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Tai Hui-Huang
Department of Shipping and Transportation Management, Dean of Marine Science and Technology, National Kaohsiung University of Science and Technology, Taiwan

Chang Chin-Wei
Taiwan Navigation Co., Ltd. Kaohsiung Branch, and Department of Shipping and Transportation Management, National Kaohsiung University of Science and Technology, Taiwan, jaime.chang@taiwanline.com.tw

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RESEARCH ARTICLE

Cost Advantages of Far East/Europe Trunk Route Deployment with Port Selection in East Asia

Tai Hui-Huang [a], Chang Chin-Wei [b,*]

[a] Department of Shipping and Transportation Management, Dean of Marine Science and Technology, National Kaohsiung University of Science and Technology, Taiwan
[b] Taiwan Navigation Co., Ltd, Kaohsiung Branch, and Department of Shipping and Transportation Management, National Kaohsiung University of Science and Technology, Taiwan

Abstract

To cater to the gradually increasing sizes of ships, several traditional container ports in East Asia built deep-water wharves to attract shipping carriers to berth, a decision that is considered highly reasonable because it allows for shipping carriers to gain a cost advantage. For traditional Far East/Europe (F/E) trunk routes, shipping carriers must deploy vessels that are large enough at hub ports to maintain low transshipment costs. However, for a port to attract shipping carriers, it should be able to first meet the cargo demand of these carriers. The port would also need to improve the loading ratio to enjoy the cost advantage. Simultaneously, the port should leverage the loading and unloading efficiency of the terminal to gain a competitive advantage. Although the port congestion observed at the F/E trunk during COVID-19 was not as serious as that in North American ports, it was sufficient to affect the route deployment and port selection decisions of shipping carriers. Currently, because the size of container carriers is the most critical factor in the reduction of shipping costs, as demonstrated in this study, the upsizing trend of container ships is regarded as a highly relevant aspect in the deployment of trunk routes and the selection of hub ports.

Keywords: F/E trunk route, Cost advantages, Port congestion, Port selection

1. Introduction

In 2020, COVID-19 resulted in severe port congestion at major North American ports and varying degrees of congestion at several Asian and European ports. This resulted in poor international logistics, which in turn forced global carriers to considerably raise their freight rates, thus escalating the problem of oligarchy in the shipping market [1].

The trunk routes of global container carriers are divided into the Trans-Pacific (T/P) route, Far East/Europe (F/E) route, and Trans-Atlantic (T/A) route. According to statistics by the United Nations Conference on Trade and Development (UNCTAD) [1], the T/P, F/E, and T/A container traffic is expected to reach 31.2, 26.3, and 8.0 million twenty-foot equivalent units (TEUs), respectively, in 2021. Shipping carriers use Asia as the main source of containers when deploying ships in the T/P and F/E routes, regardless of their direction (east or west), hence reaching 20 million TEUs or more. Therefore, when global container carriers plan their main routes, especially with the F/E main route, they consider the port capacity of China and Southeast Asia as the basis for route configuration, ship deployment, and port selection [2].

During the pandemic, most of the world's major container carriers were forced to handle competition from larger ships, low freight rates, extreme trade liberalization, and geopolitics and were also forced to cooperate to place larger container ships into the global shipping market by leveraging close strategic alliances and careful selection of ports of call and deep-water wharves. Given the low freight

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* Corresponding author at: No. 5, Jiexing 1st St., Gushan Dist., Kaohsiung City, 804003, Taiwan. Fax: +886 7 5615737.
E-mail address: jaime.chang@taiwanline.com.tw (C. Chin-Wei).

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prices in the past, shipping carriers had to combine container carriers of the same or similar size and use the same types of vessels to undertake closer joint ventures. They also had to develop a more cost-effective route deployment model. The fierce competition and mutual cooperation among these shipping carriers also resulted in serious competition among hub ports, further exacerbating the problem [3,4].

In 2017, three major container strategic alliances, including nine shipping carriers, namely, 2M (Maersk + MSC), Ocean Alliance (COSCO + CMA CGM + Evergreen), and THE (ONE + Hapag-Lloyd + HMM + YML), exhibited a serious problem of extreme oligopoly in the global container shipping market. According to statistics by Alphaliner [5], these three alliances account for 98% and 87% of the capacity share on the F/E and T/P routes, respectively. In addition, the shipping capacity controlled by these top nine container carriers accounts for more than 86% of the world's total shipping capacity. These top nine container carriers work closely together in mainline vessel configuration, which has in turn affected the global container shipping industry and caused serious challenges in the development of certain container ports in East Asia. For shipping carriers, choosing a port of call, in addition to the availability of a supply of goods, places increased emphasis on cost considerations [2]. In particular, given the requirements for container terminal machinery and drought conditions for large ships, several shipping carriers have raised concerns regarding the availability of an adequate deep-water wharf in the port of call as a necessary condition for the deployment of main navigation routes, a trend that has become increasingly clear over the years. For container carriers, planning the main route involves highly complex factors, such as the sizes of the vessels deployed, the cost of shipping, and the loyalty and sophistication of the dedicated terminal [6], and these port-of-call conditions gradually change. Therefore, choosing the port of call on the main route is a complicated process for shipping carriers.

In this study, we investigated the case of shipping carriers and vessels in Ocean Alliance. We performed a cost analysis by analyzing the cost advantages between different hub and consolidation ports during the deployment of main carrier routes in Southeast Asia. Overall, our results indicated that ship upsizing is one of the most crucial factors in F/E trunk route deployment for container carriers. We also investigated the cost and route plan changes that shipping carriers may have faced because of the severe port congestion due to COVID-19.

2. Literature reviews

2.1. Container shipping and hub ports in Asia

The F/E and T/P staggered areas from the Republic of Korea to Singapore contain several intercontinental hub ports, and these are the areas with the most transshipment cabinets and routes [7]. The volume of import and export containers in any port is a stable source of local cargo. However, the volume of transshipment containers is strongly affected by the density of the shipping route, port location, and water depth at the terminal, resulting in large variations in the volume of such containers [8,9]. In addition to the availability of a deep-water wharf, the shipping cost is a key aspect for shipping carriers to assemble and transfer routes in a certain port [10], as well as the aggregation of port routes and a diversified supply of goods. Several traditional hub ports in Asia depend on internal factors, such as sufficient cargo sources, subsidies, and terminal conditions, and external factors, such as shipping costs and the number of competing ports and routes in the vicinity. Only with these internal and external factors can the competitiveness of a port be enhanced. Otherwise, the transshipment container source would be attracted by neighboring ports, affecting the competitive position of the port [11].

Several Asian countries with deep-water ports have reported some competition among ports. Every year, global shipping carriers change the structure of the East Asian main route [12,13]. In addition, each port heavily relies on the support of national shipping carriers to thrive, meaning that local shipping carriers tend to use their own ports, which is similar to the home port effect [2]. For example, COSCO in China, HYUNDAI in Korea, and ONE in Japan attach their own fleets and routes to local ports. In addition, on the main route, shipping carriers tend to prioritize berthing at container terminals that they have invested in or at terminals under the same alliance, which also results in another hub port effect [2,14].

Several Asian ports have reported effects resulting from strategic alliances. According to Hirata [15] and Tsai and Tai [2], these strategic alliances, which involved pooling bargaining power, increased the level of dominance in choosing the port of call, with the port becoming a passive factor in this context. This phenomenon affected the breakdown of terminal leasing and operation systems in several ports in Asia, leading to the centralization of users and controllers of container terminals [6]. In addition, the widespread use of large vessels on main routes resulted in various complications in peak/off-peak flow in several Asian ports. Therefore, if large carriers invest in a large number of ships and directly allocate them to the F/E route, some deep-water ports may be able to directly absorb a large number of routes and cargo sources from neighboring ports, and other neighboring ports may be downgraded to regional ports [2].

According to a survey by the Ministry of Transportation and Communication (2016) [16], to increase competitiveness and address the trend of increasing ship sizes, several traditional container ports in Asia have built deep-water wharves to attract shipping merchants. However, because the key factor in the growth of hub ports is the supply of goods, although deep-water wharves are crucial, ports often fall into the trap of "wanting to drive shipping demand with terminal supply" during the expansion of deep-water wharves. This phenomenon resulted in idle terminals and excessive investment risks in several ports in Asia. In this scenario, if ports decide to hand over potentially idle container terminals to a holding group with container carriers for operation, or perhaps cooperate with large international terminal operators (e.g., HPH, DP World), an even larger terminal operation group is formed. However, while this may solve the current problem of excess terminal capacity in several ports, it raises some concerns regarding low-price competition and service quality, which may in turn lead to terminal monopolization. This phenomenon is currently observed in several container ports in Asia [17].

2.2. Calculation of shipping and port costs

Time and cost are the most critical factors in terms of port selection for container carriers [18]. The shipping costs of container carriers are divided into fixed and variable costs [2]. Several studies prefer listing the capital costs of ships separately when discussing fixed costs. For instance, the wage/welfare/container yard/container freight station rental fixed costs can be collectively referred to as the operation cost. Alternatively, the cost of each voyage can be listed separately. Therefore, great differences have been observed between researchers in the application of shipping costs for container ships [19,20,22].

With increasing ship sizes, a substantial decline in unit transportation costs has been observed, which has in turn affected the costs and port selection of shipping carriers. According to statistics by Alphaliner [5], as of the second quarter of 2022, vessels with 18,000 TEUs (18K) or larger operating in the global container market accounted for 12% of the global capacity, and more than 71% of all newbuilding orders were for 10K or larger vessels, with 15K or larger vessels accounting for 40% of all newbuilding orders. These massive ships are expected to be the main type of ships used by container carriers on main routes, which will directly affect the cost considerations of route deployment and port calls, resulting in an increasingly lower unit cost of container shipping [20].

The operational efficiency of container terminals is another critical factor in port selection for carriers [23]. In shipping practice, ports use different methods for terminal handling and container yard pricing. However, in academic analysis, several cost items should be simplified and omitted, or they should be differently described; otherwise, evaluating them would not be feasible [8,9,14,15,19,21]. The same ship may have different costs because of the different carriers, voyages, routes, seasons, and changes in fuel prices. Even if a ship repeatedly berths at the same port, the cost of loading and unloading operations may greatly vary every time because of the different time periods and locations, because the ship usually berths at a different terminal every time. For example, in terms of port cost, when a container ship berths at a dedicated terminal, several port charges can be ignored because they are directly classified as fixed costs.

Regarding fuel costs, carriers should be aware that the purchasing prices of fuel oil and diesel oil greatly vary between ports. They should also be aware of the fact that although the fuel consumption of different ship types is highly similar, the amounts of goods that they can carry greatly differ, resulting in a great difference in the calculation of fuel costs [8]. Therefore, in the subsequent cost model estimation of this study, the fuel cost is listed separately, and the rest of the costs are summarized as the daily time cost and port cost of a vessel to create a comparable model for application.

3. Research methodology

In this study, we considered the F/E main route as an example. The voyage from Shanghai (SHA) to Rotterdam (RTM) is approximately 10,000 nautical miles or more, and the total sailing time is approximately 30 days. This route covers the top eight most important economic powers in the world and 41.79% of the world's population. To obtain cargo sources in this region, after assessing the cargo flow, trade demand, and service frequency, shipping carriers usually deploy their largest container fleets on this route. Subsequently, they transfer the cargo to neighboring cities by using cargo ship/railway/road/river transport.

In the current shipping practice, for carriers to increase their levels of competitiveness, they use large ships and form strategic alliances to expand their market share. As shown in Table 1, the three major shipping alliances currently control nearly 99% of the F/E main route market capacity. Both 2M and Ocean Alliance control 36% of the market capacity, whereas THE controls 27% of the market capacity. Within Ocean Alliance, Evergreen invests 40,704 TEUs of transport capacity on the F/E route every week, accounting for approximately 38% of the company's total shipping capacity. Although this proportion is not as extensive as that of COSCO and CMA CGM, the proportion of the capacity invested is large. As shown in Table 2, the three major alliances counted their berthing frequencies at multiple hub ports in East Asia on the F/E main route. The results indicated that SHA, Ningbo, and Singapore (SGP) are the top three ports of call on the F/E route.

In 2022, almost all of the world's large ships (over 15K) are expected to use the F/E route. In this study, we selected Ocean Alliance as an example, which is expected to have more than one deep-water wharf, in Kaohsiung (KAO) after 2022. Similar to SGP, the Port of Tanjung Pelepas, Malaysia, is considered one of the major ports of call in Southeast Asia. The sizes of the main vessels of Ocean Alliance in this region vary between 12,000 (12K) and 24,000 (24K) TEUs. In addition, the import and export sources of each port and the nearby transshipment sources play a critical role in the berthing choices of mother ships.

Using the operating costs of shipping carriers deploying container ships in East Asia and referring to the composition of various operating costs of Tsai and Tai [2], we designed a cost comparison model of container carriers (Table 3). We then used this model on trunk and feeder routes to compare the cost savings of each transfer container when shipping carriers choose KAO rather than SGP to berth. The aim of this approach was to simulate the main route deployment planning process of shipping carriers and simplify the behavior of selecting hub ports.

Table 2. Weekly calling frequencies of Asian hub ports for major alliances.

Calling port	Frequency weekly	Rank
Busan	14	5
Xingang	6	13
Qingdao	12	6
Shanghai	27	1
Ningbo	25	2
Kaohsiung	7	12
Hong Kong	9	8
Xiamen	8	11
Nansha	6	13
Shekou	9	8
Yantian	18	4
Singapore	24	3
Tanjung Pelepas	10	7
Port Kelang	9	8
Colombo	7	12

Resource A: Summarized from Alphaliner Data base, Dec. 2021.

Given the selection of transshipment ports of Ocean Alliance, several major ports in Southeast Asia, such as Manila (MNL, the Philippines) and Haiphong (HPH, Vietnam), tend to use KAO or SGP as a transshipment port. When shipping carriers deploy their routes, the cost of transshipment is usually highly complex and is determined not only by the distance and direction of the voyage but also by the cost combination of various vessels, efficiency of terminal operations, and port costs. This phenomenon was discussed by Tsai and Tai [2], who investigated the shipping costs of carriers deployed on the T/P route. In the present study, we further explored two major transshipment markets in East Asia (Vietnam and the Philippines). Using KAO and SGP (see Fig. 1), for the westbound F/E main route, we calculated the shipping cost per unit from MNL to RTM. Subsequently, to analyze the return journey from Europe to Asia, we used the F/E route unit shipping cost for exports from RTM to HPH. During the calculation process, we substituted the cost components into Eq. (1) to compare the cost savings of shipping carriers. In addition, to investigate the

Table 1. Weekly deployment capacities at the F/E trunk route for major alliances.

% of Alliances	Shipping company	Deployed capacity (TEU)	% of company owned capacity
2M Alliance (36%)	MSC	80,777	24%
	Maersk	82,062	23%
OCEAN Alliance (36%)	COSCO Group	67,861	25%
	CMA CGM Group	62,582	24%
	Evergreen (EMC)	40,704	38%
THE Alliance (27%)	Hapag-Lloyd	32,756	23%
	ONE	33,698	28%
	HMM Co.	30,832	51%
	Yang Ming	13,689	26%

Resource: Alphaliner Monthly Monitor, March 2022.

Table 3. Notations for cost model estimations.

Notations	Contents
AC_{I_k}	The average cost (US$/TEU) for container carriers selecting I_k as the hub port for trunk route deployment (e.g., I_1 is Singapore and I_2 is Kaohsiung)
AC_{SAVING}	The average cost saved (US$/TEU) for container carriers selecting I_1 as the hub port versus I_2 for trunk route deployment
C_{Fuel}	The daily cost (US$/day) of vessel fuel (including HO and DO) for mother ships sailing on trunk routes: $C_{\text{Fuel}} = F \times T^E$, where T is the ship size of the mother vessel (TEU), F is a constant, and E is the elasticity of ship size against fuel cost
c_{Fuel}	The daily cost (US$/day) of vessel fuel (including HO and DO) for feeder ships sailing on regional and feeder routes: $c_{\text{Fuel}} = f \times T^e$, where T is the ship size of the feeder vessel (TEU), f is a constant, and e is the elasticity of ship size against fuel cost
$C_{Ship-daily}$	The daily cost (US$/day) of mother ships on trunk routes: $C_{\text{Ship-daily}} = M \times T^N$, where T is the ship size of the mother vessel (TEU), M is a constant, and N is the elasticity of ship size against daily cost
$c_{Ship-daily}$	The daily cost (US$/day) of feeder ships on regional and feeder routes: $c_{\text{Ship-daily}} = m \times t^n$, where t is the ship size of the feeder vessel (TEU), m is a constant, and n is the elasticity of ship size against daily cost
$C^{I_k}_{Port}$	The total cost (US$) of a port call and terminal handling for a mother ship at port I_k
$c^{i_k}_{Port}$	The total cost (US$) of a port call and terminal handling for a feeder ship at port i_k
$D^{I_1 \sim I_2}_{Sailing}$	The sailing time (days) of a mother ship sailing from port I_1 to port I_2, calculated as distance (nm, nautical miles)/(24 × V), where V is the speed of the container ship (kt, nm/h)
$d^{I_1 \sim I_2}_{Sailing}$	The sailing time (days) of a feeder ship sailing from port i_1 to port i_2, calculated as distance (nm, nautical mile)/(24 × V), where V is the speed of the container ship (kt, nm/h)
T & t	The sizes (TEU_S) of the mother ship (T) and feeder ship (t)
Q & q	The handling quantity of the containers (TEU_S): $Q = \text{LF} \times T$ and $q = \text{LF} \times t$, where LF is the code name of the loading factor for each voyage of the mother ship on the trunk route
R^I & r^i	Terminal gross handling efficiencies R and r in ports I and i, respectively, indicating that, along with terminal operators, operators typically use four to six gantry cranes for ship calling in the majority of hub ports, with a gross efficiency of more than 150–175 TEU/h in some megahub ports and 100–120 TEU/h in others (the uniform efficiency is 135 and 100 TEU/h for hub ports (R) and feeder ports (r), respectively)
$D^{I_k}_{Port}$	Port time (days), including the terminal waiting and handling time, of the mother ship in port I_k, calculated as $Q/(24 \times R^I)$
$d^{i_k}_{Port}$	Port time (days), including the terminal waiting and handling time, of the feeder ship in port i_k, calculated as $Q/(24 \times r^i)$.

cost decisions of shipping carriers in choosing ports, we used different types of container mother ships and feeder ships, loading factor (LF) rates, gross handling efficiency levels, and impact scenarios in the case of port congestion problems at hub ports because of the pandemic.

As shown in Fig. 1, the F/E scenario is divided into two parts: Fig. A and Fig. B. For a container exported from MNL to RTM (Fig. 1A), if a shipping company uses a container ship to transport the container from MNL to SGP and then transships the container from the far European route to RTM, then the average shipping cost per TEU is AC_{SGP}. Conversely, if a shipping carrier transports a container from MNL to KAO and then transports it to RTM, then the average shipping cost per TEU is AC_{KAO}. If the value of $\text{AC}_{\text{Saving}}$ in Eq. (1) is larger than 0, then this means that when a shipping carrier uses SGP as the transshipment port, the average cost is higher than that of using KAO, meaning that transshipping MNL container sources through KAO is more advantageous. This method, which is used in the deployment of T/P routes, clearly indicates the cost-saving advantages of carriers [2]:

$$
\begin{aligned}
AC_{Saving} &= AC_{SGP} - AC_{KAO} \\
&= (\text{Average cost of feeder ship from MNL to SGP and then on a mother ship from SGP to RTM}) \\
&\quad - (\text{Average cost of feeder ship from MNL to KAO and then on a mother ship from KAO to RTM}). \\
&= \Bigg(\left[c_{Fuel} * d^{MNL-SGP}_{Sailing} + c_{Ship-daily} * \left(d^{MNL-SGP}_{Sailing} + d^{MNL}_{Port} + d^{SGP}_{Port} \right) + c^{MNL}_{Port} + c^{SGP}_{Port} \right] \Big/ q \\
&\quad + \left[C_{Fuel} * D^{SGP-RTM}_{Sailing} + C_{Ship-daily} * \left(D^{SGP-RTM}_{Sailing} + D^{SGP}_{Port} + D^{RTM}_{Port} \right) + C^{SGP}_{Port} + C^{RTM}_{Port} \right] \Big/ Q \Bigg) \\
&\quad - \Bigg(\left[c_{Fuel} * d^{MNL-KAO}_{Sailing} + c_{Ship-daily} * \left(d^{MNL-KAO}_{Sailing} + d^{MNL}_{Port} + d^{KAO}_{Port} \right) + c^{MNL}_{Port} + c^{KAO}_{Port} \right] \Big/ q \\
&\quad + \left[C_{Fuel} * D^{KAO-RTM}_{Sailing} + C_{Ship-daily} * \left(D^{KAO-RTM}_{Sailing} + D^{KAO}_{Port} + D^{RTM}_{Port} \right) + C^{KAO}_{Port} + C^{RTM}_{Port} \right] \Big/ Q \Bigg)
\end{aligned}
\tag{1}
$$

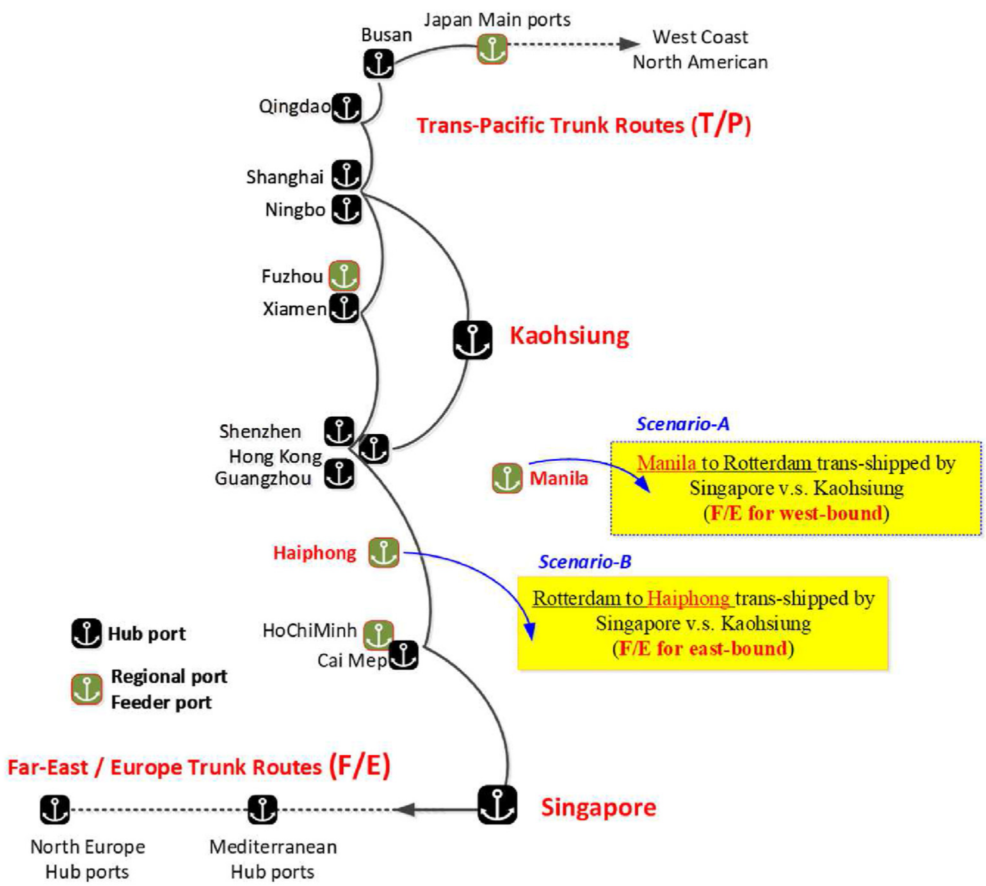


Fig. 1. Two transshipment scenarios at the F/E trunk route (Scenarios A and B).

Table 3 shows the various cost items of the main and feeder networks of the carriers, which were obtained both by referring to Tsai and Tai [2] and through data collection. As shown in the table, the cost of container vessels varies depending on the route, loading capacity, speed, fuel consumption, port conditions, and other navigational characteristics. Among these variable costs, the fuel cost is considered the most critical, which accounts for the largest proportion of the total cost. The fuel consumption of a ship completely differs depending on its status, that is, sailing, slow steaming while approaching the port, and maneuvering while berthing at the dock. Here, we used the method of Tsai and Tai [2] to calculate the fuel cost (C_{Fuel}) and daily cost ($C_{Ship\text{-}daily}$) of ships. In this research, $C_{Fuel} = 39.01*T^{0.688}$ and $C_{Ship\text{-}daily} = 117.56*T^{0.715}$ will be combined with different ship size values and substituted into the cost model to calculate the unit shipping cost.

4. Assessment results

4.1. Fig. A: transshipment cost estimation from MNL to RTM (Figs. 2–5)

A As shown in Fig. 2, if a carrier chooses to transfer MNL containers to RTM at KAO on a 12K mother ship with a 2K cargo consolidation sub-vessel, it can save approximately 1.12 USD per TEU compared with the case of SGP, which is not highly effective. However, if a larger mother ship (24K) is used, then the carrier can save approximately 4.86 USD per TEU, which is slightly more effective. With the same mother ship, if a larger feeder-ship is used, the carrier can save more costs by using SGP as a transshipment hub. If a 12K mother ship with a 5K feeder-ship is used for transshipment in KAO, then the carrier pays approximately 8.28 USD per TEU compared with the case of SGP. This means that the larger the mother ship is, the

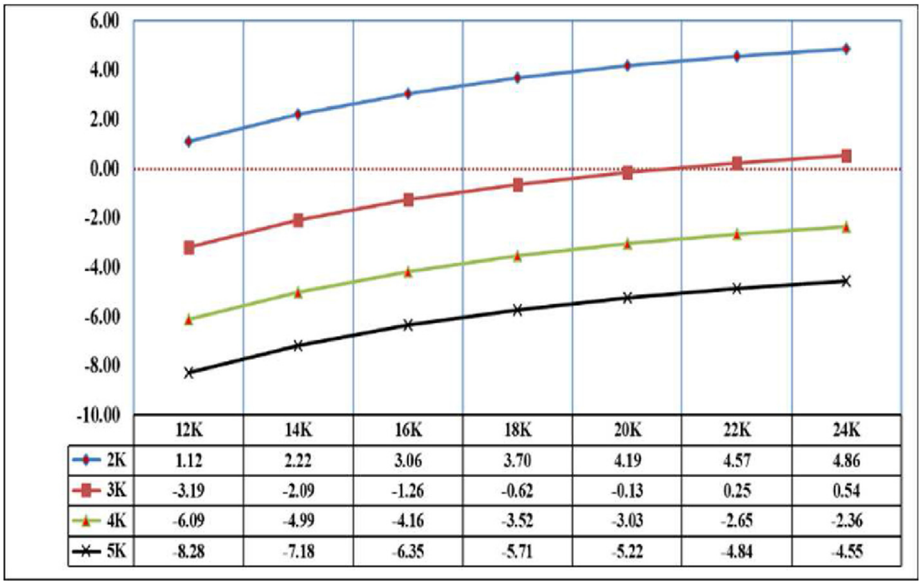


Fig. 2. Cost saving for the westbound F/E route.

more favorable it is to choose KAO as the hub port. However, for the same mother ship, the larger the feeder-ship used is, the more favorable it is to choose SGP as the transshipment port. This point indicates that KAO urgently needs a deep-water wharf to meet the transshipment and berthing requirements of large container ships.

B Fig. 3 shows a cost saving sensitivity analysis of the LF rate relative to shipping carriers. An LF rate of 1.0 means that the ship is fully loaded and that the cargo source at the port of call is sufficient. Here, when we set the feeder-ship size and mother ship size as 3K and 12K, respectively, we determined that the larger the LF rate was (0.6 → 0.8), the lower the cost savings per TEU were for shipping carriers to choose SGP (16.46 → 3.19). We also determined that when the LF rate was 0.9, the shipping carriers saved up to 1.24 USD by choosing KAO for transshipment. These findings indicate that when the supply of goods is sufficient and the mother ship

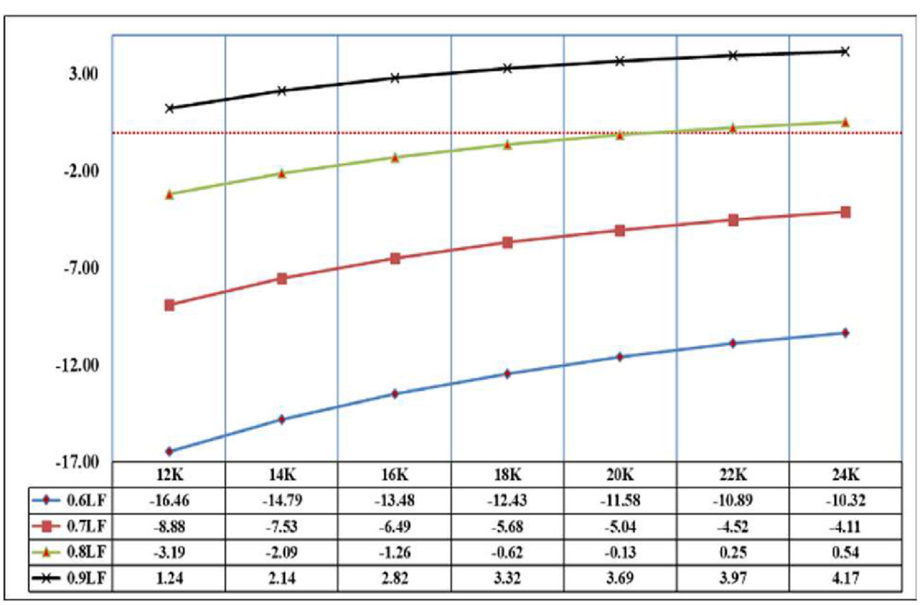


Fig. 3. Effects of mother ship LF on cost saving for the westbound F/E route.

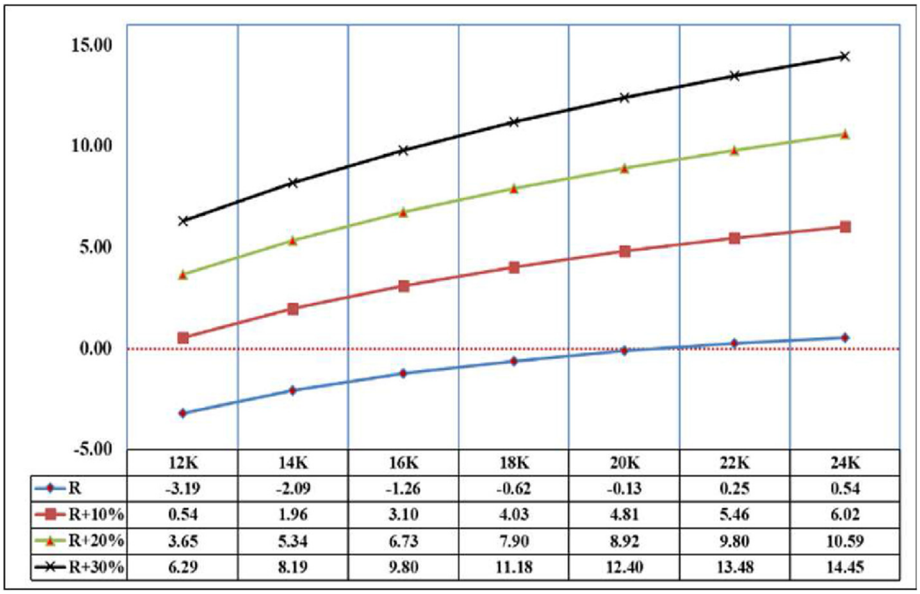


Fig. 4. Effects of KAO handling efficiency on cost saving for the westbound F/E route.

is fully loaded, the advantages of shipping carriers choosing KAO increase. In addition, the larger the mother ship is, the more favorable it is for shipping carriers to choose KAO as the hub port. This is presumably one of the important incentives for KAO to establish a deep-water wharf.

C As shown in Fig. 4, a higher gross handling efficiency (R, TEUs/h in terminal) is associated with a shorter ship berthing time. In this scenario, the operating time and cost of shipping carriers at the terminal is reduced. When we set the feeder-ship size and mother ship size as 3K and 12K, respectively, we determined that a greater loading and unloading efficiency of KAO (30% increase, $R = 135 \rightarrow 175$ TEUs/h) was associated with greater cost savings for shipping carriers ($-3.19 \rightarrow 6.29$). These findings indicate that the higher the loading and unloading efficiency is, the higher the cost advantage is for shipping carriers. They also indicate that the larger the mother ship is, the more favorable it is

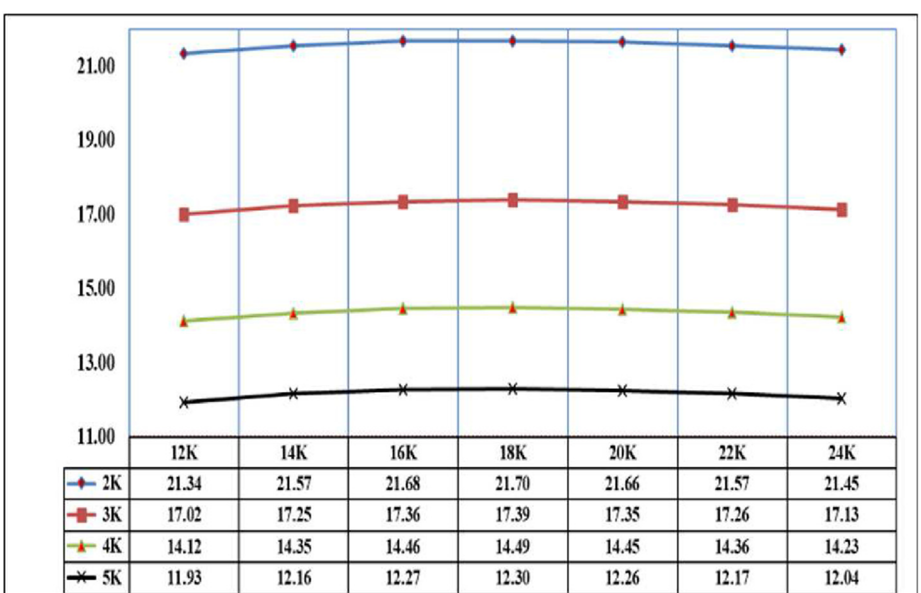
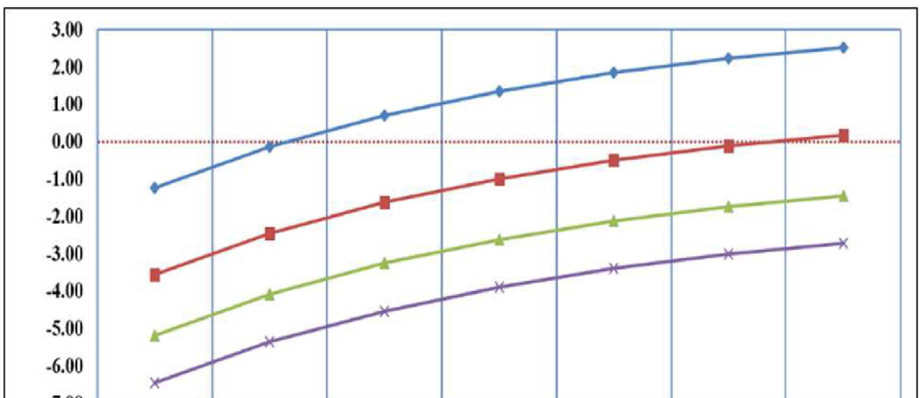


Fig. 5. Effects of COVID-19 on port selection costs for the westbound F/E route.

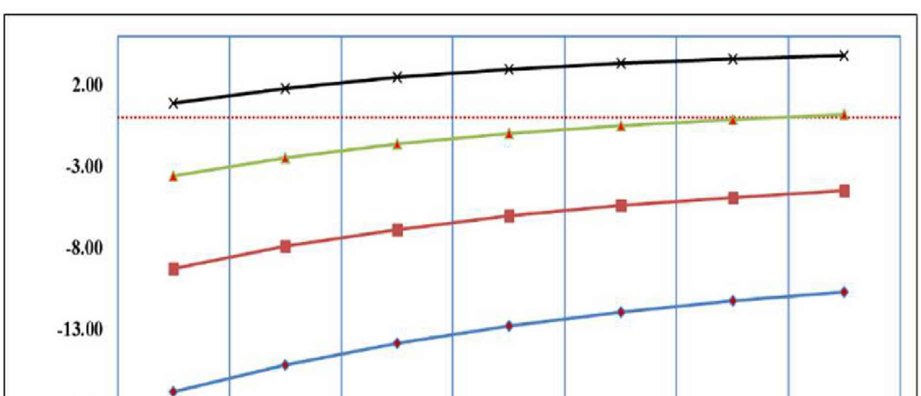
to choose KAO as the hub port. These findings clearly indicate that KAO should have an up-to-date deep-water wharf and loading and unloading equipment to maintain the transshipment advantage of mother ships.

D Fig. 5 shows an example of a mother ship on the F/E route facing port congestion because of the pandemic, forcing it to wait for approximately 48 h off the coast of SGP. In this scenario, if the shipping carrier chooses KAO for transshipment, as long as a 12K mother ship and a 2K feeder-ship are used, then the carrier can save approximately 21.34 USD per TEU compared with the case of SGP for transshipment, indicating a high efficiency. For the same mother ship, the cost savings of the shipping carrier decrease (21.34 → 11.93 USD) with the increase of feeder-ship size (2K → 5K). However, for the same feeder-ship size (e.g., 2K feeder-ship), when the size of the mother ship increases (12K → 24K), the cost savings achieved with KAO as a transshipment hub become limited (21.34 → 21.45 USD). These findings indicate that the COVID-19-associated port congestion problem faced by several large hub ports on the F/E route has been detrimental to transshipment



	12K	14K	16K	18K	20K	22K	24K
2K	-1.22	-0.12	0.72	1.35	1.85	2.23	2.52
3K	-3.55	-2.45	-1.61	-0.98	-0.48	-0.10	0.19
4K	-5.18	-4.08	-3.24	-2.61	-2.11	-1.73	-1.44
5K	-6.45	-5.35	-4.52	-3.88	-3.38	-3.00	-2.71

Fig. 6. Cost saving for the eastbound F/E route.



	12K	14K	16K	18K	20K	22K	24K
0.6LF	-16.82	-15.15	-13.83	-12.79	-11.94	-11.25	-10.68
0.7LF	-9.24	-7.89	-6.85	-6.04	-5.39	-4.88	-4.47
0.8LF	-3.55	-2.45	-1.61	-0.98	-0.48	-0.10	0.19
0.9LF	0.88	1.79	2.46	2.96	3.34	3.61	3.81

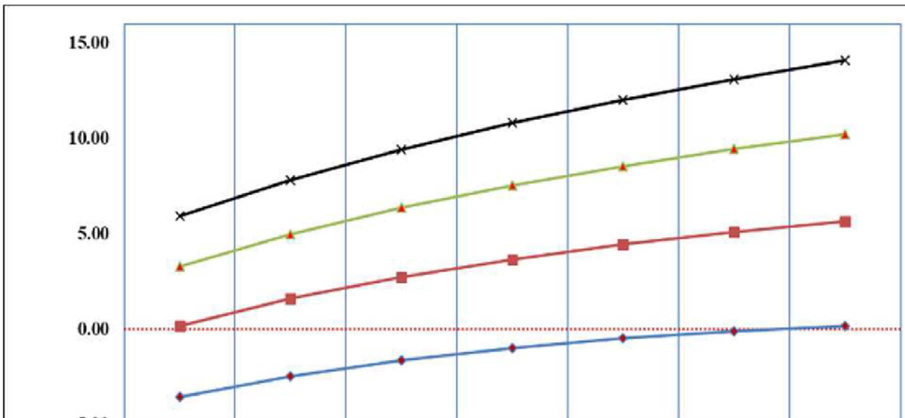
Fig. 7. Effects of mother ship LF on cost saving for the eastbound F/E route.

activities and has been directly reflected in the costs of shipping carriers, which are quite substantial.

4.2. Fig. B: transshipment cost estimation from RTM to Haiphong (Figs. 6–9)

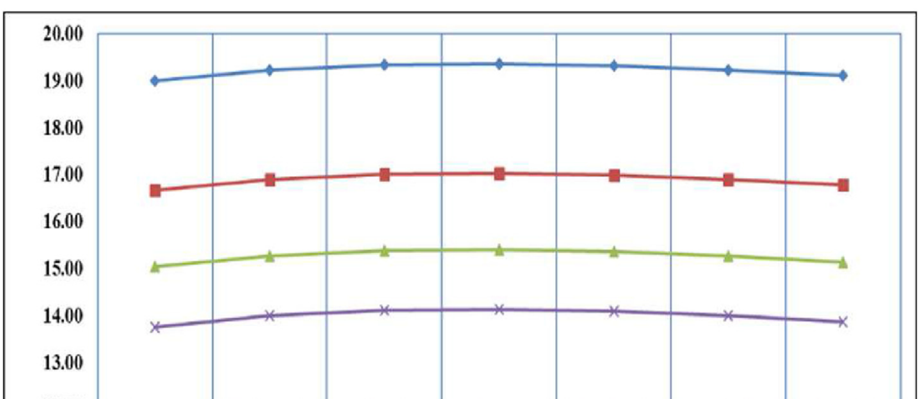
A As shown in Fig. 6, selecting SGP as a transshipment port in the eastbound F/E route is cost-effective for shipping carriers. For example, shipping carriers can save 1.22 USD per TEU by using a 12K mother ship with a 2K feeder-ship compared with using KAO. For the same mother ship size, a larger feeder-ship size is associated with larger cost savings for choosing SGP (1.22 → 6.45), but the cost savings do not increase. However, with the same feeder-ship size, a larger mother ship is associated with higher cost savings for shipping carriers selecting KAO, but the difference is not large. These findings indicate that, compared with KAO, SGP has a more competitive advantage.

B The scenarios shown in Fig. 7 are the same as those in Fig. 3. As shown in the figure, the larger the LF rate is, the larger the supply of goods is. In this scenario, the shipping carriers would



	12K	14K	16K	18K	20K	22K	24K
R	-3.55	-2.45	-1.61	-0.98	-0.48	-0.10	0.19
R+10%	0.19	1.60	2.74	3.67	4.45	5.11	5.67
R+20%	3.30	4.98	6.37	7.55	8.56	9.45	10.23
R+30%	5.93	7.83	9.44	10.82	12.04	13.12	14.10

Fig. 8. Effects of KAO handling efficiency on cost saving for the eastbound F/E route.



	12K	14K	16K	18K	20K	22K	24K
2K	19.00	19.23	19.34	19.36	19.32	19.23	19.11
3K	16.67	16.90	17.01	17.03	16.99	16.90	16.78
4K	15.04	15.27	15.38	15.40	15.36	15.27	15.15
5K	13.76	14.00	14.11	14.13	14.09	14.00	13.88

Fig. 9. Effects of COVID-19 on port selection costs for the eastbound F/E route.

have a high cost advantage for choosing SGP, but this advantage would gradually decline. This scenario indicates that the advantages of shipping carriers choosing KAO would gradually increase with the increase of the supply of goods and mother ship size, similar to the aforementioned result: the deep-water wharf built by KAO meets the berthing requirements of shipping carriers.

C The scenarios shown in Fig. 8 are the same as those in Fig. 4. As shown in the figure, the greater the loading and unloading efficiency of KAO is, the greater the unit cost savings of shipping carriers (−3.55 → 5.93) are. This scenario indicates that the higher the loading and unloading efficiency of a terminal is and the larger the mother ship is, the more favorable it is for shipping carriers to choose KAO. These findings clearly indicate that the new deep-water wharf of KAO is expected to maintain some of its transshipment advantages.

D The scenarios shown in Fig. 8 are the same as those in Fig. 5. Because of the pandemic, shipping carriers can save approximately 19 USD per TEU (with 2K feeder-ships) if they choose KAO rather than SGP for transshipment. In this scenario, regardless of the mother ship size, choosing KAO has a cost advantage, and the problem of port congestion is clearly not conducive to the transshipment activities of SGP.

5. Concluding remarks

In this study, we investigated the deployment of ships on the F/E trunk route by alliance carriers. Given the cost variations that shipping companies may face because of the COVID-19-associated hub port congestion problem, we proposed an explanation for route deployment and port selection. Many of the scenarios proposed herein still represent the actual operating behavior of current shipping companies between strong ports (e.g., SGP) and ordinary ports of call (e.g., KAO). Our results indicated that the ships deployed in different hub ports on the traditional F/E main route by shipping carriers should be large enough to reduce the unit shipping costs. For ports that are less competitive in the first place, shipping carriers should improve the loading ratio of mother ships in these ports to gain the advantage of transshipment costs. The loading and unloading efficiency of terminals is the most crucial factor in rapidly improving the competitiveness of container ports.

To increase the competitiveness of ports and cater to large ships, several traditional container ports in Asia have built deep-water wharves to attract shipping carriers to berth. This approach can help increase the berthing demands of shipping carriers. We used KAO as an example to confirm that gaining the advantages of transshipment and attracting the sources of reexport containers from neighboring countries would be difficult in the absence of a deep-water wharf.

Our results indicated that the mother ships of shipping carriers deployed on the F/E route in container ports in Asia should be sufficiently large and that the loading ratio of the mother ship to the cargo source should be sufficiently high to gain the cost advantage of transshipment. This is also a unique factor in route deployment and port selection for carriers [18]. In addition, a higher loading and unloading efficiency of terminal equipment at a port is associated with a higher overall competitive advantage for that port. Otherwise, given the current trend of large ships, traditional container ports without large cargo sources and deep-water wharves would encounter difficulties in attracting shipping carriers to berth. In addition, although the port congestion problem observed at the F/E trunk because of the pandemic is not as serious as in North American ports, it affected the route deployment and port selection decisions of shipping carriers. The limitations of this study are that neither the variations in ship sailing speed nor the variety of ship fuels were considered. Future research should therefore incorporate these two variables to make the results more applicable to the shipping industry.

Major shipping carriers within Ocean Alliance in East Asian ports consider local supply quantity and deep-water wharf conditions as the selection criteria for their ports of call. As part of Ocean Alliance, Evergreen has a fixed supply of goods and an old container terminal in KAO. However, it requires a deep-water wharf in the new port area as soon as possible and needs to equip the port with new loading and unloading machinery and equipment to allow for the deployment of larger container mother ships so as to retain its transshipment advantage in KAO.

Conflict of interest

Neither the content nor the two authors have any conflict of interest with the shipping companies and ports mentioned in this article.

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