Research on the Amount of Empty Containers in Japanese Main Ports

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ABSTRACT

Economic development is remarkable in Asia and progress of industrialization of NIES, ASEAN, and China in East Asia has increased the international physical distribution in this area. However, an imbalance of trade becomes severe in these areas. The imbalance is especially big in the Asia-North America route and the Japan-China route. The imbalance in the Asia -North America liner route is 5.04 million TEUS in 2002.The transportation ratio of loaded containers between China and Japan route is approximately 3:1 in 2000. In other words, it means that the transportation of loaded containers from China to Japan is 3, the transportation of loaded containers from Japan to China is 1.

The imbalance at a port is generally obtained by subtracting export loaded container cargo volume from import container cargo volume. However, the imbalance and the empty containers at the port are not always same. Then, in order to evaluate rationalization and efficiency of maritime container transportation, we introduce the amount of empty containers at a port as an evaluation index. However, the past data of the amount of handling empty containers have a lot of lacking portions. Then, it is necessary to estimate the past amount of empty containers in order to grasp the amount of empty containers historically. So, we construct the model that estimates the amount of empty containers using the imbalance of main port statistics in Japan.

1. Introduction

1.1 Background of Research

Economic development is remarkable in Asia and especially progress of industrialization of NIES, ASEAN, and China in East Asia has increased the international physical distribution in this area rapidly. International division of labor is developing in the countries of the East and Southeast Asia. The product produced in each country, raw material required for the production, intermediate materials, and capital goods came to be frequently conveyed in large quantities between the East and Southeast Asia, and other areas(1).

The economic development is remarkable in Asia. However, the problem of trade imbalance becomes severe in this area. Especially, the imbalances of cargoes in the Asia-North America route and Japan-China route in the Pacific Ocean are increasing rapidly. The imbalance in the Asia -North America liner route is 5 million TEUS in 2002(2). The transportation ratio of loaded containers between China and Japan route is approximately 3:1 in 2000(3). The empty containers which go back are increasing in number. As a big problem caused by the imbalance of this freight flow, a large number of empty containers become necessary to compensate this freight flow. Empty containers transportation wastes equipments of ships, and port facilities, etc. Furthermore, it has been a serious obstacle against the cost down of international physical distribution and efficient transportation.

1.2 Aim of Research

In order to perform rationalization of marine container traffic and increase in efficiency, the amount of handling empty containers in ports are calculated. In order to use empty containers effectively, it is necessary to grasp the amount of generating empty containers between 2 ports. Because, if the hinterland and industrial structure, etc. of 2 ports are known, the kind of cargo filled in the generated empty container will be known. That is, if a concrete port is known, it will become possible to perform the proposal about development of new species cargoes.

The past data of the amount of handling empty containers of each port, however, have many insufficient portions. For example, the amounts of handling empty containers before 1999 are not taken in port statistics of the five Japanese major ports. Then, in order to grasp the historical transition of an empty container, it is necessary to estimate the amount of handling empty containers before 1999. In order to perform this estimation, we construct the model that estimates the amount of empty containers using the imbalance of main port statistics in Japan.

2. Past Research and Investigation

Although the research on empty containers began from the 80s, there are few announced papers. When these references are summarized, there are many references about container fleet size. Generally the container fleet size model which predicts the optimal fleet size (the amount of demand of a container) and the minimum cost is made considering the number of times of call, cruise time, etc. The empty container is introduced into the model as one parameter in the determination of the fleet size.

Conventionally, the pattern of research has the following:
(1)The amount of generating of the empty container between areas or between port groups
(2) Inventory reduction by supplying an empty container on time
(3) Research on movement and supply of empty containers in the hinterland

Imai et al[4] presented an effective planning method, especially the short period planning for the distribution of empty sea-borne containers. Yoshikawa et al[5] discussed an effective transfer planning of empty containers especially between Japan and U.S., and an optimal transfer planning of empty containers. Miki et al[6] proposed two planning models, for decision of the number of containers carriers that should possess, and for effective transfer of empty containers. CRAINIC and GENDREAU[7] have described the allocation problem of empty containers in a land distribution and transportation system ,and have identified its basic structure and main characteristics. They provided a mathematical formulation for handling, in the single commodity case.

In connection with the rapid expansion of trade between Japan and China, a big change has arisen also in Japan-China route. As the increase of the both-way local cargo volume between Japan and China in recent years, the imbalance of both-way cargo volume is increasing. The imbalance of this freight flow produces a big problem. It means that the transportation companies face to a lot of empty container transportation. The liner group in operation investigating room of Mitsui O.S.K. Lines have investigated expansion of imbalance and analyzed increase of operation cost.

The imbalance of the both-way cargo volume between two areas is generally obtained by subtracting the exported loaded container volume from the imported loaded container volume. For example, in the case of Asia / North America route, the transfer amount of the empty container from the port group of the U.S. area to the port group of the Asian is obtained by subtracting loaded container volume from U.S. to Asian, from container cargo volume from Asia to U.S. In fact, the transfer of the empty containers exceeds the above estimated value. In the meaning, the estimate value is considered to be the minimum value[8]. From this estimated value, the amount of transfers of the empty container in Asia / North America route is increasing from 1.4 million TEUS in 1997 to 5 million TEUS in 2002[2], and its increasing rate in five years is about 3.5 times. (Fig.1)

The expense for bringing a 40 foot empty container back to Asia from North America changes with each shipping companies. We regard the expense as $500 per container temporarily[8]. Then, the expense in 1997 counts to $700 million, and that in 2002 does $2,500 million in the whole trade. Even if we consider an

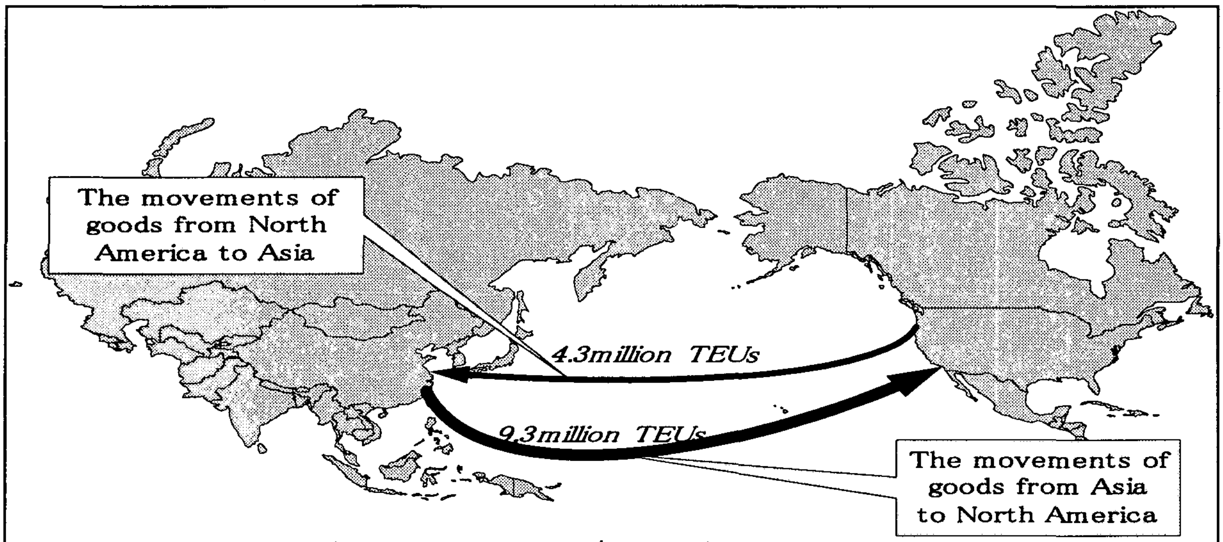

Fig. 1 Imbalance of Asia / North America container movements of goods in2002

increasing part alone, the averaged annual increasing rate is $260 million. The increase in this transfer expense and the fall of the freight for North America serve as an element to drop the profit of shipping companies greatly. This shows that the empty containers transportation is a big problem for shipping companies and shippers.

3. Comparison of Export and Import Imbalance with Amount of Handling Empty Containers

Japanese port statistics have not taken statistics of the empty container before 1999. Fig.2, Fig.3, Fig.4, and Fig.5 show the comparison of the imbalance between Japanese four main ports and the main foreign 50 ports for international trade with the amount of handling empty containers in the ports in 2000[9]. Although the data becomes close to a line of 45 degrees, in the go-around type case, that is, multi-ports calling, it turns out that the imbalance is not necessarily the same as the amount of transfer empty containers. In the case of between 2 ports, it turns out that the method of calculating the imbalance of container between 2 areas is inapplicable to the method of calculating the empty container between 2 ports.

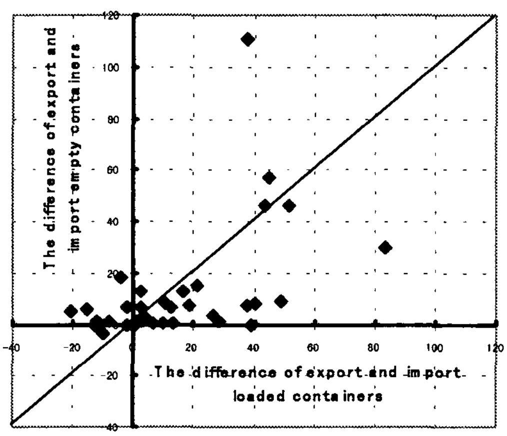

Fig.2 Comparison between the difference of the export-and-import loaded containers, and the difference of empty containers of the Port of Tokyo in 2000 (1,000TEUs)

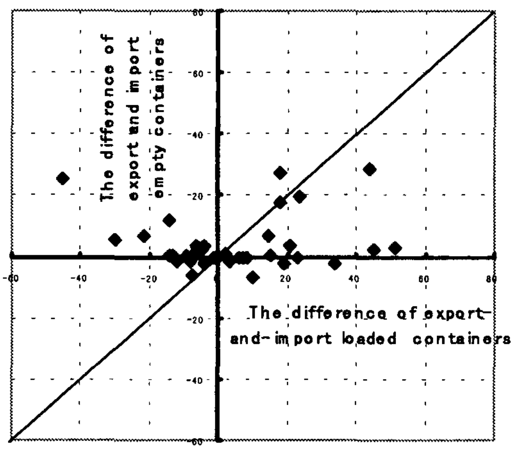

Fig.3 Comparison between the difference of the export-and-import loaded containers, and the difference of empty containers of the Port of Yokohama in 2000 (1,000TEUs)

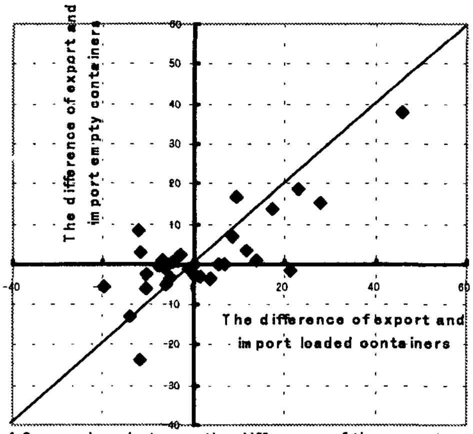

Fig.4 Comparison between the difference of the export-and-import loaded containers, and the difference of empty containers of the Port of Nagoya in 2000 (1,000TEUs)

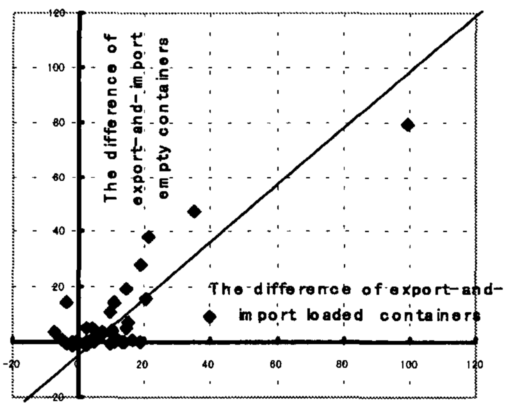

Fig.5 Comparison between the difference of the export-and-import loaded containers, and the difference of empty containers of the Port of Osaka in 2000 (1,000TEUs)

4. Transition of Freight of North American Route

4.1 Freight of Loaded containers

Since the Shipping Act of 1984(U.S.A) was enforced, the market controlling power by an alliance has been weaken and competition between shipping companies has become strong. The freight level fell greatly from 1985 to 1986.After that, the fare was recovered gently. As shipping companies invested the large vessel after 1995, the available tonnage became too large. For this reason, the freight level went down after the second half of 1995[(10)].

The container cargoes for U.S.A increased quickly by change of the exchange rate of Asia, and prosperity of U.S.A from 1997, so the freight level for North America was upgraded sharply. It resulted in a fright increase of $900 (per 40 foot container) in May 1999. However, from 2001, by the slowdown of U.S.A prosperity and the investment of large vessels, ship supply was increased. For this reason, the freight tends to fall[(10)].

Fig.6 shows the freight level transition of electric products on the North America route[(10)].Table.1 shows the freight transition of staple articles on the North America route[(10)(11)]. If we see from average value of main freights, the freight per 40 feet container is a little less than $3,000.

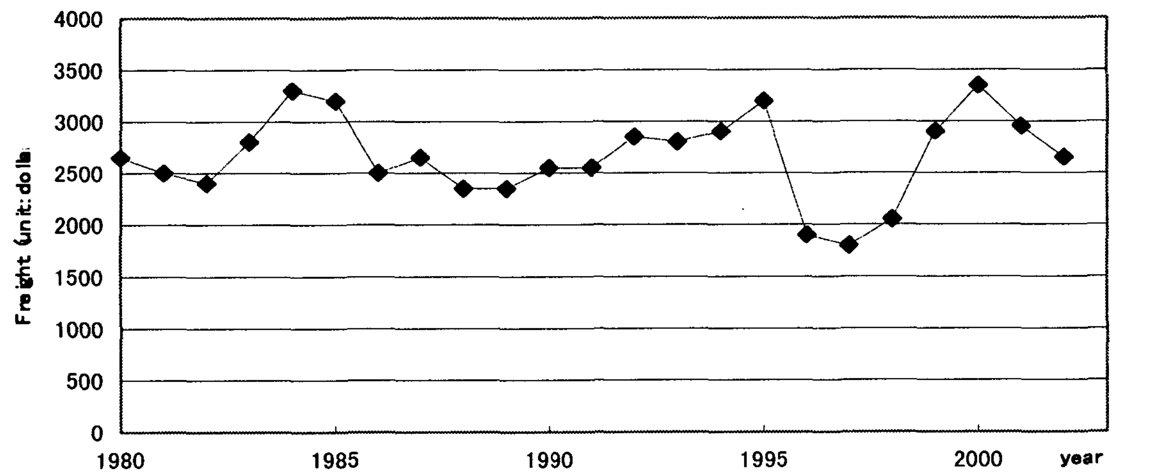

Fig.6 Transition of the freight level of the electrical machinery products on the North America routes (per 40 feet container)

4.2 Freight of Empty Container

Table.1 Transition of staple article freight on the North America routes (unit: dollar)

Time	Television	Autoparts	Tire	CKD	Average value of main freights
'75 May	2,920	3,720	2,730	-	3,123
'80 Mar	2,660	3,610	2,610	-	2,960
'85 Apr	3,220	3,830	2,750	3,050	3,213
'90 May	2,550	2,750	2,500	2,750	2,638
'95 Oct	2,450	2,620	1,800	2,620	2,373
'96 May	1,920	2,070	1,730	2,220	1,985
'97 Oct	1,822	1,962	1,490	2,101	1,844
'98 May	2,050	2,186	1,728	2,321	2,071
'99 May	2,950	3,086	2,628	3,021	2,921
'00 May	3,350	3,486	3,028	3,421	3,321
'01 May	2,950	-	-	-	2,950
'02 May	2,650	-	-	-	2,650

From the hearing to a shipping company, an empty container freight is divided into two kinds. The first empty container transport occurs when shipping companies transport the empty containers in order to realize the business chance. In this case, the freight must be paid by themselves. The freight is about $500 per 40 foot container in a North America route in 2003.The second empty container transport occurred when shipping companies is required to transport on shippers' demand. In this case, the freight is about $1,500 per 40 foot container in a North America route in 2003.Comparing the freight with those in Table.1, the empty container freight on shippers' demand is about half of the loaded container freight. Then if the freight of empty containers was supposed to be $1,500/TEU, $7,500 million were spent for the empty containers transport. It turns out that it is a big loss for each shipper and each carrier.

5. Selection of Port and Decision of Investigation Range

Firstly, the Japanese ports are chosen. By Japanese port statistics, 4 Japanese ports (Tokyo, Yokohama, Nagoya and Osaka) are chosen. Next, main container ports in Asia and North American are chosen. Main container ports are chosen by Japanese port statistics(9) and international container transport data(12) in 2000. They are 18 ports in all. As a principle, the ports where the container handling volume exceeds 10,000 TEU are adopted.

6. First Approximate Solution for Estimation of Empty Containers Amount

6.1 Composition of Data Matrix I for Japanese Ports and Asian and North American Ports

Table.2 shows a portion of data matrix I. The Asian and North American ports are arranged in a lengthwise direction (i) of this matrix, and the four Japanese major ports are arranged in the transverse direction (j) of this matrix,

Table.2 Data matrix I of the main container ports and 4 Japanese ports in 2000, an example of the Port of Tokyo[4]

	j =	1 (Tokyo)							
i =	port	X_{ij} The handling volume of the export loaded containers		Y_{ij} The handling volume of the export empty containers		Z_{ij} The handling volume of the import loaded containers		W_{ij} The handling volume of the import empty containers	
1	Busan	X_{11}	22,001	Y_{11}	47,490	Z_{11}	73,707	W_{11}	972
2	Dalian	X_{21}	6,985	Y_{21}	12,740	Z_{21}	23,592	W_{21}	191
3	Tianjin	X_{31}	3,653	Y_{31}	6,360	Z_{31}	6,252	W_{31}	84
4	Qingdao	X_{41}	5,199	Y_{41}	46,365	Z_{41}	48,994	W_{41}	536
5	Shanghai	X_{51}	29,410	Y_{51}	57,774	Z_{51}	74,166	W_{51}	999
6	Keelung	X_{61}	19,482	Y_{61}	18,272	Z_{61}	15,297	W_{61}	28
7	Kaohsiung	X_{71}	29,326	Y_{71}	111,457	Z_{71}	67,065	W_{71}	513
8	Hong Kong	X_{81}	60,843	Y_{81}	31,440	Z_{81}	144,366	W_{81}	1,167
9	Bangkok	X_{91}	11,518	Y_{91}	8,629	Z_{91}	52,093	W_{91}	226
10	Laem Chabang	X_{101}	10,290	Y_{101}	15,640	Z_{101}	31,245	W_{101}	523
11	Singapore	X_{111}	31,902	Y_{111}	9,594	Z_{111}	69,855	W_{111}	1,916
12	Port klang	X_{121}	12,963	Y_{121}	6,561	Z_{121}	25,322	W_{121}	73
13	Long Beach	X_{131}	57,019	Y_{131}	4,534	Z_{131}	59,201	W_{131}	2,395
14	Los Angeles	X_{141}	64,121	Y_{141}	3,275	Z_{141}	68,283	W_{141}	1,480
15	Oakland	X_{151}	7,917	Y_{151}	10,021	Z_{151}	56,838	W_{151}	969
16	Seattle	X_{161}	46,097	Y_{161}	6,556	Z_{161}	30,712	W_{161}	1,095
17	Tacoma	X_{171}	44,008	Y_{171}	4,791	Z_{171}	23,165	W_{171}	118
18	Vancouver	X_{181}	25,997	Y_{181}	411	Z_{181}	65,068	W_{181}	548

X_{ij} is the handling volume of the export loaded containers from 4 Japanese ports (j) to 18 Asian and North American main ports (i).

Y_{ij} is the handling quantity of the export empty containers from 4 Japanese ports (j) to 18 Asian and North American main ports (i).

Z_{ij} is the handling quantity of the import loaded containers from 18 main Asian and North American ports (i) to 4 Japanese ports (j).

W_{ij} is the handling quantity of the import empty containers from 18 main Asian and North American ports (i) to 4 Japanese ports (j).

6.2 Definition of parameter and construction of equation by data matrix II(13)

Table.3 shows data matrix II. The imbalance DS_{ij} between import and export loaded container volume of Japanese ports is defined by subtracting the exported loaded containers from imported ones. In the same way, the imbalance DE_{ij} between import and export empty container volume of Japanese ports is defined by

Table.3 Data matrix : DS_{ij} and DE_{ij} of 4 Japanese ports in 2000

	j =	1(Tokyo)		2(Yokohama)		3(Nagoya)		4(Osaka)	
i =	Busan	DSij	DEij	DSij	DEij	DSij	DEij	DSij	DEij
1	Dalian	DS_{11}	DE_{11}	DS_{12}	DE_{12}	DS_{13}	DE_{13}	DS_{14}	DE_{14}
2	Tianjin	DS_{21}	DE_{21}	DS_{22}	DE_{22}	DS_{23}	DE_{23}	DS_{24}	DE_{24}
3	Qingdao	DS_{31}	DE_{31}	DS_{32}	DE_{32}	DS_{33}	DE_{33}	DS_{34}	DE_{34}
4	Shanghai	DS_{41}	DE_{41}	DS_{42}	DE_{42}	DS_{43}	DE_{43}	DS_{44}	DE_{44}
5	Keelung	DS_{51}	DE_{51}	DS_{52}	DE_{52}	DS_{53}	DE_{53}	DS_{54}	DE_{54}
6	Kaohsiung	DS_{61}	DE_{61}	DS_{62}	DE_{62}	DS_{63}	DE_{63}	DS_{64}	DE_{64}
7	Hong Kong	DS_{71}	DE_{71}	DS_{72}	DE_{72}	DS_{73}	DE_{73}	DS_{74}	DE_{74}
8	Bangkok	DS_{81}	DE_{81}	DS_{82}	DE_{82}	DS_{83}	DE_{83}	DS_{84}	DE_{84}
9	Laem Chabang	DS_{91}	DE_{91}	DS_{92}	DE_{92}	DS_{93}	DE_{93}	DS_{94}	DE_{94}
10	Singapore	DS_{101}	DE_{101}	DS_{102}	DE_{102}	DS_{103}	DE_{103}	DS_{104}	DE_{104}
11	Port klang	DS_{111}	DE_{111}	DS_{112}	DE_{112}	DS_{113}	DE_{113}	DS_{114}	DE_{114}
12	Long Beach	DS_{121}	DE_{121}	DS_{122}	DE_{122}	DS_{123}	DE_{123}	DS_{124}	DE_{124}
13	Los Angeles	DS_{131}	DE_{131}	DS_{132}	DE_{132}	DS_{133}	DE_{133}	DS_{134}	DE_{134}
14	Oakland	DS_{141}	DE_{141}	DS_{142}	DE_{142}	DS_{143}	DE_{143}	DS_{144}	DE_{144}
15	Seattle	DS_{151}	DE_{151}	DS_{152}	DE_{152}	DS_{153}	DE_{153}	DS_{154}	DE_{154}
16	Tacoma	DS_{161}	DE_{161}	DS_{162}	DE_{162}	DS_{163}	DE_{163}	DS_{164}	DE_{164}
17	Vancouver	DS_{171}	DE_{171}	DS_{172}	DE_{172}	DS_{173}	DE_{173}	DS_{174}	DE_{174}
18	Busan	DS_{181}	DE_{181}	DS_{182}	DE_{182}	DS_{183}	DE_{183}	DS_{184}	DE_{184}

subtracting the imported empty containers from exported ones. Equation (1) shows the definition of DS_{ij} and DE_{ij}.

$$\left.\begin{aligned} DS_{ij} &= Z_{ij} - X_{ij} \\ DE_{ij} &= Y_{ij} - W_{ij} \end{aligned}\right\} \qquad (1)$$

$i \in$ I, I= {1,2,3,···,18} ={Busan, Dalian, Tianjin, ···Vancouver}
$j \in$ J, J= {1,2,3,4,} ={Tokyo, Yokohama, Nagoya, Osaka }

Using Table.3, the equation (2) is formed and the first approximate solution for the amount of handling empty containers is calculated. Table.4 shows the Tokyo port portion of equation (2). The fundamental concept of the construction of equation (2) is that DE_{ij} depends on DS_{ij}, i=n,n+1,n+2,,,,m, where m is the last port of the route. Equation (2) shows the estimating equation of DE_{ij}. using DS_{ij}.

$$a_0 + \sum_{k=1}^{n_k} a_k DS_{lj} = DE_{ij} \qquad (2)$$

Where,

$i \in$ I, I= {1,2,3,···,18} ={Busan, Dalian, Tianjin, ···Vancouver}
$j \in$ J, J= {1,2,3,4,} ={Tokyo, Yokohama, Nagoya, Osaka }

Table.4 The equations for the first order Approximate solution, an example of the Port of Tokyo

a_0	+	a_1DS_{11}	+	a_2DS_{21}	+	a_3DS_{31}	+	a_4DS_{41}	+ ··· +	$a_{17}DS_{171}$	+	$a_{18}DS_{181}$	=	DE_{11}
a_0	+	a_1DS_{21}	+	a_2DS_{31}	+	a_3DS_{41}	+	a_4DS_{51}	+ ··· +	$a_{17}DS_{181}$	+	0	=	DE_{21}
a_0	+	a_1DS_{31}	+	a_2DS_{41}	+	a_3DS_{51}	+	a_4DS_{61}	+ ··· +	0	+	0	=	DE_{31}
a_0	+	a_1DS_{41}	+	a_2DS_{51}	+	a_3DS_{61}	+	a_4DS_{71}	+ ··· +	0	+	0	=	DE_{41}
a_0	+	a_1DS_{51}	+	a_2DS_{61}	+	a_3DS_{71}	+	a_4DS_{81}	+ ··· +	0	+	0	=	DE_{51}
a_0	+	a_1DS_{61}	+	a_2DS_{71}	+	a_3DS_{81}	+	a_4DS_{91}	+ ··· +	0	+	0	=	DE_{61}
a_0	+	a_1DS_{71}	+	a_2DS_{81}	+	a_3DS_{91}	+	a_4DS_{101}	+ ··· +	0	+	0	=	DE_{71}
a_0	+	a_1DS_{81}	+	a_2DS_{91}	+	a_3DS_{101}	+	a_4DS_{111}	+ ··· +	0	+	0	=	DE_{81}
a_0	+	a_1DS_{91}	+	a_2DS_{101}	+	a_3DS_{111}	+	a_4DS_{121}	+ ··· +	0	+	0	=	DE_{91}
a_0	+	a_1DS_{101}	+	a_2DS_{111}	+	a_3DS_{121}	+	a_4DS_{131}	+ ··· +	0	+	0	=	DE_{101}
a_0	+	a_1DS_{111}	+	a_2DS_{121}	+	a_3DS_{131}	+	a_4DS_{141}	+ ··· +	0	+	0	=	DE_{111}
a_0	+	a_1DS_{121}	+	a_2DS_{131}	+	a_3DS_{141}	+	a_4DS_{151}	+ ··· +	0	+	0	=	DE_{121}
a_0	+	a_1DS_{131}	+	a_2DS_{141}	+	a_3DS_{151}	+	a_4DS_{161}	+ ··· +	0	+	0	=	DE_{131}
a_0	+	a_1DS_{141}	+	a_2DS_{151}	+	a_3DS_{161}	+	a_4DS_{171}	+ ··· +	0	+	0	=	DE_{141}
a_0	+	a_1DS_{151}	+	a_2DS_{161}	+	a_3DS_{171}	+	a_4DS_{181}	+ ··· +	0	+	0	=	DE_{151}
a_0	+	a_1DS_{161}	+	a_2DS_{171}	+	a_3DS_{181}	+	0	+ ··· +	0	+	0	=	DE_{161}
a_0	+	a_1DS_{171}	+	a_2DS_{181}	+	0	+	0	+ ··· +	0	+	0	=	DE_{171}
a_0	+	a_1DS_{181}	+	0	+	0	+	0	+ ··· +	0	+	0	=	DE_{181}

$$\left.\begin{array}{l} l = k + i - 1 \\ n_k = 18 - i + 1 \end{array}\right\} \qquad \cdots\cdots (3)$$

$l \in L$, $L = \{1,2,3,\cdots,18\}$ = {the number of lines}
$k \in K$, $K = \{1,2,3,\cdots,18\}$ = {the number of columns}
a_k : $k = \{1,2,3,\cdots,18\}$ constant

6.3 First Approximate Solution of Empty Container Amount

Multiple linear regression analysis of a multi-variable analysis is performed. As a result of analyzing, a multiple correlation coefficient becomes 0.80. A judgment zone becomes significant to 5%. Fig.7 shows the comparison between the first order approximate solution and the actual data of the difference of the empty containers.

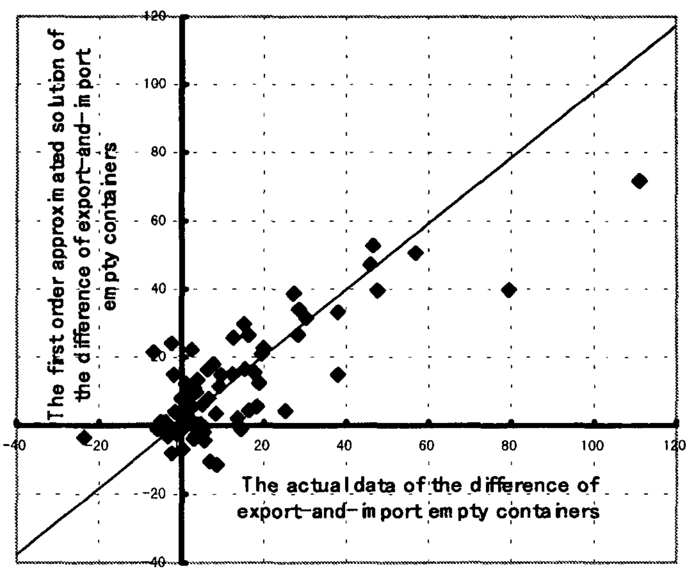

Fig. 7 Comparison between the first order approximated solution and the actual data of the difference of the empty containers of 4 Japanese ports in 2000 (1,000 TEUs)

7. Second Approximate Solution of Empty Container Amount

In this section, furthermore we consider the mutual effects between domestic ports in Japan. Then, in order to raise the accuracy of the model, the equation (2) is modified. Four columns of the difference of the loaded containers between the main foreign ports and Japanese 4 ports were introduced into the vertical direction of this matrix. Table.5 shows the Tokyo port portion of equation (4).

Table.5 The equations for the second order Approximate solution, an example of the Port of Tokyo

a_0	+	a_1DS_{11}	+	a_2DS_{21}	+	⋯	+	$a_{18}DS_{181}$	+	b_1DS_{11}	+	b_2DS_{12}	+	b_3DS_{13}	+	b_4DS_{14}	=	DE_{11}
a_0	+	a_1DS_{21}	+	a_2DS_{31}	+	⋯	+	0	+	b_1DS_{21}	+	b_2DS_{22}	+	b_3DS_{23}	+	b_4DS_{24}	=	DE_{21}
a_0	+	a_1DS_{31}	+	a_2DS_{41}	+	⋯	+	0	+	b_1DS_{31}	+	b_2DS_{32}	+	b_3DS_{33}	+	b_4DS_{34}	=	DE_{31}
a_0	+	a_1DS_{41}	+	a_2DS_{51}	+	⋯	+	0	+	b_1DS_{41}	+	b_2DS_{42}	+	b_3DS_{43}	+	b_4DS_{44}	=	DE_{41}
a_0	+	a_1DS_{51}	+	a_2DS_{61}	+	⋯	+	0	+	b_1DS_{51}	+	b_2DS_{52}	+	b_3DS_{53}	+	b_4DS_{54}	=	DE_{51}
a_0	+	a_1DS_{61}	+	a_2DS_{71}	+	⋯	+	0	+	b_1DS_{61}	+	b_2DS_{62}	+	b_3DS_{63}	+	b_4DS_{64}	=	DE_{61}
a_0	+	a_1DS_{71}	+	a_2DS_{81}	+	⋯	+	0	+	b_1DS_{71}	+	b_2DS_{72}	+	b_3DS_{73}	+	b_4DS_{74}	=	DE_{71}
a_0	+	a_1DS_{81}	+	a_2DS_{91}	+	⋯	+	0	+	b_1DS_{81}	+	b_2DS_{82}	+	b_3DS_{83}	+	b_4DS_{84}	=	DE_{81}
a_0	+	a_1DS_{91}	+	a_2DS_{101}	+	⋯	+	0	+	b_1DS_{91}	+	b_2DS_{92}	+	b_3DS_{93}	+	b_4DS_{94}	=	DE_{91}
a_0	+	a_1DS_{101}	+	a_2DS_{111}	+	⋯	+	0	+	b_1DS_{101}	+	b_2DS_{102}	+	b_3DS_{103}	+	b_4DS_{104}	=	DE_{101}
a_0	+	a_1DS_{111}	+	a_2DS_{121}	+	⋯	+	0	+	b_1DS_{111}	+	b_2DS_{112}	+	b_3DS_{113}	+	b_4DS_{114}	=	DE_{111}
a_0	+	a_1DS_{121}	+	a_2DS_{131}	+	⋯	+	0	+	b_1DS_{121}	+	b_2DS_{122}	+	b_3DS_{123}	+	b_4DS_{124}	=	DE_{121}
a_0	+	a_1DS_{131}	+	a_2DS_{141}	+	⋯	+	0	+	b_1DS_{131}	+	b_2DS_{132}	+	b_3DS_{133}	+	b_4DS_{134}	=	DE_{131}
a_0	+	a_1DS_{141}	+	a_2DS_{151}	+	⋯	+	0	+	b_1DS_{141}	+	b_2DS_{142}	+	b_3DS_{143}	+	b_4DS_{144}	=	DE_{141}
a_0	+	a_1DS_{151}	+	a_2DS_{161}	+	⋯	+	0	+	b_1DS_{151}	+	b_2DS_{152}	+	b_3DS_{153}	+	b_4DS_{154}	=	DE_{151}
a_0	+	a_1DS_{161}	+	a_2DS_{171}	+	⋯	+	0	+	b_1DS_{161}	+	b_2DS_{162}	+	b_3DS_{163}	+	b_4DS_{164}	=	DE_{161}
a_0	+	a_1DS_{171}	+	a_2DS_{181}	+	⋯	+	0	+	b_1DS_{171}	+	b_2DS_{172}	+	b_3DS_{173}	+	b_4DS_{174}	=	DE_{171}
a_0	+	a_1DS_{181}	+	0	+	⋯	+	0	+	b_1DS_{181}	+	b_2DS_{182}	+	b_3DS_{183}	+	b_4DS_{184}	=	DE_{181}

7.1 Modification of Equation

According to the above, the third terms in the left hand side are added to equation (2).

$$a_0+\sum_{k=1}^{n_k} a_k\ DS_{lj}+\sum_{k=1}^{4} b_k\ DS_{ki}=DE_{ij} \qquad (4)$$

All of the definition of i, j, k and l are the same as equation (2) and equation (3) and a_0, a_k and b_k are constants.

7.2 Second Order Approximate Solution

In this case, a multiple correlation coefficient becomes 0.90. A judgment zone becomes significant to 5%. The model accuracy becomes higher than that of former solution. Fig.8 shows the comparison between the second order approximate solution and the actual data of the empty containers.

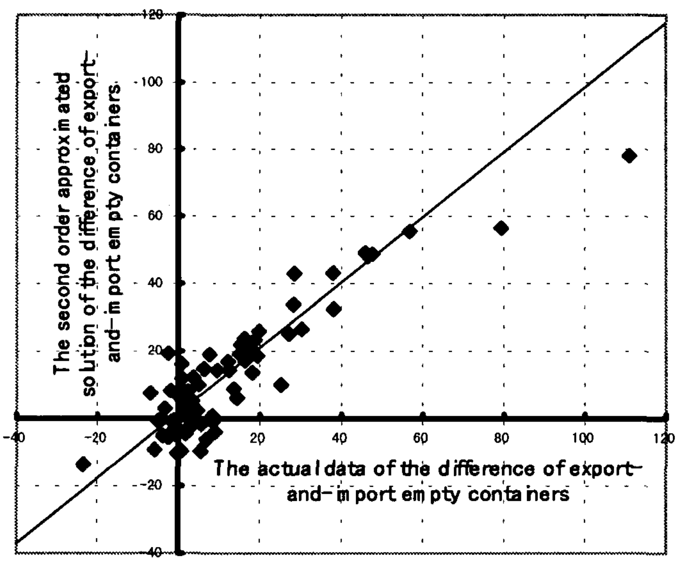

Fig. 8 Comparison between the second order approximated solution and the actual data of the difference of the empty containers of 4 Japanese ports in 2000(1,000 TEUs)

8. Conclusion.

The main results are summarized as follows:

1) In the case of between 2 ports, the imbalance obtained by subtracting export loaded container cargo volume from import loaded container cargo volume does not coincides with the imbalance amount of the empty container between 2 ports.
2) In other word, it turned out that the method of calculating the empty container between 2 areas is inapplicable to the method of calculating the empty container between 2 ports.
3) The imbalance amount of empty containers between 2 considering ports depends on not only the imbalance of the destination port but also the imbalance of the ports to be called after the considering port.
4) Further, the model which estimates the imbalance amount of empty containers between Japanese main ports and the main Asian and North American ports were constructed.

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