THE EVALUATION OF COMPETITIVENESS ON COST ADVANTAGE OF REGIONAL HUB PORT: THE CASE STUDY OF TRANS-PACIFIC ROUTE AGAINST KAOHSIUNG PORT

(DOI No: 10.3940/rina.ijme.2019.a4.544)

T Y Tsai, Taiwan International Ports Logistics Corp and National Kaohsiung University of Science and Technology, Taiwan and **H H Tai,** Department of Shipping and Transportation Management, National Kaohsiung University of Science and Technology, Taiwan

SUMMARY

Numerous conventional container ports in East Asia are evolving from intercontinental into regional hub ports. This study adopted the Port of Kaohsiung as an example of competition with neighboring ports. The results of this study demonstrated that the Port of Kaohsiung is still a competitive docking port on trans-Pacific trunk routes for North America, despite facing external threats (e.g., upsizing of ships, lack of new deep-water terminals, and new strategic alliances affecting terminal operations), overall shipping cost considerations (e.g., container volume, different ship sizes, and port selection), and increasingly intense competition with neighboring ports. Under such circumstances, the Port of Kaohsiung must keep pace with container ship upsizing, sufficiently increase deep-water terminal capacity, and improve its existing container terminals' operating efficiency to attract route deployment and larger container ships and thereby maintain its current advantages and position as a regional hub port.

NOMENCLATURE

T/P	Trans-Pacific route
TIPC	Taiwan International Ports Co., Ltd.
TEU	Twenty-foot Equivalent Unit
AC_{Ik}	The average cost in I_k hub-port
AC_{SAVING}	The average cost-saving
C_{Fuel}	The total costs of vessel fuels for ship sailing
$C_{Ship\text{-}daily}$	The daily costs of ship on different routes
$C\ \frac{I_k}{Port}$	The total costs of port for ship called on I_k port and handling in terminals
$D\ \frac{I_1 \sim I_2}{Sailing}$	The sailing time of ship sailing from I_1-port to I_2-port
$D\ \frac{I_k}{Port}$	The port time of ship in I_k-port
$T\&t$	The ship sizes (TEU) of mother ship (T) and feeder ship (t)
$Q\&q$	The handling quantity of containers (TEU)
LF	The loading-factor for each voyage
R^I	The terminal gross handling efficiency R on I-port

1. INTRODUCTION

Local supply is a stable source for a container port, ensuring minimal variations in import and export container quantities. However, the quantity of transshipped containers varies greatly due to strong external factors. Whether container carriers perform container stacking and transshipment at a port primarily depends on transport cost considerations and whether the port has a stable set of transport routes as well as resource diversity. A number of conventional hub ports are distributed across Asia, including Singapore, Tanjung Pelepas, Hong Kong, Shenzhen, Kaohsiung, Xiamen, Shanghai, Qingdao, and Busan. These locations are dependent on criteria both internal (e.g., sufficient resources, subsidy policies, and terminal conditions) and external (e.g., shipment cost considerations, number of competing neighboring ports, and route deployment). A port's competitiveness increases only if it satisfies both types of criteria; otherwise, transshipped containers will be attracted to other neighboring ports (Su, *et al*., 2016; MOTC, 2017). The number of transshipped containers is key to solidifying hub status.

The Port of Kaohsiung is Taiwan's largest container port, handling more than 70% of its container import and export operations. Because of its advantageous geographical location, the Port of Kaohsiung was a major transshipment port along the Far East–Europe trunk route, the trans-Pacific (T/P) route, and the Southeast Asia route (MOTC, 2013; Tai, 2015; MOTC, 2016), and was among the top three container ports in the world before 2000 as well as a leading intercontinental hub port. However, the outflow and transformation of traditional industries in Taiwan have caused import and export trade volumes to stagnate, and the emergence of new ports in neighboring countries (China and Southeast Asia) has also begun to diminish the Port of Kaohsiung's hub status and transshipment container sources. Various prominent container carriers have gradually altered their East Asian route structures (Tai & Lin, 2014), docking less frequently at the Port of Kaohsiung and thus severely

©2019: The Royal Institution of Naval Architects

affecting transshipped container traffic in Taiwan. Although the Port of Kaohsiung is capable of maintaining its overall yearly container quantity of more than 10 million twenty-foot equivalent units (TEU), it has witnessed a gradual decline in its status as a transshipment port (MOTC, 2017).

The Port of Kaohsiung remains an attractive site for vessel-calling on the T/P route for North America. A considerable number of transshipment containers from Vietnam and the Philippines are transshipped at Kaohsiung. The main aim of this study was to determine criteria for maintaining the Port of Kaohsiung's transshipment advantages in the future. The route deployment of container carriers at Kaohsiung and the different operating conditions for vessel allocation were examined, and a container ship transport cost model comparing the Port of Kaohsiung with neighboring transshipment ports was constructed to determine which would be more attractive as a docking site for vessels on the T/P route. The objectives of this study were thus to determine whether, compared with major neighboring ports. the Port of Kaohsiung offers cost advantages to attract route deployment and calling by mother ships, as well as to identify key operating conditions for maintaining its existing advantages and position as a regional hub port. Among the neighboring ports, Hong Kong handles more transshipment containers and is the major competitor of Port of Kaohsiung for carriers to select port of call in T/P route. This study thus chose Hong Kong as example to compare.

2. TRANSFORMATION OF REGIONAL HUB PORTS

Intercontinental hub ports, also referred to as international hub ports, are characterized by a comprehensive range of container transshipment facilities and possess all trunk route types and an interconnected collection of feeder routes (Tai, 2012; Zheng, Fu & Kuang, 2017). Once an intercontinental hub port loses vessel-callings from major trunk routes, it also loses its position as a comprehensive hub and thus becomes a regional hub port retaining only part of its regional advantage. This has already occurred in a number of Asian container ports, such as those in Japan, Taiwan, and Hong Kong. Changes in regional industrial structure have affected the status and competitiveness of these ports (Tai, 2012; MOTC, 2013).

Taiwan provides the most representative example of how industrial structure influences container ports and container quantity growth. According to Directorate-General of Budget, Accounting, and Statistics, Executive Yuan 2018 statistics, Before 1997, the traditional industry in Taiwan was oriented toward manufacturing sectors, followed by service sectors. This trend has reversed since 1997, with 2017 government statistics indicating that the output value of service industries in Taiwan represented 64.14% of GDP, whereas the industrial sector was in second place with only 34.54% and other economic sectors (fishery, agriculture, and animal husbandry) represented less than 2%. This demonstrates considerable variation in the industrial structure, which has limited the growth of import and export container volumes. As shown in Figure 1, Taiwan has been affected by the outward movement of traditional industries since the late 1990s. Development of the country's economy and industry and moving of its manufacturing-sectors overseas have reached a new trend since 2010, in which the production trade value of overseas Taiwanese manufacturing companies exceeded that of domestic ones (see Figure 1).This impeded the growth of local import and export container volumes at Taiwanese ports, and subsequent container growth became increasingly reliant on transshipment activities. MOTC(2017) shows export trade values in Taiwan by main service categories over the past 10 years, based on statistical data from the United Nations, indicating that the Taiwanese transportation industry experienced slower growth after 2011, compared with other industries. As manufacturing companies in Taiwan shift their production bases to China and Southeast Asia, this has stimulated the development of their local industries and attracted investment in deep-water port construction, enabling large vessels to dock at local ports and deliver goods directly without having to transport containers on feeder vessels for transshipment at the Port of Kaohsiung. Consequently, large vessels are growing less reliant on deep-water ports in Taiwan.

The Port of Kaohsiung provides a real-life example of the process of transformation from an intercontinental to a regional hub port. The Port of Kaohsiung was formerly the main transshipment hub port in the Asia Pacific region, the largest container port in Taiwan situated on the Asian Pacific east-west routes, and, as the point of intersection for East Asian south-north routes, a major intercontinental hub port as well. With the containerization trend of the late 1960s, the Port of Kaohsiung introduced container shipping operations. As global trade and containerization grew, the Port of Kaohsiung further developed and expanded its container terminals, becoming one of the top three ports in the world in terms of container-loading capacity (see Figure 2). Since 2000, neighboring countries such as China and the Southeast Asian nations have gradually developed deep-water ports and terminals as well as mother ports and trunk routes to attract transshipment resources. Following major changes in Taiwan's industrial structure, East Asian container shipping lines also began opting for coastal ports in China and Southeast Asia as their preferred docking sites, thus affecting the Port of Kaohsiung's competitive status (Tai, 2012; MOTC, 2013; MOTC, 2017).

 ©2019: The Royal Institution of Naval Architects

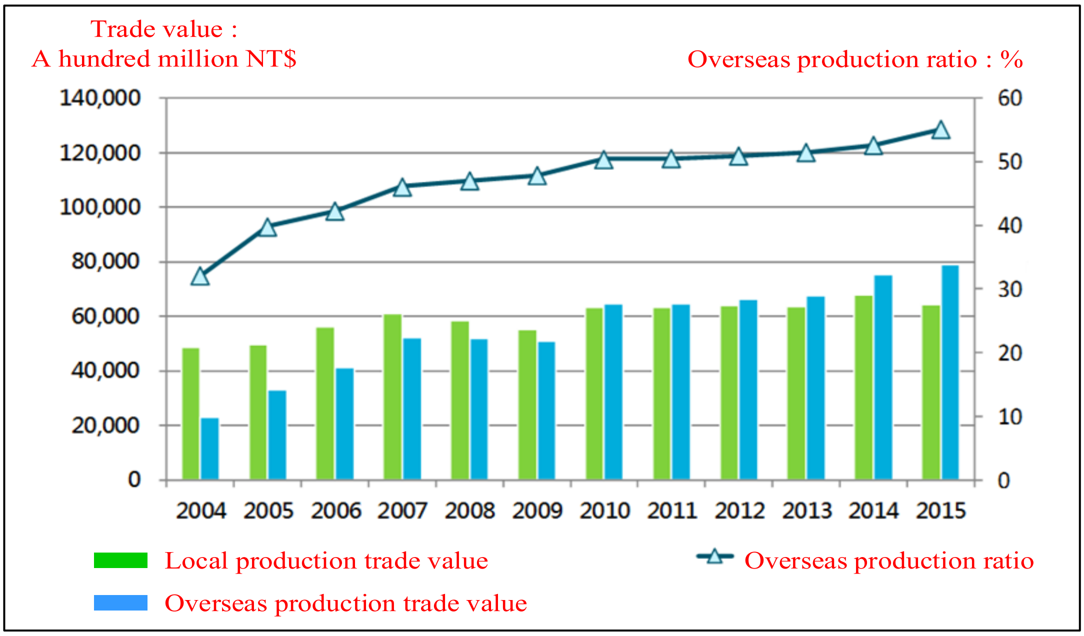


Figure 1: [Trade trends in Taiwan and proportion of overseas production]
(data source: Taiwan International Ports Corporation [TIPC], 2018)

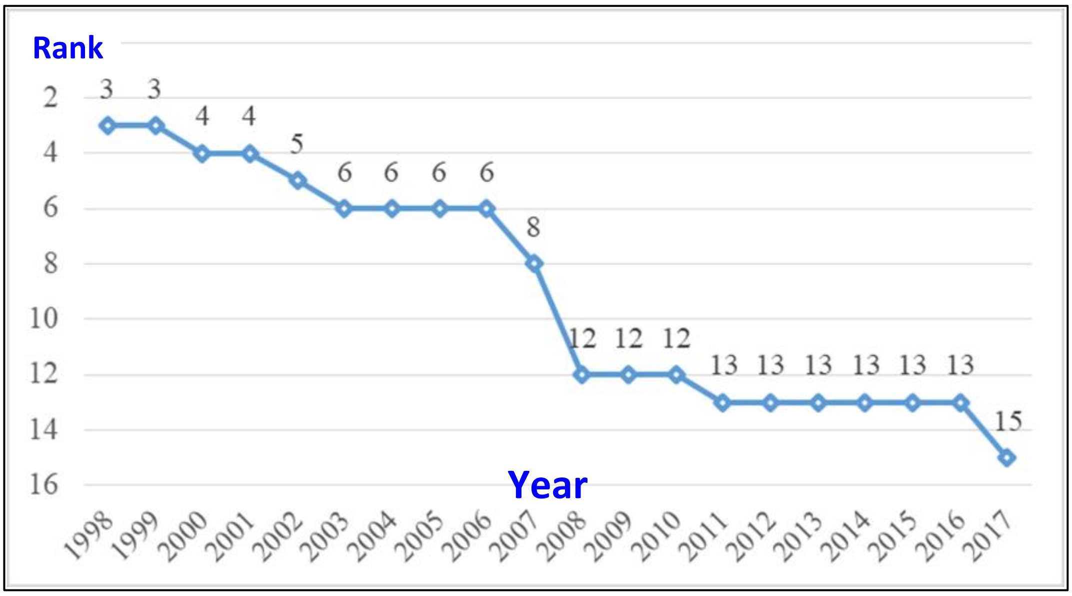


Figure 2: [World ranking of the Port of Kaohsiung by volume of containers handled]
(data source: TIPC, 2018)

3. IMPACTS ON PORT OF KAOHSIUNG'S TRANSSHIPMENT HUB STATUS

Changes in hub status can be investigated by ranking ports by container volumes handled. Specifically, the current trend of changes in container volumes handled at the Port of Kaohsiung during the past 10 years, as shown in Table 1, reveals that overall container port throughput has exhibited only slight growth, with the volume maintained at roughly 10 million TEU since 2014. Except for a slight increase to 48.39% in 2016, the volume of transshipped containers has decreased to approximately 45% in recent years, which is substantially lower than the volume transshipped at major conventional transshipment hubs. The Port of Kaohsiung receives transshipment containers primarily from the United States, China, Japan, Vietnam, and the Philippines. Confronted with competition from neighboring ports, the

Port of Kaohsiung's deep-water terminal expansion was unable to keep pace with the upsizing of container ships. Consequently, a number of megaships have bypassed the Port of Kaohsiung (MOTC, 2016), thus accelerating the decline of its major hub status and hindering industrial development activities at its terminals. External operating factors such as strategic global shipping alliances (MOTC, 2017; Tai & Yang, 2016) have also had a major impact.

3.1 INDUSTRIAL DEVELOPMENT OF KAOHSIUNG CONTAINER TERMINALS AND KEEPING PACE WITH SHIP UPSIZING

Container terminal activities at Kaohsiung are relatively well developed. Currently, the port has six container terminals and 27 wharves, mainly adopting a landlord port model in leasing them to different shipping companies. A few terminals are leased to terminal operating and handling companies, and state-owned port company (TIPC) self-manage two container berths. The location of each container terminal is shown in Figure 3 and Table 2. Dedicated (or exclusive) terminals rented by shipping companies are equipped with machinery and tools to service their own vessels. The terminals can also be used as public terminals providing services to other vessels. Moreover, vessel arrival schedules and frequencies can be regulated to meet the operational requirements of shipping companies. Terminal operators must have sufficient docking vessels and containers to meet the economies of scale for terminal management and lower the costs of port container handling. All international ports have established an operational policy, and their terminal operations system is considered appropriate if it is capable of managing terminals efficiently (Merkel, 2018). Because its rent is fixed, if a terminal is able to handle an increased transshipment volume, the average unit cost of renting can be considerably reduced, which is extremely conducive to a shipping company's competitiveness. The Port of Kaohsiung has relied on this dedicated terminal system for many years (MOTC, 2013), thus becoming a major hub port in the East Asia region. This is because terminal operators in considering terminal operating costs, converge their shipping lines and containers at the Port of Kaohsiung to attract a substantial transshipment container volume.

Currently, Evergreen Marine Corp. (EMC), Orient Overseas Container Line (OOCL), American President Lines (APL), Wan Hai Lines, Yang Ming Lines (YML), and Hyundai Merchant Marine (HMM) are the six shipping carriers renting terminals at the Port of Kaohsiung. With Kaohsiung as the transshipment terminal for shipping carriers, the operating conditions and management status of each terminal indicate that only the Evergreen terminal (4th container terminal) and Yang Ming terminal (6th container terminal) with draft of

Table 1: [Changes in container volume handled at Kaohsiung Port in the past 10 years]

Year	Total Volume	Volume of Import and Export Containers				Volume of Transshipped Containers	
		Import	Export	Total	Percentage	Transshipment	Percentage
2008	967.66	253.59	269.50	523.09	54.06%	444.56	45.94%
2009	858.13	222.64	231.42	454.06	52.91%	404.06	47.09%
2010	918.12	238.07	251.52	489.59	53.33%	428.53	46.67%
2011	963.63	249.14	264.08	513.22	53.26%	450.41	46.74%
2012	978.12	245.77	265.13	510.90	52.23%	467.23	47.77%
2013	993.77	258.37	260.68	519.04	52.23%	474.73	47.77%
2014	1059.33	278.08	279.92	557.99	52.67%	501.34	47.33%
2015	1026.44	272.30	272.10	544.40	53.04%	482.04	46.96%
2016	1046.49	269.53	270.58	540.11	51.61%	506.38	48.39%
2017	1027.10	275.30	275.41	550.71	53.62%	476.39	46.38%
2018(Q1+Q2)	518.38	145.67	143.41	289.09	55.77%	229.30	44.23%

Unit:10,000 TEU; Data source: TIPC, 2018.

©2019: The Royal Institution of Naval Architects

16 meters for large container vessels (i.e., containerships with a capacity of approximately 14,000 TEU). Under the main channel of Kaohsiung Port, there is a cross-harbor tunnel that renders berths to its north unavailable for container vessels with a draft of more than 14 meters, whereas berths south of the tunnel are restricted by a turning basin and narrow_channel. Larger containerships with a capacity of more than 14,000 TEU must therefore satisfy a number of limiting conditions (e.g., draft, load, climate, and tugboats) to safely call at the port and unload containers. Moreover, the container terminals are dispersed across the port, rendering interconnected transshipment activities impossible. For example, Evergreen, YML, and HMM each have their own wharves at different container terminals, and so transshipment containers must be transferred to different terminals using either a trailer or a ship, thus adding to transshipment operating costs. Moreover, the terminal conditions and docking arrangements of each operator differ considerably, causing excessive congestion at some terminals while other terminals remain idle. The port's total capacity therefore cannot be fully utilized or increased further (MOTC, 2017; MOTC, 2016). Given the upsizing trend in ships, global shipping carriers are actively building large container vessels capable of carrying more than 20,000 TEU, which are too large to enter the Port of Kaohsiung. Therefore, to prevent the risk of marginalization, the port has already launched construction of a seventh container terminal that is deeper and larger than the other six.

According to statistics published on the websites of the United Nations Conference on Trade and Development (UNCTAD, 2018) and Alphaliner (2018), ships with a capacity of more than 10,000 TEU accounted for only 6% of global ship capacity in 2010, but 23% in 2015 and 33% in 2018, indicating a significant upsizing of container ships. If major port terminals fail to keep pace with this ship upsizing trend, carriers will most likely deploy their shipping lines and dock their vessels elsewhere (Gomez Paz, Orive and Cancelas, 2015). The Port of Kaohsiung is also facing this problem because the number of large vessels docking here has been increasing annually since 2010 (MOTC, 2017), as shown in Figure 4. Data published on the TIPC website indicate that 312 container ships with a capacity of More than 13,000 TEU and 119 container ships with a capacity of 10,000–12,999 TEU called at the Port of Kaohsiung in 2017. Therefore, to prepare for upsized container ships and attract ocean liners, a seventh container terminal outside the second port entrance is currently under construction and investment plans are under way. The seventh terminal is expected to be completed by October 2020, offering five wharves with a pier depth of up to 18 meters for large container ships with a capacity of over 20,000 TEU. Moreover, it will have a total pier length of 2,415 meters and a container yard of roughly 147 hectares, which should provide a loading capacity of approximately 4.5 million TEU per year for the Port of Kaohsiung. Figure 5 shows the location and operating conditions of the seventh container terminal.

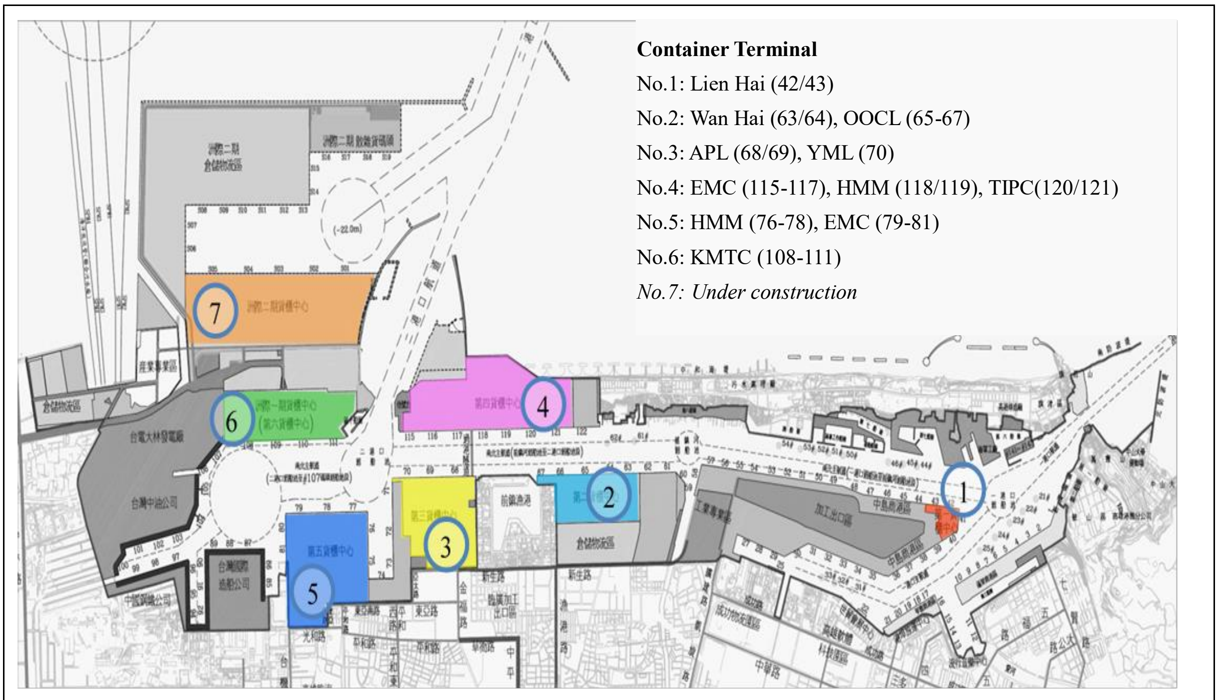


Figure 3: [Location of container terminals at the Port of Kaohsiung]

Table 2: [Characteristics and shipping carriers of Port of Kaohsiung container terminals]

Container Terminal	Container yard area (ha)	Terminal length (m)	Designed depth (m)	Operator	Alliance
1	10.5	420	10.5	Lien Hai	
2	45	521	14.5	Wan Hai	
		760	14.5	OOCL	Ocean Alliance
3	48	640	15.5	APL	Ocean Alliance
		320	14	YML	The Alliance
4	100	917	17.6	EMC	Ocean Alliance
		640	14	HMM	2M+HMM
		640	14	TIPC	
5	90	995	15	HMM	2M+HMM
		995	15	HMM	2M+HMM
6	74.8	1,500	17.6	KMTC	The Alliance
7	147	2,415	18	EMC	Ocean Alliance

Data source: TIPC, 2018

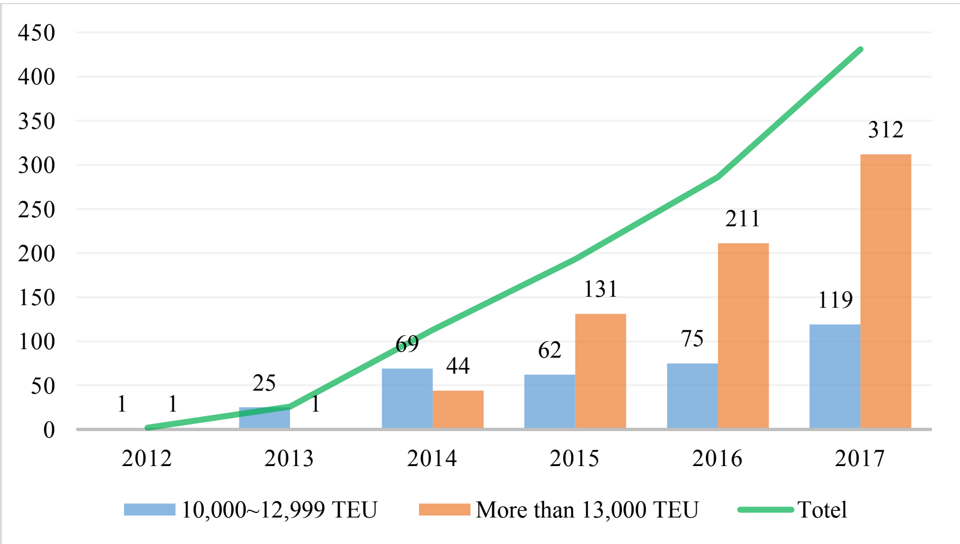


Figure 4: [Number of incoming vessels over 10,000 TEU at the Port of Kaohsiung]
Data source: TIPC, 2018

©2019: The Royal Institution of Naval Architects

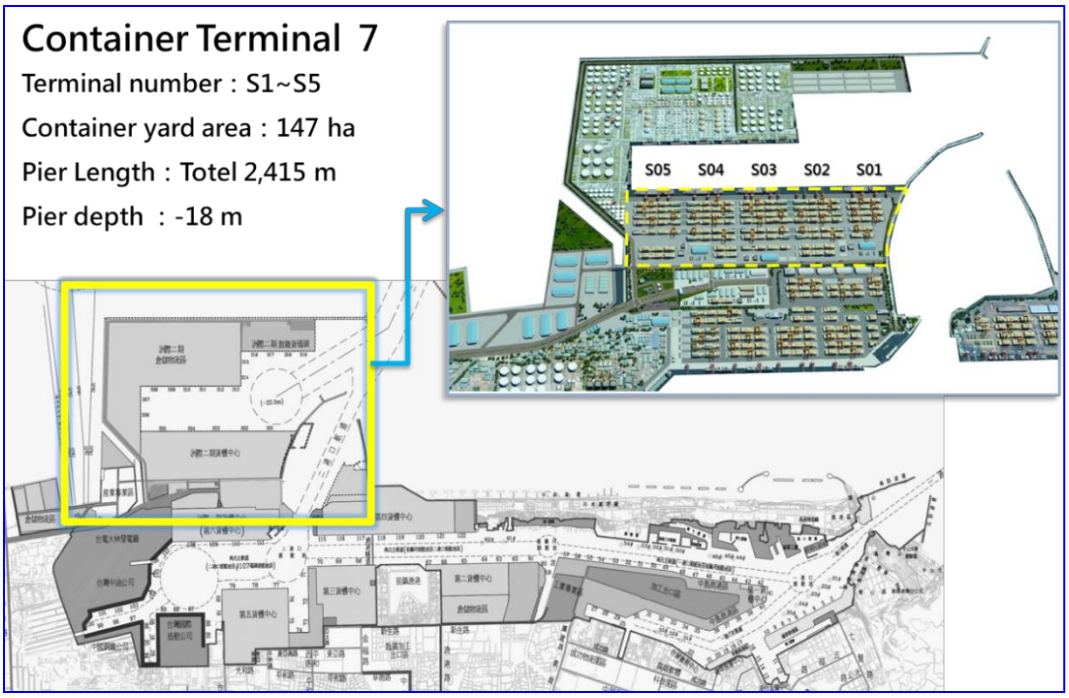


Figure 5: [Locations and operating conditions of the seventh container terminal]
Data source: TIPC, 2018

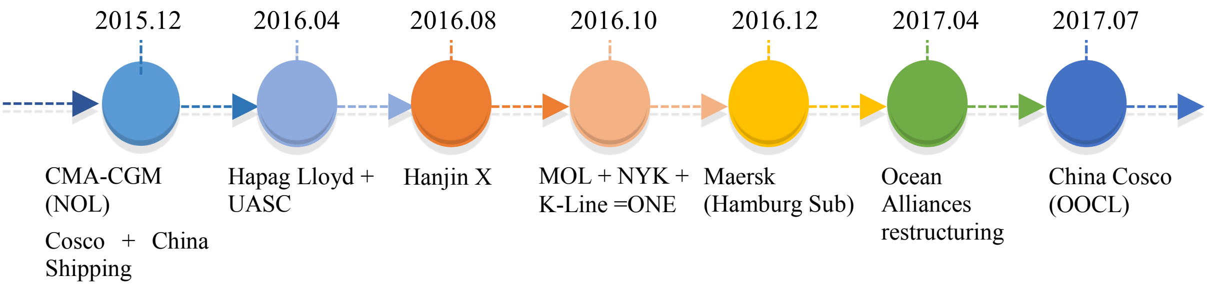


Figure 6: [Acquisition, consolidation, and alliance restructuring of global container operators between 2015 and 2018]

3.2 INFLUENCE OF RESTRUCTURED STRATEGIC ALLIANCES

The formation of a strategic alliance is a complex process. The upsizing of container ships has led to reduced transport unit costs and a surplus of vessel tonnage far exceeding actual shipping demands, which in turn has caused a dramatic drop in ocean freight in global shipping markets. Combined with oil price hikes and ongoing increases in operating costs, most shipping carriers have suffered cumulative losses, with many forced to close down or merge with other companies. Therefore, many carriers have begun moving away from price competition toward a joint venture or strategic alliance approach (Hirata, 2017), in which different carriers cooperate on managing shipping lines, continuously expanding their market (Yap & Zahraei, 2018) and effectively providing a complete range of global carrier services for shippers, thereby increasing the degree of shippers' satisfaction with carriers and carriers' operational performance. This situation intensified in 2016. Figure 6 shows the acquisition, consolidation, and alliance restructuring of global container operators during the past 3 years. For example, the CMA CGM group acquired Neptune Orient Lines (APL) in 2015, Hanjin declared bankruptcy in 2016, and COSCO acquired OOCL in 2017. APL, Hanjin, and OOCL all operate terminals at the Port of Kaohsiung, thus directly influencing its overall container volume. In April 2017, the carriers remaining in the market after the mergers and the original four shipping alliances (2M, O3, G6, and CKYHE) are restructured into three (2M, Ocean, and THE Alliance). The carriers have readjusted their lines and docking ports on trunk routes, thus causing a dramatic change in the global shipping market that has also significantly affected the Port of Kaohsiung (MOTC, 2017).

Following the strategic alliance restructuring in 2017, shipping companies had to consider other carriers when choosing their primary hub port. This had a great impact on hub ports in Southeast Asia (MOTC, 2017; Yap and Zahraei, 2018), particularly the Port of Kaohsiung. For example, after the CMA CGM group (the parent company of APL) joined the Ocean Alliance in 2017, it readjusted APL lines at Kaohsiung by removing the trunk route to the west coast of the United States, thus significantly reducing activities at Kaohsiung. According to Alphaliner (2018), the total capacity of the three new shipping alliances represents about 80% of global capacity. The new alliances have a stronger relationship, which produces a greater limiting effect. For example, carriers shipping containers from a Southeast Asian port to the Port of Kaohsiung and then transshipping them to North America would formerly dispatch feeder ships to collect the containers from various Southeast Asian ports and then transfer them to Kaohsiung, whence they would then be transshipped to their final destination. Now, however, an alliance member shipping containers to North America sends out its mother ship operating on a trunk route to berth directly at the main port in Southeast Asia, and containers from other alliance members are transferred to this mother ship and then transshipped directly to North America. In this case, no feeder ship is required to transport containers to the Port of Kaohsiung for transshipment, thereby directly reducing the volume of such activity at this port.

Following formation of the new shipping alliances, the Port of Kaohsiung witnessed a drastic decline in its transshipment container volume during the second quarter of 2017, as shown in Figure 7. This study determined the main causes of this decline, as follows:

1. The Alliance readjusted its shipping lines had added an European route in Japan. Previously, CKYH+E had four shipping lines operating on the Far East–Europe and Mediterranean routes, without connecting to a Japanese port. Japanese shipping carriers such as K-Line and NYK typically transshipped containers from Japan via the Port of Kaohsiung to their destination port. However, after alliance restructuring in the second quarter of 2017, THE Alliance added port connections to Tokyo, Nagoya, Kobe, Shimizu and other Japanese ports on the Far East–Europe trunk routes. Consequently, containers from these ports no longer needed to transship at the Port of Kaohsiung.
2. Trunk routes have been deployed in Southeast Asia. In 2018, Jakarta and Cai Mep incorporated direct shipping lines to trunk routes for the west coast of the united states. This directly influenced the volume of containers (i.e., from the United States, Vietnam, and Indonesia) handled at the Port of Kaohsiung.
3. The Japanese container operator ONE adjusted its near-sea shipping lines for THE Alliance. Asian regional lines originally operated by NYK and K-Line, particularly the feeder lines between Taiwan and the Philippines, called at the Port of Kaohsiung twice on a service loop (eastbound and westbound respectively) before alliance restructuring (first quarter of 2017), but only called once after restructuring (second quarter of 2017).
4. APL's acquisition by the CMA CGM group also influenced the supply of US containers transshipped at Kaohsiung. Containers formerly transshipped in Kaohsiung are now handled in Singapore.

In summary, Kaohsiung Port has been affected severely by changes in the new shipping environments, ship upsizing, and carriers business and financial situations (mergers, closure, or alliance restructuring), all of which have severely decreased the transshipment container volume here and jeopardized the port's hub status.

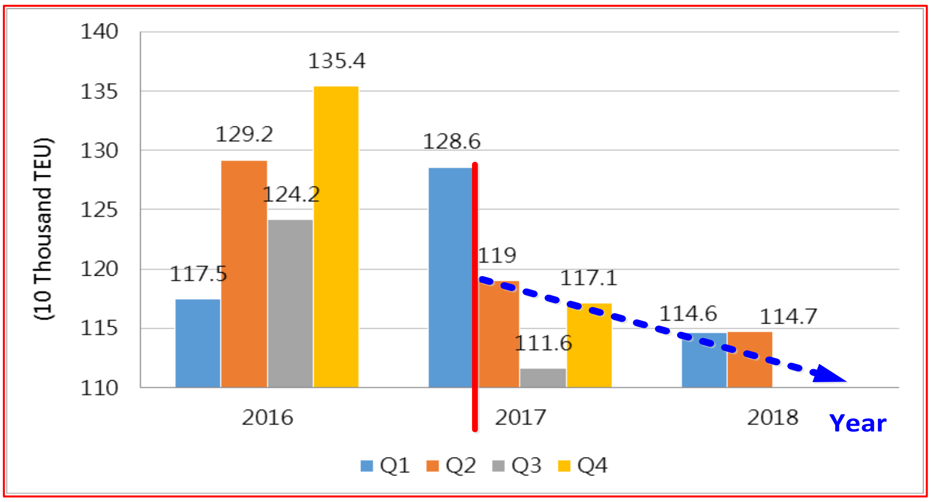


Figure 7: [Volume decline of transshipped containers at the Port of Kaohsiung following shipping alliance restructuring (Q2 2017)]

 ©2019: The Royal Institution of Naval Architects

3.3 DEPENDENCY OF KAOHSIUNG'S HUB POSITION ON SOUTHEAST ASIAN MARKETS

The Port of Kaohsiung provides transshipment between neighboring Southeast Asian countries as well as between these countries and the United States. As seen in Figure 8, in the past 5 years its transshipment markets have mostly been China, the United States, the Philippines, Vietnam, and Japan. However, after the restructuring of alliances in 2017. the decline in transshipment volume seen at the Port of Kaohsiung, as shown in Figure 7, also occurred in these five markets, particularly Vietnam and the Philippines.

Deep-water terminal construction and emerging economic power in neighboring countries, shipping alliance restructuring, and shipping carrier consolidation have affected how carriers strategize route deployment at the Port of Kaohsiung. To determine its transshipment status, mitigate the ongoing loss of transshipment containers, and expand into other container markets, the Port of Kaohsiung must comprehensively explore the port development situation in transshipment regions or countries and analyze changes in shipping company lines and the competitive strategies of neighboring hub ports, with the aim of accurately identifying markets of interest and securing container supplies from other regions (MOTC, 2016; MOTC, 2017). According to the operating policy of the new alliances formed in 2017 (Yap & Zahraei, 2018), an alliance member with mother ships that connect directly to neighboring ports in Southeast Asia no longer requires transshipment of its containers at Kaohsiung. Therefore, it's less likely to successfully convince other alliance members to continue using its transshipment services (Su, *et al.*, 2016; MOTC, 2017). At present, no mother ships berth directly at other small- to medium-sized ports in Southeast Asia, which means that Kaohsiung still has a chance to attract feeder lines, particularly from the Philippines and Vietnam, two countries near Taiwan that still possess a number of container ports, thus rendering them excellent primary targets for Kaohsiung.

Haiphong in Vietnam and the port of Manila in the Philippines, the two main countries supplying transshipment containers to Kaohsiung, were thus selected as research targets in this study. The T/P route departing from Los Angeles was adopted as an example, and Hong Kong, another transshipment hub in Southeast Asia that operates on the same route, was chosen as the subject of comparison. A comparative analysis was performed by calculating transshipment operating costs per TEU at Kaohsiung and Hong Kong, according to the capacity of mother ships operating on trunk routes and feeder-ships from feeder ports, as well as the required sailing distance, fuel, and handling efficiency in terminals. The data obtained were used to determine whether the Port of Kaohsiung retains competitive advantages on the T/P route for North America.

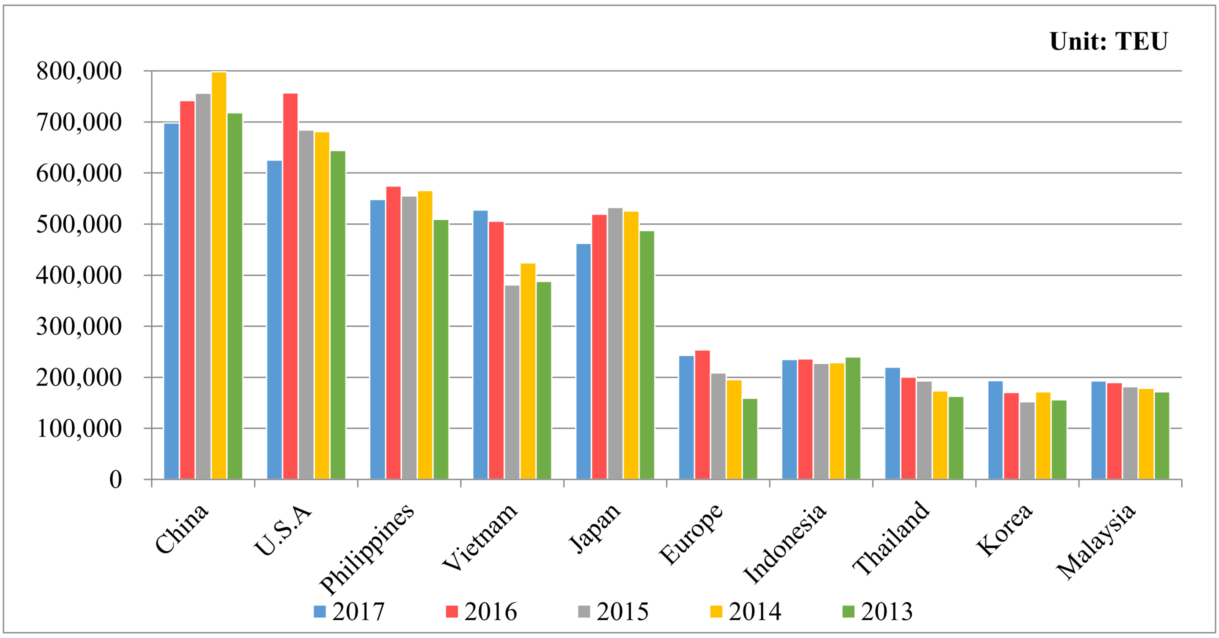


Figure 8: [Countries supplying transshipment containers to the Port of Kaohsiung during the past 5 years]
Data source: TIPC, 2018.

4. REFINED MODEL FOR ESTIMATING CONTAINER SHIP COST SAVINGS AT THE PORT OF KAOHSIUNG

T/P routes between Southeast Asia and North America cover a wide range of calling ports. Kaohsiung is highly dependent on transshipment containers from Vietnam and the Philippines. However, these containers can be transshipped at other nearby deep-water ports, such as Hong Kong, Shenzhen, or ports in southern Vietnam (Cai Mep). This study developed a container shipping cost model based on the East Asian trunk routes, ship-types, and operating conditions adopted by APL, YML, and OOCL in 2017. The model was used to compare Kaohsiung with neighboring transshipment ports to determine which of them have cost advantages and operating conditions that are able to attract route deployment and mother ship dockings.

4.1 CONTAINER SHIP OPERATING COSTS

The cost model in this study was developed on the basis of shipping carriers' operating costs when deploying container ships in the East Asian region. This model was first designed with reference to the different costs expended by shipping carriers, and then applied to different trunk and feeder routes. By means of comparative analysis, this study aimed to determine whether shipping carriers transporting containers could reduce costs more when transshipping at Kaohsiung than at other hub ports. This approach was equivalent to a simplified version of the hub port selection and trunk route deployment of shipping carriers.

Shipping carriers operating containerships incur two types of costs, namely, fixed and variable costs (Table 3). Numerous studies investigating fixed costs have enumerated a ship's capital costs, calculating the travel costs according to depreciation rate and service life and categorizing other fixed cost items under operating costs (see the items listed under "Fixed costs" in Table 3). Alternatively, annual maintenance and repair costs or costs expended on each voyage are listed separately under voyage costs, with other costs also included. Therefore, the definition of container shipping costs differs considerably among researchers (Tai & Lin, 2016; Asgari, Farahani & Goh, 2013; Stopford, 2009).

Because cost calculation is not so straightforward in practice, shipping carriers have their own methods of amortizing or calculating port fees. In research, multiple cost items must be omitted when analyzing shipping costs, or other methods are used to describe them (Hirata, 2017; Hsu, *et al*., 2017; Zheng, Fu, & Kuang, 2017; Tai & Lin, 2016; Asgari, Farahani, & Goh, 2013; Chang & Wang, 2010; Chang & Wang, 2012). Moreover, shipping carriers adopt their own preferred shipping lines, ship-types, calling ports, and container yards for handling operations. Unlike terminal operators, carriers may be confronted with highly varied cost calculation methods and combinations (Tai, 2002; Goss, 1985). For example, variable costs for the same type of ship may differ by carrier, voyage, shipping line, season, and fuel price. Ships docking in different terminals of the same port may incur substantially different costs depending on the time, location, and handling machinery and equipment. Some port costs can be avoided if a shipping carrier docks a container ship at its dedicated (or exclusive) terminal because such costs are thus categorized as fixed; for example, container yard (CY) and container freight station (CFS) rental, which covers a majority of the terminal handling costs that must be amortized. However, some amortized costs pertain to other operating expenses of container handling, in which case determining whether these are fixed or variable may be difficult.

Table 3: [The cost items of container ship]

Items	Contents	
Fixed costs	capital cost/wage/welfare/store/insurance/maintain and repair/depreciation/overhead cost/container & chassis rental/container & chassis depreciation; repair/lubricating oil/ CY & CFS rental	
Variable costs	fuel costs	FO (fuel oil or heavy oil; HO)/ DO (diesel oil)
	port costs	port expenses: customs/immigration/quarantine/dockage/pilotage in/out/towage/tugage/launch hire/ferry)/moorings/unmooring/anchorage/harbor dues/tonnage dues/berth dues/terminal expenses/
		stevedoring and handling expenses: loading/discharging/shifting/lashing/unlashing/ equipment hire/CY expenses/CFS expenses)/ transshipment expenses
	others costs	e.g. canal toll/ husbandry fee

Source: Tai & Lin (2016).

 ©2019: The Royal Institution of Naval Architects

Fuel costs are another example. Because different types of bunker products are used in various markets, shipping carriers must consider not only the substantial price difference between fuel and diesel oil (see Table 3), but also the fact that different types of ships with considerably varied carrying capacity consume similar amounts of oil. Therefore, the fuel cost per unit shipped (TEU or deadweight tonnage) varies substantially for different ship types (Tai & Lin, 2016; Chang & Wang, 2010). To construct an effective cost comparison model, fuel costs are listed separately, with the remaining items categorized as "time costs" generated during the ship's daily operations (time costs must be amortized) and "port costs" incurred during docking and container handling.

4.2 MODEL CONSTRUCTION AND DESCRIPTION

Table 4, Table 5 and Equation (1) illustrate the cost model estimation and notation methods adopted in this study, and include cost and time items for various container shipping operations. Container ships tend to generate considerably varying costs depending on the voyage characteristics (e.g., routes, loaded volume, cruising speed, fuel consumption, and port conditions). Variable costs include fuel costs, port expenses, stevedoring and handling expenses, and canal tolls, with fuel costs assuming the greatest proportion of total costs. When global oil prices rose to their peak in 2013, such costs accounted for as much as 15% to 25% of the total operating costs of container ships (Tai & Lin, 2016). In addition, a container ship consumes different amounts of fuel during ocean sailing, slow steaming (approaching a port), or maneuvering (docking at the port) (Chang & Wang, 2012; Tai & Lin, 2013). Therefore, this study used consumption both at port and during the voyage when calculating a ship's fuel costs (C_{Fuel}). Jansson and Shneerson (1982), examining the relationship between ship size and C_{Fuel}, found a nonlinear relationship expressed as $C_{Fuel} = F*T^{E}$, where F is a constant and E denotes the elasticity of fuel cost against ship size. According to data collected by Tai (2002) in Table 4, E ranges between 0.6 and 0.8, depending on ship size.

Regarding a ship's daily costs ($C_{Ship\text{-}daily}$), Tai (2002) referred to studies by Jansson and Shneerson (1982), Goss (1985), Heaver (1985), Morby (1985), and Stopford (1997) and combined the capital and operating costs of a ship as its daily costs to examine the relationship between ship size and $C_{Ship\text{-}daily}$. Tai (2002) also identified a nonlinear relationship, expressed as $C_{Ship\text{-}daily} = M*T^{N}$, where M is a constant and N denotes the elasticity of daily costs against ship size. According to data collected by Tai (2002), N ranges between 0.67 and 0.718.

Table 4: [Estimations of elasticity values]

The Elasticity against Vessel Type	A	B	E
Dry bulk vessel	0.67~0.70	0.4~0.6	0.8~1.0
Tanker	0.6~0.7	0.3~0.4	0.6~0.8
General cargo vessel	0.6~0.7	0.4~0.6	0.6~0.72
The Elasticity against Vessel Type	N		E
Container vessel	0.67~0.701		0.6~0.8
Container vessel (in this paper)	0.715		0.688

A: the elasticity of capital cost,
B: the elasticity of operating-cost,
E: the elasticity of fuel cost,
N: the elasticity of daily cost.
Source: Referred Tai (2002) with previous literatures and this study's data collection.

In the present study, data for the periods 2016 and 2017 were collected for six container ships operating on APL's NYE-route from Asia to North America, 11 container ships operating on YML's AW3-route, and 11 container ships operating on OOCL's routes of LP1 and CEC. These data were used to estimate the daily costs of ships traveling on different shipping lines. Daily costs comprised the ship's daily fixed costs, its variable costs during the voyage, and fuel costs. The exponential regression analysis results revealed that, because of the upsizing of container ships over the past 10 years, greater elasticity values of E = 0.688 and N = 0.715 were obtained in this study showed in Table 4. 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 cost of different shipping carriers.

For example, if a shipping carrier first transports outgoing containers from Haiphong (HP) to Los Angeles (LA) on a feeder-ship to Hong Kong (HK) and then uses the T/P route from Singapore via Hong Kong to transship these containers to Los Angeles, the average cost per TEU transported is $AC_{Hong\ Kong}$. Similarly, if these containers are transshipped to Los Angeles via the Port of Kaohsiung (Kao), then the average cost per TEU transported is $AC_{Kaohsiung}$.

Table 5: [Notations for cost model estimations]

Notations	Contents
AC_{I_k}	the average cost (US$/per TEU) for container carriers select I_k as hub-port on trunk-routes deployment. (e.g. I_1 is Hong Kong and I_2 is Kaohsiung)
AC_{SAVING}	The average cost-saving (US$/per TEU) for container carriers select I_1 as hub-port against I_2 on trunk-routes deployment.
C_{Fuel}	The total costs (US$) of vessel fuels (including HO and DO) for mother-ship sailing on trunk routes. $C_{Fuel}= F * T^E$; and T is the ship-size of mother vessel (TEU), F is constant, E is a elasticity for ship-size against fuel cost.
c_{Fuel}	The total costs (US$) of vessel fuels (including HO and DO) for feeder-ship sailing on regional and feeder routes. $c_{Fuel}= f * T^e$; and T is the ship-size of feeder vessel (TEU), f is constant, e is a elasticity for ship-size against fuel cost.
$C_{Ship\text{-}daily}$	The daily costs (US$) of mother-ship on trunk routes. $C_{Ship\text{-}daily} = M * T^N$; and T is the ship-size of mother vessel (TEU), M is constant, N is a elasticity for ship-size against daily cost.
$c_{Ship\text{-}daily}$	The daily costs (US$) of feeder-ship on regional and feeder routes. $c_{Ship\text{-}daily} = m * t^n$; and t is the ship-size of feeder vessel (TEU), m is constant, n is a elasticity for ship-size against daily cost.
$C^{I_k}_{Port}$	The total costs (US$) of port for mother-ship called on I_k port and handling in terminals.
$c^{i_k}_{Port}$	The total costs (US$) of port for feeder-ship called on i_k port and handling in terminals.
$D^{I_1\sim I_2}_{Sailing}$	The sailing time (days) of mother ship sailing from I_1-port to I_2-port, distance (nm; nautical mile)/(24*V), V is the speed of container ships (kt; nm/hour).
$d^{I_1\sim I_2}_{Sailing}$	The sailing time (days) of feeder ship sailing from i_1-port to i_2-port, distance (nm; nautical mile)/(24*V), V is the speed of container ships (kt; nm/hour).
T & t	The ship sizes (TEU) of mother ship (T) and feeder ship (t).
Q & q	The handling quantity of containers (TEU), Q=LF * T, q=LF * t, LF is the code name of loading-factor for each voyage.
R^I & r^i	The terminal gross handling efficiency R on I-port (or: r on i-port), consulting with terminal operators and showing that operators always using more than 4 gantry cranes once on a ship calling in most of hub-ports, the gross efficiency is more than 150 TEU/hour in in some mega-hub ports, and others just within the range of efficiency (100-120 TEU/hour). All these ones have a uniform efficiency 100 TEU/hour for hub ports (R), and 50 TEU/Hour for feeder ports (r).
$D^{I_k}_{Port}$	The port time (days) including terminal-waiting and handling time of mother ship in I_k-port, $Q/(24*R^I)$.
$d^{i_k}_{Port}$	The port time (days) including terminal-waiting and handling time of feeder ship in I_k-port, $Q/(24*r^i)$.

In Equation (1), $AC_{Saving} > 0$ means that a higher average unit cost is incurred when the T/P route is deployed via Hong Kong as the transshipment hub, compared with trunk route deployment via the Port of Kaohsiung; that is, transshipping through the Port of Kaohsiung is relatively more advantageous than through Hong Kong.

$$AC_{Saving} = AC_{HK} - AC_{Kao} \tag{1}$$

= (Average cost of per TEU on a feeder ship from HP to HK and then on a mother ship from HK to LA)

– (Average cost of per TEU on a feeder ship from HP to Kao and then on a mother ship from Kao to LA)

+ (Extraneous cost of per TEU for mother ship sailing from HK to Kao)

$$= \Big(\big[c_{Fuel} * d^{HP\sim HK}_{Sailing} + c_{Ship\text{-}daily} * (d^{HP\sim HK}_{Sailing} + d^{HP}_{Port} + d^{HK}_{Port}) + c^{HP}_{Port} + c^{HK}_{Port} \big] / q$$

$$+ \big[C_{Fuel} * D^{HK\sim LA}_{Sailing} + C_{Ship\text{-}daily} * (D^{HK\sim LA}_{Sailing} + D^{HK}_{Port} + D^{LA}_{Port}) + C^{HK}_{Port} + C^{LA}_{Port} \big] / Q \Big)$$

$$- \Big(\big[c_{Fuel} * d^{HP\sim Kao}_{Sailing} + c_{Ship\text{-}daily} * (d^{HP\sim Kao}_{Sailing} + d^{HP}_{Port} + d^{Kao}_{Port}) + c^{HP}_{Port} + c^{Kao}_{Port} \big] / q$$

$$+ \big[C_{Fuel} * D^{Kao\sim LA}_{Sailing} + C_{Ship\text{-}daily} * (D^{Kao\sim LA}_{Sailing} + D^{Kao}_{Port} + D^{LA}_{Port}) + C^{Kao}_{Port} + C^{LA}_{Port} \big] / Q \Big)$$

$$+ \big[C_{Fuel} * D^{HK\sim Kao}_{Sailing} + C_{Ship\text{-}daily} * D^{HK\sim Kao}_{Sailing} \big] / Q$$

 ©2019: The Royal Institution of Naval Architects

4.3 Case study on the T/P route

This study investigated the cost advantages of using the Port of Kaohsiung for transshipment, with Haiphong port (Vietnam) and Manila port (Philippines), the main transshipment markets of Kaohsiung at Southeast Asian and as this research targets. First, we analyzed the cost ($/per TEU) of transporting a container unit from Haiphong to Los Angeles on the eastbound T/P route, as shown in Figure 9-a. Next, we analyzed the unit transport cost of returning from North America (Los Angeles) to Asia (Manila) on the westbound T/P route, as shown in Figure 9-b. During calculation, the contents of Table 4 were substituted into Equation (1) to compare the relative cost advantages of using Hong Kong or Kaohsiung as the transshipment port. We further analyzed the effects of different influencing factors (e.g., ship-sizes of feeder and mother ship, loading-factor (LF) rate of mother ship, and handling efficiency of terminals at Kaohsiung) on shipping carriers' cost decisions when choosing Kaohsiung as a hub. The results are presented in the following sections.

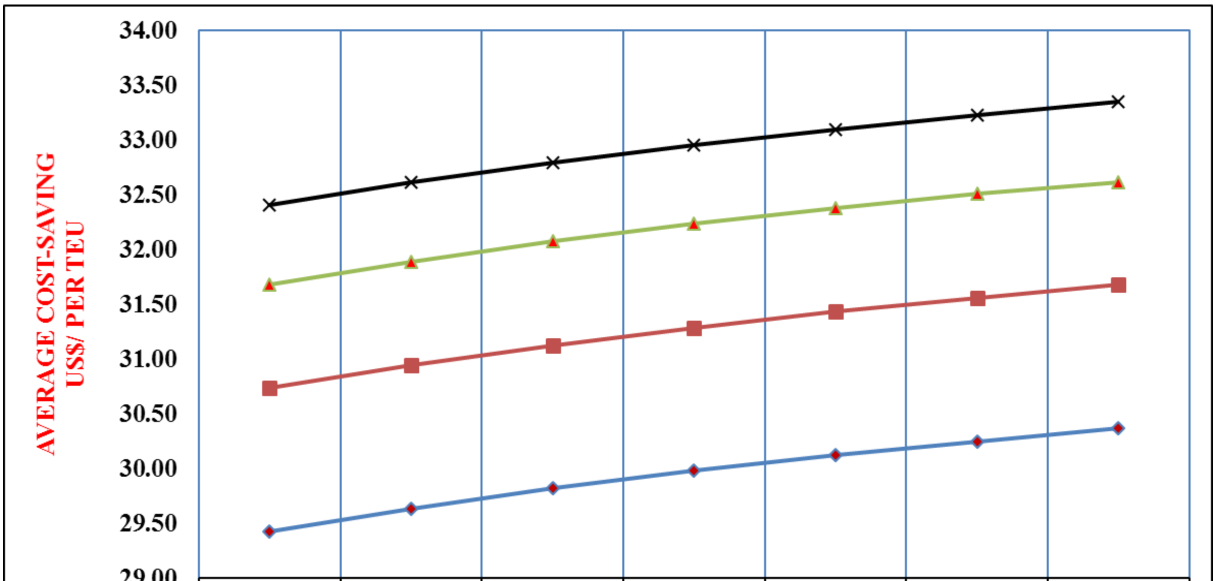
Figure 9: [Examples of two transshipment types (figure 9-a & figure 9-b)]

4.3 (a) Estimation results for Haiphong-Los Angeles (Figure 9-a)

a) A shipping carrier selecting Kaohsiung as its transshipment port has greater cost savings than one choosing Hong Kong. As seen in Figure 10, a carrier transshipping containers at the Port of Kaohsiung using a 8,000 TEU mother ship coupled with a 1,500 TEU feeder ship can save US$29.43 per TEU compared with transshipment in Hong Kong. In addition, if the containers are transported on the same mother ship type but on a larger feeder-ship, the cost savings are even greater (US$29.43 → US$32.41), indicating that Kaohsiung port is a more advantageous hub port than Hong Kong. Similarly, if the containers are transported on the same feeder-ship type but a larger mother ship, the Port of Kaohsiung is again a more advantageous hub port than Hong Kong. These results demonstrate that the Port of Kaohsiung requires an improved deep-water terminal to keep pace with ship upsizing and satisfy the docking requirements of large container ships.

b) An LF rate of 1.0 denotes that a ship is 100% loaded, supplying sufficient cargo resources to a port. The results shown in Figure 11 indicate that if the feeder-ship's size is fixed at 2,000 TEU and the mother ship at 8,000 TEU, and the LF increases (0.6 →0.9), then a shipping carrier transshipping at the Port of Kaohsiung saves less cost for each TEU (33.18 → 29.93). This result indicates that if neighboring ports have more sufficient cargo resources, shipping carriers enjoy fewer advantages in choosing the Port of Kaohsiung. However, compared with Hong Kong, the Port of Kaohsiung retains a cost advantage for transshipment on the T/P route for North America, which is explained through the remainder of the case study results.

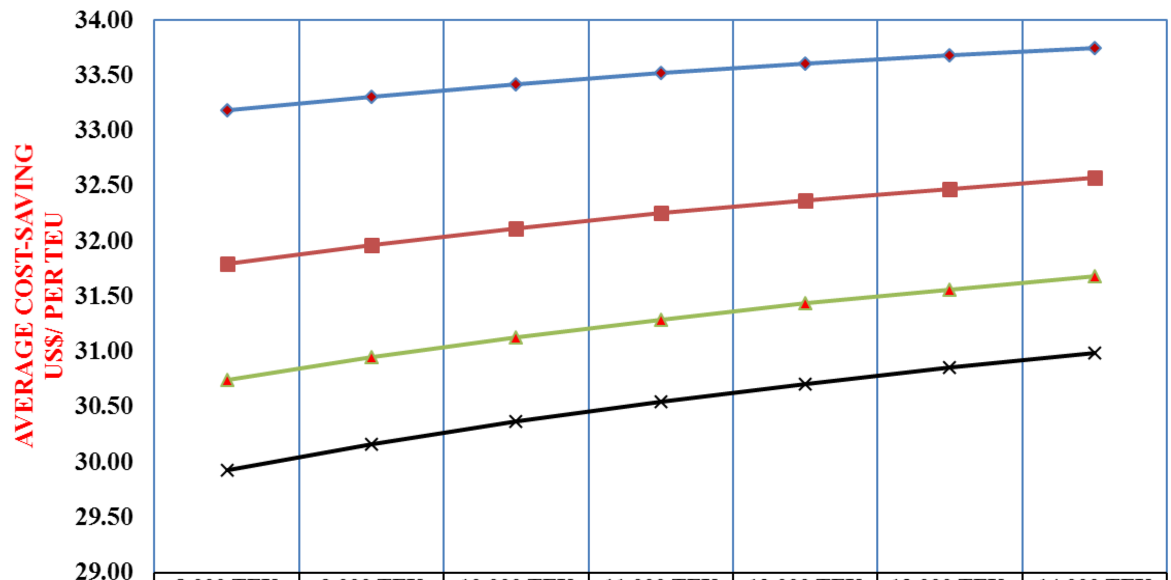
c) A high gross handling efficiency (R; TEU/per hour in terminal operating) indicates that a mother ship is berthed for a short amount of time, thus lowering operating time and costs and placing a shipping carrier at an operational advantage. As seen in Figure 12, if the feeder-ship's size is fixed at 2,000 TEU and the mother ship's at 8,000 TEU, and R increases (R = 100 → 130 TEU/per hour), then a carrier transshipping at Kaohsiung saves more cost for every TEU (30.74→40.31). This result indicates that high handling efficiency at Kaohsiung provides carriers with a greater cost advantage, particularly if they use a larger mother ship. In the future, the Port of Kaohsiung must be equipped with larger deep-water terminals (i.e., the seventh container terminal under construction), and larger handling machines and facilities should be installed to maintain the port's advantage as a regional hub.



	8,000 TEU	9,000 TEU	10,000 TEU	11,000 TEU	12,000 TEU	13,000 TEU	14,000 TEU
1,500 TEU	29.43	29.64	29.82	29.98	30.13	30.25	30.37
2,000 TEU	30.74	30.95	31.13	31.29	31.44	31.56	31.68
2,500 TEU	31.68	31.89	32.08	32.24	32.38	32.51	32.62
3,000 TEU	32.41	32.62	32.80	32.96	33.10	33.23	33.35

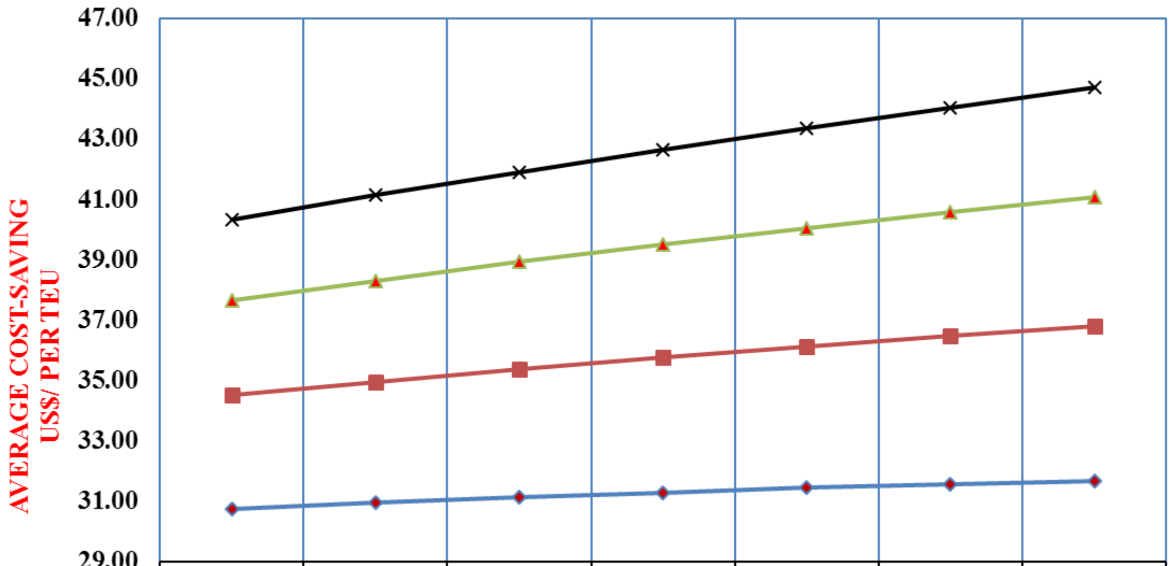
Figure 10: [Costs saved by shipping carriers transshipping at the Port of Kaohsiung (eastbound T/P)]

©2019: The Royal Institution of Naval Architects



	8,000 TEU	9,000 TEU	10,000 TEU	11,000 TEU	12,000 TEU	13,000 TEU	14,000 TEU
0.6LF	33.18	33.31	33.42	33.52	33.61	33.68	33.75
0.7LF	31.79	31.96	32.11	32.25	32.37	32.47	32.57
0.8LF	30.74	30.95	31.13	31.29	31.44	31.56	31.68
0.9LF	29.93	30.16	30.37	30.55	30.71	30.86	30.99

Figure 11: [Effects of mother ship's LF rate on cost-saving (eastbound T/P)]



	8,000 TEU	9,000 TEU	10,000 TEU	11,000 TEU	12,000 TEU	13,000 TEU	14,000 TEU
R	30.74	30.95	31.13	31.29	31.44	31.56	31.68
R+10%	34.51	34.96	35.38	35.77	36.13	36.48	36.80
R+20%	37.65	38.31	38.92	39.50	40.04	40.57	41.07
R+30%	40.31	41.14	41.91	42.65	43.36	44.03	44.69

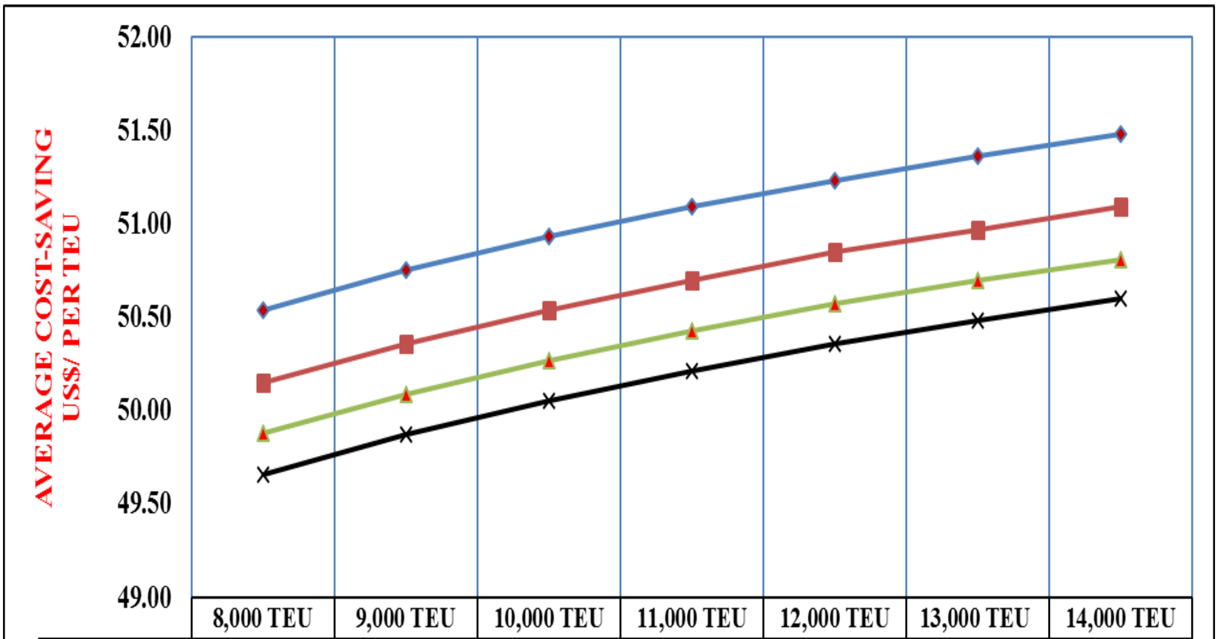
Figure 12: [Effects of Port of Kaohsiung handling efficiency on cost-saving (eastbound T/P)]

4.3 (b) Estimation results for Los Angeles-Manila (Figure 9-b):

a) As shown in Figure 13, a shipping carrier selecting Kaohsiung as its transshipment port on the westbound T/P route enjoys a greater cost advantage than one choosing Hong Kong. For example, a carrier transshipping containers at the Port of Kaohsiung using a 8,000 TEU mother ship coupled with a 1,500 TEU feeder ship can save US$50.54 per TEU compared with transshipment in Hong Kong. However, if the containers are transported on the same mother ship type but on a larger feeder-ship, the amount of cost saved does not change considerably. Similarly, if the containers are transported on the same feeder-ship type but a larger mother ship, the costs saved remain approximately the same. These results indicate that because the westbound T/P route is a return route it is essentially different from the eastbound T/P route, and therefore changes in ship size have a minimal influence on the shipping carriers' costs.

b) Figure 14 shows that if the feeder-ship's size is fixed at 2,000 TEU and the mother ship's at 8,000 TEU, and the LF increases (0.6 → 0.9) indicating increased cargo resources, then a shipping carrier transshipping at Kaohsiung saves less cost for each TEU (52.59→49.34). This result is similar to the aforementioned example on the eastbound T/P route, indicating that if neighboring ports have more sufficient cargo resources, shipping carriers enjoy fewer advantages in choosing Kaohsiung. Compared with Hong Kong, however, the Port of Kaohsiung still retains a cost advantage.

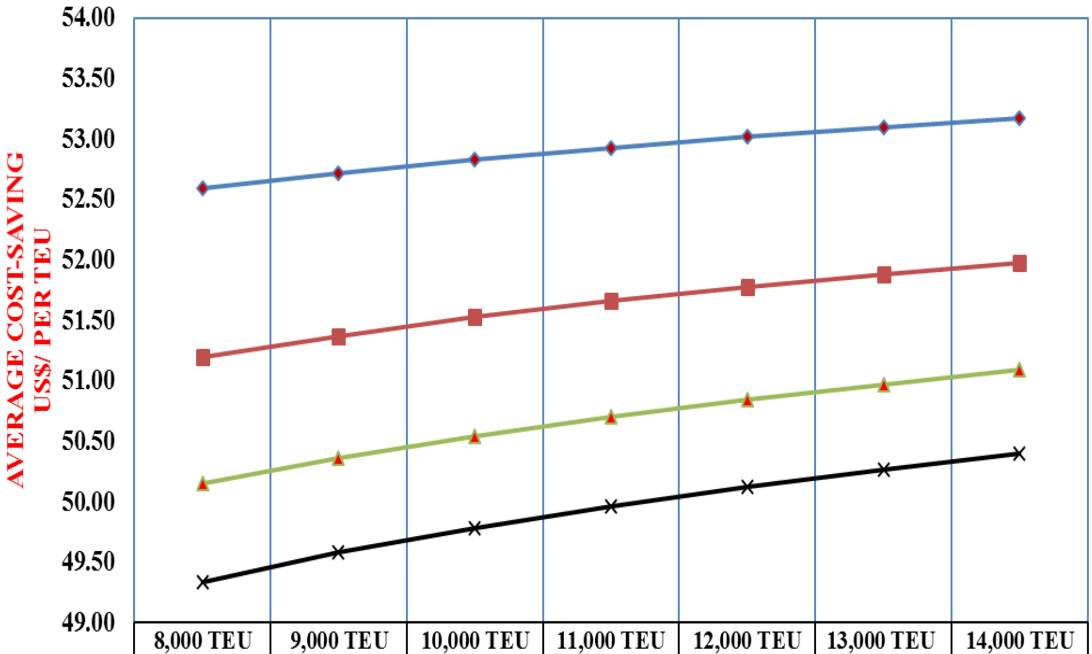
c) As shown in Figure 15, the analysis results for the westbound T/P route indicate that if the feeder-ship's size is fixed at 2,000 TEU and the mother ship's at 8,000 TEU, and R increases (R = 100 → 130 TEU/per hour), then a carrier transshipping at Kaohsiung saves more cost for each TEU (50.15→59.72). This result indicates that high handling efficiency and a larger mother ship favor selection of the Port of Kaohsiung. As already stated with regard to the result for the eastbound T/P route, Kaohsiung must build new deep-water terminals equipped with larger handling machines to maintain its advantage as a regional hub.



	8,000 TEU	9,000 TEU	10,000 TEU	11,000 TEU	12,000 TEU	13,000 TEU	14,000 TEU
1,500 TEU	50.54	50.75	50.93	51.09	51.23	51.36	51.48
2,000 TEU	50.15	50.36	50.54	50.70	50.85	50.97	51.09
2,500 TEU	49.88	50.09	50.27	50.43	50.57	50.70	50.81
3,000 TEU	49.66	49.87	50.05	50.21	50.36	50.48	50.60

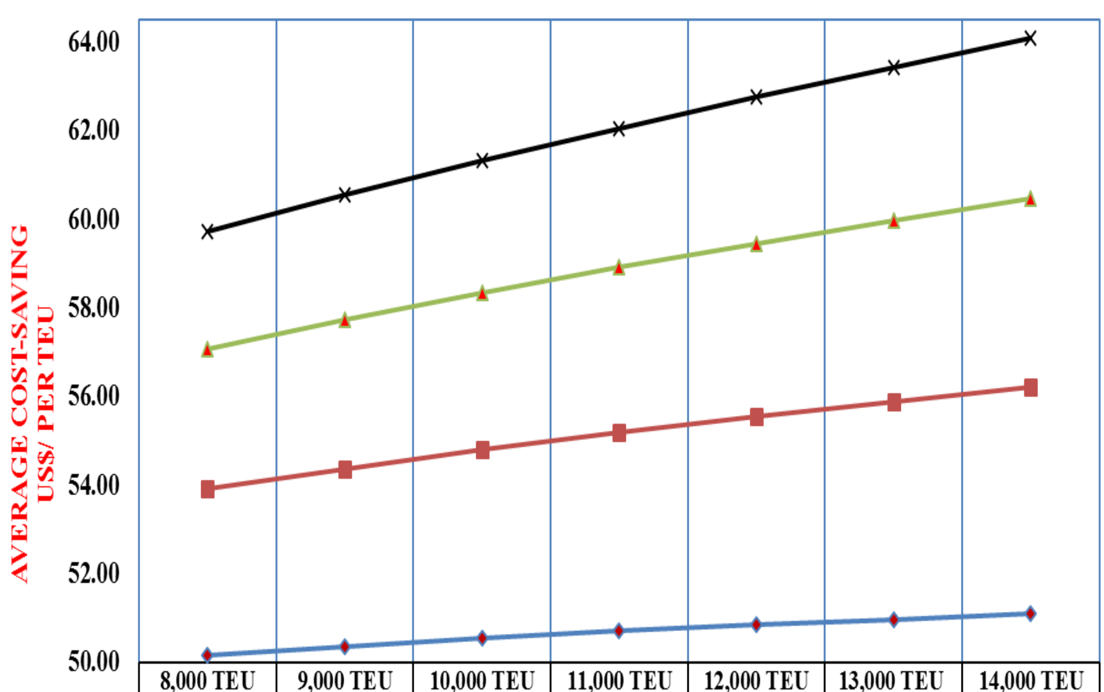
Figure 13: [Costs saved by shipping carriers transshipping at the Port of Kaohsiung (westbound T/P)]

©2019: The Royal Institution of Naval Architects



	8,000 TEU	9,000 TEU	10,000 TEU	11,000 TEU	12,000 TEU	13,000 TEU	14,000 TEU
0.6LF	52.59	52.72	52.83	52.93	53.02	53.10	53.17
0.7LF	51.20	51.37	51.53	51.66	51.78	51.88	51.98
0.8LF	50.15	50.36	50.54	50.70	50.85	50.97	51.09
0.9LF	49.34	49.58	49.78	49.96	50.12	50.27	50.40

Figure 14: [Effects of mother ship's LF rate on cost-saving (westbound T/P)]



	8,000 TEU	9,000 TEU	10,000 TEU	11,000 TEU	12,000 TEU	13,000 TEU	14,000 TEU
R	50.15	50.36	50.54	50.70	50.85	50.97	51.09
R+10%	53.92	54.37	54.79	55.18	55.54	55.89	56.21
R+20%	57.07	57.72	58.33	58.91	59.46	59.98	60.48
R+30%	59.72	60.55	61.32	62.06	62.77	63.44	64.10

Figure 15: [Effects of Port of Kaohsiung handling efficiency on cost-saving (westbound T/P)]

5. CONCLUSION

This study adopted the example of the Port of Kaohsiung to investigate the evolution of a regional hub port. Import/export cargo, affected mostly by local economy, was not included in discussion. Shipping carriers' operating costs were used to evaluate whether selected hub ports offered cost advantages for transshipment. In fact, a number of conventional container ports in East Asia, such as Hong Kong, Shenzhen, Xiamen, and Busan, are in a similar situation to Kaohsiung, characterized by changes in shipping line structure and a reduced number of trunk routes, the transformation of local industries, stagnating container volume growth, the upsizing of ships, and pressure from strategic alliances. Major conventional ports can maintain their hub position and prevent their decline only by contemplating various cost-related problems from the business perspective of shipping carriers and identifying means of attracting route deployments and container ships.

This study found that Kaohsiung has already been transformed from an intercontinental to a regional hub port, after facing external threats over the years (e.g., ship upsizing, lack of new deep-water terminals, and the impact of new strategic alliances on terminal operations). Kaohsiung has long since lost its connection to numerous Far East–Europe trunk routes even though it retains its geographical advantages and remains an attractive port on T/P trunk routes for North America. Although route deployments and port selections are based on shipping cost considerations, which vary according to container quantity and ship size, Kaohsiung remains lightly attractive and advantageous for container carriers operating on T/P routes.

At present, other international container ports in East Asia are far superior to the major container ports in Taiwan, whether in terms of terminal size, mechanical facilities, or resource abundance. Kaohsiung must strive to build new deep-water terminals and put its seventh container terminal into operation as soon as possible while enhancing the overall operating efficiency of its terminals. Such efforts are the key to attracting a continual supply of container ships and maintaining Kaohsiung's position as a regional hub port.

6. ACKNOWLEDGEMENTS

The authors would like to acknowledge the Ministry of Science and Technology, Taiwan, ROC, for providing partial funding under contract MOST 106-2410-H-022-004.

7. REFERENCES

1. ALPHALINER (2018) Monthly Monitor, August, 2018.
2. ASGARI, N., FARAHANI, R. Z. and GOH, M. (2013) *Network design approach for hub ports-shipping companies competition and cooperation*. Transportation Research, Part A, 48: 1-18.
3. CHANG, C. C. and WANG, C. M. (2010) *Assessment of the impact of a carbon tax on speed reductions and operating costs in shipping.* Transportation Planning Journal, 39(4): 441–460.
4. CHANG, C. C. and WANG, C. M. (2012) *Evaluation of the effects of green port policy: Case study of Kaohsiung harbor in Taiwan.* Transportation Research, Part D, 17(3): 185–189.
5. Directorate-General of Budget, Accounting and Statistics, Executive Yuan, R.O.C website: https://eng.dgbas.gov.tw/mp.asp?mp=2, last accessed in August 2018.
6. GOMEZ PAZ, M. A., ORIVE, A. C. and CANCELAS, N. G. (2015) *Use of the Delphi method to determine the constraints that affect the future size of large container ships*, Maritime Policy & Management, *Vol.* 42, No. 3, 263–277.
7. GOSS, R. O. (1985) *Ship costs: the overall problem and some solutions*, Maritime Policy and Management, Vol.12, *No*.1, pp.1-8.
8. HEAVER, T. D. (1985) *The treatment of ships' operating costs*, Maritime Policy and Management, Vol.12, *No*.1, pp.35-46.
9. HIRATA, E. (2017) *Contestability of container liner shipping market in alliance era*, The Asian Journal of Shipping and Logistics, 33(1) ,027-032.
10. HSU, S. K., LAI, W. S., HSU, H. H., CHEN, C. Y., TAI, H. H., LEE, Y., LEE, W. H., LIN, D. Y. and HUANG, K. L. (2017) *A strategic network model for global container shipping trend*. Transportation Planning Journal, 46(3): 269-292.
11. JANSSON, J. O. and SHNEERSON, D. (1982) *Port Economics*, The MIT press.
12. MERKEL, A. (2018) *Competitive intensity and inefficiency in European container ports: An empirical investigation using SFA*, Maritime Business Review, Vol 3, Issue: 2, 2018.
13. MORBY, D. H. (1985) *Crew costs*, Maritime Policy and Management, Vol.12, No.1, pp.55-60.
14. MINISTER OF TRANSPORTATION AND COMMUNICATION (MOTC) (2013) *A Study of the Mode for Operation of Taiwanese Container Ports in Response to Environmental Changes. MOTC, MOTC-IOT-101-H1DB001a,*

 ©2019: The Royal Institution of Naval Architects

Institute of Transportation, Taiwan.
15. MINISTER OF TRANSPORTATION AND COMMUNICATION (MOTC) (2016) *A Study of Adaptive Capacity Strengthened for Taiwan Container Ports*. *MOTC, MOTC-IOT-104-H1DB005a,* Institute of Transportation, Taiwan.
16. MINISTER OF TRANSPORTATION AND COMMUNICATION (MOTC) (2017) *A Study of Operational Trend and Capacity Utilized for Taiwan Container Terminals. MOTC, MOTC-IOT-105-H1DA005a*, Institute of Transportation, Taiwan.
17. STOPFORD, M. (2009) *Maritime Economics,* 3rd Edition, Routledge, London and New York.
18. STOPFORD, M. (1997) *Maritime Economics*, 2nd Edition, Routledge, London.
19. SU, D. T., HSIEH, C. H. and TAI, H. H. (2016) *Container hub-port vulnerability: Hong Kong, Kaohsiung, and Xiamen*, Journal of Marine Engineering and Technology, 15, Issue 1, January 2016, 19-30.
20. TAI, H. H. (2002) *Comparative analyses of costs among hub ports selection in West-Pacific Rim：application of ACS model*. Transportation Planning Journal, 14 (4): 421-442.
21. TAI, H. H. (2012) *The influence on transshipment function of Kaohsiung port by the trunk-route developments in the East Asia and Cross-strait direct shipping*. Transportation Planning Journal, 41 (4): 435-463.
22. TAI, H. H. (2015) *A comparative study on pollutant emissions and hub-port selection in Panama Canal expansion*, Maritime Economics and Logistics, Vol. 17, 2, 163-178.
23. TAI, H. H. and YANG, C. C. (2016) *A policy-making framework for enhancing Kaohsiung port's economic resilience.* International Journal of Maritime Engineering, 158(A4), A-347-A-358.
24. TAI, H. H. and LIN, D. Y. (2013) *Comparing the unit emissions of daily frequency and slow steaming strategies on trunk route deployment in international container shipping.* Transportation Research Part D: Transport and Environment, 21: 26-31.
25. TAI, H. H. and LIN, D. Y. (2016) *The Impact of trunk route deployment changes on pollutant emissions in international container shipping after Panama Canal expansion*, International Journal of Logistics Management (IJLM), Vol. 27, Issue 2. Article No: - IJLM 584086. 2016.6.30.
26. UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT (2018) *Review of maritime transport 2018*. United Nations, New York.
27. YAP, W. Y. and ZAHRAEI, S. M. (2018) *Liner shipping alliances and their impact on shipping connectivity in Southeast Asia*, Maritime Business Review, Earlycite, 2018.
28. ZHENG, J., FU, C. and KUANG, H. (2017) *Location of regional and international hub ports in liner shipping*, Maritime Business Review, Vol: 2 Issue: 2, 2017.