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DRY PORTS-SEAPORTS SUSTAINABLE LOGISTICS NETWORK OPTIMIZATION: CONSIDERING THE ENVIRONMENT CONSTRAINTS AND THE CONCESSION COOPERATION RELATIONSHIPS

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ABSTRACT

In China dry ports enter into a rapid development period now, however for many Chinese dry ports, the operation faces difficulties duo to inefficient logistics networks and cooperation relationship between dry ports and seaports. Focusing on the concession cooperation mechanism of seaports and dry ports, and the environmental constraints (carbon emissions and congestion cost), a bi-objective location-allocation MILP model for the sustainable hinterland-dry ports-seaports logistics network optimization is formulated, aiming at the system logistics costs and carbon emissions to be minimized. Moreover, for the cooperation mechanism of seaports to dry ports, a parameter called cooperation cost concession coefficient is proposed for the optimization model, and a new evaluation method based on the ordered weighted averaging (OWA) operator is used to evaluate it. Then a location-allocation decision-making framework for the hinterland-dry port-seaport logistics network is proposed. The innovative aspect of the model is that it can proposes a effective and environment friendly dry ports location strategic and also give insights into the connective cooperation relationships, and cargo flows of the network. A case study involving configuration of dry ports in Henan Province is conducted, and the model is successfully applied.

Keywords: Dry port; Port logistics; Logistics network; Location-allocation; Sustainable; Relationships evaluation

INTRODUCTION

Dry port (also known as inland port) refers to a kind of modern logistics center with customs declaration, inspection and quarantine, and other port services functions except ships loading and unloading [1]. As the growing competition of seaport for the hinterland resources and the needs of inland areas to develop open economics, dry ports in China enter into a rapid development period now. They have played a certain role in the economic development of hinterlands and the competitiveness ascension of some seaports [2]. However, many problems also exist during the development of dry ports [3], and most dry ports in China now are in a difficult operation state, which makes the research of the effective dry ports logistics network become very necessary.

Dry ports aim at moving the road transport onto the rail networks to reduce traffic congestion of the terminal cities, pollution emissions, and logistics cost [5]. So a efficient dry port relays on the coordinated development of various transportation modes, meanwhile contributes to the integration of various transportation modes [4]. In this sense, the environmental benefits of the dry ports should not be ignored.

In addition, due to the strong position of the harbors and the distinct feature of the government behavior in China, the development of Chinese dry port often relies on the support of local government and the cooperative seaports. So, in order to design an efficient sustainable dry ports-seaports network, decision makers must synthetically consider environmental constraints and cooperation mechanism among seaports and dry ports.

However, there are few researches on the dry ports-seaports logistics networks from this perspective. Roso et al. pointed out that the location of dry ports became an import issue of research due to dry ports playing a key role in connecting seaports to hinterland[5]. Heaver et al., Notteboom and Robinson proposed different spatial configuration of dry ports from the functional relationship between ports and dry ports[6-8]. Mansour identified and analyzed a number of inland port sites in the five counties surrounding Los Angeles using a location-allocation methodology[9]. Feng proposed a location-allocation NLP model for dry pots locati-seaports network, considering the probability of through the dry ports to seaports or not[10]. Ambrosino studied the location of the location of mid-range dry ports focused on the intermodal transportation networks[11]. Samir evaluated the dry ports location problemswith Multi-Criteria Decision Analysis, DELPHI Methodology and so on[12][13].

This paper studies the location of dry port and the hinterland-dry port-seaport logistics network optimization, taking into the cost concession partnership between the dry ports and seaports, and the environmental factors at the same time. The contribution of this paper lies in: firstly, focusing on the cost concession partnership mechanism of seaports and candidate dry ports, we proposed a new method based on OWA operator to evaluate the cost concession partnership between them, which laid the foundation for network location-allocation optimization; secondly, we also considered the environment factors and proposed a bi-objective location-allocation MILP model for the dry ports-seaports logistics network, which extend the interests attention from the shippers to the comprehensive benefit of the logistics network system.

MATERIAL AND METHODS

THE EVALUATION OF THE COST CONCESSION PARTNERSHIP AMONG SEAPORTS AND DRY PORTS

In china, compared with dry ports, seaports have the absolute dominant position. Dry port often relies on the efficient and beneficial relationship with one or some seaports to attract cargoes, reduce logistics cost and obtain preliminary development opportunities. And according the more and more competition in the port hinterland resources, the seaports are also willing to offer a discount to dry ports for more supply of goods. For the same seaport, the concession relationship for different dry ports are different based on the comprehensive evaluation of some basic factors, such as the cargo demand, traffic connectivity, the emphasis of the local government and so on. And the same factor between different seaports and dry ports may has different influence on the concession relationships. According to this feature, a new method based on OWA operator is proposed to figure out the cost concession coefficient for each seaport-dry port pair.

The ordered weighted averaging operator was first proposed by Yager [18], which is used to aggregate and evaluate information in multi-criteria or multi-expert decision-making problem. Suppose a function $F(U)$ is a real number set, and $U=(u_1,u_2,\dots,u_n)$. Given n weights $W=\{w_j\}_1^n$ with the domain of discourse [0,1] and $\sum_{j=1}^{n} w_j=1$ associated with function $F(U)$. Let $u_{\sigma(j)}$ be the *jth* highest element of $\{u_1,u_2,\dots,u_n\}$. $F(U)$ is an OWA operator, if

$$F(u_1,u_2,\cdots,u_n)=\sum_{j=1}^{n} w_j u_{\sigma(j)} \quad \textbf{(1)}$$

It's worth noting that weight w_i is corresponding to a certain position sequence, rather than element u_i [17]. As we know in the above, the same factor for different seaport-dry port pairs has defferent effect degrees, so for the same factor the evaluation weight may different for the different seaport-dry port pairs,which means the weights and evaluation factors has no corresponding relation. Therefore,OWA operator is an effective method to evaluate the cooperation relationship coefficient.

Suppose that the exporting cargo volume of the candidate dry port city and its surrounding cities (u_1), traffic connectivity between seaports and candidate dry ports(u_2), the emphasis and support of the local government (u_3), and the importance of the dry port to the network layout strategy of the seaport (u_4).The evaluation steps are as follows:

Step 1: Set weights $W=\{w_n\}_1^N$ by the expert evaluation method and the experts are from the seaport management and operation practice. Here $N=4$.

Step 2: Determine the evaluation matrix $P=[p_{kn}]_{KN}$. Set candidate dry port vector $X=\{x_k\}_1^K$, where K is the total number of candidate dry ports. For seaport j , Let p_{kn} is the evaluation value of factor u_n for dry port x_k and seaport j. If u_i is a quantitative factor, p_{kn} is obtained by its real value, otherwise if u_i is a qualitative factor, p_{kn} is chosen from the domain of discourse {1, 2, 3, 4, and 5}. Then the evaluation matrix $P=[p_{kn}]_{KN}$ can be obtained.

Step 3: Normalize evaluation matrix $P=[p_{kn}]_{KN}$,obtain the normalized evaluation matrix $R=[r_{kn}]_{KN}$. If the greater the p_{kn} value, the greater of the influence on dry port x_k and seaport j , then the p_{kn} is with the benefit-type attribute normalized by Equation (2), otherwise p_{kn} is with cost-type attributes normalized by Equation (3).

$$r_{kn} = \frac{p_{kn}}{\sum_{k} p_{kn}} \qquad k \in K \tag{2}$$

Step 4: Aggregate the evaluation matrix $R = [r_{kn}]_{KN}$. Let matrix $R^{'} = [r_{\sigma(kn)}]_{KN}$ be obtained from the ranking components of each row vector in $R = [r_{kn}]_{KN}$ from bigger to smaller, and let a_{kj} be the comprehensively-evaluated value of the dry port x_k and seaport j, then

$$a_{kj} = (r_{\sigma(k1)}, r_{\sigma(k2)}, \ldots, r_{\sigma(kN)})W \tag{4}$$

Step 5: Compute cost discount coefficient s_{kj}. s_{kj} is the cost discount coefficient of seaport j to dry port x_k. For seaport j, suppose $_{\max}$ is the largest one of $(a_{1j}, a_{2j}, \ldots, a_{Kj})$, and the maximum cost discount coefficient for seaport j to each candidate dry port is λ, then

$$s_{kj} = \frac{\lambda(1 - a_{kj})}{1 - a_{\max j}} \tag{5}$$

Step 6: Repeat steps 2-4 for each seaport, Suppose the number of seaports is J, then obtain the cooperation cost concession coefficient matrix $S = [s_{kj}]_{KJ}$.

THE BI-OBJECTIVE LOCATION-ALLOCATION MODEL FOR DRY PORTS-SEAPORTS NETWORK OPTIMIZATION

Problem Definition and Model Formulation

The hinterland-dry port-seaport logistics network studied in this paper is shown in Figure 1, where the cargoes transportation by road between hinterland and dry port, the cargoes transportation by rail between dry port and seaports, or the cargoes directly transport from hinterland to seaport by road with higher environmental cost.

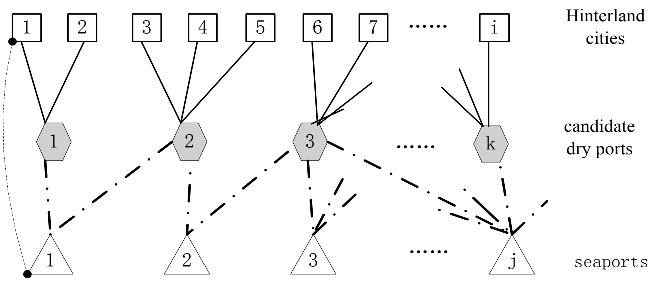

Fig. 1. The Structure of the hinterland-dry port-seaport logistics network

Based on the cooperation cost concession partnership from the Section 2.1, and taking into account the logistics transportation cost, terminal city congestion cost and emissions pollution, a bi-objective MILP location-allocation model for the hinterland-dry port-seaport logistics network optimization is established in this section. The logistics costs and carbon emissions are our objective functions to be minimized.

$$M\inf_1 = \sum_i \sum_k q_{ik} c_{ik} l_{ik} + \sum_k \sum_j s_{kj} q_{kj} c_{kj} l_{kj} + \sum_i \sum_j l_{ioj} q_{ioj} (c_{ioj} + c_d) + \sum_k b_k x_k + \sum_k \sum_j b_{kj} y_{kj} \tag{6}$$

$$M\inf_2 = \sum_i \sum_k q_{ik} K_{road} + \sum_k \sum_j q_{kj} l_{kj} K_{rail} + \sum_i \sum_j l_{ioj} q_{ioj} K_{road} \tag{7}$$

$$\sum_i q_{ik} = \sum_j q_{kj} \tag{8}$$

$$\sum_i q_{ik} \le m_k x_k \tag{9}$$

$$\sum_j q_{kj} \le m_k x_k \tag{10}$$

$$q_{kj} \le M y_{kj} \tag{11}$$

$$\sum_k q_{ik} + \sum_j q_{ioj} = q_i \tag{12}$$

$$q_{ik}, q_{kj}, q_{ioj} \ge 0 \tag{13}$$

$$x_k = \{0,1\} \tag{14}$$

$$y_{kj} = \{0,1\} \tag{15}$$

Where, the subscripts i, j, k denote hinterland cities, seaports, and dry port candidate sites, respectively. l, q, c respectively denote the distance, the cargoes volume, and the unit transportation cost, and their subscripts ik, kj, ioj denote from the hinterland city i to the candidate dry port k, from the candidate dry port k to the seaport j, from the hinterland city i to the seaport j respectively. b_k denotes the built cost per year of the candidate dry port k. b_{kj} denotes the cooperation relationship maintenance cost per year of k seaport j and the candidate dry port k (such as traffic aisle maintenance, customs clearance and inspection operations costs). K_{road} and K_{rail} denote the road and rail carbon emissions coefficients respectively. Note that c_d denotes the congestion cost coefficients of road transport, which and emissions pollution are the two factors considered in the environment Constraints. Constraints (8) specify the relationships of the input and output cargo volume of dry port k. Constraints (9) and (10) specify the capacity of the candidate dry port k. Supposed the railway capacity can meet the transportation demand expressed in Constraints (11), M is a very large constant. Constraints (12) expresses all the original cargo transportation demand can be met. Constraints (14) and (15) specify feasible values of the decision variables.

Meeting logistics cost and carbon emissions objectives

According the characters of the multi-objective programming, the objectives trade-off strategy in this paper is presented in Equation (16) [18]. The strategy comprises two steps. The first step minimizes f_1 and the minimum is denoted by f_1^*; then minimizes f_2, where ε is a relaxation coefficient for f_1. The advantages of this objectives trade-off strategy is that it doesn't need a unified dimension for the two different objective function logistics cost and pollution discharge, and at the same time decision makers can according to themselves compromise degree will of the increasing the logistics cost to decrease the environmental emissions to determine the coefficient of relaxation of the cost target function, and obtain satisfactory solution of multi-objective programming.

$$\min_{x\in X, f_1\le(1+\varepsilon)f_1^*} f_2, where f_1^* = \min_{x\in X} f_1 \quad \textbf{(16)}$$

The hinterland-dry port-seaport logistics network location-allocation framework

As a summary of the above methods for the evaluation of the cost concession partnership among seaports and dry ports and the modeling of the bi-objective MILP location-allocation model for the network optimization, we propose the hinterland-dry port-seaport logistics network location-allocation decision-making framework (see Figure 2).

From the framework we can see the decision-makers should determine the candidate dry ports firstly, collect all basic data of the hinterland cities, candidate dry ports and seaports, and then negotiate with all possible cooperative seaports to obtain the cost concession from seaports to dry ports, and finally based on the bi-objective MILP location-allocation model locate dry ports among the alternatives and allocate hinterland cargo resource to dry ports and cooperative seaports.

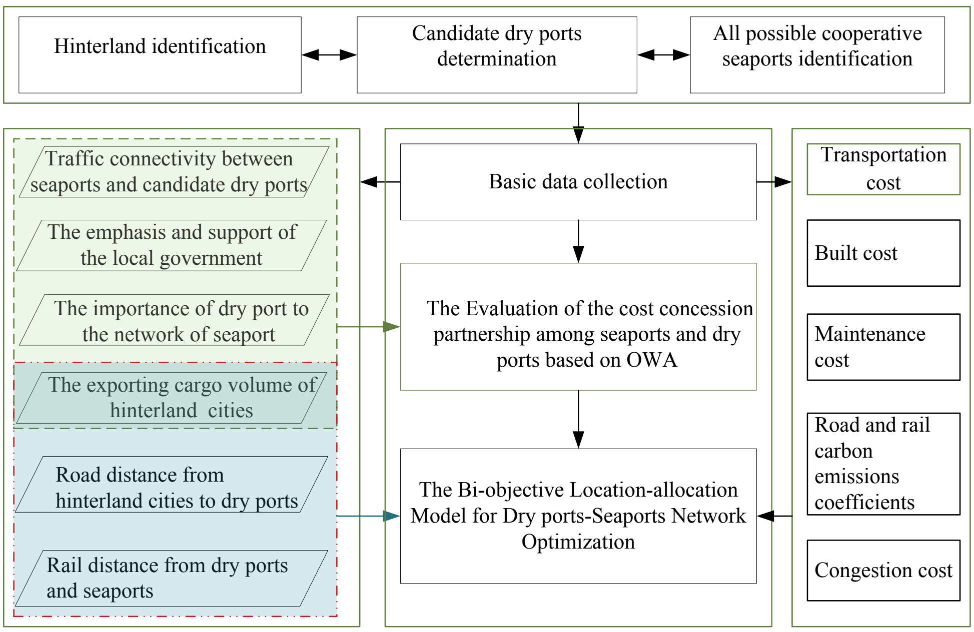

Fig. 2. The location-allocation decision-making framework for dry port-seaport network.

RESULTS

EXPERIMENTAL DATA

In this paper, dry ports in Henan province of China have been considered for the experimental study. Henan province is the core province of the Chinese Central Plains Economic Zone, who is far from the harbor. As the important region in "the Belt and Road initiative"("B&R") of China, Henan province is taking action to open to the outside world further and tring to play a more important role in"B&R". Establishing the cooperation relationship among the dry ports within it and seaports in Chinese eastern coastal, is the important way for Henan province to particapate in "B&R".

There are 18 cargoes origins in Henan, and 8 of them are chosen as the candidate dry port cities by the government (the green nodes in Figure3): Zhengzhou(ZZ), Shangqiu(SQ), Xinxiang(XX), Luoyang(LY), Hebi(HB), Nanyang(NY), Zhumadian(ZMD), Luohe(LH). And 7 seaports are considered: Tianjin(T), Qingdao(Q), Rizhao(R), Yantai(Y), Weihai(W), Lianyungang(L), Shanghai(S) (see Figure3). The basic data of hintland cities, candidate dry port cities and seaports from Chinese road and rail transport query tables and Henan statistical yearbook is shown in Table 1-2.

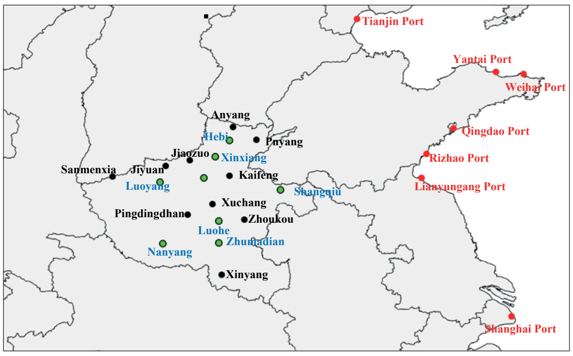

Fig. 3. The seaports, candidate dry port cities and hinterland cities of the case

Tab. 1. The basic data distance from the hinterland cities to candidate dry port cities and seaports

	distance to the candidate dry port cities (km)								distance to the seaports (km)							**cargo supply (TEU)**
	ZZ	SQ	XX	LY	HB	NY	ZMD	LH	T	Q	R	L	S	Y	W	
Zhengzhou	0	202	70	144	160	262	213	161	708	897	715	584	1046	962	1050	351718
Sanmenxia	468	470	302	128	370	388	325	353	920	1165	983	852	1314	1230	1138	5876
Luoyang	144	346	178	0	246	293	237	220	840	1026	844	713	1175	1097	1179	53790
Jiaozuo	83	292	64	117	132	352	258	236	706	987	805	674	1136	1052	1140	56884
Xinxiang	70	225	0	178	90	332	278	211	630	758	735	596	1068	886	974	33000
Anyang	174	282	174	288	42	555	380	313	541	648	583	706	1168	776	864	20870
Shangqiu	202	0	225	346	253	392	334	200	635	683	501	371	833	707	895	6038
Nanyang	262	392	332	293	394	0	173	190	930	1032	850	709	1064	1157	1245	34507
Kaifeng	67	135	137	211	227	297	253	186	780	824	642	512	974	889	974	8289
Luohe	161	200	211	220	278	200	67	0	799	914	732	545	1020	1039	1127	6502
Xinyang	318	339	296	399	486	230	106	189	984	1100	918	660	834	1225	1313	6465
Pingdingshan	142	273	213	163	275	242	149	94	813	813	716	613	906	985	1046	11836
Hebi	160	253	90	246	0	394	338	278	562	705	669	646	1026	790	851	4533
Puyang	187	246	123	301	102	449	405	302	511	654	618	604	984	739	800	18883
Xuchang	105	192	156	174	219	184	133	57	920	743	660	561	866	915	976	48453
Zhoukou	184	132	254	288	322	260	123	66	768	730	596	496	761	916	977	9444
Zhumadian	161	334	278	237	338	173	0	67	864	842	708	608	871	1028	1089	6819
Jiyuan	148	350	291	65	202	325	349	282	792	812	710	704	1056	983	1070	16443

Tab. 2. The distance from Candidate dry port cities to Seaports (km)

Distance	**Tianjin**	**Qingdao**	**Rizhao**	**Lianyungang**	**shanghai**	**Yantai**	**Weihai**
Zhengzhou	799	1061	710	559	998	969	1053
Shangqiu	672	793	560	356	795	766	850
Xinxiang	771	783	630	639	1078	929	937
Luoyang	999	1185	833	683	1122	1316	1177
Hebi	705	977	855	705	1144	1115	1192
Nanyang	1220	1431	715	929	1004	1197	1505
Zhumadian	1081	1199	916	712	897	1175	1206
Luohe	1015	1133	850	646	963	1109	1140

DETERMINING THE MODEL PARAMETERS

Firstly, as the method in section 2, the cooperation cost concession coefficient matrix $S=[s]_{8\times 7}$ is obtained, see Table3. The values of other parameters in the objective function and the constrains used in this study are taken from combination of expert survey and the references [17]. For example, congestion cost c_d =0.358￥/km-TEU, K_{rail} =0.0007ton/TEU-km, and

$$K_{road}=11.14272\times\frac{l_{ik}e^{0.047772v_{rd}}}{3280.8v_{rd}} \tag{17}$$

THE SOLUTION OF HINTERLAND-DRY PORT-SEAPORT SUSTAINABLE LOGISTICS NETWORK FOR THIS CASE

Based on the basic data and the model parameters determined in the above, we use Cplex to solve the MILP model in the section 3.1. Suppose decision makers are willing to use 3% of the higher logistics costs for carbon emissions reduction, according to the objectives trade-off strategy in the section 3.2, the relaxation coefficient should be chosen $\varepsilon=3\%$. Then we can obtain the satisfactory solution shown in Table 4, 5, 6 and Figure 4.

Tab. 3. The cooperation cost concession coefficient matrix of dry ports and seaports.

S	**Tianjin**	**Qingdao**	**Rizhao**	**Lianyungang**	**shanghai**	**Yantai**	**Weihai**
Zhengzhou	0.80	0.70	0.75	0.80	0.95	0.75	0.80
Shangqiu	0.85	0.72	0.98	0.85	0.90	0.98	0.70
Xinxiang	0.85	0.97	0.75	0.80	0.95	0.70	0.96
Luoyang	0.80	0.90	0.80	0.80	0.95	0.92	0.97
Hebi	0.79	0.99	0.98	0.93	0.93	0.97	0.99
Nanyang	0.99	0.99	0.98	0.98	0.97	0.99	0.99
Zhumadian	0.95	0.95	0.85	0.98	0.90	0.93	0.99
Luohe	0.94	0.95	0.76	0.98	0.92	0.90	0.90

Tab. 4. The candidate dry ports chosen for the satisfactory solution

Candidate dry port cities	Zhengzhou	Shangqiu	Xinxiang	Luoyang	Hebi	Nanyang	Zhumadian	Luohe
Chosen or not	1	0	1	1	1	0	1	0

Tab. 5. The hinterlands cargo allocation to dry ports (TEU)

Hinterland cargo allocation	Zhengzhou	Shangqiu	Xinxiang	Luoyang	Hebi	Nanyang	Zhumadian	Luohe
Zhengzhou	351720	0	0	0	0	0	0	0
Sanmenxia	0	0	0	5880	0	0	0	0
Luoyang	0	0	0	53790	0	0	0	0
Jiaozuo	0	0	56880	0	0	0	0	0
Xinxiang	0	0	33000	0	0	0	0	0
Anyang	0	0	0	0	20870	0	0	0
Shangqiu	6040	0	0	0	0	0	0	0
Nanyang	0	0	0	0	0	0	34510	0
Kaifeng	8290	0	0	0	0	0	0	0
Luohe	0	0	0	0	0	0	6500	0
Xinyang	0	0	0	0	0	0	6460	0
Pingdingshan	11840	0	0	0	0	0	0	0
Hebi	0	0	0	0	4530	0	0	0
Puyang	0	0	0	0	18880	0	0	0
Xuchang	48450	0	0	0	0	0	0	0
Zhoukou	0	0	0	0	0	0	9440	0
Zhumadian	0	0	0	0	0	0	6820	0
Jiyuan	0	0	0	16440	0	0	0	0

Tab. 6. The dry ports cargo allocation to seaports (TEU)

Dry Port cargo allocation	Tianjin	Qingdao	Rizhao	Lianyungang	Shanghai	Yantai	Weihai
Zhengzhou	26330	0	200000	200000	0	0	0
Shangqiu	0	0	0	0	0	0	0
Xinxiang	0	0	89880	0	0	0	0
Luoyang	0	0	0	76110	0	0	0
Hebi	44290	0	0	0	0	0	0
Nanyang	0	0	0	0	0	0	0
Zhumadian	0	0	0	63740	0	0	0
Luohe	0	0	0	0	0	0	0

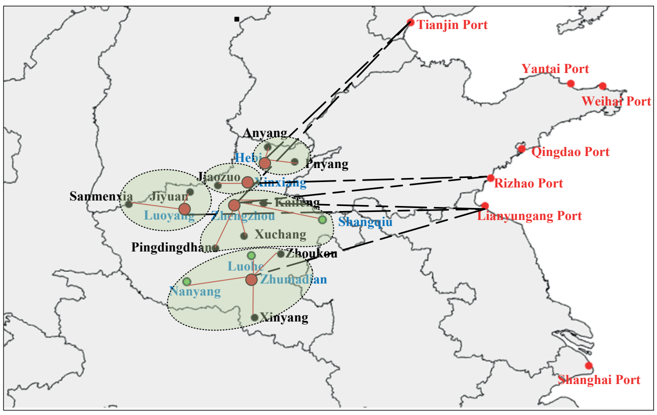

Fig. 4. The solution of hinterland-dry port-seaport sustainable logistics network

Table 4 shows the candidate dry ports location, in which "1" means the corresponding candidate dry port is chosen, and "0" is not chosen. In the satisfactory solution there are five dry ports has been chosen from the 8 candidate dry ports located in Zhengzhou, Xinxiang, Luoyang, Hebi, and Zhumadian.

Table 5 shows the the adjacency relations and cargo allocation among dry ports and 18 hinterland cities. For example, "6040" in Table 5 corresponds to Shangqiu (hinterland city) and Zhengzhou (dry port city), which means there is adjacency relation between Shangqiu and Zhengzhou dry port, and the 6040 TEU cargo supply by Shangqiu will served by Zhengzhou dry port to outside market.

Similarly, Table 6 shows the adjacency relations and cargo allocation among dry ports and 7 seaports. If the value is not "0", there is a cooperation relationship between the corresponding dry port and seaport, and the value is the cargo allocation quantity from the dry port to the corresponding seaport.

Figure 4 shows the whole Figure of the dry ports-seaports network considering the cost concession between 7 seaports and 8 candidate dry ports and the carbon emissions among 7 seaports, 8 candidate dry ports and 18 hinterland cities. And the total logistics cost of this satisfactory solution is ￥9.467966×10^{9} , and the volume of carbon emissions is 3.1138×10^{8} tons.

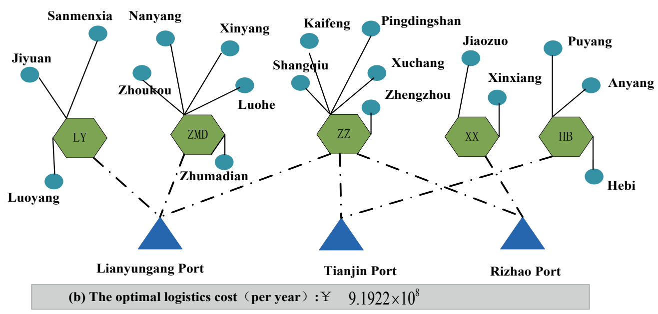

Fig. 5. (b) The optimization solution with cooperation relationships (without environmental constraints).

DISCUSSION

All the above results are based on the basic suppose that 3% logistics cost rising for the reduction of the carbon emissions, and also based on the evaluation of the cost concession partnership from seaports to dry ports. Then we will further analysis the impact of these two factors on the solution of location-allocation dry ports-seaports logistics network.

(1) Regardless of the environmental constraints, if we don't consider the cost concession agreement among seaports and dry ports, the optimization solution for the dry port-seaport logistics network is obtain in Figure 5(a).

In contrast, the solution considering the cost concession agreement is shown in Figure 5(b). And the cargo allocation from dry ports to seaports under the conditions considering the cost concession agreement or not is shown in Table7.

Tab. 7. The dry ports cargo allocation to seaports considering the cost concession or not(TEU).

consider cost concession or not	No			Yes		
Dry Port cargo allocation	Tianjin	Rizhao	Lianyungang	Tianjin	Rizhao	Lianyungang
Zhengzhou	8460	200000	200000	26330	200000	200000
Shangqiu	0	0	0	0	0	0
Xinxiang	0	140210	0	0	89880	0
Luoyang	0	0	76110	0	0	76110
Hebi	0	0	0	44290	0	0
Nanyang	0	0	0	0	0	0
Zhumadian	0	0	75570	0	0	63740
Luohe	0	0	0	0	0	0
Total	8460	340210	351680	70620	289880	339850

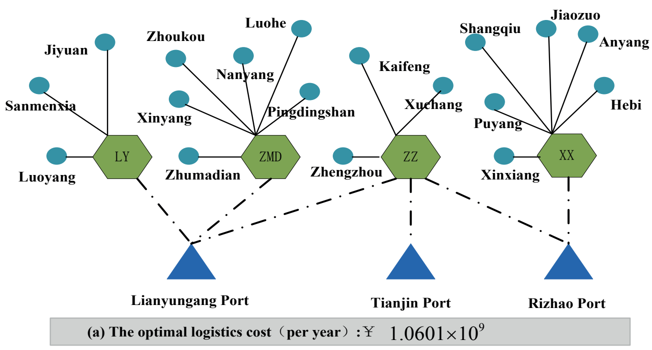

Fig. 5. (a) The optimization solution with no cooperation relationships between seaports and dry ports

In Figure5, there are four dry ports chosen by the optimization solution without considering the cost concession from the seaport to dry port, however five dry ports chosen with considering the cost concession, which means that the cost concession agreement plays an important role in the expansion and development of dry ports, and obviously it also helps to reduce hinterland logistics cost. It is consistent with the fact that most dry ports in China are growing under the support of the cooperation seaports [3].

From Table 7, we can see that the total quantity of the cargo allocation for different seaports are very different under this two conditions. Especially for the Tianjin port, the cost concession with dry ports made its cargo allocation increase from 8460 TEU to 70620 TEU, for example both Zhengzhou and Hebi dry ports have established cooperation relationship with the Tianjin port, even Tianjin port is not the nearest seaport for them, which illustrates that establishing cooperation relationship with dry ports has played a significant role in attracting hinterland cargo resources, which is consistent with the fact that Tianjin port is taking positive hinterland dry ports expansion strategy to attracting hinterland cargo resources and improving competitiveness [18].

(2) Giving relaxation coefficient $\varepsilon = 0:0.0001:0.15$, the optimal values curves of f_1 and f_2 can be seen in the Figure 6. Figure 6 shows the optimal values of the two objectives variation with the variation of the level of the Logistics cost undertaker willing to compromise for the environmental cost. It shows that as the rise of the logistics optimal cost discount, the carbon emissions decrease gradually, and the two targets tend to a stable state when ε is about 0.12. What level logistics cost discount decision makers chosen for the reduction of emissions pollution, depends on the intensity of environmental consciousness of the decision-making group.

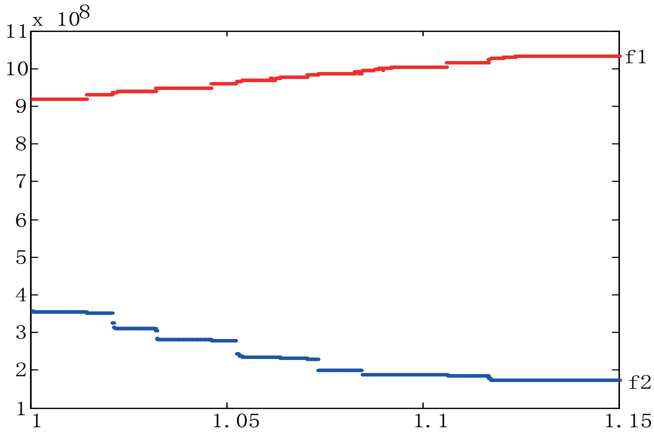

Fig. 6. Variation curves of the f_1 *and* f_2 *with* $\varepsilon = 0:0.0001:0.15$

CONCLUSIONS

In this paper, we attend to proposed a sustainable hinterland-dry ports-seaports logistics network in a new perspective of the concession cooperation mechanism of seaports and dry ports and the environmental constraints. Firstly a new multi-criteria evaluation method based on the OWA operator is proposed to evaluate the cost concession partnership among seaports and dry ports. Then a bi-objective MILP model for hinterland -dry ports-seaports sustainable logistics network optimization has been developed, and a proper trade-off strategy proposed according the characters of this model. And then the location-allocation decision-making framework for hinterland-dry port-seaport network is shown in this paper. Finally a case involving configuration of dry ports in Henan Province is studied according to this method.

This study shows that the cooperation agreement among seaports and dry ports plays a significant role in the development of dry ports, and attracting hinterland cargo resources to enhance the competitiveness for seaports. It also shows that dry ports can be a key node to establish sustainable multimodal transport network oriented cargo export/import.

In conclusion, this paper provides decision-making basis for developing a effective and environment friendly hintland cities-dry ports-seaports network, gives insights in improving opening level for the inland regions, enhancing the competitiveness for seaports, and at the same time depressing environmental influence, which are all focuses in China now. In an on-going research, we will focus on the dry ports as the key core nodes to establish and optimization the land and sea integration logistics networks, under the background of rapid development of the “ B&R” In China.

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