$$P_{ijk} = \frac{e^{V_{ijk}}}{\sum_{jk} e^{V_{ijk}}}, \tag{8}$$

$$Q_{ijk} = D_i P_{ijk}. \tag{9}$$

The subscripts i, j, and k denote freight origins, seaports, and dry port candidate sites, respectively.

In the objective function, $\sum_{k \geq 1} \psi_k \varphi_{jk} Q_{ijk} (C_{i*k} l_{i*k} + C_{*jk} l_{*jk}/m_j) + Q_{ij0} C_{ij0} l_{ij0}/m_j$ is the transport cost for freight originating from i and destined to j. $\sum_k \psi_k b_k$ is the amortized cost of setting up the dry ports, $\sum_{j,k} \varphi_{jk}(b_{jk} + a_1 Q_{jk}^{\theta_1})$ is the cost for maintaining the transport links between all links from dry ports to seaports, and $\sum_j a_2 S_j^{\theta_2}$ is the cost of maintaining the infrastructure at seaports.

The decision variables are ψ_k and φ_{jk}. ψ_k specifies if candidate site k is used as a dry port. $\psi_k = 1$ if site k is used and 0 if not. φ_{jk} specifies if port j has a partnership with dry port k so j could receive freight from k. $\varphi_{jk} = 1$ if there is a partnership between j and k and 0 if not. Constraints (3) and (4) specify feasible values of ψ_k and φ_{jk}.

Q_{ijk} is the flow of freight from hinterland origin i through dry port k to seaport j. When $k = 0$, Q_{ij0} is the flow of freight from hinterland origin i directly to seaport j. The value of each Q_{ijk} is determined in the expression (8) and (9). D_i is the total volume of freight generated at hinterland origin i, and P_{ijk} is the percentage of freight generated at i that would be routed through dry port k to seaport j. $V_{ijk} = -R_{ijk}$, where R_{ijk} is the transport cost per unit volume unit distance of moving freight from source i to seaport j through dry port k.

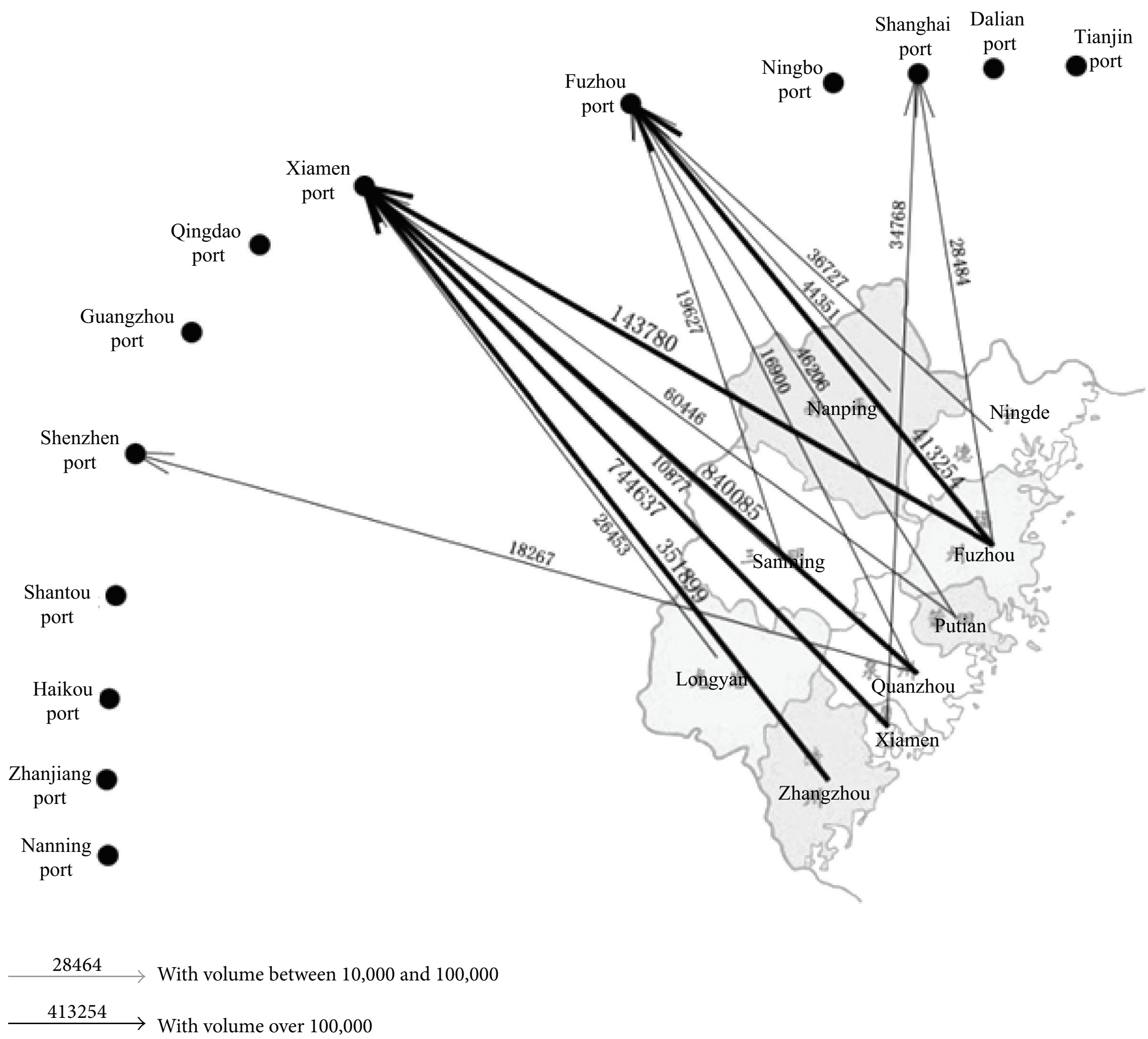


FIGURE 3: Export freight volumes between cities in Fujian province and various seaports.

Available dry ports and dry port-seaport partnerships given by the values of ψ_k and φ_{jk} are used to define feasible routes.

Q_{jk} is the volume of freight sent by dry port k to seaport j. Q_k is the total volume of freight routed through dry port k. S_j is the total volume of freight sent to seaport j. Constrains (5), (6), and (7) specify these relationships.

l_{i*k} is the transport distance between hinterland origin i and dry port k. l_{*jk} is the transport distance between dry port k and seaport j. l_{ij0} is the direct transport distance between hinterland origin i and seaport j. C_{i*k}, C_{*jk}, and C_{ij0} are the transport cost per unit volume unit distance corresponding to the above three types of distances, respectively. m_j is a parameter indicating seaport j's attractiveness to shippers, as shippers discount unit transport costs to seaports differently due to perceived differences in the levels of service at seaports. A more attractive seaport has a larger m_j.

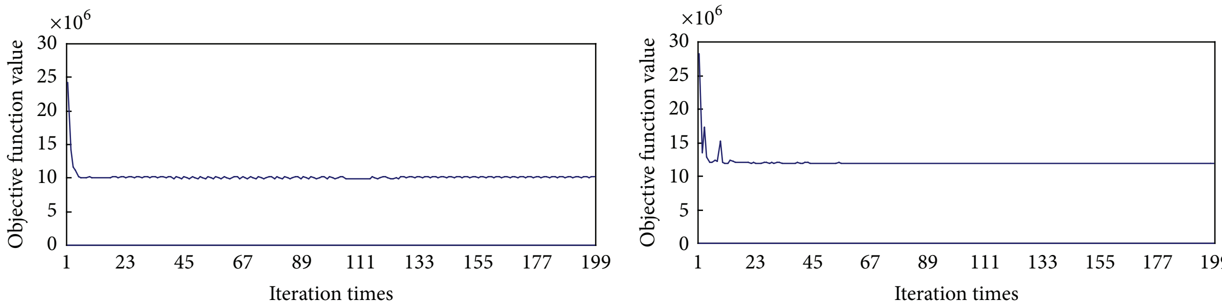
Besides transport costs, the system logistics cost contains also handling costs and the costs related to setting up dry ports and their partnerships. As stated in assumption 7, unit handling cost at dry port k is dependent on Q_{jk}, the freight volume it sends to each seaport, and unit handling cost at a seaport j is dependent on S_j, the overall freight volume of seaport j. a_1, a_2, θ_1, and θ_2 are cost parameters. b_k is the cost of amortized cost of setting up a dry port at candidate site k, and b_{jk} is the cost of maintaining a partnership between dry port k and seaport j. The values of these parameters can be established from expert survey or estimated from field data.

2.2.2. When Each Dry Port Is Dedicated to a Seaport. The model remains essentially the same, with one additional constraint added to the model:

$$\sum_j \varphi_{jk} = \psi_k. \tag{10}$$

3. Solution Algorithms

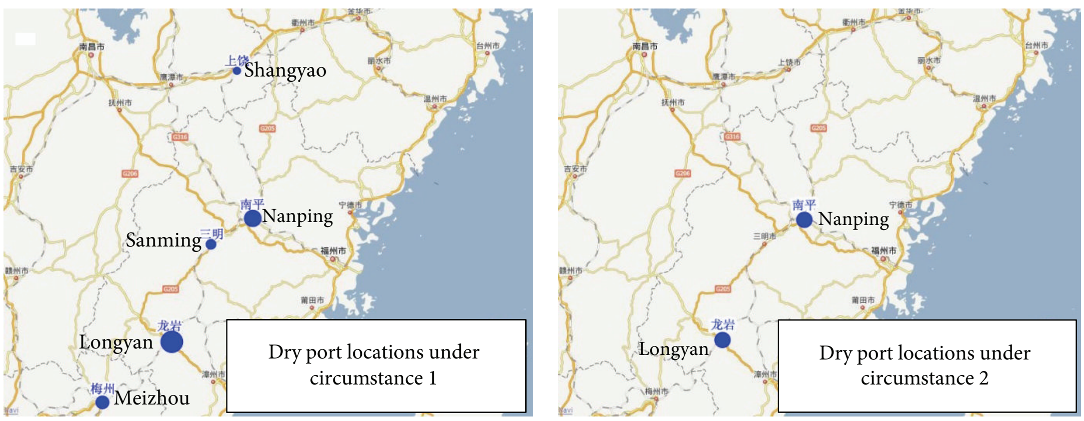
The objective of regional seaport-dry port system optimization is to determine the quantity, size, and location of



(a) Shared

(b) Dedicated

Figure 4: The iteration process.



(a) Shared

(b) Dedicated

Figure 5: Dry port locations.

the dry ports and the transport links between them and seaports so as to minimize region-wide logistics cost. In the programming model formulated above, the objective function is nonlinear, and the decision variables must take binary values. Thus common optimization techniques do not readily apply. Instead, a greedy algorithm and a genetic algorithm are combined to solve the optimization problem.

3.1. Determination of an Initial Feasible Solution with a Greedy Algorithm. A greedy algorithm is adopted to obtain a good feasible solution of the model. The basic idea of the algorithm is to start with the full network (i.e., setting up a dry port at each candidate location and linking each dry port to all seaports in the case of shared dry port or to its nearest seaport in the case of dedicated dry port) and then take out links one at a time to examine if the system logistics cost can be reduced, until no link can be taken out to further reduce the system logistics cost.

When each dry port can be shared by seaports, the steps are the following.

Step 1. Set up m dry ports, where m is the total number of candidate sites for dry ports, and link each dry port with n seaports, where n is the total number of seaports. Denote the current set of dry ports as SM and the set of links between dry ports and seaports as SN. For dry port k in SM, denote the set of links in SN that emanates from dry port k as Sk. The links in Sk are ordered by unit transport cost on the link.

Step 2. Allocate the freight volume generated from hinterland origins to routes according to the expression (8) and (9), and calculate system logistics cost according to the model.

Table 1: Seaports and their attractiveness to shippers.

No.	Name of seaport	Attractiveness to shippers
1	Tianjin	4.5
2	Dalian	4.4
3	Shanghai	10.0
4	Ningbo	4.8
5	Fuzhou	4.0
6	Xiamen	4.3
7	Qingdao	4.4
8	Guangzhou	4.6
9	Shenzhen	4.3
10	Shantou	3.0
11	Haikou	2.0
12	Zhanjiang	3.0
13	Nanning	1.0

Table 2: Hinterland freight origins in Fujian province.

No.	Name of freight origin	Demand volume (tons/year)
1	Fuzhou	597646
2	Xiamen	796707
3	Putian	117423
4	Sanming	33216
5	Quanzhou	886176
6	Zhangzhou	363424
7	Nanping	52748
8	Ningde	49893
9	Longyan	30222

Table 3: Candidate dry ports.

No.	Name of dry port
1	Nanchang
2	Changsha
3	Ganzhou
4	Nanping
5	Sanming
6	Longyan
7	Jiujiang
8	Shangrao
9	Meizhou
10	Yingtan

Step 3. Initialize $k = 0$; denote r as the number of members in set SM.

Step 4. Let $k = k + 1$.

Step 5. Start from the link in Sk with the highest unit transport cost; examine the links in Sk one by one to see if any can be removed. If yes, remove that link from Sk and SN.

Step 6. Examine if the last step removed any link. If yes, go to Step 5.

Step 7. If Sk is empty, mark dry port k from exclusion.

Step 8. If $k < r$, go to Step 4.

Step 9. Remove all dry ports marked for exclusion from SM.

Step 10. Examine if from Step 4 to Step 9 removed any link from SN. If yes, go to Step 3.

Step 11. What remains in SM and SN is an initial feasible solution for the programming problem.

3.2. Genetic Algorithm for the Location-Allocation Model for Seaport-Dry Port System Optimization. With the genetic algorithm to optimize the regional seaport-dry port system, new solution is obtained through random transformation of current solutions. The basic idea is as follows: decide for the decision variables a coding scheme; then generate the initial population, of which individuals shall be corresponding to different dry port-seaport system configurations; use the expression (8) and (9) to obtain network flows and corresponding system logistics costs to evaluate the fitness of each individual. Conduct operations of choice, crossover, and genetic mutation to this population, and after several generations, the algorithm converges, and the resulting system configuration would be adopted as the optimal solution to the programming problem. In this research, real number coding is adopted for coding and the objective function of the problem is adopted as the fitness function. Genetic operations are conducted with the roulette wheel selection based on "ranking," and single point arithmetic crossover is adopted for crossover operations. Penalty factors are added to the fitness function to account for constraint violations.

The detailed process is shown in Figure 2; the steps of the algorithm are shown next.

Step 1 (set the parameters). Set the population size "pop_size," mutation rate p_m, the crossover rate p_c, the maximum number of iterations "Gen," and the initial generation $t = 0$.

Step 2 (initialization). The initial population $P(t)$ with the size of "pop_size" is generated.

Step 3. Apply the allocation expression (8) and (9) to the chromosome in population $P(t)$ to obtain freight flows on the network.

Step 4. Apply the model's objective function to obtain the fitness of the scheme.

Step 5 (conduct genetic operations). Conduct hybrid and mutation operations with specified p_m and p_c values to generate next generation $C(t)$.

Step 6. Apply the allocation expression (8) and (9) to the chromosome in population $C(t)$ to obtain freight flows on the network.

Step 7. Calculate the fitness value of $C(t)$.

Step 8 (execute choice operation). In accordance with the roulette wheel method and the elite preservation strategy, obtain $P(t + 1)$ of population size "pop_size" from $P(t)$ and $C(t)$.

Step 9 (termination conditions). If $t < \text{Gen}$, then $t = t + 1$; return to Step 5 to continue with the evolution operation process; if $t = \text{Gen}$, terminate the algorithm and output the solution.

4. Seaport-Dry Port System Optimization for Fujian Province

Two seaports on the coast of Fujian province, Xiamen and Fuzhou, compete but also cooperate with other major Chinese coastal seaports to serve the hinterland regions of

Table 4: Export volume (in tons/year) between cities in Fujian province and various seaports.

Freight origin	Seaport												
	Tianjin	Dalian	Shanghai	Ningbo	Fuzhou	Xiamen	Qingdao	Guangzhou	Shenzhen	Shantou	Haikou	Zhanjiang	Nanning
Fuzhou	327	124	28484	1117	413254	143780	1546	367	7338	58	11	0	1240
Xiamen	945	186	34768	2775	460	744637	3681	349	8242	8	5	2	650
Putian	28	1	4048	320	46206	60446	983	5	5351	1	0	0	36
Sanming	177	1	882	100	19627	10877	80	0	974	0	0	0	497
Quanzhou	761	141	2932	1430	16900	840085	1047	292	18267	106	2	0	4213
Zhangzhou	126	42	3645	219	268	351899	619	330	3793	2188	2	16	277
Nanping	8	0	3387	278	44351	3657	74	9	829	1	0	0	153
Ningde	290	56	242	1878	36727	9574	115	5	759	167	15	1	64
Longyan	0	0	2148	7	43	26453	15	2	1466	41	0	0	46

Table 5: Unit transport cost (in Yuan/ton) between cities in Fujian province and alternative dry ports.

Freight origin	Dry port									
	Nanchang	Changsha	Ganzhou	Nanping	Sanming	Longyan	Jiujiang	Shangrao	Meizhou	Yingtan
Fuzhou	49	73	50	20	25	32	56	40	44	40
Xiamen	60	71	36	33	27	18	69	62	27	50
Putian	55	81	52	31	26	24	64	49	42	49
Sanming	33	59	32	83	0	26	42	33	26	27
Quanzhou	53	75	41	27	29	24	62	54	35	47
Zhangzhou	52	66	32	33	27	109	61	62	26	46
Nanping	35	61	38	0	83	33	44	31	32	29
Ningde	57	83	60	30	28	38	66	33	54	51
Longyan	44	58	33	25	26	1	53	47	25	38

the Fujian province. For this study, 13 seaports are considered: Tianjin, Dalian Shanghai, Ningbo, Fuzhou, Xiamen, Qingdao, Guangzhou, Shenzhen, Shantou, Haikou, Zhanjiang, and Nanning, as shown in Table 1. There are 9 hinterland freight origins in Fujian province: Fuzhou, Xiamen, Putian, Sanming, Quanzhou, Zhangzhou, Nanping, Ningde, and Longyan, as shown in Table 2. There are 10 candidate sites for dry ports: Nanchang, Changsha, Sanming, Ganzhou, Longyan, Nanping, Jiujiang, Meizhou, Yingtan, and Shangrao, as shown in Table 3. Annual export freight volumes from the hinterland origins are aggregated from customs data on export freight volumes between cities in Fujian province and the seaports (see Table 4 and Figure 3). The minimum unit transport costs between these locations are shown in Tables 5, 6, and 7. These units costs are in the unit of Yuan/ton, and they already account for 3 factors in the objective function: the cost per ton per unit distance, the transport distance, and the seaport attractiveness factor.

We look at both the case of shared dry ports and the case of dedicated dry ports. The values of other parameters in the objective function (i.e., a_1, a_2, θ_1, θ_2, B_k, and B_{jk}) used in this study are taken from a combination of expert survey and estimation of field data. Due to the economy of scale, θ_1 and θ_2 are usually greater than 0 but less than 1.

(1) When the Dry Port Is Jointly Developed and Is Shared by Multiple Seaports. When no dry port is constructed, the total cost is 3.30839873×10^7. The initial solution of the model is obtained with the greedy algorithm. The second column of Table 8 shows the initial solution, under which the total cost is 2.4182488×10^7. For the genetic algorithm, we set the selection probability for the genetic operator at 0.8, the crossover probability at 0.5, and the mutation probability at 0.01. The maximum number of iterations is 200; the iteration process is shown in Figure 4(a), and it converges to the optimum solution after 200 iterations. The fourth column of Table 8 shows the optimal solution; Figure 5(a) shows the resulting dry ports on the map. Under the optimal solution, the total cost is 1.000304×10^7.

(2) When the Dry Port Is Dedicated to a Seaport. When no dry port is constructed, the total cost is 3.30839873×10^7. The initial solution of the model is obtained with the greedy algorithm. The third column of Table 8 shows the initial solution, under which the total cost is 2.827592×10^7. For the genetic algorithm, we set the selection probability for the genetic operator at 0.8, the crossover probability at 0.5, and the mutation probability at 0.01. The maximum number of iterations is 200; the iteration process is shown in Figure 4(b), and it converges to the optimum solution after 200 iterations. The fifth column of Table 8 shows the optimal solution. Figure 5(b) shows the resulting dry ports on the map. Under the optimal solution, the total cost is 1.194766×10^7.

From the above, we can see that development of dry ports dramatically reduces system logistics cost for hinterland origins in Fujian province.

Table 6: Unit transport cost (in Yuan/ton) between cities in Fujian province and various seaports.

Freight origin	Seaport												
	Tianjin	Dalian	Shanghai	Ningbo	Fuzhou	Xiamen	Qingdao	Guangzhou	Shenzhen	Shantou	Haikou	Zhanjiang	Nanning
Fuzhou	152	239	66	45	1	30	187	87	67	41	119	78	130
Xiamen	160	226	83	65	29	1	138	57	48	22	100	142	104
Putian	160	214	70	53	115	20	126	68	59	33	111	143	70
Sanming	137	206	66	58	25	27	117	57	55	38	103	130	105
Quanzhou	157	220	76	58	20	92	132	61	53	26	109	147	109
Zhangzhou	156	220	85	68	33	66	137	54	46	20	98	138	102
Nanping	139	202	60	52	20	33	113	63	61	44	109	132	111
Ningde	136	199	55	38	102	28	111	85	73	47	125	112	129
Longyan	148	217	84	76	32	18	128	49	46	28	96	82	96

Table 7: Unit transport cost (in Yuan/ton) between alternative dry ports and various seaports.

Dry port	Seaport												
	Tianjin	Dalian	Shanghai	Ningbo	Fuzhou	Xiamen	Qingdao	Guangzhou	Shenzhen	Shantou	Haikou	Zhanjiang	Nanning
Nanchang	109	181	62	53	47	60	124	82	74	76	140	111	104
Changsha	136	203	94	91	78	96	130	57	68	99	120	91	78
Ganzhou	148	222	93	91	62	44	155	44	41	43	107	69	108
Nanping	139	202	66	52	20	33	113	63	61	44	109	97	111
Sanming	156	206	75	67	25	27	118	57	55	38	103	91	105
Longyan	148	217	84	76	32	18	128	49	46	27	96	82	96
Jiujiang	100	171	55	54	56	69	83	75	75	73	121	108	108
Shangrao	120	183	41	33	40	59	96	80	80	66	126	113	113
Meizhou	156	225	92	83	44	30	136	32	29	17	78	65	79
Yingtan	113	182	49	41	41	54	93	73	73	58	119	106	106

Table 8: Initial solution and optimization result after 200 iterations.

Dry port	Dry port throughput (shared) (the initial solution)	Dry port throughput (dedicated) (the initial solution)	Dry port throughput (shared) (the optimal solution)	Dry port throughput (dedicated) (the optimal solution)
Nanchang	0	0	0	0
Changsha	0	0	0	0
Ganzhou	0	0	0	0
Nanping	97818.44531	105605.3281	412067.5	891146.75
Sanming	63477.57422	127935.3594	31191.81445	0
Longyan	387477.7813	378427.6563	1083868.75	878881.5
Jiujiang	0	0	0	0
Shangrao	1015.576355	0	72.5763855	0
Meizhou	10148.79297	0.000772247	364213.125	0
Yingtan	0	0	0	0

5. Conclusion

With the increased competition between the regional seaport-dry port networks, optimizing system configuration has attracted attention of many researchers. The regional seaport-dry port system is a complex system. By focusing on the relationship between seaports and dry ports, this paper has developed a location-allocation model for regional seaport-dry port system optimization and has proposed an efficient solution method for the programming problem. This paper provides justifications for developing dry ports at strategic locations and lays a foundation for future research on regional resource integration.

Acknowledgments

The paper is funded by the National Natural Science Foundation of China (Project no. 51009060), the Research Basis Project of Philosophy and Social Science of Jiangsu Province (09JD017), and the Priority Academic Program Development of Jiangsu Higher Education Institutions (Coastal Development Conservancy).

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