Advanced Materials Research Vols. 452-453 (2012) pp 760-767
Online available since 2012/Jan/24 at www.scientific.net
© (2012) Trans Tech Publications, Switzerland
doi:10.4028/www.scientific.net/AMR.452-453.760

International Ferry and RORO Ship Simulation in Eastern Asia using Intermodal Freight Flow Model

SHIBASAKI Ryuichi[1, a] and FUJIWARA Toshihisa[2,b]

[1]3-1-1 Nagase, Yokosuka, Kanagawa, 239-0826
National Institute for Land and Infrastructure Management, MLIT, Japan
[2]11-4 Otemachi, Kokura-kita, Kitakyusyu, Fukuoka, 803-0814
The International Centre for the Study of East Asian Development, Japan
[a]shibasaki-r92y2@ysk.nilim.go.jp, [b]fujiwara@icsead.or.jp

Keywords: Short Sea shipping, International ferry, Intermodal freight flow modeling, East Asia

Abstract. This paper develops a simulation model to include the short-sea shipping (SSS) on the intermodal freight flow model the author already developed, in order to measure an impact of policy that encourages the utilization of the SSS. The developed model is applied to the real shipping network connecting the northern Kyushu area in Japan with China and Korea; as a result, the model reproduces the actual maritime shipping market well, and some implications are acquired such that in order to advance utilization of the SSS, a kind of drastic policy such as mutual recognition of chassis is needed.

Introduction

The short-sea shipping (SSS) by using ferry and RORO (roll-on & roll-off: designed to carry wheeled cargo) ship is useful and promising transport means for international shipping in Eastern Asia. In Europe, the SSS is established as ordinary means from long ago, especially in the North Sea, Baltic Sea, the Mediterranean, etc. Also in East Asia including Japan, China, Korea, and Chinese Taipei, the author considers that the SSS has a high potential to be utilized because these economies are located across the sea and closely connected each other especially in terms of economics. However, an advancement of the SSS in this region seems to have many twists and turns.

One of successful examples of the SSS connecting Japan and China is the Shanghai-Hakata Super Express (SSE, see Fig.1). The SSE launched on November 2003 with weekly service (now twice a week) that connects between port of Shanghai (Waigaoqiao Terminal) and port of Hakata by 28 hours. According to its website [1], they appeal that it can provide a speedy service equaling to the air cargo shipping, as well as a cheap freight charge equaling to the maritime container shipping.

There are pointed out many reasons why the growth of utilization of the SSS is so slowly in East Asia; for example, technological and managerial problems in terminal handling and custom process, and lack of commonization of trailers and chassis between countries. Therefore, in this paper, by using the intermodal freight flow model the author developed [2, 3], the author simulates impacts of policies that encourage the utilization of the SSS. Until now, the authors had developed a simulation model of international freight flow including not only maritime shipping network of the world but also land (i.e. road and rail) shipping network [2, 3], and applied to many regions' international cargo shipping not only Japan, such as to China [4] and the APEC region [3, 5]. However, in the existing model, shipping by containership is only considered as a mean of the maritime shipping. This paper first extends to include the SSS into the simulation model; thereafter applies to the real shipping network connecting the northern Kyushu area in Japan with China and Korea.

Fig.1 The Shanghai-Hakata Super Express (pictured at port of Hakata by the authors on January 2009)

Outline of the Existing Model

The detail of the existing model is described in [3]. The model outputs freight flow patterns on maritime and land networks, given a regional cargo shipping demand (OD cargo volume), the service level at each port (e.g., the number of berths by water depth and port charges), and information related to the shipping network (costs and time, etc.). The outputs can be also tabulated for each port to calculate the handling volume and transshipment cargo volume by port.

The model focuses on the behavior of shippers and ocean-going container carrier groups. Referring to the freight charges and shipping time by route indicated by each carrier group, a shipper selects a carrier group for maritime transport, the ports to be used for import/export, and the land transport route and mode for each cargo. Shippers determine their selections so as to minimize recognized generalized costs, including not only shipping cost and time, but also factors which cannot be observed by the model developer. Ocean-going container carrier groups, for which maritime container cargo shipping demand is given as an input, is assumed to behave so as to maximize profit for each group. Each group determines freight charges by port pair (combination of ports for export and import) and a maritime transportation pattern (ports of call, transshipment ports, and vessel sizes) as well, so that the profit (= income – costs) of that group is maximized, considering the behavior of other groups, i.e., the freight charges, shipping times, and transportation pattern of competing groups. An ocean-going container carrier behaves to shortsightedly maximize its own income in the short term under the condition that its cost is fixed, considering the shipper's behavior only in selecting a carrier. However, the carrier cannot predict the mid-term behavior of shippers, such as selection or change of ports used for export and import.

In order to describe above, two models were developed. The first is a short-term model, in which maritime container cargo shipping demand and shipping cost by port pair is unchanging for each carrier group, so that each carrier group determines its freight charges by port pair so as to maximize its own income. The second is a mid-term model, in which shipping demand by port pair can be changed, reflecting the shipper's unrestricted choice of ports used for export/import, but shipping demand by regional pair (i.e., demand from a 'true' origin to a 'true' destination) is fixed. In the mid-term model, shippers and carrier groups are countervailing forces, and neither has the power to control the international maritime container shipping market. Therefore, the authors assume that a Nash equilibrium is reached, in which all shippers and all ocean-going shipping companies cannot improve their own objective function so long as the behavior of the other party does not change.

Model Extension to Include the SSS

The ocean-going carrier model described in the previous chapter is developed, with focusing on only the container shipping company. Because most of the SSS companies are small and the SSS market seems quite competitive (not oligopolistic unlike the long-haul container shipping market), the author assumes that the SSS companies do not have any influence to the market and do not develop any model to describe their behaviors. Instead of them, their service frequency and vessel size are given at the shippers' choice of the shipping mode in the shipper model as input condition.

Concretely, a SSS link is added, if necessary, on the shipping network of the shipper model, along a maritime container shipping link, as shown in Fig.2. The maritime container shipping link shown in Fig.2 is directly connected between an export port and an import port, irrespective of the actual maritime shipping route, because the actual route is decided by the carrier model according to each carrier's behavior to maximize its own profit.

The cost function of the maritime container shipping link was defined, as described in [3].

$$GC_{ij} = \left\{ -\frac{1}{\theta} \cdot \ln \sum_{g \in G} \exp\left(-\theta \cdot GCM_{ijg} \right) + \zeta \right\} + \sum_{i,j \in k} vt_{shpr} \cdot \left(TPX_i + TPM_j \right). \tag{1}$$

where i: export port, j: import port, g: carrier group, G: set of carrier groups, GCM_{ijg}: generalized cost (JPY/TEU) of maritime container shipping when using a carrier group g from export port i to import port j, θ: variance parameter (JPY^{-1}), ζ: adjustment parameter to avoid the maritime link cost being negative, TPX_i: lead time when exporting in port i (hours), TPM_j: lead time when importing in port i (hours), vt_{shpr}: value of time for shipper (JPY/TEU/hour). The generalized cost of maritime container shipping GCM_{ijg} is formulated as

$$GCM_{ijg} = p_{ijg} + vt_{shpr} \cdot TM_{ijg}\ . \tag{2}$$

where p_{ijg}: freight charge (JPY/TEU), TM_{ijg}: total time (hour) of maritime shipping (including waiting time).

Meanwhile, the *SSS link* cost GF_{ij} (for ferry) and GR_{ij} (for RORO ship) are respectively defined as

$$GF_{ij} = pf_{ij} + vt_{shpr} \cdot \left(TFM_{ij} + \frac{1}{2} TFF_{ij} + TFPX_i + TFPM_j \right), \text{ and} \tag{3}$$

$$GR_{ij} = pr_{ij} + vt_{shpr} \cdot \left(TRM_{ij} + \frac{1}{2} TRF_{ij} + TRPX_i + TRPM_j \right). \tag{4}$$

where pf_{ij}, pr_{ij}: freight charge (JPY/TEU) for ferry and RORO ship shipping from export port i to import port j, TFM_{ij}, TRM_{ij}: maritime shipping time (hours) of ferry and RORO ship, TFF_{ij}, TRF_{ij}: average interval time (hours) on a service (inverse of frequency), $TFPX_i$, $TRPX_i$: lead time when exporting (hours), $TFPM_j$, $TRPM_j$: lead time when importing (hours). Note that the SSS link cost is also defined as a cost per TEU for consistent model calculation, although a cargo is not always loaded in a container.

The freight charge pf_{ij} and pr_{ij} are assumingly defined as linear functions of shipping distance, that is,

$$pf_{ij} = af_1 \cdot l_{ij} + af_2 + af_3, \text{ and} \tag{5}$$

$$pr_{ij} = ar_1 \cdot l_{ij} + ar_2 + ar_3\ . \tag{6}$$

where l_{ij}: distance (nautical miles) between port i and port j, af_1, ar_1: coefficient on proportional term of maritime shipping cost to link distance, af_2, ar_2: coefficient on fixed term of maritime shipping cost, af_3, ar_3: coefficient on terminal handling (mainly due to interchange of chassis).

The maritime shipping time TFM_i and TRM_i are defined, irrespective of type of vessel, as

$$TFM_{ij} = TRM_{ij} = l_{ij} / v_{ij}\ . \tag{7}$$

where v_{ij}: vessel speed (knots) for each route.

Another note is that a shift from air transport is not considered in this model. As described in the introduction, some of the SSS companies aim to attract a cargo from the air transport market; however, consideration of air transport in the model is very difficult. The author will try to develop for future.

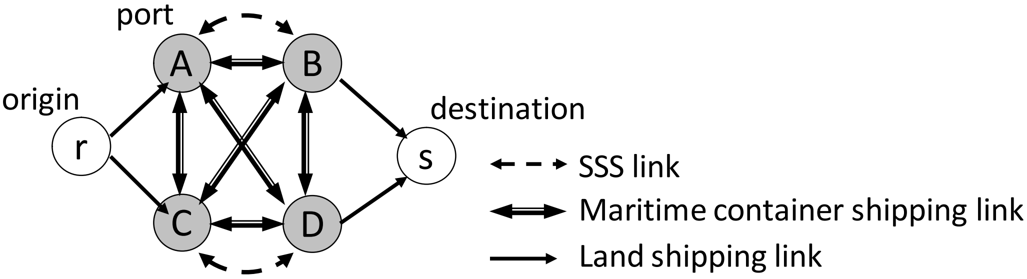

Fig.2 Schematic view of network structure of shipper model in this paper

Data Preparation and Parameter Setting

The model in this paper only considers five SSS routes connecting North Kyushu area in Japan with China and Korea, as shown in Tab.1. In addition, hinterland transport network on land is only considered in Japan for simplicity; i.e. cargo in other countries than Japan are originated from and destined into the ports. Note that frequency of service in some SSS routes will be improved from a case of scenario 0 (described as ‘s0’ in Tab.1), which describes the actual situation for confirming model accuracy (see next section), to other cases (described as ‘s1 and others’ in Tab.1), which are set for usage of policy simulation.

The lead time for the SSS at export and import ports is assumingly set by country as shown in Tab.2, which also assumes to be improved in some policy scenarios. The coefficients on maritime shipping cost included in Eq. 5 and Eq. 6 are set as shown in Tab.3, according to a description in a Japanese handbook on cost-benefit analysis of port investment. The coefficients on terminal handling charge also included in Eq. 5 and Eq. 6 are assumed by reference to a drayage cost in hinterland transport, based on the fact that interchange of chassis is actually required twice at export and import port each, which will be also improved in the policy simulation.

All of other input data and parameters such as maritime container shipping and land transport costs are similarly set as the existing model [2, 3], except for cargo shipping demand which is renewed in a year-2008 basis.

Tab.1 SSS routes considered in this paper and parameters setting

origin and destination ports	countries	name	type	frequency per week		distance (NM) l_{ij}	vessel speed (knot) v_{ij}	shipping time (hour) l_{ij} / v_{ij}
				s0	s1 and others			
Hakata - Shanghai	Japan-China	SSE	RORO	2	6	502	20	25.1
Kitakyushu (Shimonoseki) - Shanghai	Japan-China	Shagnhai-Shimonoseki	RORO	2	6	544	20	27.2
Kitakyushu (Shimonoseki) - Qingdao	Japan-China	Orient Ferry	RORO	2	6	556	20	27.8
Kitakyushu (Shimonoseki) - Busan	Japan-Korea	Kampu Ferry/ Grand Ferry	ferry	13	13	121	20	6.1
Hakata - Busan	Japan-Korea	Camellia Line	ferry	7	7	117	20	5.9

Tab.2 Lead time set in this paper (hours, common for ferry and RORO ship)

country	s0 and s1		s2 and others	
	export	import	export	import
Japan	6	6	3	3
China	12	12	6	6
Korea	6	6	3	3

Tab.3 Coefficients in freight charge (in Eq. 5 and Eq. 6) set in this paper

coefficient	maritime shipping cost				terminal handling charge			
	proportional term to istance		fixed term					
unit	'000 JPY/NM		'000 JPY		'000 JPY			
vessel type	common for all scenarios					s0, s1, s2	s3	s4 and others
ferry	af_1	2.5	af_2	15.0	af_3, ar_3 (common for ferry and RORO)	20×2	20	0
RORO	ar_1	1.5	ar_2	1.5				

Confirmation of Model Accuracy

Fig. 3 shows a comparison between the actual and estimated amount of maritime containers handled at each Japanese port. From the figure, it is found that the model extended in this paper well reproduces the actual as well as the already existing model (before extention) does, from the viewpoint of container cargo throughput in ports including port Hakata and Kitakyushu.

For each SSS route which is added in this paper, Tab.4 shows a comparison between the actual and estimated cargo flow. Note that definition of cargo flow (i.e. unit of cargo and whether empty cargo is

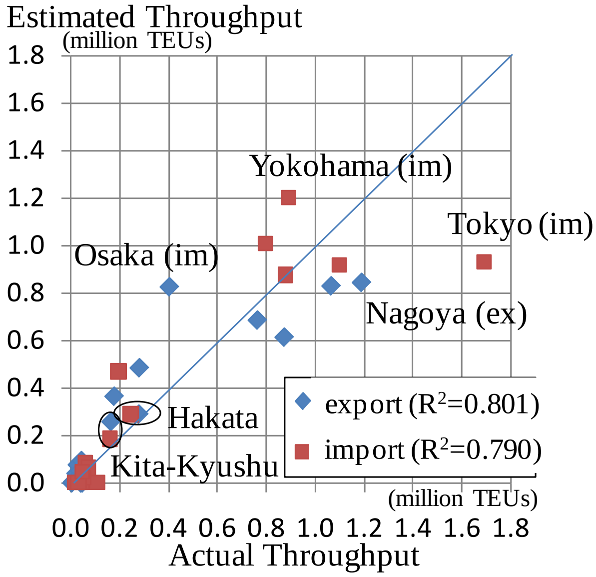

Fig.3 Comparison of present and estimated container cargo throughput in Japanese ports (excluding empty containers)

Tab.4 Comparison of present and estimated cargo flow for each SSS route

origin and destination ports	countries	name	type	Actual flow (units, including empty cargoes)	Estimated flow (TEUs, excluding empty cargoes)	
					export	import
Hakata - Shanghai	Japan-China	SSE	RORO	30,000-40,000	9,967	16,209
Kitakyushu (Shimonoseki) - Shanghai	Japan-China	Shagnhai-Shimonoseki Ferry	RORO	12,000-15,000	10,067	13,744
Kitakyushu (Shimonoseki) - Qingdao	Japan-China	Orient Ferry	RORO	22,000-25,000	2,569	5,048
Kitakyushu (Shimonoseki) - Busan	Japan-Korea	Kampu Ferry/ Grand Ferry	ferry	60,000	21,545	17,153
Hakata - Busan	Japan-Korea	Camellia Line	ferry	more than 30,000	24,695	17,950

included or not) is different between the actual and estimated. Judging from the table, the estimated cargo flows in the SSE and two ferry routes connecting Japan and Korea relatively approximate the actual; on the other hand, the differences between the actual and estimated flow in other two RORO ship routes connecting Japan and China are significant. For the Shanghai-Shimonoseki ferry, the estimated flow is quite larger than the actual. The reason is partly considered that the actual port that this ferry calls at in China is Suzhou, which is located away from a center of cargo shipping demand in Shanghai area. On the other hand, for the Orient ferry, the estimated cargo flow is much lower than the actual. The reason is so difficult to explain that further investigation is needed.

Policy Simulation using the Model

Policy scenarios considered in this paper are listed in Tab.5. ‘s1’ (scenario 1) is increasing scenario on service frequency of three RORO ship routes as described in Tab.1. Note that it should be checked ex-post whether enough cargo volume per vessel is ensured or not. ‘s2’ is reducing scenario of the lead time for export and import due to trade facilitation and related investment, as described in Tab.2. ‘s3’ and ‘s4’ are standardization scenarios of carrying vehicle (chassis) to save its interchange at port as shown in Tab.3; in ‘s3’ reducing by once for interchange of chassis is assumed, while in ‘s4’ no interchange at any ports is assumed. ‘s5’ is quite hypothetic scenario on decreasing all land shipping cost in Japan to be half. ‘s7’ is reducing scenario of the lead time at port on container shipping. ‘s6’ and ‘s8’ are combination of them.

Fig.4 shows estimation results on the amount of cargo handled at port of Hakata and Kitakyushu by policy scenario. In both ports, most of cargo are handled as container. However, shares of the SSS increase in both ports as policy to encourage utilizing it implements more (as described as the estimation results in s1 to s4). In particular, in s4 (representing thorough standardization of chassis), the expected total volume carried as the SSS cargo is doubled or tripled, compared with its volume in s0; i.e. the expected increasing volume in s4 meets with the increase of service frequency. In other words, simple increase of service frequency (e.g. s1) is not adequate to increase the cargo volume of the SSS thus drastic policy such as mutual recognition of chassis by both countries as assumed in s4 is needed for improving level of service of the SSS.

When land shipping cost is reduced to be half (s5), especially export containers are expected to increase for each Japanese port. On the while, simultaneous implementation (s6) of reducing land shipping cost and encouraging the use of the SSS is expected to increase the import cargo of the SSS. That is, when land shipping cost is reduced, there are expected to increase export containers as well as import SSS cargo, in case that the SSS is enough convenient for usage.

It is matter of course that when the lead time of container shipping is reduced (s7), container volume is expected to increases while the SSS cargo is expected to decrease. However, the simultaneous implementation of all policies (s8) including land shipping cost reducing and the SSS encouragement will bring significant increase in the entire cargo volume of the port.

Tab.5 Policy scenario set in this paper

senario	description
s0	default (estimated result to the actual, shown in the previous section)
s1	increasing frequency of RORO ship service (see Tab.1)
s2	in addition to s1, shortening lead time of the SSS (see Tab.2)
s3	in addition to s2, decreasing terminal handling charge (see Tab.3)
s4	in addition to s2, removing terminal handling charge (see Tab.3)
s5	decreasing all land shipping cost (including both manetary cost and shipping time) in Japan to be half of them
s6	s4+s5
s7	shortening lead time of container shipping in port of Hakata and Kitakyushu from 48 hours to 24 hours (for both export and import)
s8	s6+s7

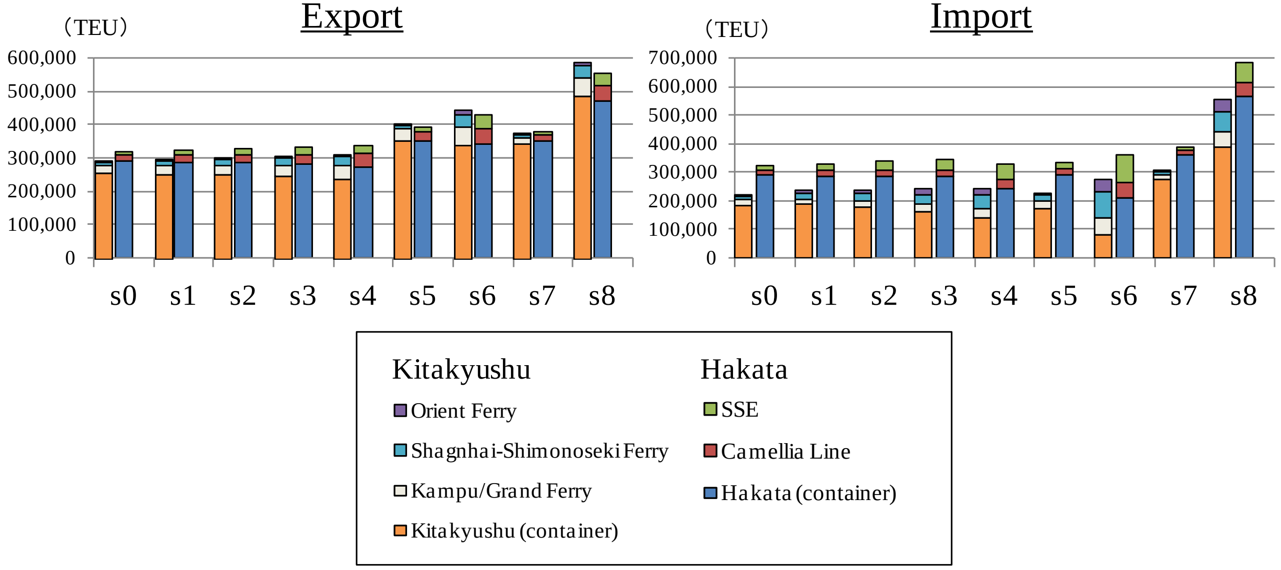

Fig.4 Estimated cargo flow handled at port of Hakata and Kitakyushu by policy scenario

Summary

In this paper, in order to simulate the impact of policies that encourage the utilization of the SSS, the intermodal freight flow model the author had developed is extended to include the SSS, then applied to the real shipping network connecting the northern Kyushu area in Japan with China and Korea.

As a result, it is found that the newly developed model reproduces the actual well as a whole. Also, some implications are acquired such that in order to advance the utilization of the SSS, a drastic policy such as mutual recognition of chassis is needed.

Since the SSS has high potential to be widely utilized in East Asia, a development of this kind of model and implementation of policy simulation using such models are important and quite supportive.

Also, further works for improving the model accuracy such as revise of cost function of the SSS and inclusion of air shipping, as well as applying to other SSS routes in other regions, should be countinuously conducted .

References

[1] Shanghai-Hakata Super Express Website. http://www.ss-express.biz/index.html (accessed on 8 August 2011)

[2] R. Shibasaki: A Cost Minimization Model of a Large-Scale International Maritime Container Shipping Network regarding Characteristics of Ports. Presented at 90th Annual Meeting of the Transportation Research Board, Washington, D.C. (2010).

[3] National Institute for Land and Infrastructure Management, MLIT, Japan: *Impacts of Trade and Transport Policy on International Cargo Shipping and Economic Activities*. submitted to the 33rd APEC Transportation Working Group Meeting (TPT-WG), Maritime Expert Group (MEG), Tokyo, Japan (2010).

[4] R. Shibasaki and T. Watanabe: Future Forecast of Chinese Trade Amount and International Cargo Flow, Proc. of 10th International Conference on Traffic & Transportation Studies (ICTTS 2010), Kunming, China (2010).

[5] R. Shibasaki and T. Watanabe: Future Forecast of Trade Amount and International Cargo Flow in the APEC Region: An Application of Trade-Logistics Forecasting Model. Proc. of the Eastern Asia Society for Transportation Studies, Vol.8, Jeju, Korea (2011).