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Strategic port management by consolidating container terminals☆

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ABSTRACT

Container ports or terminal operators need operational efficiency and effective management to gain global market competitiveness, as world container ships continue to be larger, global shipping alliance reshuffles and becomes larger. This study investigated the effects of integrated operations of the existing separate container terminals using scenario analysis. The scenario analysis is attempted based on actual vessel arrival data on additional effects that Busan New Port can obtain from the use of a infrastructure pool by consolidating all five terminals. The results explain the benefits of terminal consolidation: the reduction of a vessel waiting time, balanced utilization across terminals at the port, and an increase of overall profits to the actors.

1. Introduction

Container ports or terminal operators need operational efficiency and effective management to gain global market competitiveness, as world container ships continue to be larger, global shipping alliance reshuffles and becomes larger. At the core of the growing demand for large-scale precursors is to create conditions for mega vessels to make port calls, reduce port costs, and reduce the vessel turnaround time. In order for a ship to call a port, the infrastructure of port or terminal must be improved.

To reduce port costs, the shippers and carriers will try to cut terminal handling charges (THC) and reduce unnecessary costs caused by inter-terminal transport (ITT). In order to reduce the vessel turnaround time (VTT), the loading time, the waiting time for a vessel to berth, the filing time, etc. must be reduced. In particular, the most effective way to reduce the VTT is to reduce the time that a vessel waits for a particular berth at a port.

This is because a loading time and filing time vary depending on port or terminal, but not significantly, while waiting time for a berth at the port differs by the vessel size (Leach, 2014; World Shipping Council, 2015). Therefore, terminal operators are under pressure to expand infrastructure, renovate equipment and place new orders for large equipment, increase capacity for expansion of equipment, increase productivity of loading and unloading, increase capacity, and enhance cooperation between terminals.

However, the important thing is that there are not many means of effective use of the terminal. In addition, it is not known exactly whether global carriers or carrier alliances will choose these terminals, since many of the port and terminal options have changed due to the dynamics of the shipping and port market environment. In other words, there are not many means to respond to a large customer and shipper/carrier alliance at an individual terminal level, and the investment risk for a response is very huge.

Most of the world major container terminals are separated by individual operators, although they vary in sizes and capacity. Independence of these terminals creates various problems, including frequent ITT, inefficiency in utilization of facilities and equipment, and excessive competition (Kim, Park, Cho, & Kim, 2017; Wong, Ma, & Leung, 2018). The problems become even greater at transshipment ports where laden containers handled at peak time should be linked between mother vessels and feeder lines. The most notable reason is the simultaneous occurrence of vessels in a queue for a particular berth at a terminal and idle berth at other terminals at the same port due to insufficient capacity at a specific terminal assigned to a vessel (i.e. home berth). Terminal B, for example, has an idle berth at the time when a vessel is waiting to be berthed at Terminal A. In other words, from a port's perspective as a whole, rather than from an

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individual terminal's point of view, there might be enough facility capacity for vessels to avoid waiting at a destined terminal. However, operating separate terminals independently does not effectively utilize the entire port. Accordingly, the ports of Hong Kong, Dalian in China, and Kobe in Japan integrated some of their terminals in the ports in order to efficiently utilize the entire port resources and strengthen their competitiveness.

From this example, one of the most realistic and credible responsive strategies to a port or terminal can be terminal consolidation in a port. An integrated operation of the terminals in the port enables the relocation of existing equipment and resources to cope with the needs of the increased vessel size and seasonal volume, to utilize the dead space, which was not used due to separate operations for each terminal, and to secure an additional container yard. In addition, it can be expected that consolidating terminals will reduce costs by achieving economies of scale, especially by reducing the vessel turnaround time. Physical integration of individual terminals (i.e. independent business entities) is challenging, but this is why the need for integrated operations of terminals is constantly being discussed.

Despite of the expected benefits of innovative terminal operations (Wong et al., 2018), little empirical analysis has been conducted to understand and present the effects of this long-discussed, integrated operations of the container terminals. In addition, no empirical analysis is found to demonstrate how much VTT can be reduced through the innovative integrated operation of the terminals in terms of the vessel waiting time. Reducing the number of vessels waiting for a berth in a port boundary is critical for the competitiveness of the port or terminals, and for the improvement of service levels, beyond just reducing the time required for ships to wait for berthing.

Therefore, this study conducts an empirical analysis of the effects of integrated operation of the existing separate container terminals with a case study of Busan New Port. Busan New Port is suitable for analysing simulated effects of terminal consolidation since five terminals currently operates independently without any collaboration or consolidation strategies at the port, which is known as one of the most segregated ports in the world. The empirical analysis of terminal consolidation will be available as an important reference for future discussion of terminal consolidation and will be the initiative talk for further academic research.

2. Literature review

Competition and collaboration in the maritime container industry are still significant research topics (Kim, 2011). Cooperation of the maritime port industry began with a discussion of vertical integration and horizontal integration (Notteboom, 2002), but later became important for inter-port and intra-port cooperation (Li & Oh, 2010) in terms of competition and co-opetition (Song, 2003). This is basically because many ports or terminals have been looking for ways to cooperate for mutual benefit to respond to the recent changes of customers' power through alliances. The needs of cooperation of port industry have been carried out in several forms, including the development and operations of terminals through (a) joint ventures between terminal operators, (b) integration of governance, and (c) collaborative operation of terminals (Barnard, 2016; Dooms, Van Der Lugt, Parola, Satta, & Song, 2019; Martin, 2019).

However, the most effective tactic is to consolidate the terminals in a port, regardless of port or terminal level, structure of governance, or financial structure. That is, the most realistic, effective response to the dynamic change of business environment is to consolidate or integrate the terminals. For that reason, although some studies suggest terminal consolidation as one of the alternatives for efficient operation of ports or terminals, there are not many empirical studies analyzing the effects of integrated operations of terminals. This is because integrating governance between ports is possible by policy and political decision of the public sector, but physically integrating individual enterprise terminals is more difficult to analyze the feasibility and provide the expected benefit.

Thus, the actual cases of terminal integration are examples of the integration of the port governance. The recent integration being pursued in China also addresses the integration between ports (Huo, Zhang, & Chen, 2018). The reason is that it is very difficult to physically integrate the terminals to respond to the increase of vessels, reorganization of carrier alliance. Davidson (2015) also suggested that physical integration would be the best option for multiple terminals operated by different agents, but virtual integration could be a more desirable alternative to realistic challenges. Therefore, OSC (2009) proposed a hybrid terminal as a way to overcome the difficulties of physical integration of terminals (Ocean Shipping Consultant, 2007). This study suggests sharing facilities through virtual integration rather than physical integration and allocating costs and revenues based on the facilities and resources assigned and utilized. Wong et al. (2018) simulated facility sharing with collaboration in the port of Hong Kong and concluded that high transshipment container vessels were allowed to be assigned to an idle berth within the same terminal to avoid unnecessary ITT. Their proposed model also saved a great amount of traveling distance of transshipment, reduced air pollution and balanced the berth utilization than home berth approach.

As we have discussed so far, most of the preceding studies have been conceptual consideration of cooperation between terminals or ports. In the case of ports dealing with transshipment containerized cargo, the need for terminal consolidation is greater than that of import and export container ports due to the larger-linked volume. Nevertheless, few studies have been conducted on transshipment container ports to the author's knowledge. Therefore, this is one of the leading studies to demonstrate the effect of terminal consolidation via a transshipment container port. The results and implications of this study will guide new directions for future research and terminal operators.

3. Busan New port

Busan New Port opened in 2006 and currently operate five container terminals (Fig. 1). Because the terminals are independently operated without collaboration and cooperation, the unbalanced utilization problem is the source of rapid increase in a vessel waiting time and non-value-added volume due to additional ITT.

First, container vessels waiting in Busan New Port are classified as vessels in waiting and vessels in congestion. When a vessel waits more than 12 h, the status of the vessel is classified as congestion, while the status of waiting is for a vessel waiting for a berth in the port less than 12 h. If a vessel waits more than 12 h, the carrier pays the public water fee to the Busan Port Authority. In 2013, the total number of vessels in waiting in the port was 53, but the figure has risen sharply upward to 225 in 2015 and 257 in 2016 (See Fig. 2). The number of vessels in congestion was eight in 2013, but increased to 87 in 2015 and 101 in 2016. Most of these vessels are small- and medium-sized ships that serve Intra-Asia Trade Lane. The status of waiting and congestion are caused by the low priority of schedule for mega vessels to enter the terminal that they want to stop at Busan Port, rather than by the lack of berthing capacity in the port. In other words, ships often wait for a call from a terminal to load/unload containers, even though one or more berths are available at other terminals within the port.

The second major problem of operating disintegrated terminals is an increase of the ITT container volume. Inter-terminal transportation (ITT) means that the container in transit is unloaded to a terminal and loaded from another terminal. The ITT volume in Busan

Fig. 1. Terminals and terminal operators in Busan New Port.
Source: Authors' drawing using Google Map.

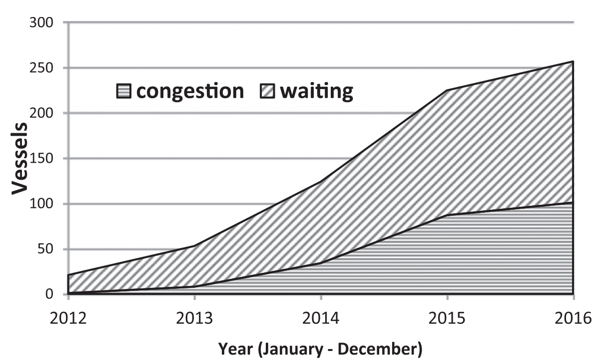

Fig. 2. The status of waiting and congestion at Busan New Port.
Source: Authors' drawing using data from Ministry of Oceans and Fisheries of Korea, 2012–2016.

New Port increased from 358,000 TEUs in 2010–1,529,000 TEUs in 2016 (Kim et al., 2017). Instance of ITT is costly because the shipping liner should pay for it, and this practice ultimately harm the port's market competitiveness. In fact, most transshipment container terminals would put an effort to reduce ITT volume regardless of the cost-paying entity. The Port of Singapore, for example, justified the development of the new port of TAUS to reduce ITT costs.

4. Methodology

4.1. Data

The container volume of the year of 2016 was collected from the Busan Port Authority (BPA) database; BPA-net(www.bpa-net.com). The data of vessel status over arrival, berthing and departure time at each terminal of Busan New Port in 2016 was downloaded from Port-MIS (Ministry of Oceans & Fisheries of Korea, 2019). Berth windows of each terminal was collected from five port terminal operators of Busan New Port. Idle time used the analysis of this study was identified from the data of vessel status by matching with berth window of each terminal. The data of berth window provides handling volume of a vessel at each time window as well as time information of vessel movement.

4.2. Assumptions

4.2.1. Assumption 1

A terminal that operates a specific berth that a vessel intends to be moored is excluded from the allocation regardless of whether or not the other berths are idle at the same terminal. In other words, ships waiting for berthing at Berth 1 in Terminal 1, even if Berth 2 or Berth 3 are idle at the same terminal, Terminal 1, the vessel was not assigned to the berths.

4.2.2. Assumption 2

The idle time for a berth is calculated as the difference between the departure time shown in the berth window for each terminal and the berth time for the next vessel. The time of vessel congestion available from the Port-MIS was matched to the time window of an idling terminal.

4.2.3. Assumption 3

If there is an idle berth in another terminal but the delay time for a vessel waiting for a berth scheduled to be assigned is shorter than the idle time, it is not assigned to the idle terminal. For example, on November 27, 2016, Vessel A waited for 29 h and 30 min at Berth 1 in Terminal 2, but the idle time of Berth 2 in Terminal 1 was 11 h and

10 min at the same time, so Berth 2 in Terminal 1 is not considered as an idle terminal for the vessel.

4.2.4. Assumption 4

No matter which a terminal has an idle berth, this berth is not considered an available one if the length of the berth cannot accommodate a ship because another berth in the same terminal in contact with another vessel. Therefore, to avoid inappropriate vessel assignment, the berth is excluded from the list of idle berths to which a vessel can be assigned if it is difficult to accommodate the congestion vessel due to a length limit, considering total vessel lengths berthing for each terminal in this time window. In terms of the vessel length to be accommodated, this study applied additional 20% of a vessel length considering the vessel mooring space of the vessel. For example, on May 6, 2016, if a 255-meter-long vessel was waiting for the availability of Berth 1 at Terminal 1 for 22 h, a minimum of approximately 306 m of berthing space is required, including an additional 20% mooring space. At the same time, even if Berth 3 of Terminal 5 has not been in operation for 52 h, the total length of the three Berths 1, 2, and 4 at Terminal 5 is only 166 m, making it impossible for the vessel to be berthed at Berth 3 of Terminal 5. For calculating the total length of berths being used, 20% of the mooring space of each vessel at berthing was considered.

Assumption 5

Even if there are several idle berths in one terminal, which meets all aforementioned conditions, this is considered to be one berth available for a vessel in standby. In other words, we would like to know if there is even one idle berth in all other berths except the terminal which another delayed vessel has assigned to.

4.3. Scenarios

In this study, a scenario analysis is attempted based on actual vessel arrival data on how much additional effects Busan New Port can obtain from the use of a pool by consolidating all five separate terminals. The following scenarios are set up for analysis of the average vessel waiting time reduction, which is a core of this study.

4.3.1. Scenario: AS-IS

As-Is represents the current operational strategy with the separately operated terminals and assumes that the current governance structure and operations are adhered to the current practice without any changes or improvements. This scenario allows a vessel to wait for berthing until the terminal which is assigned to the vessel is available. Even if there is an idle berth at other adjacent terminals at a port, it cannot accommodate the vessel without a prior schedule.

4.3.2. Scenario: A

Scenario-A assigns vessels in a queue for berthing to one of terminals, which carries one or more idle berths regardless of the distance between terminals. For example, in Fig. 1, a vessel assigned to Terminal 2 could be redirected to Terminal 5 if Terminal 5 carries an idle berth. Thus, this scenario finds the number of idle berths of each terminal at time window t (1). The status of a berth is a binary variable of 1 or 0 (2). Evaluation of idle berth of this Scenario A can be expressed as:

$$\mathrm{T}_{B_{it}} = \sum_{j=1}^{n} B_{ijt}\,,\ \forall\ i,\ t \tag{1}$$

$$B_{ijt} = \begin{Bmatrix} 1, \text{ if a berth } j \text{ of a terminal } i \text{ is idle at time window } t \\ 0, \text{ otherwise} \end{Bmatrix} \tag{2}$$

where, i: a terminal, i = {1, 2, …, m} ∈ Mj: a berth, j = {1, 2, …, n} ∈ Nt: time window$T_{B_{it}}$: total number of idle berths of a terminal i at time window t.

Based on the current Busan New Port system, which consists of five terminals (i.e. $m = 5$), Scenario-A assumes that a vessel in congestion ($V'' \subseteq V$) is placed in an idle berth ($N' \subseteq N$) in general, without considering container yard capacity. It allocates a vessel waiting for a berth over 12 h at the port if there are no vessels handled by the berth in the time window (t). However, the idle berth should be larger than the vessel being assigned to the berth (3).

$$\mathrm{L}_{s\in V''}(B'_{ijt}) \le L_{ij} \tag{3}$$

where,s: a ship, s = {1, 2, …, v} ∈ V.V": a set of ships in a queue more than 12 h at a port, V" ⊆ V$L_{s\in V''}$: length of one of the ships waiting for more than 12 h and being assignedL_{ij}: Length of a berth j of a terminal iB'_{ijt}: selected idle berth j of a terminal i to accommodate a vessel in congestion at time window t.

4.3.3. Scenario: B

Scenario-B is a scenario in which a vessel waiting in a queue to be berthed are not assigned to one of idle berths which are located more than 1 Km away from the originally assigned terminal, taking into account the non-value-added activities of containers between terminals. To consider the constraint, this scenario estimates the available length of a terminal i at time window t. The available length of terminal i at time window t (AL_{it}) is the difference between the length of terminal i (L_{i}) and the sum of the length of berthed ships by applying additional 20% of a berthed ship length ($\alpha = 1.2$) (4).

$$AL_{it} = L_i - \sum_{s=1}^{v} (\alpha \cdot L_{sit}),\ \forall\ i,\ t \tag{4}$$

where,

$\mathrm{AL_{it}}$: Available length of a terminal i at time window t [meters].

$\mathrm{L_i}$: length of a terminal i [meters].

a: margin of berthed ship length (20% of ship length).

$\mathrm{L_{sit}}$: length of a berthed ship s at a terminal i at time window t [meters], s ∈ V′.

V′: a set of ships berthed at a terminal, V′ ⊆ V.

To allocate a ship in a queue ($s \in V''$), the available length of terminal i at time window t (AL_{it}) should be longer than the length of vessel to be accommodated (5).

$$AL_{it} \ge L_{s\in V''} \tag{5}$$

Then, the scenario identifies the number of berths available at a terminal i (1). Once the number of berths ($\mathrm{T}_{B_{it}}$), and their locations are identified, the limited travel distance is set to 1 Km. This reflects the expert opinions of Busan New Port. Scenario B considered available length of each terminal (ALi) given that berthed other vessel in same time. In addition, in Fig. 1, the vessels scheduled to Terminal 1, 2, or 3 are not assigned to one of Terminals 4 and 5, and vice versa.

5. Result and discussion

The results show that 85 vessels (84.2%) in case of Scenario-A and 60 vessels (59.4%) in case of Scenario-B can reduce the number of vessels waiting for a berth in a queue at the port (Table 1). This result provides a significant implication in the port optimization in a system's view from both Scenario-A and Scenario-B. In other words, in Scenario-A, vessel congestion may occur due to lack of berthing facilities when the port separates small individual terminals. However, if the terminals at the port are shared, 85 vessels in congestion could be reduced by utilizing idle berths at other terminals at the port.

As in Scenario-B, at least 60 container vessels did not have to wait at the port, even assuming the constraint of not using terminals

Table 1
The number of vessels in congestions and assigned to the other idle berths for each scenario (2016).

Terminals	AS-IS	Scenario-A		Scenario-B	
	Congestion	Congestion	Assigned to an idle berth	Congestion	Assigned to an idle berth
Terminal 1	6	1	5	5	1
Terminal 2	57	11	46	23	34
Terminal 3	21	1	20	4	17
Terminal 4	16	2	14	8	8
Terminal 5	1	1	–	1	–
Total	101	16	85	41	60

(or berths) more than 1Km away, considering the reality of terminal operations. In this study, a vessel experiencing only relatively long average waiting time were targeted, but if the vessels with short average waiting time were included, the reduction in an average vessel waiting time would be even greater.

By fully utilizing idle berths, all terminals in the port can be used in a balanced manner by solving problems of both vessels congesting and idle berths simultaneously. Based on the analysis of a container volume loaded/unloaded to/from vessels that has been reassigned to idle berths, it is believed that the considerable number of containers assigned to highly utilized terminals was redistributed to other terminals of a low utilization rate. The handling volume by fully utilizing idle berths of each terminal is the loss of containers (VW_i) and the increase of container (VT_i) as follow (6):

$$\Delta V_i = \sum_{j=1}^{n} VW_i - \sum_{j=1}^{n} VT_i \tag{6}$$

where, ΔV_i: volume variation of a terminal i [Box and TEU]VW_i: volume of containers scheduled at a terminal j, but handled by other terminals due to congestion of terminal i [Box and TEU]VT_i: volume of containers, which are transferred from other terminals to a terminal i and handled by the terminal i [Box and TEU].

For example, 7580 TEUs handled at the Terminal 1, which had a high facility utilization rate as of 2016, could have been reassigned to and handled at other terminals with the reduction of waiting time at a port (Table 2).

Even considering the operation conditions, 2718 TEUs were able to be handled without waiting unnecessarily. In this study, the affected container volume may seem small, as conservative analysis was conducted only on vessels waiting for a berth more than 12 h in 2016. However, if the number of vessels in the queue at the port and mega vessels increase in the future, the volume and ratio of the volume handled without delay can be further increased by releasing this constraint. In addition to the volume perspective, the effect will be further increased if the value of time of the containerized commodity is taken into account. In addition, a port authority, which operates a transshipment container port, will not only maximize the utilization of existing facilities, but also gain intangible benefits such as a service level of the port without additional investment and a superior marketing effect in the global competition.

Table 2
Containers in TEU and boxes handled in 2016 for each scenario.
Source: Calculated based on the statistic data of Busan Port Authority (2018).

Terminals	AS-IS	Scenario-A (Compare to AS-IS)		Scenario-B (Compare to AS-IS)	
	TEUs*	Boxes	TEUs	Boxes	TEUs
Terminal 1	2,418,702	-4934	-7580	-1769	-2718
Terminal 2	4,626,435	-1627	-2499	-859	-1320
Terminal 3	1,925,545	1773	2724	2628	4037
Terminal 4	2,322,165	-3741	-5747	-2302	-3536
Terminal 5	1,541,859	8529	13,102	2302	3536

Note: The ratio of TEU/BOX in this study is 1.54 based on the performance of Busan New Port.

The effect of terminal consolidation is not only the balanced use of idle berths and facilities, but also various revenue generation and cost savings for terminal operators and shippers. First of all, it is important to be able to handle additional volumes by increasing the utilization of the facilities from the point of view of the terminal operators. An additional revenue generation will be possible by attracting and processing the Phase-In & -Out volumes in freed space through active marketing.

Phase-In-&-Out refers to cargo that is to be fully unloaded from a vessel and loaded the whole volume onto another vessel due to repair or replacement of ships, or regular inspection. For Busan New Port, the ratio of Phase-In-&-Out shipments is 0.66%, relatively lower than 2.33% for other terminals, but the terminal operators can generate significant additional revenue if the volume is increased. Although the Phase-In-&-Out volume is recognized as spot-based cargo, it is also possible to secure a stable demand through marketing.

From the shipping liner's point of view, cost reduction is an important factor in decision making. In the case of Busan New Port, the reduction in ITT volume due to terminal integration has a direct cost saving effect on the shippers and carriers because the cost of ITT is the cost that shipping companies must pay to the terminal operators. Although it is practically difficult to integrate the five terminals at Busan New Port into one terminal, the cost savings will increase if the ratio of space used for public use is increased and sufficiently large enough.

Ship operating costs are reduced by the amount of waiting time due to the resolution of the vessel's congestion. The average size of the ships at Busan New Port was assumed to be 1083 TEUs in 2016 and 1035 TEUs in 2017, respectively, and the cost calculation was based on 1000 TEU-class ships.

The average daily operating cost of these average-sized ships is about $26,900. Given the average vessel waiting time of 12 h, the cost-per-ship savings are expected to be $1143,000 for Scenario-A and $807,000 for Scenario B. The vessel waiting time due to congestion is expected to increase and the vessel size entering the port will increase, so that the relative cost savings will increase sharply (Kim et al., 2017).

6. Conclusion

This study conducted empirical analysis for five terminals in Busan New Port based on three scenarios. The expected effects of terminal consolidation are three categories: reduction of the vessel waiting time, balanced utilization across terminals at the port, and an increase of overall profits to the actors. First of all, it is analysed that Scenario-A and -B can reduce 84.2% and 59.4% of vessels waiting more than 12 h, respectively, at the port. The previous unbalanced utilization of the terminals now balanced across the port, thereby providing system optimal to accommodate more vessels with a shorter average vessel turnaround time. The port would be able to reduce the cost by minimizing ITT volume and attract more Phase-In &-Out container volume with balanced and increased overall utilization in the port.

The results of this study would be used as important guides for the port authorities or stakeholders who are currently planning terminal integration and design. Furthermore, if physical integration of the terminals is not possible, the introduction of a hybrid terminal might be considered one of viable options.

However, this study is analysed only by considering the current state of a berth in individual terminals (idle time, berth length, etc.). In actual operations, if you have room at a berth, but do not have room for equipment, you will certainly not be able to accommodate unscheduled vessels. In future research, analysis will be conducted considering the operational capability of each terminal and the capacity of the terminal yard.

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