IMPACT OF CHINESE PORT POLICY USING THE MODEL FOR INTERNATIONAL CONTAINER CARGO SIMULATION

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Abstract: Until now, the authors have been developing a model for international container cargo simulation (MICCS) which can produce the movement of the cargo with the volume of OD container cargo as a given input, focused in East Asian region, in order to simulate and evaluate international freight transport policy. This paper aims to evaluate the effects of the policies on port investment in China, using the model with two cross-sectional data in different years. The outputs of the model, incorporating with initial condition of transport environment in 1998 and OD container volume in 2003, are compared between cases with and without port investments during these five years in China. By this, it will become clear how degree these policies contribute to the change of container cargo flow on maritime and land transport network.

Key Words: international container cargo, port investment, model simulation, Chinese trade
1. INTRODUCTION

During the past decades, Asian economies achieved the great development. Due to this reason, Asia is becoming one of the biggest freight goods generations and consumptions areas in the world. In particular, called as ‘World’s Factory’, China imports a huge amount of raw materials from overseas, and exports the products to the world everyday. China now ranks third in terms of trade amount, which earns 1,411 billion US dollars in 2005, behind the U.S. and Germany. Since 1999, the growth of trade amount always surpasses that of nominal GDP, except in 2001 where world trade temporarily shrunk due to the event of the 9-11. Now, Chinese trade amount keeps a pace to become triple during five years.

Consequently, Asian ports including Chinese ports are also becoming the busiest ports in the world. In terms of container handled, 20 of the world’s top 30 container ports in 2006 were located in Asia including nine Chinese ports. In particular, Hong Kong, Shanghai, Shenzhen top the four ports with Singapore in the world. In accordance with this, at a lot of Chinese ports there are heavily invested in order to improve their infrastructure and facilities and to construct new terminals and berths, as well as major Asian ports. As a matter of course, their main purpose for investment might have been to cope with the drastic increase on trade amount and cargo volume.

However, it is also obvious that port investment itself affects the cargo flow including the volume handled at the port in question, because it improves efficiency and convenience of the port. In particular, because the ports in mainland China was behind in their growths compared with their surrounding ports such as Hong Kong, Kaohsiung (Chinese Taipei), and Busan (South Korea), their expectancies to catch up with these surrounding ports and to become the regional dominant port might have accelerated the investments. As results, some of them including port of Shanghai and Shenzhen now take positions as regional center ports and threaten their rivals.

The authors (Shibasaki et al. 2005a) have been developing a model which can simulate the movement of international container cargo with the volume of OD container cargo as a given input, focused in East Asian region, in order to evaluate international freight transport policy such as port investment, as well as improvement of interconnectivity between port and road. Furthermore, in addition to the international maritime shipping network and Japanese hinterland network in the above model, Ma et al. (2005) developed a model incorporating Chinese hinterland transport network, which enables to simulate on international freight policy in China.

According to these backgrounds, this paper aims to evaluate the effects of the policies on port investment in China already done, using the developed model above with two cross-sectional data in different years (1998 and 2003). In other words, the outputs of the model, incorporating with initial condition of transport environment in 1998 and OD container volume in 2003, are compared between cases with and without port investment during these five years in China. By this, it will become clear how degree these policies contribute to the change of container cargo flow on both maritime and land transport network. In addition, before that, the model output in 2003 with port investment using initial values in 1998 is compared with the actual situation, for an examination of model predictability. If it succeeds in predicting the actual from past data, a reliability of the model for future simulation will be increased.

Table 1 World’s top 30 container ports in 2006
2. ROUGH DESCRIPTION OF THE EXISTING MODEL

In this paper, we basically apply the Model for International Container Cargo Simulation (MICCS) already developed by authors (Shibasaki et al. 2005a). In this chapter, rough description of the MICCS including model structure, making data for the input, and reproducibility of the model are briefly described.

2.1 Model Structure

The authors developed a model to reproduce the international maritime container cargo flow between the major container ports of East Asia including Japan and China and other areas, as well as the land transport of container cargo in Japan, when the OD cargo flows between regions are given.

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, the major actors in the container cargo transport market, according to respective assignment principle. Specifically, networks were developed for container cargo transport not only between ports (i.e. on maritime), but also in a port and a hinterland area. As shown in Figure 1, in the MICCS the above problem was dealt with as following treatments;

1) The model is divided into two sub-models, a carrier sub-model and a shipper sub-model, and they pursue their optimal behavior independently based on each principle;
2) Carriers minimize their total maritime shipping cost by group under condition that their OD cargo volume between ports is given respectively. Here, each carrier group will decide their transport pattern, with taking into account not only monetary cost that they have to
actually pay, but also their service level (such as freight rates and transport time including waiting time) that appeal to shippers, in order to collect their cargo;

3) Shippers minimize their own transport cost from their origin to their destination by container under condition that the freight rates of maritime shipping between ports are given by carrier group; and

4) The calculation in these two sub-models is done independently and alternately reflecting their interferences, until resulted in equilibrium. The OD cargo volumes between ports by carrier group, which is the inputs of the carrier sub-model, are acquired from the results of shippers’ choices of the route and carrier group, through calculation in the shipper sub-model. On the other hand, the freight rates of maritime shipping between ports by carrier group, the inputs of the shipper sub-model, are acquired from the results of carriers’ decision of the transport pattern, through calculation in the shipper sub-model.

As mentioned in Shibasaki et al. (2005a), the representative network simulation model that considers shippers’ and carriers’ behaviors and their interaction is the Freight Network Equilibrium Model (FNEM) proposed by Friesz and Harker (Friesz et al. 1985, Harker 1987). However, according to Crainic et al (1997), network simulation models such as FNEM, often require a huge amount of computation and thus they are impractical. Therefore, these models have not been applied to real transport networks, apart from the domestic cargo transport system by railways in the US (Harker and Friesz, 1985). On the other hand, simple disaggregated models or shortest route search methods, such as Southworth and Peterson (2000) and Malchow and Kanafani (2001), are still in use for simulating real cargo movements. Another research trend is, as Christiansen et al. (2004) mentioned in his review on maritime shipping modeling, to apply integer or linear programming on the very simple and/or hypothetical network, because it is difficult to be solved on the huge network. He also pointed out that there are few applications of network assignment methodology for ship routing and scheduling problems. That is the case for the papers focusing on international container cargo shipping market in China. For example, Song (2006) applies a logit model for choice of export port of the international cargo from inland cities in the middle part of China, whereas Cullinane et al. (2002) does multi-objective programming approach for choice of export port and hinterland transport mode on very simplified hypothetical network reflecting Chinese geographical feature.
However, network assignment approach can deal with larger and more complicated network compared with disaggregated model and integer programming, and at the same time, consider flow dependent link cost including the effect of congestion and economy of scale, unlike shortest route search. Therefore, it is effective for being applied on the actual huge network of international cargo shipping including maritime and hinterland transport; in addition, it is quite reasonable and calculable, because the severe competition of freight rates in the international container cargo transport market (i.e. no profit expectation for every link) can be assumed, despite the limited number of carriers. Specifically, the international container shipping market is approximated to consist of numerous shippers and several carrier groups in a state of equilibrium, as a result of behaviors to minimize transport cost by each shipper and the total transport cost by each carrier group.

2.1.1 Carrier Sub-model
Container carriers minimize their total maritime shipping cost by group under condition that their OD cargo volume between ports is given respectively. Each carrier group determines the patterns of maritime shipping, namely ports where cargo is transshipped and the sizes of vessels that call in each port, based on information on several types of port charges such as harbor, handling, and terminal charges, and state of congestion in each port, transport cost by type of ship, etc.

Containers will be carried from a port of origin to a destination port, through paths on the network according to path costs, which are defined as the sum of link costs on those paths. Each link has a corresponding flow-dependent or independent link cost (for details definition of link cost function, see Shibasaki et al. 2005a). There are two types of flow-dependent link on the network. One is the congestion by centering link flows, where the link cost function will be an increasing function of link flows. In the MICCS, shipping congestion of vessels waiting to berth will rise when a lot of ships are centered into the port.

Another type of flow-dependent is the economies of scale of transport, where the link cost function will be a decreasing function of link flows. There are three types of economies of scale in the MICCS. First, larger vessels are potentially efficient in terms of transport cost per TEU, since the cruising resistance of vessels rises to the second power with respect to size while the transport capacity of vessels increases to the third power. Second, also in a given vessel size, transport in larger quantity will be naturally advantageous, because its load factor may be improved, or even if it does not change, traffic frequency increases and the time cost falls. Third, the economies of scale in the volume handling in a port exist. Because of the large fixed cost when leasing or constructing container terminals, handling costs per TEU could be decreased as the handling volume increases.

The 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 because the alliances of the container cargo carrier, especially in deep-sea shipping, are very solid, they may minimize the total cost in each alliance. Each carrier group is expected to minimize their total cost; 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 as mentioned above, 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, the model regards the present conditions as the starting-point, and inputs the present flow pattern as the initial values, from which the model intends to simulate the future transport pattern. This dependence on initial value holds true of not only within the carrier sub-model, but also the interaction between the carrier and shipper sub-model.

2.1.2 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 shipping costs between ports given by each carrier and the conditions on hinterland transport. The model in this paper limits consideration of hinterland transport to Japan due to the data availability (in next chapter, Chinese hinterland network will be incorporated). Transport to and from countries other than Japan assumes that all cargo originates from and is destined for particular ports, and that the shipper selects the carrier only. It is also assumed that the amount of OD cargo between regions or ports is given, i.e. transport demand does not change irrespective of the change in service level. Road transport is only considered as transport means, based on past and present performances in Japan.

In this sub-model, all link cost functions on international maritime shipping (which is composed of hypothetical links) and land transport are assumed to be flow-independent. In reality, at some ports, congestion might be observed when containers are carried into and out of a terminal through the gate. However, mainly because of the lack of data, we assume that the volume of container vehicles has no influence on land transport time. Another requirement of the sub-model is to consider that the selection of carriers, hinterland transport modes, and loading/unloading ports for shippers would be much affected by factors other than those explicitly included in the model. Accordingly, stochastic assignment (SA), which is able to consider variance in shippers’ behavior under the framework of network assignment methodology, is used in this sub-model. Specifically, a logit-based stochastic assignment based on the random utility theory is performed according to the Dial algorithm (1971). The parameter, $\theta$, of the logit model included in the likelihood equation is estimated by calibration in order to reproduce the real conditions as accurately as possible, together with other unknown parameters included in cost functions.

2.2 Preparation of Input Data

The model has developed as of 2003 in principle, where the latest data is available such as the Survey Report of International Container Cargo Flow, conducted by the Japanese government every five years. The input data required in the MICCS can be divided into five types as mentioned in Shibasaki et al. (2005a). Sources or estimation methodology for these five types of data are simply summarized as follows, although all of the data is difficult to obtain or estimate.

1) **OD container cargo volume by region or port**, which is the most difficult to be obtained, as the estimation methodology is described in detail in Shibasaki et al. (2005b). Note that the OD volume should be prepared in regional or port basis, not country basis, and in TEU basis.

2) **Service level at each port**, such as number of berths by depth and charges for berthing and terminal handling, which is estimated respectively from various data sources such as Containerisation International Yearbook. The ports dealt with in the previous model are shown in Figure 2.

3) **Operational costs for international maritime shipping and domestic hinterland transport.** The former is estimated by ship-size according to the methodology proposed by Mori et al.
Transport network data such as physical distance for each link. The data on physical distance on the sea is acquired from distance tables, while both distance and time on land transport in Japan are drawn from the results of shortest-path search based on the land transport network for international maritime container cargo developed by the authors (Shibasaki et al. 2004).

Initial values needed for model calculation, such as cruise link flows by carrier and total volume of containers handled by port. The former data is not normally available; therefore, it is estimated by multiplying the actual service capacity data, which is acquired from container service databases such as the International Transport Handbook, by the load factor for each port pair. The latter one is acquired in the estimation process of OD volume (also see Shibasaki et al., 2005b).
2.3 Unknown Parameter Estimation and Model Performance

The model includes five unknown parameters: two time-value parameters defined by actors (i.e., carrier and shipper), \( v_{\text{t carr}} \) and \( v_{\text{t shpr}} \); parameters regarding waiting time for entering the port, \( \gamma_1 \) and \( \gamma_2 \) (see Shibasaki et al., 2005a for detail); and a parameter indicating the degree of variance in terms of shippers’ behavior, \( \theta \). These parameters are obtained by optimally reproducing the actual flow of each link. With reference to Frank-Wolfe’s algorithm, the algorithm to obtain the optimal solution is employed as follows:

1) The steepest descent direction regarding the objective function around the initial values is approximated by measuring a change of the objective function for a marginal change of each parameter;
2) The minimum solution is obtained by repeated golden section linear search within the pre-defined range of each parameter along with the steepest descent direction obtained in 1);
3) If a difference between the new and the previous solution is lower than a small constant, the new solution is regarded as an optimal solution; otherwise, return to 1), regarding the new solution as initial values. The estimation results of unknown parameters are shown in Table 2.

As mentioned above, every unknown parameter must be set for its initial value and upper and lower limit, which are also shown in the table. For examining model convergence, the authors confirm whether iterative calculations in the carrier sub-model and between the carrier and shipper sub-model really converge. For the convergence process between two sub-models as well as in the carrier sub-model, the convergence rate is gradually decreasing after rapid decrease in the first few iterations.

As examples of model reproducibility, the total volume of containers handled at Japanese ports (left side) and those transshipped across all Asian ports (right side) are shown in Figure 4. The total volume is shown only for Japanese ports because the loading/unloading port selection behavior for shippers and hinterland transport are only considered for Japan in this “basic” model. From the left side of the figure, the total volume of containers handled in each Japanese port is relatively better reproduced, although there is underestimation in port of Tokyo and overestimation in several medium-sized ports. For port of Tokyo, in terms of the summation of ports in Tokyo Bay including port of Tokyo, Yokohama and Chiba, the estimated volume is almost equal to the actual. The better accuracy of the model when aggregated by small port cluster holds true to other regions in Japan such as Ise Bay (port of...
Nagoya and Yokkaichi) and North Kyusyu (port of Hakata and Kita-Kyusyu). In terms of transshipment of containers in all Asian ports as shown on the right side of Figure 4, there is underestimation in the larger hub ports. On the other hand, in some Chinese ports such as Shenzhen and Shanghai, which are reported to have no actual transshipment due to a lack of statistics, transshipment cargo is estimated by the model, although it is reasonable to deem that there are transshipment to some rates, judging from other sources and interview results. Moreover, if the transshipped volume is summed up by regions (e.g. port of Hong Kong and Shenzhen, and port of Kaohsiung and Shanghai) as well as the case in Japanese ports above, the estimated volume approximates the actual, although underestimation in Port of Singapore and Tanjung Pelepas cannot be explained, remaining to be solved.

Table 2 Estimated results of unknown parameters in the model

<table>
<thead>
<tr>
<th>parameter</th>
<th>( \theta )</th>
<th>( v_t_{\text{shpr}} )</th>
<th>( v_t_{\text{carr}} )</th>
<th>( \gamma_1 )</th>
<th>( \gamma_2 )</th>
<th>error rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>unit</td>
<td>-</td>
<td>1,000 JPY/h</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>initial value</td>
<td>0.01*1</td>
<td>1.348*2</td>
<td>1.348*2</td>
<td>120*1</td>
<td>5*1</td>
<td>0.0690</td>
</tr>
<tr>
<td>lower limit</td>
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<td>0.01</td>
<td>0.01</td>
<td>10</td>
<td>1</td>
<td>0.0748</td>
</tr>
<tr>
<td>upper limit</td>
<td>0.1</td>
<td>10.0</td>
<td>10.0</td>
<td>1000</td>
<td>10</td>
<td>0.0733</td>
</tr>
<tr>
<td>estimated</td>
<td>0.01414</td>
<td>1.631</td>
<td>1.441</td>
<td>129.6</td>
<td>5.09</td>
<td>0.0648</td>
</tr>
</tbody>
</table>

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

Figure 4 Reproducibility of total and transshipped volume of containers

3. MODEL EXTENSION AND POLICY SIMULATION IN CHINA

3.1 Data Preparation for Model Extension and Recent Port Investment in China

In order to incorporate Chinese land network, ADC WorldMap™ database which works on GIS software, MapInfo, is basically used, as shown in the network of Figure 7. Note that in the network road and inland water transport are included; in other words, railways is not included. The cost function of land transport is formulated as the summation of monetary cost and time cost as well as Japanese network. In addition, for the simulation focusing on Chinese ports, several Chinese ports are added as also shown in Figure 7.

One of other preparation needed is the OD volume originated from/destined into China,
which should be re-estimated in regional (i.e., provincial) basis, not in port basis. As described in Shibasaki et al. (2005b) for detail, OD volume in country basis is divided into 31 regions except Hong Kong, basically in proportion to the share of trade amount by partner country according to China Customer Statistics data. For reference, Figure 5 shows the trade partner country by Chinese regions (in this figure, 31 provinces are aggregated into eight regions) in 2003. The size of circle graph shows the trade amount of the region. As for the biggest trade partners for the entire of China, which are Japan, the U.S. and EU, in order of the trade amount in 2003, every region excluding North West has constant deals with them. As for the other countries such as South Korea, Chinese Taipei, Hong Kong, ASEAN, and Russia, the region that has a border with or that is geographically close to them has close relationship between them. For example, South Korea has a close relationship with Central Coast area and to the north, as does Chinese Taipei with Central and South Coast area, Hong Kong with South Coast, and ASEAN (especially Vietnam and Myanmar) with South West.

Moreover, for the simulation with initial condition of transport environment in 1998 and OD container volume in 2003, two types of the year-1998 data (i.e. other data than the OD volume) should be prepared, among five types of input data mentioned in Section 2.2. As for the service level in each port described in 2), the number of berths by port in both 1998 and 2003 are shown in Table 3. As shown in the table, in almost all ports deeper berths have been constructed then started in operation; for example, in port of Tianjin, Ningbo, and Shenzhen, deeper berths than 15.0m was opened during these five years, as was in port of Dalian, Qingdao, Shanghai berth(s) between 14.0m and 15.0m. Port of Hong Kong also increased their number of deeper berth than 15.0m. In addition, the initial values needed for model calculation described in 5) are estimated as follows: For the initial flows between ports, the MDS database is used for both year-1998 and 2003, instead of International Transport
Handbook in the previous model, because it covers wider and more detailed area than other sources; for the initial total volume of containers handled by port, is acquired from the same procedure when estimating the year-2003 data, by using Containerization International Yearbook data etc. (see Shibasaki et al., 2005b)

Table 3 Number of berth in Chinese ports by depth in year 1998 and 2003
(Made by authors from Containerisation International Yearbook and other sources)

<table>
<thead>
<tr>
<th></th>
<th>1998</th>
<th>2003</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>~8.9m</td>
<td>10.9m</td>
</tr>
<tr>
<td></td>
<td>~8.9m</td>
<td>10.9m</td>
</tr>
<tr>
<td>Dalian</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Tianjin</td>
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<td>0</td>
</tr>
<tr>
<td>Qingdao</td>
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<td>0</td>
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<tr>
<td>Lianyungang</td>
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<td>0</td>
</tr>
<tr>
<td>Shanghai</td>
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<td>7</td>
</tr>
<tr>
<td>Ningbo</td>
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<td>0</td>
</tr>
<tr>
<td>Nanjing</td>
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</tr>
<tr>
<td>Wuhan</td>
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<tr>
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<tr>
<td>Fuzhou</td>
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<tr>
<td>Xiamen</td>
<td>0</td>
<td>1</td>
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<tr>
<td>Shantou</td>
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<td>Shenzhen</td>
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<td>Guangzhou</td>
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<td>Zhongshan</td>
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<td>Fangcheng</td>
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<td>Haikou</td>
<td>0</td>
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</tr>
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<td>Hong Kong</td>
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</tr>
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</table>

3.2 Reproducibility of the Extended Model and Simulation Result with Port Investment

In the extended model, five unknown parameters described in Section 2.3 are predetermined as shown in Table 3, mainly due to difficulty of new calibration on such huge network. The estimation result of the total (i.e. sum of export, import, and transshipped) cargo volume handled in Chinese ports including Hong Kong is shown in Figure 6. In the figure, two kinds of estimation results are shown: The first result is acquired by inputting year-2003 data for all inputs described in Section 2.2 including OD container volume, level of service in each port, and initial values. Another is estimated from initial values in 1998 and other inputs in 2003. In other words, the former indicates reproducibility of the model using current data, whereas the latter shows time transferability or predictability of the model using past data when future OD volume and investment plan of each port are given.

From the figure, in some ports, especially located in Pearl River Delta of South China such as Shenzhen, Guangzhou, Zhongshan and Hong Kong, the estimated volumes from past data are closer to the actual than the estimated from current data; however, both estimated volumes are overestimated in the port close to a central city in the region such as Tianjin (closest to Beijing, a national capital), Shanghai, and Fuzhou (a capital city of Fujian Province), while underestimated in the ports located in secondary cities for each region such as Qingdao, Ningbo and Xiamen. In addition, both estimated volumes are also overestimated in the ports along the Yangtze River such as Nanjing, Wuhan and Chongqing. Here, Figure 7 shows Chinese hinterland cargo flow (in 2003) estimated using past initial value (in 1998). It is not comparable to the actual flow because this kind of data is not available; however, according to authors’ interview survey to several experts, it is found that there is not big difference from the actual that they empirically feel, except for inland ports along the Yangtze River which are predicted to overuse for the cargo from/to inland cities.
Figure 6 Reproducibility of total volume of containers in Chinese ports (in 2003)

After all, judging from these results, the model reproducibility using current data and predictability using past data on Chinese container cargo flow are acceptable to some degree.
Further mentioning, it is highly likely that the model can predict the actual situation from past data, at least, at the same level as the reproduced by the model using current data. However, several problems remain to be solved, especially for concentration to the ports which are closet to central cities of each region and overestimation on the advantage of river transport.

3.3 Simulation Result without Port Investment and Comparison

In the simulation shown in the previous section using past data, the result is predicted under the situation that level of service in each port has been improved by investment during five years from 1998 to 2003, as shown in Table 3. Here, the authors prepare another simulation under the assumption that any new investment in Chinese ports has not been done throughout these five years, keeping in the 1998 level of port service. In other words, the simulation without port investment is calculated based on year-1998 data on the number of berth in each Chinese port as well as initial value, while year-2003 OD cargo volume as given, as the same in the case with port investment.

Table 4 shows a comparison of the simulation results between the cases with and without investment in Chinese ports. Please note that the total volumes in local (i.e. export and import) cargo throughout all Chinese ports are the same between both cases, because a given OD is the same. For transshipment cargo including domestic and foreign feeder transport, the total volume throughout China in the case with investment is almost twice as much as in the case without investment. As a result, the total volume of entire (i.e. sum of local and transshipped) cargo in the case with investment is 17% larger than in the case without investment.

From the viewpoint of cargo volume handled in each port, in some ports the volume has increased by investment, but in other ports it has decreased due to negative impact from neighbor ports’ investment. For example, in port of Shanghai and Shenzhen, the volume of transshipped cargo has drastically increased, as that of local cargo also increases. On the other hand, in several ports hatched in Table 4 including Qingdao, Xiamen and Hong Kong, the volume of local cargo has decreased by the investment; as a consequence, the total volume has also decreased although the volume of transshipment cargo has increased. There is an interesting finding that most of ports with this negative impact against investment are similar to the ports which are underestimated in the prediction using past data shown in the previous section, except for port of Hong Kong. These facts imply that the potential of these ports are always underestimated in our model; however, further discussion is of course needed which is a reasonable explanation that the model structure has some problem to be solved or that their potential are actually weak.

Another discussion is the land transport cost of the cargo exported from/imported into China, which has reduced by 5.9%. Also, their land transport amount (in tonnage-km basis) has reduced by the same rate. Figure 8 shows the difference of cargo flow on Chinese hinterland network between two cases. From the figure, it is found that in the majority of the links the number of flows has decreased during five years, especially for links in a north-south direction. In other words, with exploit of scale of economies in port handling due to the increases in cargo volume by port investment, the distance of land transport was considered to become shorter. That also means the hinterland area for each port becomes clearly divided.
Table 4 Comparison of the simulation results in Chinese ports between “with port investment” and “without investment” case

<table>
<thead>
<tr>
<th>Port</th>
<th>Local (export and import) with</th>
<th>Local (export and import) without</th>
<th>Transhiped with</th>
<th>Transhiped without</th>
<th>Total with</th>
<th>Total without</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>with</td>
<td>without</td>
<td>ratio</td>
<td>with</td>
<td>without</td>
<td>ratio</td>
<td>with</td>
</tr>
<tr>
<td>Dalian</td>
<td>1,000</td>
<td>919</td>
<td>9%</td>
<td>81</td>
<td>72</td>
<td>13%</td>
<td>1,080</td>
</tr>
<tr>
<td>Tianjin</td>
<td>3,420</td>
<td>3,380</td>
<td>1%</td>
<td>118</td>
<td>58</td>
<td>102%</td>
<td>3,540</td>
</tr>
<tr>
<td>Qingdao</td>
<td>997</td>
<td>1,240</td>
<td>-20%</td>
<td>216</td>
<td>80</td>
<td>172%</td>
<td>1,210</td>
</tr>
<tr>
<td>Lianyungang</td>
<td>0</td>
<td>1</td>
<td>-100%</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Shanghai</td>
<td>9,180</td>
<td>9,020</td>
<td>2%</td>
<td>2,970</td>
<td>561</td>
<td>429%</td>
<td>12,100</td>
</tr>
<tr>
<td>Ningbo</td>
<td>147</td>
<td>0</td>
<td>-</td>
<td>9</td>
<td>0</td>
<td>-</td>
<td>155</td>
</tr>
<tr>
<td>Nanjing</td>
<td>745</td>
<td>943</td>
<td>-21%</td>
<td>9</td>
<td>0</td>
<td>-</td>
<td>755</td>
</tr>
<tr>
<td>Wuhan</td>
<td>252</td>
<td>155</td>
<td>62%</td>
<td>14</td>
<td>2</td>
<td>532%</td>
<td>266</td>
</tr>
<tr>
<td>Chongqing</td>
<td>199</td>
<td>288</td>
<td>-31%</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>199</td>
</tr>
<tr>
<td>Fuzhou</td>
<td>832</td>
<td>598</td>
<td>39%</td>
<td>43</td>
<td>29</td>
<td>48%</td>
<td>875</td>
</tr>
<tr>
<td>Xiamen</td>
<td>269</td>
<td>515</td>
<td>-48%</td>
<td>138</td>
<td>50</td>
<td>175%</td>
<td>407</td>
</tr>
<tr>
<td>Shantou</td>
<td>2</td>
<td>0</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Shenzhen</td>
<td>2,890</td>
<td>1,970</td>
<td>47%</td>
<td>2,500</td>
<td>16</td>
<td>15700%</td>
<td>5,390</td>
</tr>
<tr>
<td>Guangzhou</td>
<td>2,740</td>
<td>1,300</td>
<td>110%</td>
<td>58</td>
<td>23</td>
<td>155%</td>
<td>2,800</td>
</tr>
<tr>
<td>Zhongshan</td>
<td>439</td>
<td>8</td>
<td>5680%</td>
<td>22</td>
<td>0</td>
<td>-</td>
<td>461</td>
</tr>
<tr>
<td>Zhuhai</td>
<td>0</td>
<td>2</td>
<td>-100%</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Zhanjiang</td>
<td>281</td>
<td>0</td>
<td>-</td>
<td>17</td>
<td>0</td>
<td>-</td>
<td>298</td>
</tr>
<tr>
<td>Fangcheng</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Haikou</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>8,310</td>
<td>11,400</td>
<td>-27%</td>
<td>6,350</td>
<td>5,320</td>
<td>19%</td>
<td>14,700</td>
</tr>
<tr>
<td>total</td>
<td>31,700</td>
<td>31,700</td>
<td>0%</td>
<td>12,500</td>
<td>6,210</td>
<td>102%</td>
<td>44,200</td>
</tr>
</tbody>
</table>

* = (with case)/(without case) - 1

Figure 8 Difference of the hinterland flow of international container cargo in China between “with investment” and “without investment” case in 2003
4. CONCLUSION

In this paper, using the Model for International Container Cargo Simulation (MICCS) developed by the authors, the effects of the policies on port investment in China was evaluated with two cross-sectional data in different years 1998 and 2003. The outputs of the model, incorporating with initial condition of transport environment in 1998 and OD container volume in 2003, were compared between cases with and without port investments during these five years in China. By this, how degree these policies contribute to the change of container cargo flow on maritime and land transport network was clarified.

As the results, the total cargo volume handled in China was proved to increase by 17%, by investment in Chinese ports including constructing new berths and deepening existing berths during five years from 1998 to 2003, compared with the simulation result without any investment. As for each port, the impact of the port investment differs according to its location; the port investment is more critical to the ports, located not in the regional center, but in its vicinity area. Another finding is that the total land transport cost has decreased and the hinterland area for each port is clearly divided, due to port investment and the increases in cargo volume.

In addition, the authors confirmed in this paper that the model can predict the actual situation from past data at the same level as the model reproducibility using current data. The model reproducibility using current data and predictability using past data on Chinese container cargo flow are acceptable to some degree, although several problems remain to be solved, especially for concentration to the ports which are closet to central cities of each region and overestimation on the benefit of river transport.

After year 2003 simulated in this paper, almost all Chinese ports keep, or even more, accelerate their investment. Most famous investment now in China is Yangshan Terminal in Port of Shanghai, which is newly constructed in Yangshan Island, located around thirty kilometers far from the offshore of Shanghai City and connected with the Donghai Bridge. The first berth in the terminal opened in December 2005 and until year 2020 more than thirty berths are planed to open. Under these circumstances, it is very important and useful to develop a model that can predict future container movement like the MICCS.

For the future work, firstly the authors should improve the accuracy of the model continuously, including detail parameter estimation and improvement of the accuracy of the input data. Second, the model should be extended geographically to Southeast Asia and others in order to evaluate the policies on cross-border issue, as well as in other means in order to evaluate many types of policy such as cabotage regulation. Also, the authors will use the model to forecast the future, by collaborating with some trade models that can predict the cargo demand themselves.

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