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The Impact of Distance and Narrow Waterway on Voyage Cost: Cost Formulation and Implementation on a Dry Bulk Carrier

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Abstract

This paper investigates the impact of distance and narrow waterway factors on voyage costs. The data set is taken from a Turk shipping company and consists of real dates. In the study, it was seen that the fuel consumption rate of the ships whose routes are narrow waterways such as straits and canals was higher for the fact that the vessels have to maneuver more on such routes. On the contrary, ships which sailed on the open seas consumed lower fuel. At the end of the study, it was determined that of bunker cost rates caused by the impact of these geographical factors could increase up to 30 percent among the total amount of voyage costs.

Keywords: *Shipping, Voyage Costs, Cost Formulations, Costs Analyses.*

Mesafe ve Dar Suyollarının Sefer Maliyetlerine Etkisi: Maliyet Formülasyonu ve Dökme Yük Gemisi Üzerine Bir Uygulama

Öz

Bu çalışmada kat edilen mesafe ve dar su yollarının sefer maliyetleri üzerine etkisi incelenmiştir. Çalışmada kullanılan veri seti bir Türk denizcilik şirketinden alınmış ve gerçek verilerdir. Çalışmada, rota üzerinde yer alan boğaz ve kanal gibi dar suyolları sebebiyle manevra kabiliyetini artırmak zorunda olan gemilerin yakıt tüketiminin arttığı, buna karşılık sadece açık deniz seyri yapılması durumunda ise yakıt tüketiminin azaldığı görülmüştür. Çalışmanın sonunda, coğrafi faktörlerin etkisiyle oluşan maliyetlerin sefer maliyetleri içindeki payı % 30'lara kadar çıkabildiği tespit edilmiştir.

Anahtar Kelimeler: *Taşımacılık, Sefer Maliyetleri, Maliyet Formülasyonu, Maliyet Analizi.*

1. Introduction

Tramp shipping can be defined as a transportation service in which ships that have no set routes or fixed time tables set their own speed among different ports [1]. In tramp ships, liquid bulks such as petroleum, LNG and LPG, and dry bulks such as coal, grain, iron ore, cement and bauxite are carried [2]. This mode of transport which is called bulk cargo transport accounts for 75 per cent of world's maritime transport [3].

In this mode of transport, the ships' operations such as the arrival and discharge, actual port time and leaving the harbor depends on cargo and cargo's compliance with the ship [1][2][4]. Therefore, ships may have to wait for days, even weeks at a specific harbor or an anchoring area until matched load is found. In other words, ships are directed to where the matched load is. Due to this, each ship which has the capacity to carry the load is in a competition with the others [2]. Price mechanism in competitive tramp shipping is determined considering supply and demand in perfect competition market conditions [5][6][7]. Just because of this reason, the increase in the input costs cannot be covered with the evenly increase in the freight rates [8]. Accordingly, it is impossible to arrange the expense fluctuations and freight rates correspondingly in the sector [9]. In consideration of the denoted freight risk, ship-owners should principally adopt a cost-oriented management mentality in terms of sustainability. This understanding which is also named as cost leadership is the main strategy in global competitive environment which is the result of economic, social and technological change [10]. In this way, taking steps against sector-specific cycle becomes possible [11].

The explanations about voyage costs have indicated that there are structural, administrative, oceanographic and geographical variables affecting a ship's level of voyage costs. The oceanographic and geographic variables that affect the costs can be listed as current, density, depth, wind, friction, climate variation and transit of gulfs, bays, straits and canals [4][12][13][14][15]. These factors are especially manifested in canal and strait tolls and bunker prices.

Gilman (1977), presented the cost differences for various types of ships on a typical voyage. That's because, each voyage has distinctive variables such as maneuvers, climate conditions and canal or strait transit situations on course. As a result, bunker consumption amount differs from ship to ship [12]. Given that the ship is cruising at a constant speed, its bunker consumption during cruise is parallel to the cruising range [15]. On the other hand, frictions occurring out of oceanographic reasons causes to an increase in the bunker consumption. In essence, in the area of trade, friction of distance has a significant influence on costs as well as distance and friction can be interpreted as distance, time, cost and energy consumption[4].

Likewise, as a result of the geographical structure on the route, ships may have to go through narrow waterways such as straits, canals and archipelagos. While cruising through these areas, ships have to use marine diesel-oil (MDO) which is far more expensive than international fuel-oil (IFO) in order to increase its maneuvering capacity. Yet, the ratio of MDO to the total bunker fuel is about 20 per cent. In other words, about 80 per cent of the total bunker fuel relates to heavy fuel oil [16]. In addition, there are also strait and canal tolls which have to be paid in order to pass. The sea routes for world shipping are shown in Figure 1.

As seen in Figure 1, global shipping routes have taken shape with the impact of time, safety, security, costs and means of transport. Ships have to transit through narrow waterways such as straits, canals and archipelagos on navigation zones from time to time. Undoubtedly, the tolls of the transits reflect badly on voyage costs as bunker consumption and tolls increase.

There are some background studies

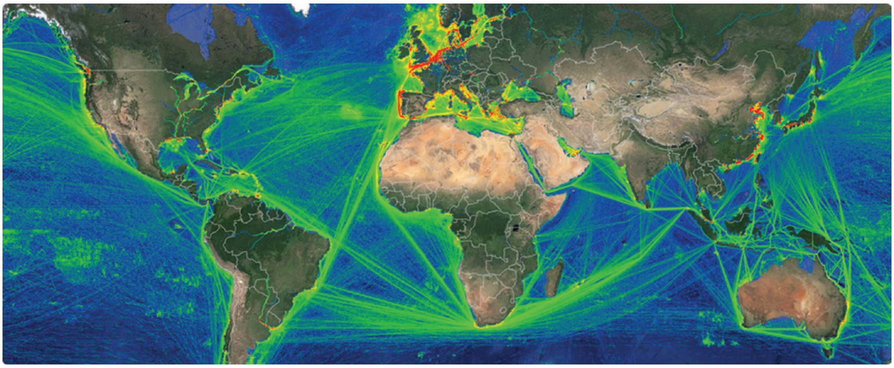

Figure 1. *Global shipping routes [17]*

regarding voyage costs and the factors affecting voyage costs in international and published literature [14] [18] [19] [20] [21] [22] [23] [24] [25] [26] [27] [28][29][30]. In these studies, the main focus has been on ship size and ship speed and these factors are elaborated. It has been manifested that total costs scale up as the ship size and ship speed expand while the increase in ship size help reduce the costs per ton. Besides this, the researchers have offered suggestions for reducing these costs. In other respects, Borger and Nonneman (1981), in their statistical studies, considered the matter from a different angle and pointed out that the fright rates would reduce if the size of dry bulk carriers increased [5].

Different from the background studies, the impact of geographical factors on costs is also emphasized in this research. Furthermore, a linear model that formulates the cost structure of dry bulk carriers is suggested. Thus, it is thought that this study contributes to international literature. In this study however, only the impact of distance and narrow waterways on voyage costs are investigated. The impact of other geographical factors such as weather conditions and unforeseen delays has not analyzed.

The remainder of this paper is organized as follows. In section 2, information about the cost formulation and transport costs has been given. In section 3, information about the data set that is used in the study has been given. In section 4, findings and results related to the information on the impact of distance and narrow waterway on voyage costs have been discussed. Finally, we concluded by giving a summary of the implementation in Section 5.

2. Cost Formulations and Transport Cost

The cost formulation is adapted to tramp shipping by inspiring from the liner shipping cost formulation prepared by Wong et al. [14] and is checked by experts such as researcher, shipbuilder, master and technical manager. Moreover, cost formulation represents the overall costs of dry bulk carriers operating in tramp vessel market under pure competition market conditions. To specify the problem for cost formulation, some postulates are used in this process as set forth below:

The fixed cost of a dry bulk carrier chance depends on its ship size, ship speed and ship age.

• The variable cost of a dry bulk carrier chance depends on voyage

• Loading factor for a dry bulk carrier between ports is available and given.

A voyage starts when the ship starts sailing to the loading port where the cargo is and ends when it unloads the cargo to the port of discharge. The elapsed time period to find the cargo is included in the voyage.

Transport Cost = TC
= f(Capital costs + Running costs + Voyage costs) (1)

Capital costs = f(Deposit + Repayment of loan princial + Interest) (2)

Running costs = f(Manning + Insurance + supplies + Administration and management) (3)

Voyage costs = VC = f(Handling costs + port costs + bunker costs + passing costs) (4)

per ton,

C_{fiq}^{pa} : Bunker cost for waiting time at port and anchoring dry bulk carrier i fuel consumption per day in USD per ton,

T : Strait or canal passing fee,

$$\sum_{i=1}^{n} C_i^y = \sum_{i=1}^{n} C_{ci}^y + \sum_{i=1}^{n} C_{pi}^y + \sum_{i=1}^{n}\sum_{q=1}^{m} S_i(L_k)\left(O_{iq}^k + O_{iq}^d\right) + \sum_{i=1}^{n}\sum_{q=1}^{m} C_{wiq}^t E_{iq}^t + \sum_{i=1}^{n}\sum_{q=1}^{m} E_{iq}^l C_{fiq}^l + \sum_{i=1}^{n}\sum_{q=1}^{m} E_{iq}^{pa} C_{fiq}^{pa} + \sum_{t=1}^{n}\sum_{q=1}^{m} E_{iq}^b C_{fiq}^b + \sum_{t=1}^{n}\sum_{q=1}^{m} T_{iq} \quad (5)$$

$$\sum_{i=1}^{n} VC = \sum_{i=1}^{n}\sum_{q=1}^{m} S_i(L_k)\left(O_{iq}^k + O_{iq}^d\right) + \sum_{i=1}^{n}\sum_{q=1}^{m} C_{wiq}^t E_{iq}^t + \sum_{i=1}^{n}\sum_{q=1}^{m} E_{iq}^l C_{fiq}^l + \sum_{i=1}^{n}\sum_{q=1}^{m} E_{iq}^{pa} C_{fiq}^{pa} + \sum_{t=1}^{n}\sum_{q=1}^{m} E_{iq}^b C_{fiq}^b + \sum_{t=1}^{n}\sum_{q=1}^{m} T_{iq} \quad (6)$$

C_i^y : Total transportation cost for dry bulk carrier i within one-year in USD,

q : Number of voyage for dry bulk carrier i within one-year,

S_i: Ship size for dry bulk carrier i

L_k: Loading factor for dry bulk carrier i at port k, k ∈ (k_1, k_2, k_3...k_m) in percentage,

O_{iq}^k : Loading fee for dry bulk carrier i at loading port k in USD per tone/hour,

O_{iq}^d : Unloading fees for dry bulk carrier i at unloading port d, d ∈ (d_1, d_2, d_3...d_m) in USD per tone/hour,

C_{ci}^y : Annual capital cost for dry bulk carrier i in USD,

C_{pi}^y : Annual running cost for dry bulk carrier i in USD,

C_{wiq}^t: Daily wharfing fee for ship i at port t, t ∈ (k, d) in USD per day,

E_i^t : Number of berthing days for dry bulk carrier i berthing at port t in day, t ∈ (k, d) in percentage,

E_i^l: Number of sailing days for laden dry bulk carrier i sailing duration l in voyage,

E_i^b : Number of sailing days for unloaded dry bulk carrier i unloaded sailing duration b in voyage,

E_i^{pa} : Number of anchoring days for dry bulk carrier i waiting time at port and anchoring duration a in voyage,

E_i^v : Number of voyage days for dry bulk carrier i total voyage duration v,

C_{fiq}^l : Bunker cost for dry laden bulk carrier i fuel consumption per day in USD per ton,

C_{fiq}^b : Bunker cost for dry unloaded bulk carrier i fuel consumption per day in USD per ton,

According to cost formulations, total costs are mainly divided into two parts: Variable costs and standing costs. Variable costs consist of handling costs, port costs and bunker costs which may differ according to the voyage. As for standing costs, they consist of capital costs and running costs. Depending upon navigation, voyage costs involve bunker costs, pilot wages, strait and canal passing fees in their entirety and cargo handling expenses, tugboat, pilotage, port charges and other expenses all together.

3. Material

In this study, the research is done voyages costs of a Turkish Flagged dry bulk carrier of 76197 dwt named 'M/V Ince Anadolu' as shown in Figure 2 in 2014. The data set of the voyage costs of the ship is taken from its shipping company and consists of real dates.

Figure 2. *M/V Ince Anadolu dry bulk carrier ship*

Moreover, the date set has included the information about number of voyages, duration of each voyage and voyage costs such as bunker costs and pass fees. In this respect, the ship cruised five times in 2014 and the technical information concerning the voyage legs and daily bunker consumption is given in Table 1 below.

Considering the ship's loading status and voyage legs in 2014, it is explicitly seen that the average cruising speed of the ship is 12 knots. Besides, the ship's daily bunker consumption while loaded is 26 ton/day and it is 1,5 ton/day (idle) in the harbor.

The ship's nautical mile information among its voyage legs were obtained from Netpas Distance that provides paid access. In addition to this, the real voyage dates and durations of the ship being talked about are given in Table 2 below.

As it is seen in Table 2, the ship's longest voyage duration is 131 days in number 5 and its shortest voyage duration is 26 days in number 3. The voyage durations consist of the elapsed time period while the ship waits for matched load in tramp shipping, cargo handling period and time at sea. In the light of this information, the total voyage costs of the ship are shown in Table 3 below.

As can be seen in the Table 3, the components of voyage costs comprise of bunker costs, pass fees and other

Table 1. *Voyage legs and bunker consumption of the ship*

Type **Dwt** **Eco. Spd.** **Age**	: Dry Bulk Carrier : 76197 : 12 knot : 3	**Daily Bunker Consumption**				
		Loading Status:	**At Sea**		**In Port**	
			IFO	MDO	Idle	Wrkg
		Laden	26	1,5	1,5	2,5
		Ballast	22	1,5	-	-
No	**Voyages**	**Voyage Legs**			**Distance**	
1	Muuga Port (EE) - Mundra Port (IN)	..... Muuga Port - Mundra Port			+ 7.306 **7.306*+**	
2	Yuzhny Port (UA) - BİK Port (IR)	Mundra Port- Yuzhny Port Yuzhny Port- BIK Port			4.121 4.490 **8.611***	
3	Mundra Port (IN) - Yuzhny Port (UA)	BIK Port- Mundra Port Mundra Port- Yuzhny Port			1.292 4.121 **5.413***	
4	Novorossiysk Port (RU) - BİK Port (IR)	Yuzhny Port- None Port None-BIK Port			374 4.596 **4.970***	
5	Paranagua Port (BR) - BİK Port (IR)	BIK Port-Paranagua Port Paranagua Port-BIK Port			9.294 9.294 **18.588***	
*** Total nautical miles**						

Table 2. *Voyage dates and durations of ship*

No	**Voyages**	**Date**	**Durations**
1	Muuga Port (EE) - Mundra Port (IN)	17.12.2013-24.01.2014	**38**
2	Yuzhny Port (UA) - BİK Port (IR)	24.01.2014-15.03.2014	**51**
3	Mundra Port (IN) - Yuzhny Port (UA)	15.03.2014-10.04.2014	**26**
4	Novorossiysk Port (RU) - BİK Port (IR)	10.04.2014-23.05.2014	43
5	Paranagua Port (BR) - BİK Port (IR)	23.05.2014-01.10.2014	131

costs. Other costs are port charges, extra insurance premium against the risk of pirates, commission and dispatch.

Table 3. *Components of the total voyage costs of ship*

Voyages	Durations	Voyage costs	Of which Bunker	Pass	Other
1	**38**	**$1.384.433,96**	$671.699,00	$221.300,00	$491.434,96
2	**51**	**$1.320.191,28**	$590.319,00	$221.282,00	$508.590,28
3	**26**	**$918.316,15**	$394.715,40	$227.557,00	$296.043,75
4	**43**	**$1.269.119,73**	$713.060,00	$227.504,00	$328.555,73
5	**131**	**$1.351.206,36**	$1.023.163,05	-	$328.043,31

4. Finding and Discussion

Before presenting the impact of geographical factors like distance and narrow waterway on voyage costs, the necessary information about the ship's voyages in the relevant year are obtained by using the Netpas Distance system which provides whole e-world map control and voyage estimate service. The map obtained from the Netpas Distance system is shown in Figure 3.

Figure 3. *Voyage legs of the ship in 2014*

The ports that the ship called at and the routes that the ship followed in 2014 are obviously seen in Figure 3 above. It is seen that, the ship sometimes sailed along the ocean and it sometimes passed through narrow waterways such as Gibraltar, Turkish Straits and Suez. A sure thing is that every voyage has its distinctive maneuvers, climate conditions on courses as well as canal and strait transits. All these factors influence the voyage costs negatively and give rise to an increase in the costs. Within this framework, in Table 4 below, the total bunker consumption of the ship after the stated voyages is shown.

Bunker costs constitute between 47 and 53 percent of the total voyage costs – that is to say – bunker costs can be said to be the most important component of voyage costs [3][8][25][31][32][33]. Bunker costs are affected by the distance of every transport. Accordingly, as the time distance increases, the voyage costs in total increase, too. Depending upon bunker prices, bunker costs are connected with bunker consumption. Beyond any doubt, rising bunker prices causes bunker costs to scale up. Given the increased bunker costs, shipping lines are challenged to keep a tighter control on bunker consumption. This objective has given incentives for initiatives in the field of (1) the use of cheaper grades of bunker fuel, (2) actions in the field of vessel design and (3) actions with regard to the commercial speed of the fleet and the scale of the vessels [16]. As for bunker consumption, it is directly proportionate to machine power and it is affected by the type, size, speed, loading status and working hours of the ship and oceanographically factors such as topography, distance, water depth and weather conditions [13][14]. Whereas the ship's fuel consumption both in port and en route increases depending upon its size, the fuel consumption of the ship on the sea is directly proportional to voyage distance considering that the ship is navigating at a constant speed [15]. Put it differently, ship's daily fuel consumption

Table 4. Total and average bunker consumption of the ship

Voyages	Durations*	At Sea**	Mil***	IFO Cons.	MDO Cons.	Total Bunker Cons.	Av. Cons. ton/day
1	38	25,37	7.306	816,30	75,80	892,10	23,47
2	51	15,59	4.490	663,00	105,50	768,50	15,06
3	26	14,31	4.121	479,40	42,30	521,70	20,06
4	43	15,96	4.596	900,00	70,00	970,00	22,55
5	131	32,27	9.294	1155,25	233,38	1388,63	**10,60**

* Real Voyage Duration
** Netpas: Elapsed time during cargo handling
***Netpas: Distance between cargo handling ports

is different in different voyages based upon the ship's maneuvers particular to the voyage, weather conditions on routes and canal and strait transition states as well as variables such as sufficiency of crew and hull and machine status.

Besides, as a result of the fuel type used in order to enhance the capacity of maneuverability and the maneuvers of the ship while transiting the straits and canals, the bunker consumption and costs increase. Additionally, the ship has to pay canal and strait toll fees to transit through the narrow waterways. In this context, in Table 5 below, there is a sequence of the straits and canals on the ship's route and the amount of the fees that have to be paid in order to pass through them.

waterways that the ship transited through, it only had to pay a fee in Suez. Even so, the ratio of the costs out of strait and canal toll fees to the total voyage costs still rose about 27 per cent due to the passing fee in Suez. In its voyage number 2, the ship transited through the Suez Canal twice, first to get to the loading port and then to carry the load to the port of discharge. In order to be able to make a more meaningful comparison with the other voyages in which there are strait or canal transits, the pass fee paid while navigating to the loading port is not taken into account. In this case, the ratio of the adjusted costs to the total voyage costs is 17 per cent ($ 221.282,00/$1.320.191,00).

No matter that the distance increases or decreases, the pass fee does not change. As

Table 5. The percentage of contribution of pass fees to the total voyage costs

Voyages	Mil	Strait and cannel	Pass Fee	Total Voyage Cost	Pass Fee %
1	**7.306+**	Gibraltar-Suez	$221.300,00	$1.384.433,96	16
2	**8.611**	Suez-Turkish Turkish-Suez	$188.461,00 $221.282,00	$1.508.652,28	27
3	**5.413**	Suez-Turkish	$227.557,00	$918.316,15	25
4	**4.970**	Turkish-Suez	$227.504,00	$1.269.119,73	18
5	**18.588**	-	-	$1.351.206,36	0

As it is clearly seen in Table 5, the ship transited through the canals and straits in its first and the next three voyages in the relevant year. Among all the narrow

a cost constituent, what increases while the distance grows is the bunker cost. Thus, as the distance is shortened, the percentage of pass fees in total transport costs will increase and so will the total voyage costs. As it is seen in Table 5, the percentage of pass fees in total voyage costs decrease as the distance grows. Although the only voyage in which the distance grows is voyage number 3, the rate is higher in proportion to the preceding short sea voyage. This is because this voyage lasts a short time compared to the others.

On the other hand, no pass fees were paid in voyage number 5, since there were no strait or canal transits in its voyage legs. By this means, economizing was possible in this voyage. Would it also be possible for the ship to achieve saving in the way that it did in number 5 if it followed a different route on which there were no canal or strait transits in its other voyages, too? In this context, an alternative route to the ship's first voyage is in Figure 4 below.

periods in the Suez Canal [34]. Yet, the point to be considered here is the geographical position of the loading and the discharge port of the ship. In this regard, as it is seen in Figure 4, in voyage number 1, the ship spent 25,30 days at sea regardless of the times it spent to find load and stayed in port. If the ship had followed the alternative route rather than the one with the strait and canal transitions, the sea time of the ship would have been 42,53 days. Despite getting rid of the pass fee which cost $221.300,00 that had to be paid in the alternative route, ship's turnaround cycle got 17,23 days longer. As a matter of course, this situation brings about more bunker costs and loss of time. The negative influence of time loss is that the ship has the risk of missing the next cargo and cruising less than expected per year. The reflection of bunker costs on

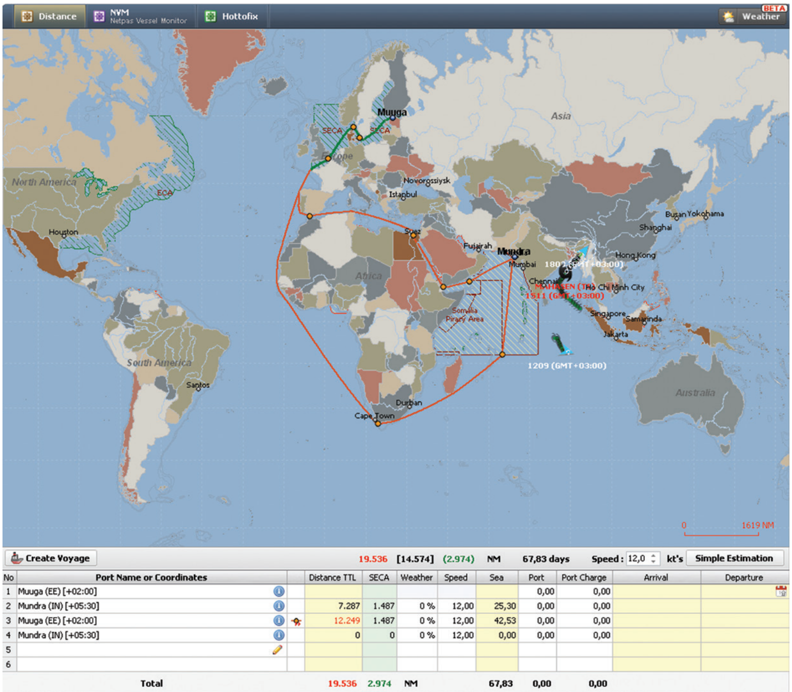

Figure 4. *Actual and alternative route of the first voyage*

In his study, Notteboom (2012) has indicated that Cape route has started to become an alternative competitive route due to high canal toll fees and long waiting

total costs when the alternative route is preferred is shown in Table 6 below.

According to Table 6, when the ship navigates on the alternative route, it cuts

Table 6. Comparison between actual route and alternative route

Voyage: 1	Suez Route	Cape Route	Difference
Distance TTL	7.287 nautical miles	12.249 nautical miles	-4.962 nautical miles
Sea	25,30 days	42,53 days	-17,23 days
IFO Cost	=25,30×26×$ 730,00 =$480.194,00	=42,53×26×$730,00 =$807.219,40	-$327.025,40
MDO Cost/ton	=25,30×1,5×$1.000,00 =$37.950,00	=42,53×1,5×$1.000,00 =$63.795,00	-$25.845,00
Total Bunker Cost	=$480.194,00+$37.950,00 =$518.144,00	=$807.219,40+$63.795,00 =$871.014,40	-$352.870,40
Pass Fee	=$221.300,00	=$0,00	$221.300,00
Total cost	=$518.144,00+$221.300,00 =$739.444	=$871.014,40+$0,00 =$871.014,40	**-$131.570,40**

back on pass fees but this time, bunker costs scale up. What's more, the increase in bunker costs surpass the saving level and causes the voyage expenses cost $131.570, 40 more than estimated. In respect to this, the most convenient route is set by using the results of a cost-benefit analysis comparing the costs that geographical factors led and the cost structure of alternative routes. Global shipping routes are set by considering and estimating factors such as time, safety, security and costs. Besides, while determining the most appropriate routes, factors such as piracy and political risks are also taken into consideration as in Figure 3 and 4.

5. Conclusions

Global financial crises that influence world trade adversely affect the maritime sector in a negative way, either. In an atmosphere of crisis, a global recession takes place which affects the economy adversely and the shaken economy results in a sharp drop in world trade. Paying regard to the fact that more than 90 per cent of the world's trade consists of maritime transportation which is the key stone for globalization, this economic collapse indispensably influence maritime transportation in a terrible way. Therefore, in terms of sustainability, it is suggested that dry bulk carrier owners carrying on business in perfect competition market should focus on cost leadership strategy in order to avoid the destructive effects of global competition. In this study, a linear model is principally proposed in order to be able to bring the costs under control. It can be affirmed that the rate of the costs forming with the effects geographical factors such as distance and strait/canal transitions can reach about 30 per cent of the total voyage costs. However, selecting alternative routes may cause other problems such as enhancement of bunker costs, loss of time and decrease in the volume of trade.

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