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BREAK-EVEN ANALYSIS OF FUEL CONSUMPTION FOR SHIPS SAILING THROUGH THE SUEZ CANAL OR THE CAPE OF GOOD HOPE

Ming-Tao Chou[1], Yu-Ping Hsu[2] and Yuan-Tai Chang[3]

Key words: Suez Canal; Cape of Good Hope sea route; fuel efficiency.

ABSTRACT

This study calculates the navigation efficiency for sailing through the Suez Canal and Cape of Good Hope. To this end, navigation efficiency was derived from the fuel consumption ratio and greenhouse gas emission levels. The research aims at identifying the travel costs of sailing to Rotterdam in Europe through the Suez Canal and Cape of Good Hope and proposing suggestions and policies based on the results. The preliminary research results show that the fuel consumption saved for the ship sailing through Suez Canal from the highest to the lowest is Singapore > Hong Kong > Kaohsiung > Shanghai > Busan; the carbon emission saved for the ship sailing through Suez Canal from the highest to the lowest is Singapore > Hong Kong > Kaohsiung > Shanghai > Busan. The higher the ratio of fuel consumption, the lower the navigation efficiency for the ship sailing through Suez Canal; thus, more fuel was consumed, and travel costs were higher. On the contrary, the lower the ratio, the higher the navigation efficiency; that is, less fuel was consumed, and travel costs were lower, which is relatively environment-friendly.

I. INTRODUCTION

Given the fierce competition in the shipping industry and the emergence of larger-sized vessels, controlling cargo and fuel costs becomes a key factor in operating regular ocean carriers. For instance, it is important for ocean carriers to make good use of resources (Wernerfelt). Because China is now the global production center, most products are produced in China and shipped to the rest of world (Verny and Grigentin, 2009). For instance, if a ship is to travel from Asia to Europe, the distance and time will be the determining factors, provided the quantity of cargo is sufficient, which makes it more likely for the ship to travel through Suez Canal despite the higher tolls. However, on the return trip, cost efficiency is a priority owing to the low quantity of cargo, and a sea route in the southern end of Africa may be used instead (Suez Canal Authority, 2017). For trips from Asia to Europe, most ocean carriers choose to sail through Suez Canal, as the route not only features mesmerizing geographic locations but is also the most time efficient and shortest path, which is appealing to carriers. The short distance and low fuel consumption compared to the African route can dramatically reduce the cost of fuel for ocean carriers. For instance, the newly created North Pole route, thanks to the melted ice in summer, shows that the analysis of route efficiency is often a key factor (Xu et al., 2011).

The fuel cost accounts for 50–70% of the operating cost for ships (Chia and Xiao, 2012). Since the distance of navigation and fuel consumption are positively correlated, the higher the distance, the more fuel is consumed. Therefore, fuel costs have become an increasingly important factor to ocean carriers in terms of control and evaluation (Lin and Chang, 2018). Nowadays, oil prices are affected by new technologies and international trends. The fluctuation of oil prices tends to affect the cost and service of shipping companies (Oriental Securities Investment Advisory Co., 2017). Assuming other conditions remain unchanged, when fuel price increases, the total revenue decreases if the freight income remains the same, and vice versa (8. The Transportation Logistics Company,2016). Thus, to obtain long-term interests and competitive advantages, relevant strategies should be adopted (Porter, 1985).

The primary subject of this research is Evergreen Marine Corp's ship, EVER LINKING (Maritime Traffic,2017), which sails from major ports of Asia to the port of Rotterdam in the Netherlands. This case study mainly identifies whether oil

Paper submitted 07/23/19; revised 09/10/19; accepted 05/07/20. Corresponding Author: Ming-Tao Chou (Email: mtchou@mail.cjcu.edu.tw)
[1] *Department of Aviation and Maritime Transportation Management, Chang Jung Christian University, Tainan, Taiwan R.O.C.*
[2] *Department of Tourism, Food and Beverage Management, Chang Jung Christian University, Tainan, Taiwan R.O.C.*
[3] *Department of Aviation and Maritime Transportation Management, Chang Jung Christian University, Tainan, Taiwan R.O.C.*

prices affect the ocean carrier's assessment of different routes and decision-making. The analysis result will help ocean carriers select the optimal route while taking into consideration the changes in international oil prices and the quantity of cargo. The major Asian ports selected in this paper are Busan, Kaohsiung, Shanghai, Hong Kong, and Singapore, which are divided into two groups for analytical purposes: through the Suez Canal to Europe or through the Cape of Good Hope route.

II. LITERATURE REVIEW

This chapter, using literature review, introduces the Suez Canal and Cape of Good Hope routes, in addition to exploring the fuel and cost efficiency of vessels. The shortest route from Asia to Europe is the one from Red Sea to the Mediterranean through Suez Canal. The Suez Canal passes through the Gulf of Aden, which is located at the southeastern exit of the Mediterranean and is known as "the heart of world strategy" by westerners. On its west lie the Aden and Djibouti ports—the two transit and strategic ports for fuel replenishment and trade. They are also the ports that ships sailing through the Suez Canal must pass through. Since the opening of the Suez Canal, the distance between the Atlantic and Pacific oceans through the Mediterranean Sea and Indian Ocean has considerably shortened. Although the Suez Canal has a high-priced toll, its services are highly adequate, which can save time and shorten the navigation range, thereby reducing oil consumption and carbon emission levels (Fletcher, 1958; Griffiths, 1995; Gkonis and Psaraftis, 2017; Hua, 2005; Guo et al., 2012; Zheng et al., 2015; Dragović et al., 2018; Wang and Wei, 2014). The Suez Canal is superior to the Cape route in terms of navigation conditions. Sawtooth waves are commonly seen along the Cape of Good Hope route, which could easily cause fractures in vessels and make navigating the route less safe. Therefore, the Suez Canal has become one of the most frequently used sea routes in the world.

The route through the Cape of Good Hope in Africa is known as the Cape route, which refers to the port routes from Asia to Europe through the southernmost tip of Africa—the Cape. Before the Suez Canal's opening, this route was the most frequently used route that connected Europe to Asia. Because large ships with a capacity of more than 250,000 tons cannot pass through the Suez Canal, ships such as large oil tankers still use the Cape route to get to Europe for trading purposes (Suez Canal Authority, 2017). Generally, the criteria of route planning are primarily based on the objectives of "saving operation cost" and meeting "actual container transportation demand." Therefore, the Suez Canal is usually considered as the basis for route planning (Wang and Wei, 2014).

In this study, the 8,508-TEU ship of Evergreen Marine is selected. The engine used in this ship is MAN B&W 9K98ME7.1, with a horsepower of 56,070 kW and 97 rpm. The fuel consumption rate is 174g/kWh under normal conditions (Taim 2011) and the trend of crude oil prices from 2014 to 2017 is decrement (Marine Engines and System, 2014; Bureau of Energy, 2016). Based on the assumption that the price of a barrel of crude oil ranges 30–70 US dollars, the break-even analysis is carried out by considering the profit earned from the loading of containers. If the cargo quantity for the ship navigating through the Suez Canal fails to reach the break-even point, it may result in a loss for the ocean carrier. This study explores whether sailing through the Cape route, instead of the Suez Canal, can be an alternative route for ocean carriers to reach the break-even point.

III. RESEARCH METHODS

This study uses the 8,508-TEU ship of Evergreen Marine that has the gross tonnage of 99,946, maximum speed of 24.5 knots, and average speed of 14.8 knots. The ship's engine is MAN 9K98ME7-1, with a fuel consumption rate of 174g/kWh (Tai, 2011). The price range is set between 30 and 70 US dollars per barrel of crude oil (7 barrels are around 1 ton of crude oil), and the formula proposed by Chou et al.(2017) is adopted. It is assumed that the freight charge for ships from Asia to Europe in 2017 is about 1,000 or 1,200 USD per TEU. Using the fuel consumption formula, the fuel consumption rate and the fuel required by the distance are calculated. The sensitivity analysis of the increase in the variable oil prices is then conducted to analyze the profit and loss resulting from ships sailing through the two routes.

The formula indicates the two different routes: the Suez Canal and the Cape of Good Hope. B in formula (1) stands for the fuel consumption per voyage (ton/per unit) from Busan to Rotterdam through the Suez Canal. H stands for the maximum horsepower of the ship (unit: kW). C_1 represents the engine fuel consumption factor, which is 174g/kWh per 24 hours. T, sailing time, is approximately equal to (distance ÷ speed)/24 (unit: day). AS and MS are the average speed and maximum speed (unit: nautical mile/hr). C_2, the CO_2 emission coefficient of a single voyage is 74.1, which is the recommended coefficient of the reference diesel fuel emission, 74,100 $kgCO_2/TJ$ (1.0=100%) (International Energy Agency, 2017).

The formula used to calculate the fuel consumption is as follows:

$$\mathbf{B=H*C_1*24*T*(AS/MS)} \tag{1}$$

$$\mathbf{E=B*C_2} \tag{2}$$

The definitions are listed as follows:

B	Fuel consumption per voyage
C_1	Engine fuel consumption factor
H	Maximum horsepower
T	Voyage time (days)
AS	Average speed
MS	Maximum speed
E	CO_2 emission per voyage
C_2	CO_2 emission factor

Table 1. Routes through the Suez Canal and the Cape of Good Hope

Through Suez Canal (Through Cape of Good Hope)	Distance (knots)	Average speed (knots)	Voyage time (days)	Fuel consumption (tons)	Fuel consumption per day (tons)	Fuel consumption per TEU (tons)
Busan– Rotterdam	1,0824.42 (14,108.94)	14.8 knots	30.47 (39.72)	7,135.47	234.15	0.84 (1.09)
Shanghai– Rotterdam	10,483.75 (13,795.03)	14.8 knots	29.52 (38.84)	6,910.90	234.15	0.81 (1.07)
Kaohsiung–Rotter-dam	9,993.06 (11,790.59)	14.8 knots	28.13 (37.38)	6,587.44	234.15	0.77 (1.03)
Hong Kong–Rotter-dam	9,781.57 (13,099.24)	14.8 knots	27.54 (36.88)	6,448.02	234.15	0.76 (1.01)
Singapore–Rotterdam	8,321.15 (11,790.59)	14.8 knots	23.43 (33.19)	5,485.31	234.15	0.64 (0.91)

Source: International Container Shipping Sea Rate, 2017.

Table 2. Actual Fuel Consumption

Through Suez Canal (Through Cape of Good Hope)	Actual fuel consumption (tons)	Actual fuel consumption per TEU	CO2 emission (tons)	CO2 emission per TEU (tons)
Busan–Rotterdam	4,310.41 (5,618.34)	0.51 (0.66)	13,743.26 (17,901.72)	1.61 (2.10)
Shanghai–Rotterdam	4,174.75 (5,493.34)	0.49 (0.65)	13,302.01 (17,503.43)	1.56 (2.06)
Kaohsiung–Rotterdam	3,979.35 (5,287.12)	0.47 (0.62)	12,679.40 (16,846.35)	1.49 (1.98)
Hong Kong–Rotterdam	3,895.13 (5,216.27)	0.46 (0.61)	12,411.05 (16,620.60)	1.46 (1.95)
Singapore–Rotterdam	3,313.58 (4,695.15)	0.39 (0.55)	10,558.06 (14,960.16)	1.24 (1.76)

IV. EMPIRICAL ANALYSIS

The case study mainly focuses on Evergreen Marine's 8,508-TEU container ship, which uses the engine of the MAN 9K98ME7-1 model; the fuel consumption of the ship sailing to various ports in Asia is calculated. The distance and time required to sail from Busan port to Rotterdam port through the Suez Canal are used as the calculation criteria for evaluating the fuel consumption and carbon emissions of the ship's engine as well as for analyzing the cost of having a ship sail through the Suez Canal.

Assuming that other conditions remain unchanged, fuel consumption B and carbon emissions E for the voyage through the Suez Canal from Busan to Rotterdam are used to calculate the result. Given the following conditions—maximum speed: 24.5 knots, average speed: 14.8 knots, maximum horsepower: 56,070kw, and engine fuel consumption factor: 174g/kWh—the sailing time can be calculated by dividing the sailing distance between the two ports by the sailing speed (14.8 knots) (Chou et al., 2017).

Table 1 shows the time, distance, speed, and fuel consumption of the routes from different ports in Asia to Europe through the Suez Canal and the Cape of Good Hope. Take the voyage from Busan port to Rotterdam port through the Suez Canal as an example, wherein the maximum horsepower of the ship is 56,070kw. Based on its maximum horsepower, the fuel consumption per day is 56,070*174*24/1,000,000 =234.15 (tons), the fuel consumption for a voyage is 234.15*30.47=7,135.47 (tons), and the fuel consumption (ton) per TEU is 7,135.47/8,508=0.84 (the ship used in this study features 8,508 TEUs). In other words, the fuel consumption per TEU is 0.84 tons.

Table 1 is based on the maximum fuel consumption; however, in practice, the ship does not sail at the maximum speed. Therefore, the estimated fuel consumption must be multiplied by the weight value; that is, the average speed is divided by the maximum speed to calculate the fuel consumption.

Table 2 shows the actual fuel consumption of the route from Busan port to Rotterdam port. The fuel consumption based on the maximum horsepower is 7,135.47; the maximum speed of the ship is 24.5 knots; and the average speed is 14.8 knots. According to the formula actual fuel consumption (tons) = fuel-consumption (tons) * (average sailing speed/maximum speed), the result is 7,135.47* weight (14.8/24.5) = 4,310.41 tons. Thus, the actual fuel consumption of the route from Busan to Rotterdam is 4,310.41 tons. The actual fuel consumption is divided by the ship's TEUs to calculate the actual fuel consumption per TEU: 4,310.41/8,508=0.51 tons. In terms of carbon emissions of diesel engines, the carbon dioxide emission coefficient is 74.1 (Zheng et al., 2015). Based on the actual

Table 3. Ratio of Actual Fuel Consumption

	Busan– Rotterdam	Shanghai–Rotterdam	Kaohsiung–Rotterdam	Hong Kong–Rotterdam	Singapore–Rotterdam
Ratio of fuel consumption	0.772	0.753	0.758	0.754	0.709

Table 4. Break-even Point for Ships Sailing through the Suez Canal

The revenue is 1,000 USD per TEU for the Suez Canal route.										
Oil price (USD)	Busan–Rotterdam		Shanghai–Rotterdam		Kaohsiung–Rotterdam		Hong Kong–Rotterdam		Singapore–Rotterdam	
	Break-even point (TEU)	Propor-tion of loaded cargo	Break-even point (TEU)	Propor-tion of loaded cargo	Break-even point (TEU)	Propor-tion of loaded cargo	Break-even point (TEU)	Propor-tion of loaded cargo	Break-even point (TEU)	Propor-tion of loaded cargo
30	1,653.6	19%	1,625.1	19%	1,584.1	19%	1,566.4	18%	1,444.2	17%
40	1,955.3	23%	1,917.3	23%	1,862.6	22%	1,839.0	22%	1,676.2	20%
50	2,257.0	27%	2,209.6	26%	2,141.2	25%	2,111.7	25%	1,908.1	22%
60	2,558.8	30%	2,501.8	29%	2,419.7	28%	2,384.4	28%	2,140.1	25%
70	2,860.5	34%	2,794.0	33%	2,698.3	32%	2,657.0	31%	2,372.1	28%

Table 5. Break-even Point for Ships Sailing through Cape of Good Hope

The revenue is 1,000 USD per TEU for the Cape route.										
Oil price (USD)	Busan–Rotterdam		Shanghai–Rotterdam		Kaohsiung–Rotterdam		Hong Kong–Rotter-dam		Singapore–Rotterdam	
	Break-even point (TEU)	Propor-tion of loaded cargo	Break-even point (TEU)	Propor-tion of loaded cargo	Break-even point (TEU)	Propor-tion of loaded cargo	Break-even point (TEU)	Propor-tion of loaded cargo	Break-even point (TEU)	Propor-tion of loaded cargo
30	1,179.9	14%	1,153.6	14%	1,110.3	13%	1,095.4	13%	986.0	12%
40	1,573.1	18%	1,538.1	18%	1,480.4	17%	1,460.6	17%	1,314.6	15%
50	1,966.4	23%	1,922.7	23%	1,850.5	22%	1,825.7	21%	1,643.3	19%
60	2,359.7	28%	2,307.2	27%	2,220.6	26%	2,190.8	26%	1,972.0	23%
70	2,753.0	32%	2,691.7	32%	2,590.7	30%	2,556.0	30%	2,300.6	27%

fuel consumption *74.1*0.043, the formula calculating the carbon dioxide emission is 4,310.41*74.1*0.043=13,743.26 tons. Because the CO_2 emissions per TEU are the actual fuel consumption per TEU*74.1*0.043, the CO_2 emissions per TEU can be calculated using the following formula: (0.51*74.1*0.043) = 1.63 tons.

The calculated ratios of fuel consumption listed in Table 3 display the navigation efficiency. The actual fuel consumption per TEU from Asia to Europe through the Suez Canal is divided by the actual fuel consumption per TEU from Europe to Asia through the Cape of Good Hope so as to obtain the ratio of actual fuel consumption. Take the Busan–Rotterdam route as an example: 0.51/0.66=0.772. Thus, the higher the ratio, the lower the efficiency of sailing through the Suez Canal, and more fuel is consumed. On the contrary, the lower the ratio, the higher the navigation efficiency, and less oil is required.

4.1. Amount of fuel consumption

According to the results of this study, the fuel consumption for the ship sailing from various ports in Asia to the European ports through the Suez Canal is as follows: 4,310.41 (tons) for Busan; 4,174.75 (tons) for Shanghai; 3,979.35 (tons) for Kaohsiung; 3,895.13 (tons) for Hong Kong; and 3,313.58 (tons) for Singapore. The fuel consumption for the ship sailing

Table 6. Break-even Point for Ships Sailing through Suez Canal

The revenue is 1,200 USD per TEU for the Suez Canal route.										
Oil price (USD)	Busan–Rotterdam		Shanghai–Rotterdam		Kaohsiung–Rotterdam		Hong Kong–Rotterdam		Singapore–Rotterdam	
	Break-even point (TEU)	Proportion of loaded cargo	Break-even point (TEU)	Proportion of loaded cargo	Break-even point (TEU)	Proportion of loaded cargo	Break-even point (TEU)	Proportion of loaded cargo	Break-even point (TEU)	Proportion of loaded cargo
30	1,378.0	16%	1,354.2	16%	1,320.0	16%	1305.3	15%	1,203.5	14%
40	1,629.4	19%	1,597.8	19%	1,552.2	18%	1532.5	18%	1,396.8	16%
50	1,880.9	22%	1,841.3	22%	1,784.3	21%	1759.7	21%	1,590.1	19%
60	2,132.3	25%	2,084.8	25%	2,016.4	24%	1987.0	23%	1,783.4	21%
70	2,383.7	28%	2,328.4	27%	2,248.6	26%	2214.2	26%	1,976.7	23%

Table 7. Break-even Point for Ships Sailing through Cape of Good Hope

The revenue is 1,200 USD per TEU for Cape route.										
Oil price (USD)	Busan–Rotterdam		Shanghai–Rotterdam		Kaohsiung–Rotterdam		Hong Kong–Rotterdam		Singapore–Rotterdam	
	Break-even point (TEU)	Proportion of loaded cargo	Break-even point (TEU)	Proportion of loaded cargo	Break-even point (TEU)	Proportion of loaded cargo	Break-even point (TEU)	Proportion of loaded cargo	Break-even point (TEU)	Proportion of loaded cargo
30	983.2	12%	961.3	11%	925.2	11%	912.8	11%	821.7	10%
40	1,310.9	15%	1,281.8	15%	1,233.7	15%	1,217.1	14%	1095.5	13%
50	1,638.7	19%	1,602.2	19%	1,542.1	18%	1,521.4	18%	1369.4	16%
60	1,966.4	23%	1,922.7	23%	1,850.5	22%	1,825.7	21%	1643.3	19%
70	2,294.2	27%	2,243.1	26%	2,158.9	25%	2,130.0	25%	1917.2	23%

Table 8. Range of Break-even Point for Different Loaded Cargo

	Busan–Rotterdam	Shanghai–Rotterdam	Kaohsiung–Rotterdam	Hong Kong–Rotterdam	Singapore–Rotterdam
Through Suez Canal	16%~34%	16~33%	16%~32%	15%~31%	14%~28%
Through Cape route	12%~32%	11%~32%	11%~30%	11%~30%	10%~27%

through the Cape of Good Hope in South Africa is as follows: 5,618.34 (tons) for Busan; 5493.34 (tons) for Shanghai; 5,287.12 (tons) for Kaohsiung; 5,215.27 (tons) for Hong Kong; and 4,695.15 (tons) for Singapore.

Therefore, according to the fuel calculation results, navigating through the Suez Canal can save fuels for Singapore > Hong Kong > Kaohsiung > Shanghai > Busan.

4.2. Carbon emission

According to the fuel emission coefficients released by Bureau of Energy, Ministry of Economic Affairs (2016) and the fuel consumption and carbon dioxide emission coefficients, the research results show that carbon dioxide emissions resulting from sailing through the Suez Canal are 13,734.26 (tons) for Busan; 13,302.00 (tons) for Shanghai; 12,679.41 (tons) for Kaohsiung; 12,411.06 (tons) for Hong Kong; and 10,588.05 (tons) for Singapore. Carbon dioxide emissions resulting from sailing through the Cape of Good Hope are 17,901.72 (tons) for Busan; 17,503.42 (tons) for Shanghai; 16,846.34 (tons) for Kaohsiung; 16,620.59 (tons) for Hong Kong; and 14,960.15 (tons) for Singapore. The saved carbon emissions for the ship sailing through the Suez Canal are 4,167.47 (tons) for Busan;

4,201.40 (tons) for Shanghai; 4,166.92 (tons) for Kaohsiung; 4,209.53 (tons) for Hong Kong; and 4,402.08 (tons) for Singapore.

Therefore, sailing through the Suez Canal can save carbon emissions for Singapore > Hong Kong > Kaohsiung > Shanghai > Busan.

Based on these results, it is understood that the distance traveled will affect fuel consumption and carbon dioxide emissions as well as reflect in the cost of navigation. Finally, according to the fuel consumption ratios in Table 3, the navigation efficiency for the ship sailing through the Suez Canal from the highest to the lowest is Singapore > Hong Kong > Kaohsiung > Shanghai > Busan. Based on the fact that Hong Kong and Singapore are geographically close to the Suez Canal and that ships departing from Hong Kong or Singapore can sail to Europe in relatively short distances, these trips result in a larger reduction of fuel and carbon dioxide emissions. Thus, the route from Asia to Europe through the Suez Canal can help save a large amount of fuel and carbon emission. Busan port is at high latitude; therefore, the distance from Busan to the destination is relatively long.

4.3. Calculation of the break-even point for fuel prices

According to the international crude oil trend chart released by Bureau of Energy, Ministry of Economic Affairs of Taiwan [20], the price of a barrel of crude oil is set at 30–70 US dollars, and the amount of crude oil consumed per ton of crude oil for ships is about seven barrels of crude oil; that is, the price of crude oil per ton is approximately 210–490 US dollars. According to the standards set by the Suez Canal Authority, when a container ship is fully loaded, the value for SDR/SCNT is 5.41. Based on the formula of toll set by the Suez Canal Authority, the calculated result is 748,396 USD (the toll is 1SDR=1.35USD) (Suez Canal Authority, 2017).

Assuming that the revenue per TEU is 1,000 USD and that the oil price is 30–70 USD, the break-even point for the ship sailing through the Suez Canal or the Cape of Good Hope can be calculated on the basis of the fuel cost and toll. Following that, the break-even points for the ship sailing though the Suez Canal and the Cape of Good Hope are calculated as per the different price points, 30, 40, 50, 60, and 70 USD, as shown in Tables 4 and 5. Considering Busan as an example, when the oil price reaches 50 USD, if the ship passes through the Suez Canal, it indicates that the revenue can cover the fuel cost and the toll if 2,257 TEUs are loaded onto the ship, which accounts for 27% of the total capacity; further, if the ship passes through the Cape of Good Hope, the revenue can cover the fuel cost and the toll if 1,966.4 TEUs are loaded onto the ship, which accounts for 23% of the total capacity.

Table 8 is compiled on the basis of the aforementioned break-even points between cost and revenue. When the oil price is between 30 and 70 US dollars and the freight charge fluctuates between 1,000 and 1,200 US dollars, as per the ship's 8,508 TEUs in this study, the revenue earned by the ship can cover the fuel and toll costs so long as the quantity of loaded cargo reaches the percentages listed in Table 8.

V. CONCLUSION AND MANAGEMENT IMPLICATIONS

5.1 Conclusion

With the ebbs and flows in international crude oil prices, coupled with the fierce competition in the current sea transportation market, many ocean carriers have either merged with other companies or gone bankrupt. As a result, ocean carriers try to minimize costs. Nowadays, sailing from Asia to Europe through the Suez Canal is a more common practice than sailing through the Cape of Good Hope owing to the shorter distance. However, since the Suez Canal charges higher tolls than the Cape of Good Hope, ocean carriers also need to consider the sailing conditions and the risks of encountering pirates. This study, excluding other external factors, considers only the fuel consumption and carbon emission levels and obtains the following conclusions.

Singapore port is closer to the European ports than other ports in Asia are. As the distance from the port to the Suez Canal is shorter than other ports and using this port is more cost-effective, Singapore port firmly takes the leading position among all the hub ports.

The results of this study reveal that the fuel consumption of the ship is positively correlated with the speed of the ship and the distance of navigation. The ports in Asia are closely related to the navigation efficiency of ships sailing to Europe. For ports with higher latitudes, such as Busan port, more fuel consumption and carbon emissions are required owing to a higher fuel consumption ratio and a longer navigation distance. However, in the future, the opening of the Arctic route will grant Busan port a relatively competitive advantage.

When selecting a route, ocean carriers mainly consider minimizing costs and maximizing operation.

Based on the oil price of 30–70 US dollars and the freight charge of 1,000–1,200 US dollars, the required cargo quantity that is sufficient to cover the fuel cost and toll is calculated.

5.2 Management implications

The study aims to identify the costs of sailing to Rotterdam in Europe through the Suez Canal and the Cape of Good Hope. We hope that the results can help shipping carriers select the optimal route while considering changes in international oil prices and the amount of cargo. Although the study considers two critical factors, namely, oil price and cargo quantity, another key factor, that is, time is ignored. Time is the reason why container ships are selected to sail from Asia to Europe through the Suez Canal; although expensive canal fees must be paid to use such ships, navigational distance is shortened, indicating only a few days at sea. By contrast, large bulk carriers are usually selected to sail from Asia to Europe through the Cape of Good Hope; although this selection saves on expensive Suez Canal fees, such carriers spend more days at sea. In practice, the most important factor for container ships is time, followed by navigational distance and oil consumption (oil price). The most important factors for large bulk carriers are navigational distance and oil consumption, rather than time. These factors explain why almost all container ships are always selected to sail from Asia to Europe through the Suez Canal, rather than through the Cape of Good Hope and largest bulk carriers are always selected to sail through the Cape of Good Hope, rather than through the Suez Canal. That is, shipping carriers do not need to select the Suez Canal or the Cape of Good Hope because container ships are assigned by shipping carriers to sail through the Suez Canal and large bulk carriers are assigned by shipping carriers to sail through the Cape of Good Hope. Therefore, researchers should consider the three factors, namely, oil price, amount of cargo, and time in future studies.

Suez Canal boasts its unique geographical environment, significantly reducing the distance and sailing time from Europe to Asia and creating greater economic benefits while reducing the impact of transportation on the environment (Fletcher, 1958; Griffiths, 1995). Environmental issues have recently become an integral part of all the relevant discussions, and more melted ice in the Arctic may help boost the Arctic route (International Energy Agency, 2017). From the perspective of the maritime industry, ocean carriers not only need to reach the break-even point but also to develop themselves into sustainable large enterprises. Shorter navigation distances will help reduce fuel consumption, which, in turn, will lower carbon emissions, thereby reducing the environmental impact.

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