3. THE MODEL

We apply the bi-level air transport market model (Takebayashi, 2011, 2012, 2013), which is a demand-supply interaction model. The basic structure of bi-level model is described in the former works. Notations are listed in the Appendix.

3.1 The shippers

In the model, container shippers choose the best available routes comparing each disutility. For shipper's route choice behavior, we adopt the Stochastic User Equilibrium (SUE) with capacity constraint model. The general formulation of the SUE with capacity constraint (Bell, 1995; Zhou et al., 2005; Takebayashi, 2011, 2012, 2013) is

$$\text{Object}: \min \Gamma(x_k^{rs}) = \frac{1}{\theta}\sum_{rs\in\Omega}\sum_{k\in K^{rs}} x_k^{rs}(\ln x_k^{rs} - 1) + \sum_{rs\in\Omega}\sum_{k\in K^{rs}} u_k^{rs} x_k^{rs} \tag{1}$$

Subject to

$$\sum_{k\in K^{rs}} x_k^{rs} = X^{rs}, \forall rs \in \Omega\ , \tag{2}$$

$$x_{l^n} = \sum_{rs}\sum_{k} x_k^{rs}\delta_{l^n}^{rsk} \le V_{l^n},\ \ \forall l^n \in I^n, n \in N^+\ , \tag{3}$$

$$x_k^{rs} \ge 0, \text{ for } \forall k \in K^{rs} \ and\ rs \in \Omega\,\cdot \tag{4}$$

In objective function (1), the first term of right-hand side is the entropy term. Constraint (2) means an origin-destination (OD) flow conservation. Constraint (3) is a link flow capacity constraint.

The disutility of shippers choosing route *k* of *rs* is defined as a function with deterministic costs:

$$u_k^{rs} = \alpha_1(t_k^{rs} + w_k^{rs}) + \alpha_2 p_k^{rs} + \sum_{l\in I^{Av}} \frac{\alpha_3}{V_l}\delta_l^{rsk}\,. \tag{5}$$

Shipper's disutility function including congestion cost U_k^{rs} is described as

$$U_k^{rs} = u_k^{rs} + \sum_{l}(\lambda_l)\delta_l^{rsk}\,. \tag{6}$$

Congestion cost λ_l is obtained as a value of Lagrange multiplier reflecting the behavior of constraint (3) (Lam et al., 2002) and λ_l is given as nonnegative if capacity constraint in link l is active or zero otherwise.

3.2 The carriers

The liner-ship company (carrier) aims to maximize its profit by controlling capacity V_l. The lLiner-ship company *n*'s profit maximization problem is formulated as

$$\max_{V^n} \pi^n(V^n, \tilde{V}^{-n}, \tilde{\mathbf{p}}^{-n}) = \sum_{rs}\sum_{k}\sum_{l^n\in I^n} p_{l^n}\hat{x}_k^{rs}\delta_{l^n}^{rsk} - \sum_{l^n\in I^n} C_{l^n}^{OP}V_{l^n}\ , \tag{7}$$

subject to

$$\mathbf{G}(V^n) \le \mathbf{0}\,, \tag{8}$$

$$\hat{x}_k^{rs} = \arg\{\min : \Gamma(x_k^{rs}) \text{ subject to (2) to (4)}\},\ \forall k \in K^{rs} \quad \text{and} \quad rs \in \Omega\,, \tag{9}$$

where $\mathbf{f}^n = \{ f_{l^n \in I^n} \}$, and $\mathbf{p}^n = \{ p_{l^n \in I^n} \}$.

Objective function (7) is composed of revenues (first term) and costs (second term). Constraint (8) is a general form of constraint of liner-ship companies such as a maximum vessel size available at port *h*, which is relevant to V_l. Constraint (9) means that the container cargo flow defined as a best response function to liner-ship company's behavior $\hat{x}_k^{rs}$ can be obtained as a solution of the SUE.

4. SCENARIO STUDIES

4.1 Outline

This paper aims to discuss the effectiveness of tasks that the port of Hanshin proposed. Firstly, we confirm the workability of each task. But due to the inaccessibility of detail information and data about international shipping, we should carry out the approximate calculation, so our numerical computation is currently a trial. Please note that our computation results are regarded as suggestions and not regarded as forecasted outputs."

In this numerical computation, we deal with a duopoly market. This situation is regarded as too simplified, but in the particular OD market, most of carriers (or alliances) actually provide similar shipping services with similar transport capacity. Therefore, general characteristics of the market can be figured out on the duopoly assumption. We assume two representative carriers in the market whose profiles are set by reference to profiles of HKYH alliance and Maersk/A.P. Moller Group. We use the following OD zones and the representative ports listed in Table 4. OD flow bound for EU or North America is the aggregated volume.

Table 4 OD Zones and Ports

OD zone	Cities/Areas	Representative Ports	Note
Keihin	Tokyo Metropolitan Area, Hokkaido, Tohoku	Keihin, Niigata	Connectivity to other zones in Japan is given by scenario.
Chukyo	Nagoya Metro. Area, Tokai, Hokuriku	Ise	
Hanshin	Osaka Metro. Area, Chugoku, Shikoku	Hanshin, Maiduru	
Hakata	Kyushu/Okinawa	Northern Kyushu	
Korea	Korea	Busan	
Bohai Area	Northeastern China	Dalian	
Yellow Sea Area	Shandon Prov.	Qindao	
Shanghai	Shanghai	Shanghai	
Southern China	Shenzhen/Guangzhou	Shenzhen	
Hong Kong	Hong Kong/Macao	Hong Kong	
Taiwan	Taiwan	Kaohsiung	
Thailand	Thailand	Laem Chabang	
Malaysia	Malaysia	T.J. Perepas	
Singapore	Singapore	Singapore	
Indonesia	Indonesia	T.J. Priok	
EU	EU	Rotterdam	
North America	USA, Canada	Long Beach	

Before examining the scenario, we verify how the model works. We evaluate the path flow of cargos from/to Japan given by PIERS (2010) and find that the R^2 is 0.63 around. Some of path flows are overestimated because so many cargos are transshipped at some major ports such as Singapore and Busan with the effect of economy of scale in transport capacity. But most of flows are well estimated. Thus, the model is workable for understanding the market behavior.

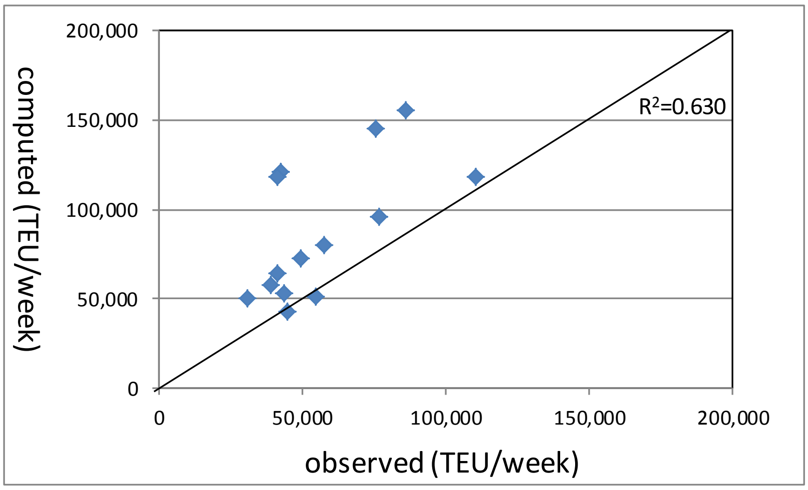

Figure 3 Model accuracy

As for the scenario of constructing deeper berths, we assume that a 16m depth berth, which is the regular depth in Japan for big vessels, can be used for 8000 TEU vessels and a 18m depth berth can be used for 13000 TEU vessels.

In the following section, we discuss three types of scenarios to examine the effectiveness of tasks. We set (i) Lowering port charges, (ii) Constructing deeper berths, (iii) Concentrating domestic feeder services to Hanshin as the scenarios.

4.1.1 Lowering port charges (Scenario I)

This task is planned for attracting carriers who avoid using Hanshin because of its higher charges. In particular, this task aims to invite the carriers operating long-haul trunk lines such as Euro-bound and trans-Pacific services, and then a lowering-charges is workable to these carriers.

4.1.2 Constructing deeper berths (Scenario II)

This task is also planned for attracting carriers who avoid using Hanshin because of its shallow berths. Constructing deeper berths may lead to inviting larger size vessels of trunk lines. In the scenarios, we set up a couple of vessel size combinations for trunk lines using Hanshin.

4.1.3 Concentrating domestic feeder services to Hanshin (Scenario III)

This task is planned for increasing the terminal demand at Hanshin itself. The “incentive strategy” employed by local ports increases leak cargos to rival ports, and then the presence of Hanshin in the market is falling. In order to raise the presence of Hanshin, the task like this scenario is supposed to be effective. We assume a 50% reduction of the port charge at Hanshin.

4.2 Results and discussions

We have comprehensive outputs, for example path flow, link flow, transshipment cargo volume, transport capacity provided for the particular OD pair. We summarize these outputs and focus on the effectiveness of strategy given by scenario.

Table 5 shows the comparison of main outputs of Scenario I. From the results, lowering port charges invites more container cargos at Hanshin and the volume increases 1.5%. And the average load factor increases 0.9%, and thus the profitability of carriers using Hanshin is improved.

Contrarily, Scenario II does not seem effective from the result. Developing minus 16m (Case 1) and minus 18m (Case 2) berths at Hanshin does bring the increase of cargo volume but it is smaller than that of Scenario I. Looking at the average load factor in both cases, the value of these indices goes down, especially the load factor in Case 2 seriously decreases. These results suggest that constructing deeper berths may be effective in terms of inviting more cargos but it may not effective because from the viewpoint of load factor carriers do not have any motivation for using bigger vessels. And then, Scenario II does not work well alone.

Table 5 Summary of Results: at Hanshin

	Default	Scenario I	Scenario II		Scenario III	
			Case 1	Case 2	Case 3	Case 4
Total Cargo Volume (TEU/week)	139576	141693 (+1.5%)	140779 (+0.9%)	140543 (+0.7%)	157788 (+13.0%)	161927 (+16.0%)
Load factor (%)	57.9	58.8 (+0.9%)	57.3 (-0.6%)	50.7 (-7.2%)	59.2 (+1.3%)	62.4 (+4.5%)

Scenario III consists of two cases: one is establishing long truck feeder services to Nagoya Area (Case 3) and the other is to Kyushu Area (Case 4). Obviously, extending feeder services works well. The handled cargo volume rises 14% and the average load factor rises 1%. This suggests that carriers also increase their profitability by Scenario III task, and therefore this task is workable.

Finally, let us consider the impact of each task on Hanshin by destination. Table 6 lists the total cargo flow, available transport capacity, and the load factor. As for the North America/NA bound traffic, there might be no impact on gathering the NA bound cargos but the Scenario III is effective. Thus, reinforcing feeder services from/to Kyushu area is workable for gathering more cargos bound for NA. The EU bound cargos has the same tendency as the NA bound cargos with the third task, but the load factors of the EU bound traffic is less than that of the NA. Thus, the third task is also workable for gathering the EU bound cargos but its effect is smaller than that of the NA.

From these computations, we have the following suggestions:

1) The task of expanding a truck feeder service network is workable for gathering more cargos and increasing the load factor of long-haul transport. In particular, expanding the network to western area of Japan, such as Kyushu, is very effective for gathering the NA and EU bound cargos.
2) The task of constructing deeper berths does not independently work as effectively as we expect.
3) The task of lowering port charges does not independently work as effectively as we expect.

Table 6 Summary of Results by Direction: at Hanshin

	Scenario I	Scenario II		Scenario III	
		Case 1	Case 2	Case 3	Case 4
North America					
Total Cargo Volume (TEU/week)	5848	5848	5848	5887	7315
Load factor (%)	67.7	67.7	67.7	68.1	84.6
Europe					
Total Cargo Volume (TEU/week)	3051	3062	3134	3079	4616
Load factor (%)	21.7	12.1	19.1	21.9	32.8

Suggestion 2) and 3) are meaningful. The effectiveness of each task is often discussed independently but that may not make sense. These tasks will work effectively by combining with other tasks for gathering local cargos, such as the first task.

5. CONCLUDING REMARKS

In this paper, we apply the bi-level transport market model to estimate the effectiveness of tasks proposed in the strategy plan of the port of Hanshin and obtain some meaningful suggestions for managing Hanshin. The most important suggestion that we have is that tasks proposed by Hanshin in the plan will work effectively by combining with other tasks for gathering local cargos. However, due to the limit information about the market, this computation should be a test case. In the future study, we will upgrade the estimation with more detailed information. –information of shipper's behavior, transshipment cargo volume at some major ports such as Busan and Singapore where it is much overestimated. This overestimation is supposed to be relevant to the tendency "economy of scale works too strong." We need to check the market structure again and clear this overestimation.

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Appendix
List of notations

Variable	meaning	Variable	meaning
rs	OD pair of origin r and destination s	k	service route in rs OD market
Ω	set of OD pairs	K^{rs}	set of service routes provided for rs OD market
$l^n(l^R)$	commercial link operated by carrier n (or HSR)	$I^n\ (I^R)$	set of links operated by carrier n
x_k^{rs}	cargo flow from r to s on route k	I^{AV}	Set of links which are available for cargo shippers
x_{l^n}	cargo flow of link l^n	X^{rs}	OD volume of rs OD market
u_k^{rs}	disutility of shipper who chooses route k of rs OD market for shipping without congestion	$\hat{x}_k^{rs}$	optimal flow of route k in rs OD market
p_{l^n}	tariff on link l^n	N	set of carriers
V_{l^n}	Total capacity provided by carrier n on link l^n.	v_{l^n}	the vessel size on link l^n
$C_{l^n}^{OP}$	operating cost per 1TEU on link l^n	$\Gamma(x_k^{rs})$	optimal value function for shipper's route choice behavior
$\alpha_i\ (i=1, 2, 3)$	parameters in disutility function (5)	t_k^{rs}	travel time including feeder time
p_k^{rs}	Total shipping cost	θ	predetermined distribution parameter in SUE
$\delta_{l^n}^{rsk}$	dichotomous variable that takes one when kth route in rs OD market on link l^n, otherwise it takes zero	λ_{l^n}	congestion cost on link l^n
$\mathbf{G}(\mathbf{V}^n)$	the general form of constraints with capacity of carrier n	$\tilde{\mathbf{V}}^{-n}$	the optimal strategy vectors of competitor against carrier n shown as "-n"