The effect of consolidation and privatization of ports in proximity: Case study in Kobe and Osaka ports

Hoshi TAGAWA[1], Tomoya KAWASAKI[2], Toshihiro WATANABE[3] and Shinya HANAOKA[4]

[1]Non-member of JSCE, Master Student, Dept. of Transdisciplinary Science and Eng., Tokyo Tech.
(2-12-1-i4-22, O-okayama, Meguro-ku, Tokyo, 152-8550, Japan)
E-mail: tagawa.h.ab@m.titech.ac.jp
[2]Member of JSCE, Assistant Professor, Dept. of Transdisciplinary Science and Eng., Tokyo Tech.
[3]Non-member of JSCE, Researcher, Japan Maritime Center
[4]Member of JSCE, Professor, Dept. of Transdisciplinary Science and Eng., Tokyo Tech.

This study explores the effects of "consolidation" and "privatization" where the ports are located in proximity. It is assumed that main benefit of consolidation is assumed as economies of scale due to the aggregation of container cargoes in one berth while that of privatization is cost reduction of the port management. Methodologically, we employ agent-based simulation model in order to express interactions among agents related to port management and operation. Simulation model developed is applied to the case of Kobe and Osaka ports in Japan. We found that consolidation has larger impact than privatization in terms of cargo volume and social benefit. In particular, in case future container cargo is expected to increase, consolidation should be done preferentially to increase cargo volume of Hanshin port (Kobe and Osaka) and social benefits of the region. However, Busan port is still dominant after consolidation and privatization are achieved.

Key Words : *ports in proximity, privatization, consolidation, agent-based model, Japan*

1. Introduction

In Japan, growth rate of container cargo handled and the number of trunk lines have been substantially lower than other East Asian ports (i.e. Busan, Shanghai) for last two decades. Due to the loss of comparative competitiveness of Japanese ports, large portion of container cargo from/to Japan tranships in Busan port instead of Japanese transhipment ports (i.e. Kobe, Osaka). Specifically, according to the database of Datamyne, container cargo from Japan bound for North America in 2015 is transhipped 29,089 TEU at Kobe port and 84,405 TEU at Busan port. Note that Osaka port deals with only few container cargo bound for North America. Under such situation, Japanese Government launched the policy for "International Container Strategic Port" in 2009 so as to regain transhipment container cargo originated at Western Japan from Busan port. Fundamental idea behind the policy is "consolidation" of large-scale container ports in proximity since the number of Japanese container ports are too many (i.e. 120, MLIT (2016)) to work economies of scale and intensive investment of the ports. In the policy, "Kobe and Osaka (Hanshin port)" and "Tokyo and Yokohama (Keihin port)" are designated as targets of consolidation of ports in proximity. Another prominent characteristic of this policy is "privatization" of port management body which are used to be managed by local governments (i.e. Kobe city and Osaka city).

In case Kobe and Osaka port is consolidated, it will be monopolized port for their hinterland cargo since competition between Osaka and Kobe will be disappeared while economies of scale will be can be expected for consolidated port especially for transhipment cargo which is competing with Busan port. Japanese government intends to consolidate management body of both ports and not to be just cooperation of two ports. Several existing study examines (i.e. e.g. Zhou, 2015; Li and Oh, 2010) cooperation of multiple ports in proximity, which remains two ports separately. In this study, consolidation is defined as managing multiple ports in proximity by one port management company. Note that the term "cooperation" refers to multiple different ports are separately operated but they cooperate each other (e.g. revenue sharing). While several examples of cooperation can be found in the real field, a few examples of "consolidation" of the different ports can be found (e.g. "Seattle and Tacoma port" and "Copenhagen and Malmö port"). Thus, the effect of consolidation is not well discussed. Although port privatization has been spreading in several countries, Baird (2002) points out that a role of public sector remains significant in some cases especially in the legal field. Cullinane *et al.* (2005) analyses port efficiency for the top 30 ports in the world by data envelopment analysis and concludes private port is not always more efficient operation than public ports especially in the monopolistic situation. Thus, the effect of privatization of Hanshin port needs to be carefully examined in the combination with consolidation.

Therefore, the objective of this study is to explore the effects of the four possible combination cases in terms of consolidation and privatization for Kobe and Osaka ports. Four possible patterns of the relationship of Hanshin port are as follows;

Pattern 1: "consolidation and private"
Pattern 2: "consolidation and public"
Pattern 3: "non-consolidation and private"
Pattern 4: "non-consolidation and public"

The effects of four patterns are examined by using indicators such as container cargo volume, social benefit, profit of each agent, frequency of trunk lines and freight rates. Since Japanese government aims to increase trunk lines for North America, competition between Hanshin (Osaka and Kobe) and Busan port originated from Western Japan bound for North America port is analysed.

This paper is structured as follows. Section 2 conducts extensive reviews for existing literatures regarding multiple ports in proximity and port privatization. Section 3 explains the target of study and actual situation of competition between Hanshin and Busan ports. In Section 4, a simulation model is developed by agent manner for four patterns considering interaction among the agents. Subsequently, as case study, developed models is applied to Hanshin port and examine the effect of privatization and consolidation in Section 5. Finally, conclusion and directions for further researches are given in Section 6.

2. Literature review

This section describes the existing literatures of the relationship of ports in proximity and privatization of port.

(1) Relationship of ports in proximity

Relationship of ports in proximity have extensively discussed especially in the context of cooperation and competition in the previous studies. Fremont and Lavaud-Letilleul (2016) define six types of relationships of ports in proximity. In their definition, there is a group for "cooperation". However, there is no categories of "consolidation", which is the form that multiple ports are operated by one company. This is due to few examples of "consolidation" of the different ports (e.g. "Seattle and Tacoma port" and "Copenhagen and Malmö port"). Langen (2009) mentions that conditions of success the consolidation of Copenhagen and Malmö port is four factors; (1) both ports understand the economic effect of the consolidation, (2) leadership of both leader, (3) substantial political and societal support for merger, and (4) focus on visible results of the merger. In case for Seattle and Tacoma, they establish The Northwest Seaport Alliance (NWSA), which is a newly established organization for managing both container and terminal from a single point of view. This makes possible to manage more efficient than case without consolidation.

Cooperation and change in governance structures of ports in geographical proximity is rather important issue in terms of economic cluster concept (De Langen and Haezendonck, 2012). Therefore, port cooperation and/or consolidation of port management body become major theme and treated port governance and cooperation in several papers (Notteboom and Yap, 2012; Donselaar and Kolkman, 2010; Huo *et al*., 2018).

In the context of competition between Kobe and Busan, Ishii (2013) analyses competition between two ports by game theory and concludes that the charge setting at Kobe port is not appropriate. Thus, Kobe port loses their market share in 1990s.

On the other hand, Donselaar and Kolkman (2010) conclude social benefits of cooperation can be expected little or nothing by utilising port infrastructure and space, segmentation or bundling of goods flows or speciation of port in Dutch case. The reason is that port authority is just a coordinator of ports and it is difficult to change the principle of economic market as a commercial organisation. In particular, there are a lot of stakeholders in port management rather than other infrastructures.

There are several papers how to collaborate multiple ports. Shinohara and Saika (2018) worked out the typology of port cooperation and concluded to

manage port facilities efficiently and effectively with limited funding, a system should be devised under which nearby ports are managed in cooperative manner that emphasizes the ports to fulfil complementary roles. In order to compete with rival ports, Song (2003) suggested that port operators adopt a new strategic approach called coopetition meaning a mixture of competition and co-operation, having a strategic implication that those engaged in the same or similar markets should consider a win–win strategy, rather than a win–lose one. Dung-Ying *et al.* (2017) analyse the coopetition among shipping lines with nonlinear mixed integer problem which emphasis the significance of collaborative relationships among carriers while competing with each other to optimize their own profits.

Regarding port consolidation of multiple ports in China, Guo *et al*. (2017) provides several implications for port integration, such as (i) an incentive mechanism to two ports, (ii) regulation of limitation of tariff rate and mechanism of cost recovery is needed due to less competition by integration (iii) transfer of port facilities by utilizing subsidies.

(2) Port privatization

Although port privatization has been spreading in several countries in order to manage the ports efficiently, Baird (2002) points out that a role of public sector still remains significant in some cases especially in the legal field. Cullinane *et al.* (2005) analyses port efficiency for the top 30 ports in the world by data envelopment analysis and concludes private port is not always more efficient operation than public ports especially in the monopolistic situation. According to Farrell (1999), the reasons to spread port privatization can be divided into two parts. Firstly, port is relatively easier to divide into infrastructure and service comparing to other transport infrastructure. Secondly, since the mid-1980s, the port operation cost is reduced because of economies of scale and improved labour productivity of port.

There are several levels of port privatization as Baird (1995, 1997) suggests as Table 1. In case of Hanshin port (consolidated port of Osaka and Kobe ports), the regulator is to be public (local government) and the operator is private company. On the other hand, the landowner is both public (i.e. crown company) and private. Thus, Hanshin port is classified as tool port or landlord port.

3. Target of the study

(1) Definition of consolidation and privatization

Hanshin port is established for the purpose of managing two ports together. However, governance system of Hanshin port prevent joint management of two ports. Hanshin port is managed by semi-crown company where major shareholders are national government (34.2%), Kobe city (30.8%), Osaka city (30.8%). Therefore, Hanshin port has limited discretion power for important decision making and port asset are possessed by Kobe and Osaka city. Port charge is also determined by each city, which aims to maximize social welfare of the cities. Besides, Hanshin port received staffs from Kobe and Osaka city government which cannot be refused. Therefore, there is a conflict between Hanshin port and investor, and it is difficult to make a long-term strategy and accumulate know-how in this company. Consequently, as described above, Hanshin Port is practically not consolidated nor privatized even though management body of Hanshin port is corporatized.

In this study, it is assumed that consolidation represents a state where both ports are managed by one company and independent from each city in terms of decision making. In that case, cargos to North America from Kobe and Osaka can be handled in same berth. Similarly, other cargos are gathered and handled for each destination (e.g. Asian route, domestic route). This makes it possible to concentrate vessels in one terminal and to achieve economies of scale. Besides, it can be considered that frequency of trunk line increases by consolidation. Consequently, waiting time in the berth expects to be decreased comparing to non-consolidation case (i.e. Kobe and Osaka are separately managed and operated). However, consolidation generates monopoly situation for Hanshin port for their hinterland cargoes. This is an adverse impact on hinterland cargoes

Table 1 The matrix of port functions

	Port functions		
Port models	Regulator	Landowner	Operator
Public port	Public	Public	Public
Tool port	Public	Public	Private
Landlord port	Public	Private	Private
Private service port	Private	Private	Private

Source: Baird (1995, 1997)

in terms of freight rate.

As Roland (2008) mentioned, privatization does not achieved unless there is discretionary power for decision making no matter private or public organization provide services. Tezuka (2015) also point out that ownership does not matter for privatization but discretionary power is much important to achieve substantial privatization. Thus, in this study, “public” refers to current port management company, which aim is to maximize social welfare of major stakeholders of Kobe and Osaka city. On the one hand, in case of “private”, this study assumes there is discretionary power to determine port planning and operation and maximize their own profit. However, it seems difficult to totally separated from the city government as Shinohara and Saida (2018) mentioned, privatized port management company is outsourced from local government and each city determine port charges even though privatization is achieved as mentioned in Figure 1. Besides. one of the prominent difference between public and private of port management company is permission of deficit. Private company are not permitted to get deficit, while public case accept financial deficit if social welfare is maximized. This is also reflect the simulation model developed in this study.

(2) Study area and route

In this study, competition between Hanshin (Osaka and Kobe) and Busan port for four combinations in terms of privatization and consolidation is analysed for container haulage between Western Japan and North America. Target of container cargoes are generated in hinterland of Hanshin port or other Western Japan area as shown in Figure 3. Since the ports of Western Japan except Hanshin port has no direct service to North America, cargo generated Western Japan needs at least one transhipment at Hanshin or Busan port. In this study, eight ports of Western Japan are considered as shown in Figure 1. Cargoes dispatched in these ports are likely to be transhipped at Hanshin or Busan bound for North America. In this case, Hanshin and Busan ports are competed for transhipment handling. As for the cargoes generated at hinterland of Hanshin port (e.g. Kobe and Osaka), Hanshin port are mostly used as loaded port. However, even in this case, competition between direct shipment from Hanshin port and transhipment at Busan port is observed as shown in Figure 2.Transhipment at Busan port is for cargoes loaded at Hanshin port accounts for 12.9% in 2015. This might be due to high level of service and lower port charges of Busan port for North America route.

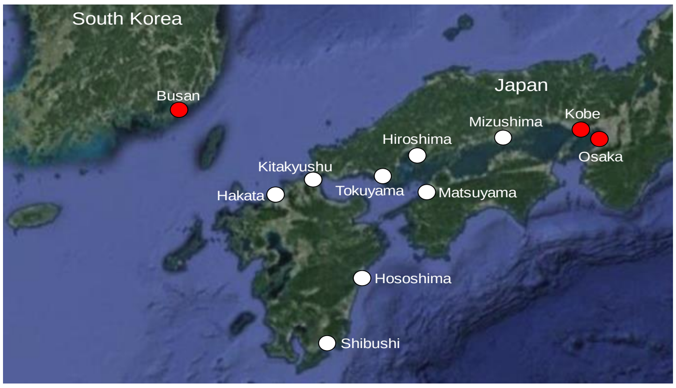


Fig. 1 Location of target ports

Source: Google Map modified by authors

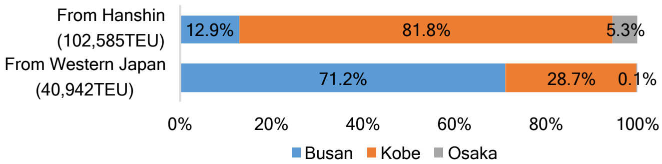


Fig. 2 Share of loaded port for mother vessel

Data source: Datamyne

4. Simulation model

The notations of agent based simulation model of this study are given as follows.

i	Port name of transshipment port (Port a , Port b , Port c)
k	Port name of origin port (Port 1 … Port10)
Π_i	Profit of Port i [$]
CS_i	Consumer surplus [$]
SW_i	Social welfare [$]
Pt_i	Profit of Terminal operator [$]
Ps_i	Profit of shipper [$]
GC_i	Generalized cost of shipper [$/TEU]
GC_{ik}^t	Generalized cost of shipper using port k at year t [$/TEU]
K_i	Annual handling capacity [TEU/year]
QB	Container cargo volume in the target berth [TEU]
e_i	Port charge [￥/year]
r_i	Lease charge of berth [$/TEU]
w_i	Loading/unloading charge [$/TEU]
τ_i	Freight rate [$/TEU]
f_i	Frequency [times/week]
Q_i	Total container cargo to North America using Port i [TEU]

QO_k	Total container cargo to North America from Port k [TEU]
q^t_{ik}	Total container cargo to North America from Port k transshipment at port i [TEU]
mc_p	Maintenance cost [$/TEU-year]
mc_t	Marginal cost of terminal operator [$/TEU]
y_i	Fuel surcharge (trunk line) [$/day-vessel]
N_i	Navigation distance from port i to North America (trunk line) [km]
V_i	Navigation speed (trunk line) [km/day]
S_i	Capacity of vessel (trunk line) [TEU/vessel]
z_i	Fuel surcharge (transshipment) [$/day-vessel]
n_{ik}	Navigation distance from Port i to Port k (transshipment) [km]
v_i	Navigation speed (transshipment) [km/day]
s_i	Capacity of vessel (transshipment) [TEU/vessel]
gt_i	Gross tonnage of vessel using port i [t]
T_{ik}	Navigation time from Port k to North America transshipment at port i [day]
$W(f_i)$	Container waiting time for a loading/unloading service at port i [day/time-TEU]
α	Value of time [$/day-TEU]
$\vartheta, \beta, \gamma, \varepsilon, \mu$	Parameter

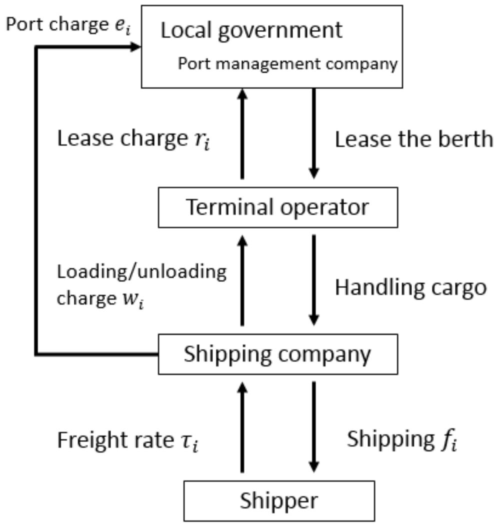
(1) Interrelationship among agents of port management and operation

The port management and operation is complex and several agents are involved and interact each other. Bonabeau (2002) states the benefit of agent-based model (ABM) is to provide a natural description of a complex system which behavior of agents interact each other. Therefore, in this study, ABM is applied to describe the port management and operation systems. The relationship among agents other than port management company (i.e. terminal operator, shipping company, shipper) are identical for public and private cases, as shown in Figure 3. The role and relationship in port management and operation system is addressed following sections.

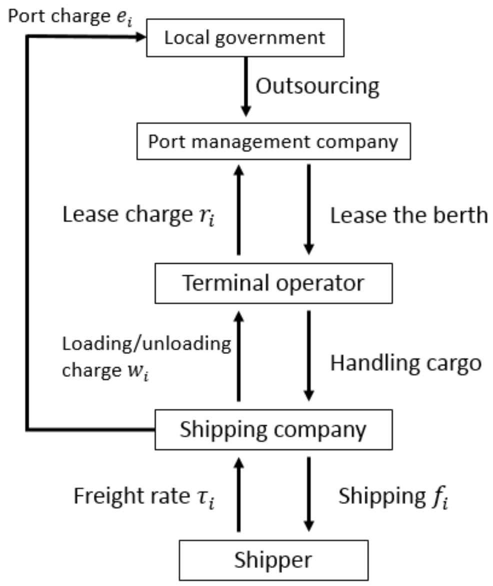
(2) Port management body

a) Public case

In public case, local government is the decision maker as port management body and has discretionary power to determine port charge (e_i) for shipping company and lease charge of berth (r_i) levied from terminal operator. In general, public body attempts to maximize social benefit (SB_i). Matsushima and Takauchi (2014) addresses that social benefit equals to domestic benefit, which is



(a) Public



(b) Private

Fig. 3 Relationships of stakeholder

calculated as the sum of all agents' profit and consumer surplus. Thus, profit of terminal operator and shipping company (Pt_i , Ps_i) is also incorporated into calculation of social benefit as shown in Equation 1. Port management company in public case determines port charges (e_i) to maximize social benefit.

Equation 2 shows profit of port management company (Π_i). Port charge (e_i) and lease charge of berth (r_i) are considered as revenue whereas maintenance cost of berth (mc_p) is considered as expenditure. Frequency (f_i) represents the number of trunk lines per week. In order to calculate a yearly profit, frequency (f_i) is multiplied by 52. The consumer surplus (CS_i) of Equation 3 is calculated by the rule of half as Winkler (2015) applied. Consumer surplus is determined by demand function and liner relationship between generalized cost (GC_{ik}^{t}) and container cargo (q_{ik}^{t}) is assumed for the simplicity.

$$\max_{e_i} SB_i = \max_{e_i}(\Pi_i + Pt_i + Ps_i + CS_i) \quad (1)$$

$$\Pi_i = (52 \cdot f_i) \cdot e_i gt_i + r_i - mc_p K_i \quad (2)$$

$$CS_i = \sum_k \frac{1}{2}(q_{ik}^0 + q_{ik}^t)(GC_{ik}^0 - GC_{ik}^t) \quad (3)$$

b) Private case

In private case, local government levies port charge (e_i) from shipping company, which is same action as the case of public. However, since port management company is separated from local government, they have discretionary power of decision making to increase their profit, which is not influenced from local government. The difference between public and private of port management company is their objective. Basso and Zhang (2008) and Zhang and Zhang (2003) express that objective of private company is profit maximization. Therefore, port management company in private case is formulated to pursue profit maximization as shown in Equation 4, which is similar to Equation 2.

$$\max_{r_i} \Pi_i = \mu \cdot (52 \cdot f_i) \cdot e_i gt_i + r_i - 0.9 \cdot mc_p K_i \quad (4)$$

In general, private company is likely to be more cost efficient than public organization since private company is financially independent. In this study, it is assumed that maintenance cost (mc_p) is reduced due to privatization. Therefore, adjustment factor for maintenance cost is set as 0.9, according to interview survey, as shown in Equation 4.

The revenue of port management company is lease charge of berth (r_i) and port charge (e_i). The port is possessed by local government even though privatization case. Thus, port charge is determined by local government to maximize social benefit as indicated

$$Q_i = \sum_k QO_k \frac{\exp(-\theta \cdot GC_{ik})}{\sum_i \exp(-\theta \cdot GC_{ik})} \quad (7)$$

$$GC_{ik} = \alpha[T_{ik} + \beta \cdot W(f_i)] + \gamma \cdot \frac{QB}{K_i} + \tau_i + \frac{z_i n_{ik}}{s_i v_i} \quad (8)$$

$$T_{ik} = \frac{N_i}{V_i} + \frac{n_{ik}}{v_i} \quad (9)$$

$$W(f_i) = \frac{7}{f_i} \quad (10)$$

in Equation 3. The port charges collected is directly to be revenue of port management company. Port management company determines lease charge of berth (r_i) to maximize their own profit.

(3) Terminal operator

In Japan, terminal operator is basically a private company and determines loading/unloading charge (w_i) to maximize their profit as shown in Equation 5. As an expenditure, marginal cost of loading/unloading (mc_t) and lease charge of berth (r_i) paid to local government is incorporated.

(4) Shipping company

Shipping company is also private and determine freight rate (τ_i) and frequency (f_i) to call the Hanshin and Busan port in order to maximize their profit as shown in Equation 6. As Sheng *et al*. (2017) and Yin *et al*. (2014) discussed, this study consider three types of cost for shipping company. First part is fuel cost for the main engines, which is proportionally changed with navigation distance (N_i). Second part is loading/unloading charge (w_i) and third part is operation cost which include the cost for crews, insurance, etc. In this study, operation cost is assumed as fixed value. In addition to these three costs, port charge (e_i) is considered as an expenditure of shipping company.

(5) Shipper

Shipper choose route (i.e. transshipment port or direct shipment) by logit model based on generalized cost (GC_{ik}), which are changed as a result of behaviour of other agents. Generalized cost (GC_{ik}) is calculated by Equation 8. It consists of frequency, lead time and charges, which is the important factors for shipping company (e.g. Kavirathna *et al.*, 2018; Kawasaki and Matsuda, 2015). The congestion cost is incorporated as QB / K_i on the basis of De Borger and Van Dender (2006) and Basso and Zhang (2007).

The freight rate (τ_i) and cost of transshipment ($z_i n_{ik} / s_i v_i$) are also components of generalized cost. Cost of transshipment ($z_i n_{ik} / s_i v_i$) only represents fuel surcharges since, according to interview survey, the fuel cost is dominant for vessel operation cost than other costs (e.g. port charge). Following Tran and Takebayashi (2016), navigation time and waiting time are calculated by Equation 9 and Equation 10, respectively.

(6) Solution algorithm

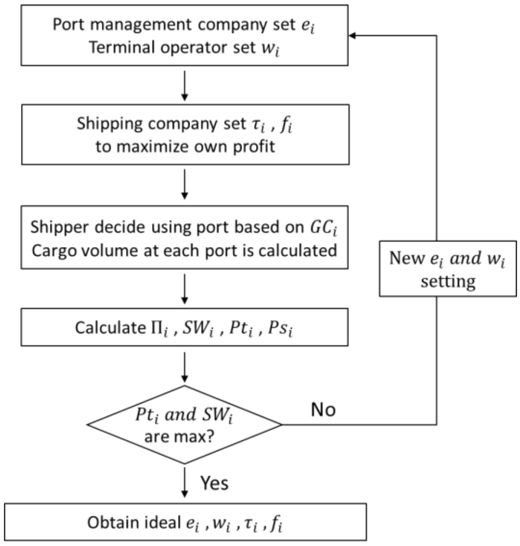
Calculation is done for every year from 2015 until 2030. In order to solve this optimization problem, Hooke-Jeeves pattern search (Hooke and Jeeves, 1961) is applied. Pattern search is widely used solution algorithm for solving multi-agents optimization problem (e.g. Saraswati and Hanaoka, 2014). The algorithm for each public and private case is shown in Figure 11. In private case, local government firstly set e_i and port management company set r_i Subsequently, terminal operator set w_i and shipping company set f_i and τ_i based on Equation 6. Note that terminal operator repeatly set new w_i to maximise their Pt_i. After that, shipper determines to select route (i.e. port) based on Equation 7. Finally, Pt_i and SB_i are repeatly calculated until maximum values are obtained in order to obatin optimum e_i and w_i. In public case, the number of variables is different from private case and the algorithm is also different. However, the principle of calculation is basically identical. Public case is calculated as shown in Figure 11.

5. Numerical Analysis

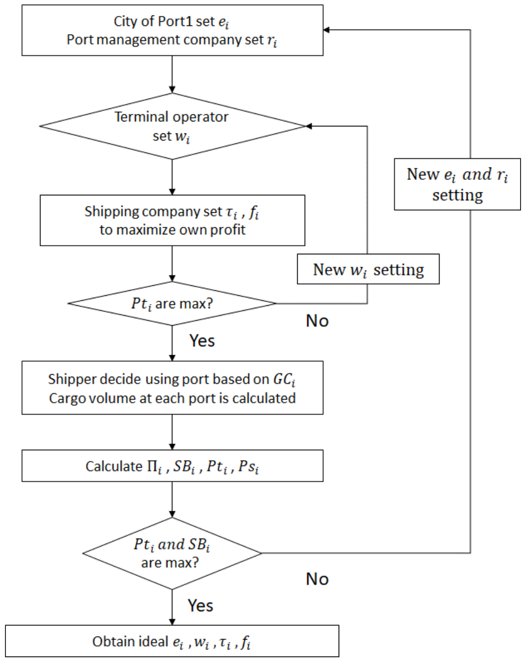
(1) Future container cargo demand

As one of the input data, future container cargo volume is needed. Figure 12 shows total container cargo volume from target ports of Japan to North America for the cases of “high-increase,” “middle-increase,” and “decrease”. Actual container volume between 2004 and 2016 (MLIT, 2017) is

$$\max_{\tau_i, f_i} Ps_i = \tau_i Q_i - w_i Q_i - \varepsilon \cdot (52 \cdot f_i) \cdot \frac{y_i N_i}{V_i} - (52 \cdot f_i) \cdot e_i gt_i \quad (6)$$



(a) Public



(b) Private

Fig.4 Solution algorithm

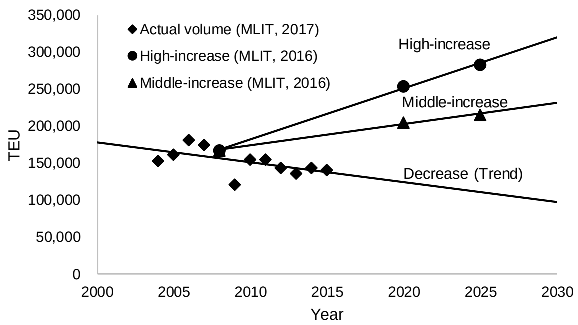


Fig.5 Calculation of future cargo from targets ports to North merica

continuously decreasing. Hence, we conduct a simulation in case container cargo will decrease in the future. For decrease case, trend line is estimated by least-square method as shown in Figure 12. Apart from actual container volume, MLIT (2016) forecast container volume for 2020 and 2025 based on economic condition, which is divided into "high-increase" and "middle-increase". From these forecasting results, MLIT (2016) seems to be optimistic even though recent trend of container cargo volume is decreasing. In the simulation, these two increase cases are also considered.

(2) Input data and assumptions

In order to simulate the effect of consolidation and privatization of Kobe and Osaka ports, input data are prepared as shown in Table 4 and 5. Some of the values are calculated by authors to match real values. For example, "lease charge of berth (r_i)" is obtained by ratio of revenue per berth and total port area (i.e. r_i = revenue of berth / total port area) of the port. The real data of revenue and total area are obtained from Kobe-Osaka International Port Corporation.

In this study, there are several assumptions which could influence input parameters. Firstly, the destination port is only assumed as Los Angeles port for the purpose of simplicity. This means all cargo from Western Japan bound for North America are arrived at Los Angeles port where container cargo volume from target ports is the largest among North American ports. Thus, navigation distance between each hub port and Los Angeles port is obtained, which are shown in Table 2 while those between origin ports and hub ports are shown in Appendix A. As a utilization of Hanshin port, cargoes are assumed to be aggregated in one of the berths of Kobe port, where currently used for North American route, in case Kobe and Osaka is consolidated (i.e. Hanshin port). By identifying the berth for North American route, it becomes possible to calculate the capacity and maintenance cost for case of consolidation. Also, in case consolidated, the values of Kobe port in Table 2 is used for Hanshin port.

Second assumption is that freight rate (τ_i) and frequency (f_i) of Busan port is constant over the year from 2015 until 2030. This means that Busan port does not discount any more in terms of freight rate and increase frequency of trunk lines for the purpose of compete with Hanshin port. The idea behind this is that, according to interview survey with several shipping lines, Busan might not be well taken into consideration Hanshin port as competitor due to relatively small share of Japan-oriented container cargo in Busan port.

Third assumption is that capacity of vessel (s_i, S_i) is determined as average size of actually operated ones and fixed by each port. This means vessel size of call of port is differed from each port (i.e. Kobe, Osaka, and Busan port). By determining vessel size, it becomes possible to calculate and determine navigation speed, gross tonnage of vessel and fuel surcharge by

Table 2 Input parameters

		Kobe	Osaka	Busan	Data source
Fuel surcharge (trunk line) [USD/day-vessel]	y_i	21,646	14,789	32,544	Notteboom (2009)
Navigation distance from port *i* to LA port [km]	N_i	9,469.09	9,490.21	9,764.86	Searates.com
Navigation speed (trunk line) [km/day]	V_i	17.2	16.2	17.9	WAVE (2011)
Fuel surcharge (transshipment) [USD/day-vessel]	z_i	1,019	1,019	3,267	Notteboom (2009)
Navigation speed (transshipment) [km/day]	v_i	11.4	11.4	13.0	WAVE (2011)
Maintenance cost [$/TEU-year]	mc_p	14.1	14.1	—	KOIPC* website
Marginal cost of terminal operator [$/TEU]	mc_t	50	50	—	KOIPC website
Value of time [$/day-TEU]	α	5,280	5,280	5,280	WAVE (2011)
Annual handling capacity [TEU/year]	K_i	840,000	360,000	400,000	Ishii *et al.*(2013)
Gross tonnage of vessel using port i [t]	gt_i	40,000	70,000	95,000	WAVE (2011)
Vessel size (trunk line) [TEU]	S_i	6,000	4,000	8,000	OC (2017)
Vessel size (feeder line) [TEU]	s_i	140	140	706	OC (2017)
Port charge [USD/year]	e_i	2.70	2.70	—	KOIPC website
Lease charge of berth [USD/TEU]	r_i	6,164,846	1,648,263	—	KOIPC website
Loading/unloading charge [$/TEU]	w_i	250	250	—	KOIPC website
Freight rate [$/TEU]	τ_i	403	403	270	Searates.com
Frequency [times/week]	f_i	8	3	38	OC (2017)

* KOIPC: Kobe-Osaka International Port Corporation

referring Notteboom (2009). Note that bunker price is set as 372 USD/ton which is as of November 2017 (Ship&Bunker, 2017). Other parameters ($\beta = 5$, $\gamma = 650$, $\varepsilon = 1/10$, and $\mu = 1/10$) are estimated so that the difference between actual and estimated container volume of each port in 2015 is minimized. Maintenance cost of private port is assumed to be reduced by 10% compared with public port. This value is determined by the summary of interview surveys with several shipping lines and port management bodies. Besides, sensitivity analysis is done for 0% and 20% cases. As a result, no prominent change in terms of container handling volume for each port is not observed. This is because port charge, lease charge of berth, loading unloading charge are not changed for any cases.

(3) Simulation results and discussions

a) Container volume and social benefit

Simulation results of the effect of consolidation and privatization of Kobe and Osaka ports are discussed. Table 3 to 5 show simulation results of three cases such as decrease, middle-increase, and high-increase for future container volume. In decrease case (Table 3), higher container volume at Hanshin port (sum of Kobe and Osaka ports) can be received in the pattern of non-consolidation and public of Kobe and Osaka ports. One of the reasons of this is the lowest freight rates (i.e. 308 USD/TEU in 2030) among four patterns. In the situation where cargo decreases, Kobe and Osaka ports attempt to set freight rates lower so that container volume is obtained from neighbouring competitors. Besides, public port management company is able to reduce freight rates since they are not as sensitive as private company in terms of profitability. On the other hand, in case of consolidation, Hanshin port is monopolistic for their hinterland cargoes. In this case, Hanshin port attempts to obtain more profit by setting high freight rates while freight rate of non-consolidation case is lower due to competing each other. As for privatization, public case is consistently larger container volume over the year regardless of consolidation or non-consolidation. This is due to slightly lower freight rates of public case rather than private case.

Table 3 Simulation results (Decrease case)

	Cargo volume of Hanshin port* (TEU)		Social Benefit (Mil. USD)		Freight rate (USD/TEU)		Frequency (times/week)	
	2015	2030	2015	2030	2015	2030	2015	2030
Consolidation/Private	99,042	79,529	12.7	6.7	359	358	11	10
Consolidation/Public	100,268	80,328	12.0	6.2	344	341	11	10
Non-consolidation/Private*	93,221	80,750	14.3	8.5	354	312	10	10
Non-consolidation/public*	94,834	82,598	14.4	8.4	366	308	11	10

*sum of cargo volume in Kobe and Osaka in case non-consolidation

Table 4 Simulation results (Middle-increase case)

	Cargo volume of Hanshin port* (TEU)		Social Benefit (Mil. USD)		Freight rate (USD/TEU)		Frequency (times/week)	
	2015	2030	2015	2030	2015	2030	2015	2030
Consolidation/Private	127,974	156,036	23.3	34.2	383	434	12	14
Consolidation/Public	128,875	156,944	22.5	33.9	369	418	12	14
Non-consolidation/Private*	118,193	147,874	20.6	26.9	383	372	12	13
Non-consolidation/public*	107,203	132,267	21.1	27.4	387	380	11	12

*sum of cargo volume in Kobe and Osaka in case non-consolidation

Table 5 Simulation results (High-increase case)

	Cargo volume of Hanshin port* (TEU)		Social Benefit (Mil. USD)		Freight rate (USD/TEU)		Frequency (times/week)	
	2015	2030	2015	2030	2015	2030	2015	2030
Consolidation/Private	146,601	207,342	30.1	54.4	395	454	13	16
Consolidation/Public	147,680	212,446	29.4	54.7	381	436	13	16
Non-consolidation/Private*	140,051	196,773	27.1	42.3	397	389	13	14
Non-consolidation/public*	127,054	179,670	27.1	44.1	403	403	12	14

*sum of cargo volume in Kobe and Osaka in case non-consolidation

Simulation results for high and middle increase cases shown in Table 4 and 5 are discussed. It can be observed that consolidation tends to be effective to increase social benefit and container volume at Hanshin port even though consolidation case set higher freight rate. These are opposite results of the case where future container demand decreases. This is because higher frequency is received for consolidation case. This makes Hanshin port more attractive and thus shipping company chooses Hanshin port in consolidation case. Consequently, social benefit of consolidation case is generally higher than non-consolidation case. From these results, aggregation of container cargo into one specific berth caused by consolidation is effective to increase total container cargo volume, social benefit, and frequency in the situation where future container cargo is expected to increase. On the other hand, difference between public and private of four indicators are relatively small which is similar results of decrease case. This implies that the effect of consolidation is much larger than privatization. Thus, if cargo volume is expected to increase, consolidation should be done preferentially.

b) Transshipment cargo

The main objective of the policy of "International Container Strategic Port" launched by Japanese government is to increase transhipment cargo of Hanshin port in the competition with Busan port. Figure 6 shows cargo volume of Hanshin (Kobe and Osaka) and Busan ports for four patterns in case future cargo volume is "middle-increase". In addition to four patterns, simulation result of current status is also shown for the purpose of comparison. Note that current status refers to the state where indicators affecting the choice of shipping company and shippers, such as port charge and frequency are constant over the years. In Figure 6, container cargo volume refers to the sum of transhipment cargoes and hinterland cargoes of Hanshin port. Since the simulation results of high-increase and middle-increase cases show similar tendency, only the result of middle-increase case is provided. From Figure 6, it can be understood that consolidation and privatization of Kobe and Osaka port is effect to increase their competitiveness against Busan port. In particular, consolidation would increase the share of Hanshin port approximately 10 points comparing to current status. Transhipment cargo (i.e. cargoes originated from ports of Western Japan) volume is the largest in the case of "non-consolidation and private". In consolidation case, Hanshin port is monopolistic for their hinterland cargo since competition between Kobe and Osaka is disappeared. In this case, freight rate is set as relatively high as shown in Table 4. Therefore, cargoes from Western Japan gradually avoid making transhipment at Hanshin port for consolidation case. Besides, in general, maintenance cost of private case is lower than public case. This makes freight rate lower and eventually, frequency of shipping company becomes higher. In conclusion, "non-consolidation and private" is a better form for Hansin port.

6. Conclusion

In this study, an agent-based simulation model to explore the effects of the four combination in terms of "consolidation or non-consolidation" and "private or public" for Kobe and Osaka ports. In the model, interaction among stakeholders (local government, terminal operator, shipping company and shipper) are considered. Aggregation of cargos and vessels of

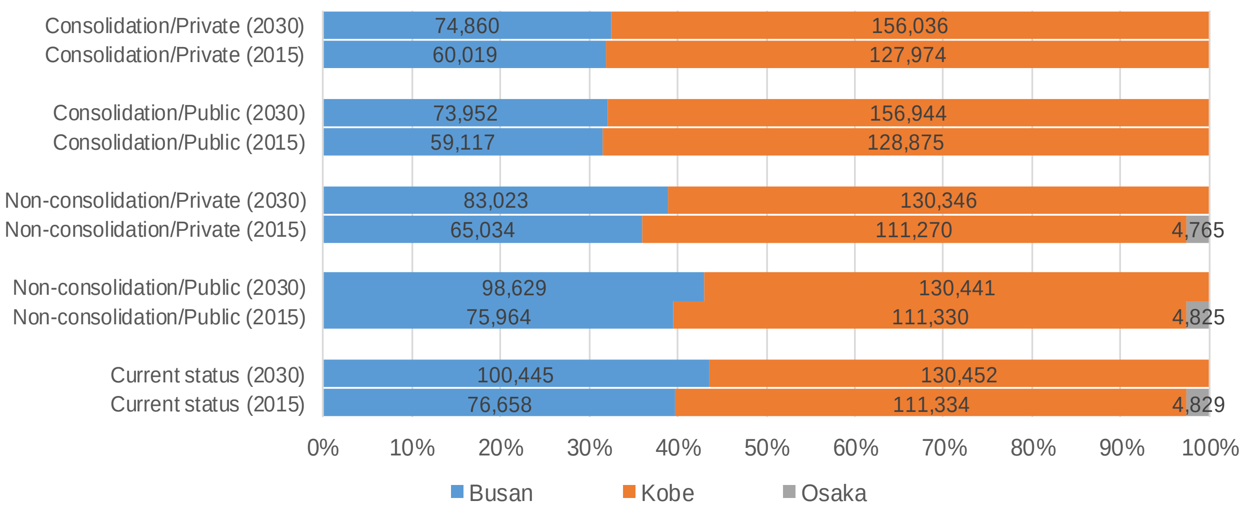


Fig. 6 Cargo volume of each port for four pattern (Middle increase case)

Kobe and Osaka ports for one berth are assumed as effect of consolidation while profit maximization of port management company and reduction of maintenance cost are considered as effect of privatization.

Through this study, the followings are clarified. Firstly, in case cargo increases in the future, social benefit and cargo volume handled in Hanshin port is the largest for consolidation case. Consolidation has much larger impact comparing to privatization. Thus, if future cargo volume is expected to increase, consolidation should be done preferentially. However, consolidation of Hanshin port induces monopoly for hinterland cargo. In this case, freight rate of Hanshin port increases. Thus, transhipment cargo originated from East Japan is not increased as much as non-consolidation case.

Secondly, in case future cargo decreases, social benefit and cargo volume receives larger for non-consolidation case. This is because monopolistic cargo of consolidation is not large in future container cargo decreasing situation and lower freight rate can receive more cargoes. As for privatization, to maximise own profit private set higher freight rate. Note that effect of privatization is much smaller than consolidation as well. In summary, total container volume in case future cargo decreases, “non-consolidation and public” receives the largest.

Thirdly, transhipment cargo volume is the largest in case of “non-consolidation and private” case regardless of cargo increasing and decreasing. In particular, transhipment cargo is increased in this pattern as a hub port of East Asia.

Finally, even though changing a relationship with ports in proximity is effective to increase container cargo from current situation, it is still inferior to Busan port. This is due to huge difference in terms of the level of service (i.e. freight rate and frequency).

Several issues remain for further research. Target cargo of this study only considers North America route in order to observe the effect of consolidation and privatization of ports in proximity, which is the main objective. However, in order to obtain more accurate results, other route (e.g. Asia, Europe route) is preferable to be considered. However, in this case, calculation process would be increased. This would be a future study.

ACKNOWLEDGMENT: Authors thank to several port management companies of Japan and shipping companies to kindly accept interview surveys.

APPENDIX A　Navigation distance between origin and hub ports (km)

n_{ik}	Kobe	Osaka	Busan
Kobe	0	27.2	739.1
Osaka	27.2	0	760.7
Mizushima	152.9	174.5	602.1
Hiroshima	285.4	307.0	506.9
Tokuyama	388.8	410.4	377.4
Matsuyama	286.9	308.6	489.0
Kitakyushu	452.1	173.8	288.4
Hakata	546.4	568.0	229.0
Hososhima	462.6	473.4	537.0
Shibushi	569.2	585.0	558.2

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