SIMULATION OF THE INTERNATIONAL CONTAINER CARGO MOVEMENT IN CHINESE PORTS BY INCORPORATING CHINESE LAND TRANSPORT NETWORK

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1. Introduction

During the past decades, Asia is becoming one of the biggest freight goods generations and consumptions areas in the world. Consequently, Asian ports are also becoming the busiest ports in the world. In terms of container handling, 20 of the world's top 30 container ports are located in Asia in 2004. Within them, there are 9 Chinese mainland ports; it is very important to quantitative analysis the impacts of the movements of imported/exported container cargo in China on Chinese and other countries' ports in detail.

The authors had developed a model (Ieda et al. 2000 and Shibasaki et al. 2005) in order to produce the simulations of link flows on the international freight container transport networks, which incorporates sea shipping transport network and Japanese land transport network with the given container cargo OD. This model can consider the use of different types of ships, transshipments, and the number of different berth at each port. In this paper, by expanding the developed model, the simulation is examined on China's international freight transport situation such as the impacts of the port berths construction on China's port and other countries' ports container handling.

2. Method Description and Dataset Preparations

We develop a model to reproduce the international maritime container cargo flow within all of Japanese ports handling containers, the major ports of East Asia especially China, and other areas, as well as the land transport of container cargo, not only in Japan but also in China, which is newly incorporated in the paper, under the given OD cargo flows between these regions. Container cargo flows were treated as traffic flows on the networks, in a manner that reflects the behavioral principles of shippers and carriers each other, according to network assignment principles such as user equilibrium (UE) assignment and system optimum (SO) assignment respectively. This model consists of two sub-models; one is for the carriers and the other is for the shippers. They pursue their optimal behaviors independently based on each principle, while exchanging information on OD cargo flows by carrier (from shipper to carrier) and freight rates between ports (from carrier to shipper), until resulted in equilibrium.

(1) The carrier sub-model

At this sub-model, each container carrier determines the patterns of maritime transport, namely ports where cargo is transshipped and the sizes of vessels that call in each port, based on information of ports charges, terminal handling charges, congestion situation in each port, and transport cost by each type of ship, etc. There are six types of links, but for the formulations of link functions of both sub-models and parameter estimation, since the space is limited, please refer the paper of Shibasaki et al (2005) for the details, where no differences from the model in this paper, in terms of the carrier sub-model. The conceptual network of each port is shown in Figure 1. Seven ship-size categories are prepared for the model, as shown in Table 1. As the ship size increases, it needs the deeper berth when calls at a port. Berths in ports are also classified into seven categories. By this way, it can also examine the impact of the berths construction and ship fleet arrangements on the whole transport network.

This sub-model is expected to provide a solution for minimizing the total cost by each carrier group (GSO: Group-based System Optimum assignment). GSO is a unique assignment methodology, derived from the normal System Optimum (SO) assignment, which minimizes the total transport cost. This methodology is based on the fact that the alliances of the container cargo carriers, especially in long-distance shipping, are very solid; they may minimize the total cost in each alliance. However, there is interference between carrier groups in berthing because all berths are assumed for public use without any distinction for group.

The solution uses Frank-Wolfe's algorithm (cf. Sheffi 1985) on the flow-dependent network. Because some of the link costs include decreasing flow functions, there is a non-convex problem with a number of local minimums. This fact may be interpreted practically in that the real state of observed transport depends heavily upon past history. Accordingly, this model regards the present conditions as the starting-point, and input the present flow pattern as the initial values, from which the model intends to simulate the future transport pattern.

*Keywords: international container cargo, Chinese ports, land transport network

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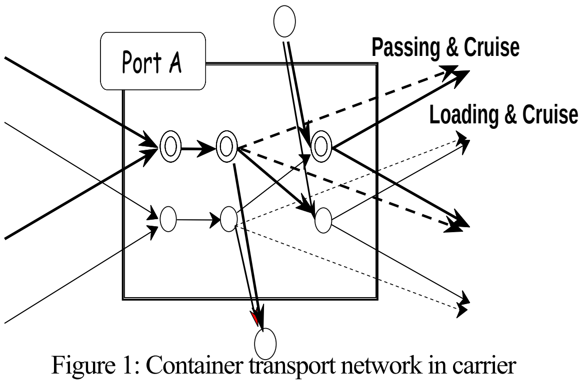

Figure 1: Container transport network in carrier

Table 1. Ship-size category used in the model

Category No.	Size (TEU)	Average Size (TEU)	Berth depth that each category of ship can enter
1	- 500	250	over 7.5m
2	500 - 1000	750	over 9m
3	1000 - 2500	1750	over 11m
4	2500 - 4000	3250	over 13m
5	4000 - 6000	5000	over 14m
6	6000 - 8000	7000	over 15m
7	8000 -	9000	over 16m

(2) The shipper sub-model

It is assumed that each shipper determines the routes involved in hinterland transport, loading and unloading at ports, and carriers, after considering international maritime transport costs between ports given by each carrier and the conditions on hinterland transport. This study limits consideration of hinterland transport to Japan and China due to the data availability. Transport to and from countries other than Japan and China assumes that all cargo originates from and is destined for particular ports, and that the shipper selects the carrier only. Road and water transport are only considered for hinterland transport in Japan and China, based on past and present performances. Although the behavior of carriers of hinterland transport should be also considered, judging from the severe competition among them in the reality, the shipper may be regarded as having initiative in the hinterland transport market, therefore, the behavior of entities other than shippers is ignored. Note that definitely different from those in the carrier sub-model. That is because, regarding the international maritime transport network, the shipper would select a carrier only based on such service levels as freight rates and frequency of service, without selecting a maritime transport route, such as ports of transshipment or the size of the ship.

There are thirteen types of links, please refer the paper of Shibasaki et al (2005) for the details. In this sub-model, all link cost functions on international maritime transport and land transport are assumed to be flow-independent while some links on domestic water shipping are flow-dependent. Furthermore, mainly because of the lack of data, we assume there are no influences of the volume of container vehicles on land transportation time.

Another requirement of the sub-model is that, regarding selection of carriers, hinterland transport modes, and loading/unloading ports for shippers, they should be affected by factors other than those explicitly included in the model. Accordingly, the stochastic user equilibrium assignment (SUE), which is able to calculate with flow-dependent link cost functions and simultaneously consider the variance of shippers' behavior, is used in the sub-model. Specifically, a logit-based stochastic assignment based on the random utility theory is performed according to the Dial algorithm (1971). The parameter, θ, of the logit model included in the likelihood equation is estimated by calibration in order to reproduce the real conditions most accurately, together with other unknown parameters included in cost functions. The successive average method proposed by Fisk (1980) is used as a means to solve.

3. Data Preparation

The model includes 87 ports, of which are top 40 Japanese container ports, 7 Chinese container ports (Dalian, Tianjin, Qingdao, Ningbo, Shanghai, Xiamen, Shenzhen), 23 other major East and South Asian ports, and 17 representative ports in countries or continents other than Asia. For East and South Asian ports, we set at least one port at one country. For other continents than East and South Asia, in consideration of further application purpose, each APEC member country is exceptionally dealt as single while other countries are aggregated into 8 continents, which concept is definitely in accordance with Shibasaki et al. (2005).

The input data required for this model could be divided into five types; 1) amount of OD container cargo by region or port, 2) initial flows of cruise links by carrier, 3) service level on each port, 4) operational costs for international maritime transport and hinterland transport, and 5) transport network data. This model was basically developed by year-2003 data. The partial container OD data were estimated by our estimation methodology which is elaborately described in Ma et al. (2005) and Shibasaki et al. (2005). In particular, in Ma et al. (2005), OD data between China and Japan is estimated on the regional (i.e. province and prefecture) level.

Data on initial cruise link flow (by carrier and ship-size) is estimated from actual capacity data in service for each link, which is acquired from container service database such as International Transport Handbook, multiplied by load factor for each port pair. Data on port service level, maritime operational costs, and initial total volume by port are estimated respectively from various data sources. For Chinese land transport network, there are 31 Chinese cities, 3180 nodes of Chinese road network, 516 nodes of Chinese railway network, and 3 nodes of Chinese inland waterway network. The land network information such a link length is obtained from ADC WorldMap database.

4. Estimation Results of Unknown Parameters

The estimation result of unknown parameters is shown in Table 2. For the estimation, the combination of linear searches by the golden section and approximate derivation of steepest descent directions were used. Through trial and error process with simultaneous pursuit of accuracy and efficiency of estimation, we set five as the number of times of the golden section per linear search, and three as the number of repeating times of derivation of steepest descent directions.

Every unknown parameter needs to be initially set shown in the Table 2. The estimated values of parameters are not so different with the initial values except for the two time values (Vt shpr and Vt carr). The reason of the two time values become larger than initial value is considered that because Japanese average speeds of each transport mode were used for China due to the data availability, it will underestimate the transport time in China by comparing its long link length. Therefore, time value will become larger to counteract the effect of the transport time underestimation. Compared with error rates (i.e. square root of error sum of square / sum of initial flow) among four cases including above two cases and other two cases that values are set at upper limit and lower limit, the difference of error rate between initial values and estimated parameters are found to be not negligible. Figure 2 shows the estimated waiting time function based on estimated γ1 and γ2 shown in Table 2. It indicated that when congestion factor is larger than 0.4, estimated waiting time starts to increase with high rate.

Table 2: Estimated results of unknown parameters in the model

parameter	θ	vt shpr	vt carr	γ1	γ2	error
unit	-	(1,000 JPY/h)		-	-	rate
initial value	0.01*1	1.348*2	1.348*2	120*1	5*1	0.0886
lower limit	0.001	0.01	0.01	10	1	0.0925
upper limit	0.1	10.0	10.0	1000	10	0.9772
estimated	0.0099	3.825	2.626	118	8.10	0.0847

source: *1 empirically set based on past results etc.
*2 the Guideline of Port Investment Evaluation

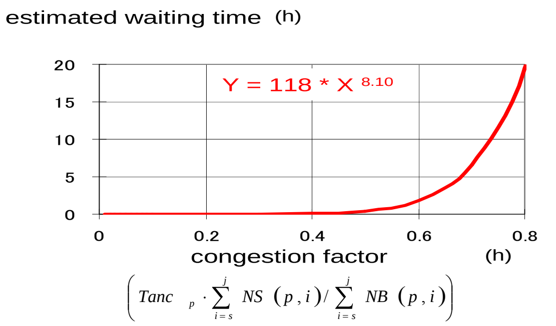

Figure 2: Estimated result of waiting time function

5. Reproducibility of the Model and Simulations

The reproducibility of the amounts of handled containers in Chinese and Japanese ports and transshipped containers across all Asian ports seems to be better shown in Figure 3. Regarding the amount of handled containers in Chinese ports shown in the left side of the figure, Shanghai and Shenzhen ports, are a little bit overestimated. In terms of transshipment of containers in Asian hub ports, as shown in the right side of Figure 3, overestimation in some ports and underestimation in others are observed. In particular, some ports in China, which are said to have no actual transshipment due to a lack of statistics data, transshipment rate are estimated for the model. However, it is reasonable to consider that some transshipment might exist, judging from other sources and interview results.

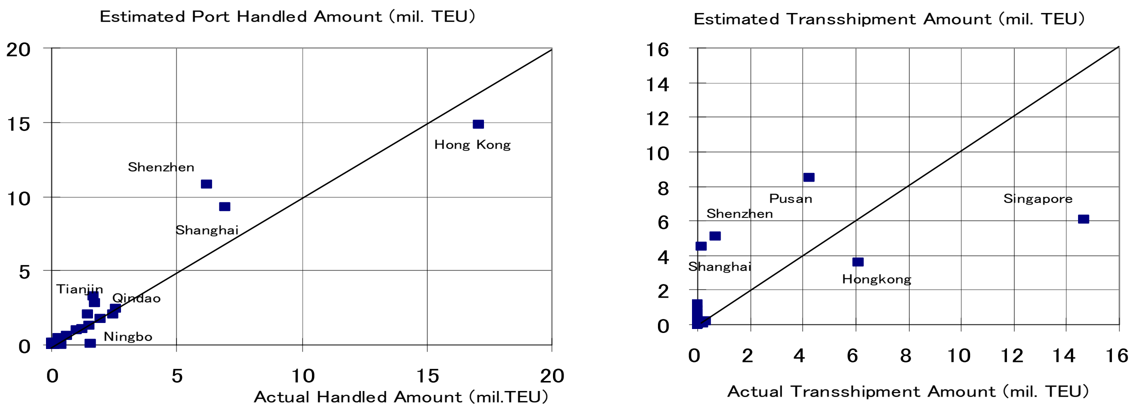

Figure 3. Reproducibility of the total and transshipped amount of containers

6. Port Berth Construction Simulation by using this model

Recently, many Chinese ports are expanding their capacity especially the number of deep berths. They are very cost-consuming projects. Meanwhile, Japanese are addressing to reduce their port charges in order to enhance competitive capability in terms of international transshipment. It is very important to know what impact of such project on the whole international container cargo transport network. By using this model, we did the simulation on Shanghai Port, assuming it construct 53 berths in type 7 and 4 berths in type 6, which can handle over 8000TEU and over 6000TEU container ships, based on the plan of Yangshang container terminal in Shanghai.

The change of container handled at main Chinese ports and Japanese ports are shown in Figure 4, It can see most of Chinese ports' container handling volume will increase such as port of Dalian, Tianjin, Shanghai and Shenzhen. However, the volume in Qindao and Ningbo, Hong Kong will decrease; it is considered that these three ports are very close to Tianjin, Shanghai, and Shenzhen respectively. By the expansion project of Shanghai port, it will enhance its hub-port function; therefore, it will take more freight goods from other ports near to it. On the other hand, it also can see such project will have negative impact on most of Japanese big ports. It can also illustrate such severe competition on the international container cargo markets.

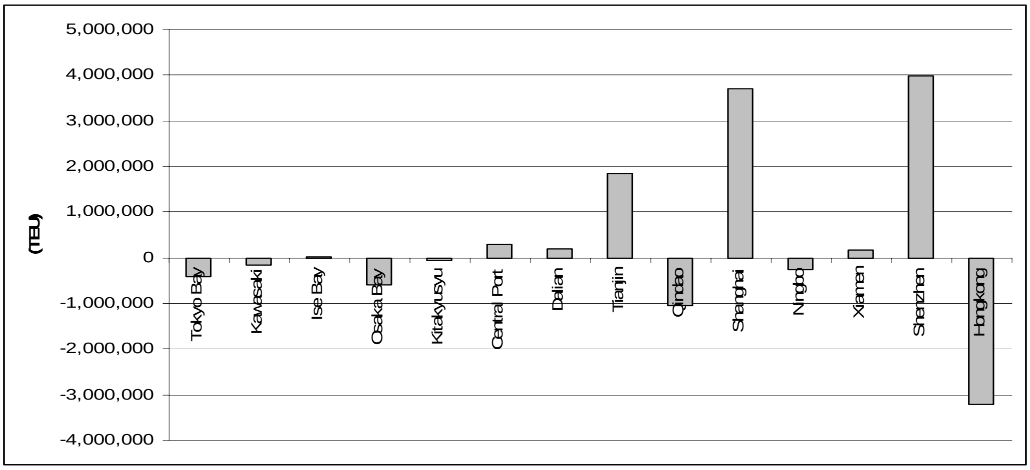

Figure 4: The change of container handled at main Chinese ports and Japanese ports

7. Conclusion

Under the severe competition in the international container cargo transport market recently, we have developed and improved the model illustrating these container cargo flows, when the amount of OD container cargo is given as input. Our model can simulate the effect of port improvement policy, such as the port berth construction policy, and trade policies on container cargo flows and the amount handled in each port on the whole network. In this paper, it can show some images of the impact of the big port berth construction project in China on the whole international container cargo transport network.

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