근해운송을 고려한 국제컨테이너 화물운송의 최적화

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Optimization of the Transportation of International Container Cargoes Considering Short Sea Shipping

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목 차

Key Words : international container cargo transportation, short sea shipping, multimodal transportation, linear program

Abstract

This paper considers the problem of determining the cargo flow and the transportation mode in each trade route while satisfying the demand. Especially, the problem incorporates short sea shipping in Korea, which is becoming more important in order to improve efficiency of Logistics. The objective is to minimize the sum of shipping and inland transportation costs. To solve optimally the problem, this paper employs a linear programming model, which is an operations research technique for optimization. The problem is formulated by extending the well-known network design problem by considering capacity at seaport and limitation of total number of vehicles. The model is solved using CPLEX, a commercial linear program software. The test results using a real cargo flow data in Korea show that the model represents closely the real situation.

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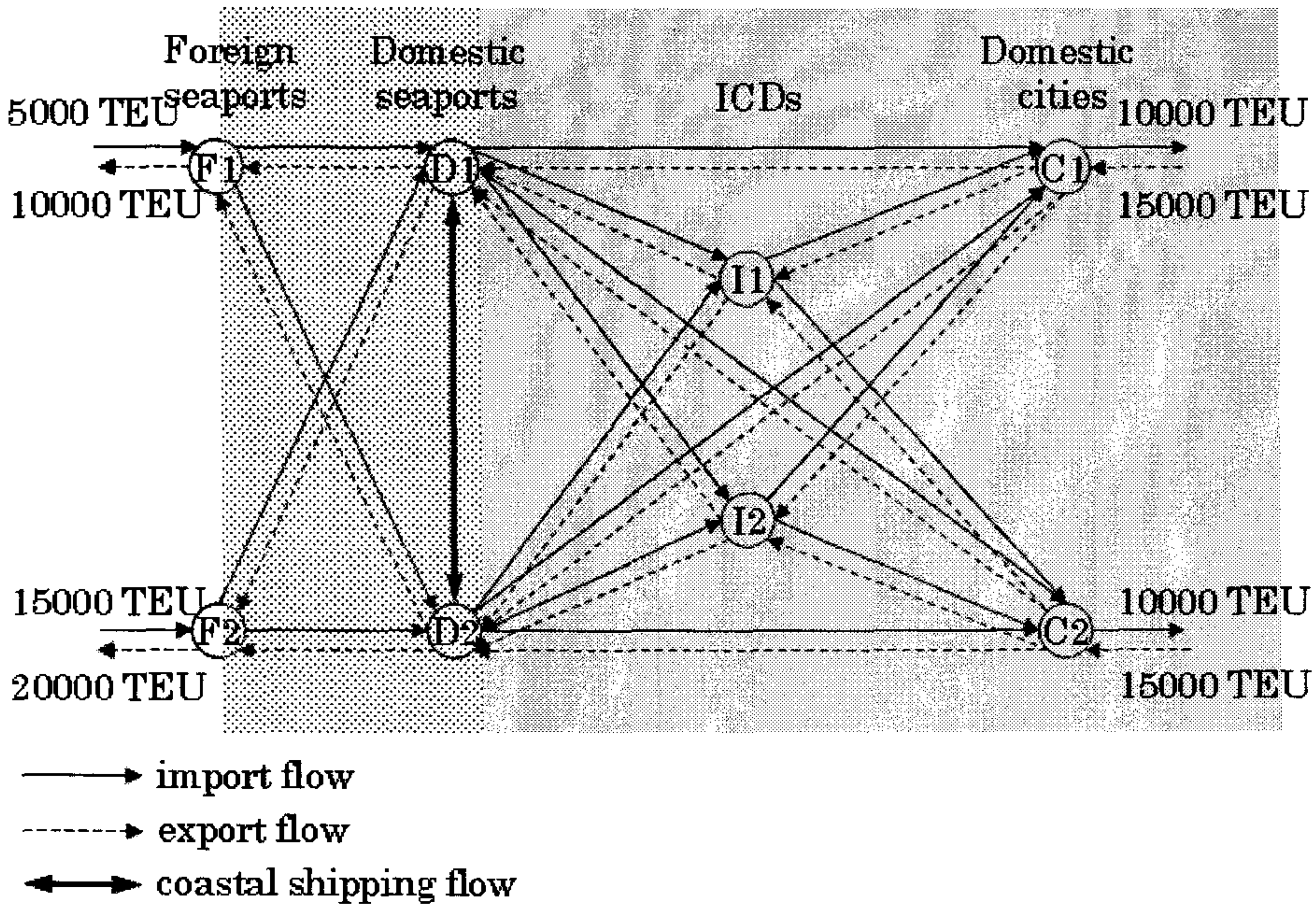
Ⅰ. Introduction

There is and will be fierce competition between countries in Northeast Asia due to the economic success of the country. Therefore, Korean government has made many efforts in a strategy to be a Logistics hub in the region. However, it is well known that there is still great inefficiency in the transportation of international trade cargoes. One of the reasons may be an ill-balanced cargo flows. That is, most of these cargoes have been handled at seaports of Busan and Gwangyang, far from Seoul and Gyounggi province in which nearly 40% of Korea's population lives. One of methods for improving the efficiency may be a promotion of short sea shipping.

In this research, we consider a multimodal transportation problem (MTP) in Korea, which is the problem of determining the cargo flow quantity, i.e., volume of container cargoes, and the transportation mode in each trade route, while satisfying the demand of cargoes in foreign seaports and Korean cities with the supply in Korean cities and foreign seaports, respectively. The objective of the problem is to minimize the total logistic costs, i.e., shipping and transportation costs (more detailed definition for the costs is given later). The MTP can be considered as a special case of the well-known network design problem (See Magnanti and Wong (1984) for more details of the network design problem), in that the MTP determines the flow quantity in each trade route while satisfying the demand and supply. In the MTP, however, we should determine the transportation mode in each trade route and consider two restrictions: maximum cargo volumes capacitated at each seaport and maximum cargo volumes carried by available number of vehicles at each transportation mode.

There are several previous research articles closely related to the MTP. Note that all of the previous research consider routing problems while the MTP determine the transportation flow. Min (1991) considers the problem of determining the transportation route and mode (among truck, airplane, ocean-ship) while sending cargoes to a destination located in oversea country. The objective is to minimize the cost and time, and risk factors. To solve the problem, he employs a goal programming model subject to chance constraint needed to calculate the risk. Barnhart and Ratliff (1993) consider the problem of determining the minimum cost routing for each shipment with the combination of truck and rail. The cost includes the transportation and inventory holding costs. To solve the problem, they employ a shortest path and weighted b-matching algorithms. More recently, Boardman *et al.* (1997) considers the problem of determining the transportation route and the combination of transportation modes



<Figure 1> An example of the cargo flow network

(truck, rail, air, barge) while minimizing cost and time. To solve the problem, they suggest a sort of shortest path algorithm.

In this paper, we employ a linear programming model to solve the MTP, which is an operations research technique and is commonly used to solve a problem like that considered in this paper. A case study is performed on the container cargo data in Korea and test results are reported. The next section describes the MTP in more detail and Section Ⅲ presents a linear programming model. Then, a case study on the real data of international container cargoes in Korea is performed and test results are summarized in Section Ⅳ, and finally, this paper is completed with concluding remarks as well as future research directions.

Ⅱ. Problem Description

This section starts by explaining the cargo flow network. Figure 1 shows an example of the network. In the figure, the dotted region represents sea and the shaded region represents the inland of Korea. In the network, each node corresponds to foreign seaports, domestic seaport, inland container depots (ICD), and domestic cities, e.g., nodes F1 and F2 are foreign seaports, D1 and D2 are domestic seaports, I1 and I2 are ICDs, and C1 and C2 are domestic cities. Also, each arrow represents transportation flow of cargoes, i.e., solid arrows represent import flows, dotted arrows represent export flows, and bolded arrow represents coastal shipping flow. In the figure, the numbers located at the most left side imply the supply and the demand amounts in foreign seaports, while those located at the most right side imply those at domestic cities. For example, 500 twenty foot equivalent units (TEU) and 10000 TEU are the number of supplied cargoes and the number of the demanded cargoes in foreign seaport F1, respectively. The transportation in the country is done by trucks and trains in a direct way to a destination (cities or domestic seaports), by coastal shipping and by the way of an ICD. It is assumed that trains and trucks are operated between seaports and the ICD while trucks are only operated between ICDs and cities, according to the real situation in Korea. Here, the flow between ICDs is assumed not to occur based on the real situation in Korea.

Now, the MTP can be described as follows: for a given cargo flow network, the problem is to determine the cargo flow quantity and the amount transported by each transportation mode over one planning period while satisfying the demand of cargoes in domestic cities and foreign seaports using the supply in foreign seaports and domestic cities, respectively, for the objective of minimizing the sum of shipping and transportation costs. The shipping cost implies the total cost charged while transporting cargoes between foreign anddomestic seaports. The cost includes the holding and transit costs, and terminal handling charge, where the holding cost implies the cost occurred while cargoes are held during the transportation, the transit cost implies the cost charged for transporting cargoes, and the terminal handling charge is the cost occurred for the stevedoring service of cargoes at a domestic seaport. Here, we do not take account of the terminal handling charge at foreign seaports since we assume that the charge at foreign seaports is already given before shipping cargoes from foreign seaports. (Note that this model considers cargoes after shipping from foreign seaports.) Second, the transportation cost implies the total cost charged while transporting cargoes in the country, which includes the holding and transit costs.

The problem considers two restrictions: capacity restriction and vehicle restriction. The capacity restriction implies that there is a limitation on the total cargo volume that can be handled at each seaport. The vehicle restriction consists of two restrictions that are different with respect to transportation mode types (This model considers three transportation modes, truck, train, and barge, which are main transportation means in Korea). For truck, the restriction is given in the form of the total available time of trucks, which implies the total time of trucks (available at each Korean seaport or Korean city) that can be operated during the planning period. On the other hand, the restriction for train and barge is given in the form of the maximum number of trains (barge), which implies the total number of trains (barges) operated on each train (shipping) line during the planning period.

Finally, other assumptions made in the models are summarized as follows: (a) every parameter used in the model is given and deterministic; (b) single product type is considered; (c) one type of ship is used while shipping cargoes from foreign seaports to domestic seaports; (d) while transporting cargoes, one type of container is used, and traffic congestion never occurs; and (e) all transportation modes are perfect in state, i.e., they are not out of order throughout the planning period.

Ⅲ. Linear Program

In this section, we present a mixed integer programming model to solve optimally and represent the MTP. First, the notations used in the formulation are summarized below. (Note that parameters and variables given below are for one planning period)

I set of foreign seaports

J set of domestic seaports

K set of domestic cities

C set of ICDs

M set of modes

nm TEU that can be carried by mode m

nf_i TEU that can be carried by vessel departed from (arriving at) foreign seaport i

t_{ijm} transit time via mode m from depot i to destination j

cd_{ijm} cost of transporting an unit of cargo (TEU) via mode m from depot i to destination j which is calculated as

$$cd_{ijm} = h \cdot t_{ijm} + cm_{ij}$$

where h is the inventory holding cost per TEU and unit time and cm_{ij} is the transit cost per TEU from deport i to destination j

cf_{ij} cost of shipping an unit of cargo from depot i to destination j, calculated as

$$cf_{ij} = cd_{ij4} + thc_j$$

where thc_j is the terminal handling charge per unit TEU

u_j	available time of mode 1 at domestic seaport j
sf_i	supply amount from foreign seaport i
sd_k	supply amount from city k
df_i	demand amount in foreign seaport i
dd_k	demand amount in city k
a_j	capacity of domestic seaport j
b_c	capacity of ICD c
SI_{ij}	import amount from foreign seaport i to domestic seaport j
SE_{ji}	export amount from domestic seaport j to foreign seaport i
DI_{jk}	import amount from domestic seaport j to city k
DE_{kj}	export amount from city k to domestic seaport j
AI_{jkm}	import amount via mode m from domestic seaport j to city k
AE_{kjm}	export amount via mode m from city k to domestic seaport j
CI_{jck}	import amount from domestic seaport j to city k via ICD c
CE_{kcj}	export amount from city k to domestic seaport j via ICD c
TI_{jcm}	import amount from domestic seaport j to ICD c via mode m
TE_{cjm}	export amount from ICD c to domestic seaport j via mode m
TI_{ckm}	import amount from ICD c to domestic seaport j via mode m
TE_{kcm}	export amount from city k to ICD c via mode m
BI_{jbk}	import amount from domestic seaport j to city k via domestic seaport b
BE_{kbj}	export amount from city k to domestic seaport j via domestic seaport b

Now, the linear programming model is given below.

$$[P] \text{ Minimize } \sum_{i\in I}\sum_{j\in J} cf_{ij}\cdot(SI_{ij}+SE_{ji})+\sum_{j\in J}\sum_{k\in K}\sum_{m\in\{1,2\}} cd_{jkm}\cdot(AI_{jkm}+AE_{kjm})$$

$$+\sum_{j\in J}\sum_{b\in J-\{j\}}\sum_{k\in K} cd_{jb3}\cdot(BI_{jbk}+BE_{bjk})+\sum_{j\in J}\sum_{c\in C}\sum_{m\in M} cd_{jcm}\cdot(TI_{jcm}+TE_{cjm})$$

$$+\sum_{c\in C}\sum_{k\in K} cd_{ck1}\cdot(TI_{ck1}+TE_{kc1})$$

subject to

$$\sum_{j\in J} SI_{ij}=sf_i \qquad \text{for all } i\in I \qquad (1)$$

$$\sum_{j\in J} DE_{kj} = sd_k \qquad \text{for all } k\in K \tag{2}$$

$$\sum_{j\in J} DI_{jk} = dd_k \qquad \text{for all } k\in K \tag{3}$$

$$\sum_{j\in J} SE_{ji} = df_i \qquad \text{for all } i\in I \tag{4}$$

$$\sum_{i\in I} SI_{ji} = \sum_{k\in K} DI_{jk} \qquad \text{for all } j\in J \tag{5}$$

$$\sum_{k\in K} DE_{kj} = \sum_{i\in I} SE_{ji} \qquad \text{for all } j\in J \tag{6}$$

$$\sum_{i\in I}(SI_{ij} + SE_{ji}) + \sum_{b\in J-\{j\}} \sum_{k\in K}(BI_{bjk} + BE_{kjb}) \le a_j \qquad \text{for all } j\in J \tag{7}$$

$$\sum_{j\in J} \sum_{k\in K}(CI_{jck} + CE_{kcj}) \le b_c \qquad \text{for all } c\in C \tag{8}$$

$$DI_{jk} + \sum_{b\in J-\{j\}} BI_{bjk} = \sum_{m\in\{1,2\}} AI_{jkm} + \sum_{b\in J-\{j\}} BI_{jbk} + \sum_{c\in C} CI_{jck} \qquad \text{for all } j\in J \text{ and } k\in K \tag{9}$$

$$DE_{kj} = \sum_{m\in\{1,2\}} AE_{kjm} + \sum_{b\in J-\{j\}} BE_{kbj} + \sum_{c\in C} CE_{kcj} \qquad \text{for all } j\in J \text{ and } k\in K \tag{10}$$

$$\sum_{k\in K} CI_{jck} \le \sum_{m\in\{1,2\}} TI_{jcm} \qquad \text{for all } j\in J \text{ and } c\in C \tag{11}$$

$$\sum_{j\in J} CI_{jck} \le TI_{ck1} \qquad \text{for all } c\in C \text{ and } k\in K \tag{12}$$

$$\sum_{j\in J} CE_{kcj} \le TE_{kc1} \qquad \text{for all } c\in C \text{ and } k\in K \tag{13}$$

$$\sum_{k\in K} CE_{kcj} \le \sum_{m\in\{1,2\}} TE_{cjm} \qquad \text{for all } j\in J \text{ and } c\in C \tag{14}$$

$$SI_{ij} \le nf_i \cdot V_{ij} \qquad \text{for all } i\in I \text{ and } j\in J \tag{15}$$

$$\sum_{k\in K} t_{jk1} \cdot AI_{jk1} + \sum_{c\in C} t_{jc1} \cdot TI_{jc1} \le n_1 \cdot u_j \qquad \text{for all } j\in J \tag{16}$$

$$AI_{jk2} \le n_2 \cdot V_{jk} \qquad \text{for all } j\in J \text{ and } k\in K \tag{17}$$

$$TI_{jc2} \le n_2 \cdot V_{jc} \qquad \text{for all } j\in J \text{ and } c\in C \tag{18}$$

$$\sum_{k\in K} t_{ck1} \cdot TI_{ck1} + \sum_{j\in J} t_{cj1} \cdot TE_{cj1} \le n_1 \cdot u_c \qquad \text{for all } c\in C \tag{19}$$

$$\sum_{k\in K} BI_{jbk} \leq n_3 \cdot V_{jb} \quad \text{for all } j\in J \text{ and } b\in J-\{j\} \quad (20)$$

$$SE_{ji} \leq nf_i \cdot V_{ji} \quad \text{for all } i\in I \text{ and } j\in J \quad (21)$$

$$\sum_{j\in J} t_{kj1} \cdot AE_{kj1} + \sum_{c\in C} t_{kc1} \cdot TE_{kc1} \leq n_1 \cdot u_k \quad \text{for all } k\in K \quad (22)$$

$$AE_{kj2} \leq n_2 \cdot V_{kj} \quad \text{for all } j\in J \text{ and } k\in K \quad (23)$$

$$TE_{cj2} \leq n_2 \cdot V_{cj} \quad \text{for all } j\in J \text{ and } c\in C \quad (24)$$

$$\sum_{k\in K} BE_{kbj} \leq n_3 \cdot V_{bj} \quad \text{for all } j\in J \text{ and } b\in J-\{j\} \quad (25)$$

$$SI_{ij},\ SE_{ji} \geq 0 \quad \text{for all } i\in I \text{ and } j\in J \quad (26)$$

$$DI_{jk},\ DE_{kj} \geq 0 \quad \text{for all } j\in J \text{ and } k\in K \quad (27)$$

$$AI_{jkm},\ AE_{kjm} \geq 0 \quad \text{for all } j\in J,\ k\in K, \text{ and } m\in\{1,2\} \quad (28)$$

$$CI_{jck},\ CE_{kcj} \geq 0 \quad \text{for all } j\in J,\ c\in C, \text{ and } k\in K \quad (29)$$

$$TI_{jcm},\ TE_{cjm} \geq 0 \quad \text{for all } j\in J,\ c\in C, \text{ and } m\in\{1,2\} \quad (30)$$

$$TI_{ckm},\ TE_{kcm} \geq 0 \quad \text{for all } c\in C,\ k\in K, \text{ and } m\in\{1,2\} \quad (31)$$

$$BI_{jbk},\ BE_{kbj} \geq 0 \quad \text{for all } j\in J,\ b\in J-\{j\}, \text{ and } k\in K \quad (32)$$

The objective function denotes the sum of shipping and inland transportation costs. Constraints (1) - (4) represent the supply and demand restrictions. In more detail, constraints (1) and (2) represent the supply restrictions, which imply that the cargoes going out from a foreign seaport and a domestic city should be equal to the supply amount in the seaport and the city, respectively. On the other hand, constraints (3) and (4) represent that demands in a foreign seaport and a domestic city should be satisfied, respectively. Constraints (5) and (6) represent the flow conservation, which implies that the amount of cargoes coming to a domestic seaport is equal to the amount of cargoes going out from the seaport. Constraints (7) and (8) states that the total amount of cargoes handled at a domestic seaport and an ICD cannot exceed the capacity of the seaport and the ICD, respectively. Constraints (9) and (10) generate the amount of cargoes transported directly (via truck and train), via barge, and by way of an ICD. In constraint (9), the cargoes transported from a seaport come from directly foreign seaports and via the other seaports, which are denoted in the first term and second term, respectively. Constraints (11) - (14) calculate the amount of cargoes transported via truck and train. Constraints (15) - (25) represent that the total transported amount of cargoes cannot exceed the amount that can be transported by available vehicles. In particular constraints (16), (19), (22) represent that the total time required for using trucks is less than or equal to their available time at each depot. Finally, the other constraints (26) - (32) are the conditions on the decision variables.

Ⅳ. A Case Study

In this section, a case study on the container cargo data in Korea is performed. First, the container cargo data in Korea is summarized and then test result is summarized. In this test, CPLEX 9.1, a commercial linear program software package, was used to solve the linear program.

The data includes three modes for inland transportation (truck, train, and barge), two ICDs (Uiwang and Yangsan), five domestic ports (Busan, Gwanyang, Incheon, Ulsan, and Pyeongteak), and forty three domestic cities (Gangwon 1, 2, 3, Gyunggi 1, 2, 3, Gyungnam 1, 2, 3, Gyungbuk 1, 2, 3, Gwangju 1, 2, Daegu 1, 2, Daejon 1, 2, Busan 1, 2, 3, Seoul 1, 2, 3, 4, 5, Ulsan 1, 2, Incheon 1, 2, 3, Cheonnam 1, 2, 3, Cheonbuk 1, 2, 3, Chungnam 1, 2, 3, and Chungbuk 1, 2, 3). Note that we aggregated cities according to an expert's advice in transportation due to excessively many cities in Korea.

In case of foreign seaports, we selected seaports in different way according to short sea shipping (SSS) and deep sea shipping (DSS). Since the main purpose of this research is to focus on short sea shipping in the region, we attempted to cover up as detailed and numerous level of seaports as possible for the SSS transportation whereas covering up only representing major seaports in terms of cargo volumes for the DSS transportation. The selected seaports in the short sea shipping route group are major seaports handling Korea's international container cargoes in the region. In sum, thirteen seaports and twenty two SSS seaports were selected for the model, and they are seaports of Western Europe, Eastern Europe, North America (except the US), Detroit, Houston, Long Beach, New York, Savannah, Seattle, South America, Middle East, Central Asia, Africa, Yokohama, Yamaguchi, Tokyo, Osaka, Nagoya, Hakata, Other ports in Japan, Hong Kong, Kaohsiung, Keelung, Other ports in Taiwan, Shanghai, Xingang, Dalian, Qingdao, Ningbo, Weihai, Yantai, Other ports in China, Singapore, Malaysia, Other ports in Southeast Asia.

The number of TEUs transported by a transportation mode was set to 1 for a truck, 50 for a train, 215 for a barge and the number of TEUs by a ship was set to 1100 for Southeast Asian countries, i.e., SP, ML, OS, 600 for the others for the SSS region, and 6000 for the DSS region. Also, the inventory holding cost was set to $ 0.42 using the method given in Chang and Sung (2002). Table 1 summarizes the supply and demand data in foreign seaports and domestic cities in year 2005.

<Table 1> Supply and Demand Data (TEU)

(a) Foreign Seaport

	WE	EE	NA	DT	HS	LB	NY	SV	ST	SA	ME	CA
Supply	659592	146124	102012	0	3648	161544	49164	48240	125544	167364	71808	59964
Demand	414295	112354	180957	2506	3013	366083	50201	41404	182113	355768	343669	173546
	AF	YK	YM	TK	OS	NG	HT	OJ	HK	KS	KL	OT
Supply	22584	121560	1044	94116	130056	68964	101904	341016	556032	479580	25008	13236
Demand	178751	45706	30848	72168	61287	47429	27776	118043	301084	62347	68662	23437
	SH	XG	DL	QD	NB	WH	YT	OC	SP	ML	OS	
Supply	185632	205663	134818	202341	82663	40196	24866	108700	150612	119544	17448	
Demand	206996	234683	106751	174024	81057	43575	56309	19372	78326	111331	402349	

WE: Western Europe, EE: Eastern Europe, NA: North America (except the US), DT: Detroit, HS: Houston, LB: Long Beach, NY: New York, SV: Savannah, ST: Seattle, SA: South America, ME: Middle East, CA: Central Asia, AF: Africa, YK: Yokohama, YM: Yamaguchi, TK: Tokyo, OS: Osaka, NG: Nagoya, HT: Hakata, OJ: Other ports in Japan, HK: Hong Kong, KS: Kaohsiung, KL: Keelung, OT: Other ports in Taiwan, SH: Shanghai, XG: Xingang, DL: Dalian, QD: Qingdao, NB: Ningbo, WH: Weihai, YT: Yantai, OC: Other ports in China, SP: Singapore, ML: Malaysia, OS: Other ports in Southeast Asia

Source: Korea Customs and Trade Development Institute

(b) Domestic City

	GW1	GW2	GW3	GG1	GG2	GG3	GN1	GN2	GN3	GB1	GB2
Supply	1545	5365	3150	135168	471827	138460	30257	87091	75570	34504	69230
Demand	657	10897	9194	90985	508915	71670	41459	289190	183390	44027	48514
	GB3	GJ1	GJ2	DG1	DG2	DJ1	DJ2	PS1	PS2	PS3	SU1
Supply	88778	11949	11461	67686	16724	40742	7600	124846	56957	97515	97048
Demand	286480	235019	17173	63717	37957	105488	6629	176397	39945	43564	36597
	SU2	SU3	SU4	SU5	US1	US2	IC1	IC2	IC3	CN1	CN2

Supply	426534	28509	1777007	184403	28916	54112	326	220836	66609	8393	12639
Demand	308764	13196	198946	93818	79159	565335	706	126240	136998	7127	9231
	CN3	CB1	CB2	CB3	CUN1	CUN2	CUN3	CUB1	CUB2	CUB3	
Supply	32756	68092	6035	3150	12843	40051	62972	74371	27717	12843	
Demand	320270	165617	5449	3782	95188	96527	79344	81813	33603	9243	

GW1: Gangwon1, GW2: Gangwon2, GW3: Gangwon3, GG1: Gyunggi1, GG2: Gyunggi2, GG3: Gyunggi3, GN1: Gyungnam1, GN2: Gyungnam2, GN3: Gyungnam3, GB1: Gyungbuk1, GB2: Gyungbuk2, GB3: Gyungbuk3, GJ1: Gwangju1, GJ2: Gwangju2, DG1: Daegu1, DG2: Daegu2, DJ1: Daejon1, DJ2: Daejon2, PS1: Busan1, PS2: Busan2, PS3: Busan3, SU1: Seoul1, SU2: Seoul2, SU3: Seoul3, SU4: Seoul4, SU5: Seoul5, US1: Ulsan1, US2: Ulsan2, IC1: Incheon1, IC2: Incheon2, IC3: Incheon3, CN1: Cheonnam1, CN2: Cheonnam2, CN3: Cheonnam3, CB1: Cheonbuk1, CB2: Cheonbuk2, CB3: Cheonbuk3, CUN1: Chungnam1, CUN2: Chungnam2, CUN3: Chungnam3, CUB1: Chungbuk1, CUB2: Chungbuk2, CUB3: Chungbuk3

Also, Table 2 summarizes the capacity of each domestic seaport. Remaining data are not given in this paper due to space limitation.

Test results are summarized in Table 3, which shows the solution of the CPLEX and the real data on the ratio (share) of the throughput at each domestic seaport versus the total container cargo volume imported into and exported from Korea, and the ratio (share) of the volume transported by each transportation model among total cargo container volume.

<Table 2> Capacity of Domestic Seaport

Port	Capacity (TEU)
Busan	7847811
Gwangyang	1386600
Incheon	1195395
Ulsan	314253
Pyeongteak	227591

Source: Each Regional Ports Maritime Affairs and Fisheries Office

<Table 3> Comparison of the Model's Result with Real Data

(a) Share of the total container cargo volume at each domestic seaport (%)

	Model*	Real*	Difference**
Busan	75.8	68.5	7.3
Gwangyang	12.5	11.4	1.1
Incheon	8.4	11.0	-2.6
Ulsan	1.6	3.3	-1.7
Pyeongtaek	1.7	2.4	-0.7

* throughput / total cargo volume·100

** Model - Real

(b) Share of the total container cargo volume by each transportation mode (%)

	Model*	Real*	Difference**
Truck	83.3	87.3	-4
Train	14.0	9.9	4.1
Coastal shipping	2.6	2.8	-2.2

* *cargo volume / total cargo volume·100*

* Model - Real

As can be seen from the table, the model represents the real situation quite well, i.e., all differences between model's result and real data are within 10 %. Therefore, it can be argue that the model can be used when analyzing the possible effect on the cargo flow in Korea if future situation on the international cargo trade in Korea changes, e.g., effects occurred when some seaports are developed more, transit costs become different, fast vessles are used for some trade routes, etc.

V. Concluding Remarks

In this paper, we considered the problem of determining the transportation flow quantity and the transportation mode in each trade route, for the objective of minimizing the sum of shipping and transportation costs, restricted to maximum cargo volumes capacitated at each seaport and maximum number of vehicles available at each transportation mode. To solve optimally and represent the problem, this paper employed a linear programming model. The case study on the container cargo data in Korea indicates the model represents the real situation quite well and hence can be used for further analysis.

There are some future research directions. First, it is worth to consider more transportation modes such as airplane, etc. Second, the demand in foreign cities (not that in foreign seaports used in this paper) is worth to be considered. In this case, the capacity of foreign seaports and all parameters corresponding to inland transportation should be used. Third, it is meaningful to consider traffic and environmental factors.

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