The Economical and Environmental Analysis of Fuel Switching of Istanbul Ferries

İstanbul Yolcu Gemilerinin Yakıt Değişiminin Ekonomik ve Çevresel Analizi

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Abstract

Ship emissions have become a subject that has been widely addressed in the last two decades. The ships, whose role in international transportation are indisputable, appear to be examined in detail in terms of the harmful impacts to the environment. Many studies are carried out on a global, regional and national scale in order to reduce and control ship emissions. To this end, some regions in the world have been identified as Emission Control Areas (ECA) and the sulfur content in the fuel contents of commercial vessels wishing to enter these regions must be in lower levels. In this study, the economic and environmental analysis of the fuel changes of the passenger ships operating in the Bosphorus in case the Bosphorus is declared as ECA. As a result, it was determined that the environmental performance of the vessels improved significantly, and that there was an additional financial burden in the economic sense.

Keywords: *Ship emissions, Fuel switching, Emission Control Area*

Anahtar Kelimeler: *Gemi emisyonları, Yakıt değişimi, Emisyon kontrol alanı*

JEL Code: Q4, Q5, R4

1. Introduction

Shipping-related emissions and abatement technologies have been being focused particularly on last two decades. As the most important stakeholder of global freight trade, ships can carry 90 % of the total freight. On the other hand, shipping activities have significant impacts on environmental and economical issues. Furthermore, these impacts are generally accepted as interdependent. For instance, advanced abatement technologies can reduce the harmful environmental impacts; however, the cost for these technologies are generally very high. In addition, using these technologies may also be costly. Nevertheless, these technologies may save the shipowner from paying significant amounts of fines.

The first global studies on this subject were realized by Corbett et al., (1999). This study is one of the first studies to examine the amount of NO_x and SO_x on a global scale. In the study, based on ship activities in 1993, the amount of ship-related NO_x and SO_x was calculated in the global scale and it was resulted that is at the amounts are 3.08 and 4.24 Tg in terms of nitrogen and sulfur, respectively. Vardar and Kesgin, (2001) conducted one of the first studies on the regional measurement of ship emissions. In this study, it is aimed to measure the total amount of ship emissions in Istanbul and Çanakkale Straits. For this purpose, the total emission value is calculated based on the annual number of ship passes and the fuel consumption data of these ships. As a result, the amount of annual ship emissions in the Turkish Straits has been determined as 700,836 tons. It was also calculated that the vessels were responsible for 10 % of the total NO_x generated in Istanbul. Endresen et al., (2003) examined the global ship emissions and their environmental impacts. Total fuel consumption information is used for the calculation of ship emissions. Corbett and Koehler, (2003), updated their ship emissions inventory on a global scale. In this study, the engine powers and engine working hours of the vessels were taken into account and as a result the ship-related NO_x emissions were found to reach 6,87 Tg. Eyring et al., (2005) calculated ship emissions in 2020 and 2050 for four different scenarios based on the estimated fuel consumption, based on the information in the Special Report on Emission Scenarios (SRES) published by the Intergovernmental Panel on Climate Change (IPCC). According to this publication, the total fuel consumption in the year 2001, which was considered as the base year, was estimated to reach 280 t, and this value was expected to reach 382 t in 2020 and 536 t in 2050 even in the best scenario. Endresen et al., (2007) studied the historical development of sulfur dioxide (SO_2) and carbon dioxide (CO_2) amounts between 1925-2002 in their study. Accordingly, SO_2 and CO_2 values in 2002 increased by 3.4 and 2.8 times compared to 1925.

The International Maritime Organization (IMO) has conducted three comprehensive studies on ship emissions. In the IMO, (2000) study, the total expenditure of marine fuels for 1996 was calculated and the geographical distribution of ship emissions for the same year was examined. In addition, the environmental impacts of ship-related NO_x and tropospheric ozone have also been examined and recommendations and determinations have been made on technical and operational measures to reduce ship emissions. In this study, emission factors have been developed for various types of pollutants. In the IMO, (2009) study, ship emissions between 1990 and 2007, emission reductions as a result of the implementation of Annex VI of the International Convention on the Prevention of Pollution by Ships (MARPOL), the future status of ship-based emissions and ship-based CO_2 production compared with other transport methods is presented. IMO also introduced emission factor recommendations in this study. IMO, (2014) studied on flue gas emissions from international maritime activities and the amounts of these emissions were calculated by different methods for 2007-2012. In addition, a projection was made for 2012-2050. In this study, current emission factors have been developed for various types of pollutants.

It is also extremely important to reduce the costs as well as environmental risks by utilizing cost-effective methods. Lindstad et al., (2011), examined the effects of speed reduction on the reduction of emissions and costs. According to the results of the study, emissions decreased by 28 % at the cost of zero reduction, and cost of $ 20 per ton CO_2 reduction for 33 % reduction and $ 50 per ton CO_2 reduction for 36 % reduction. Corbett et al., (2009) studied the efficiency and cost of speed reduction. According to their results, the reduction of speed by half means that CO_2 emissions are reduced by 70 %, while a 20 % CO_2 reduction per tonne CO_2 reduction target for container ships is around $ 30-200. Ballini and Rozzo, (2015) conducted a study on the cost difference between the vessels anchored in the ports and the use of their own generators or coastal electricity. As a result of the study, the authors found that 60 % of the passenger ships anchored in Copenhagen could obtain health-cost savings of € 2.8 million per year if they used coastal electricity. Tzannatos, (2010) studied the potential gains of coastal electricity use in ships in the port of Piraeus. As a result, he found that the use of very low sulfur fuel would result in a total cost of € 16 million. On the other hand, the total cost of using coastal electricity is € 11.8 million. Cariou, (2011) has emphasized whether this method is sustainable as an emission reduction measure considering the costs of speed reduction. According to the findings of the study, although the reduction in emissions by 11 % was observed between 2008 and 2010, it was noted that this method is only sustainable in the long term, as long as fuel prices for container vessels are around $ 350-400.

There are strict rules and regulations to reduce shipping-related emissions and Emission Control Areas (ECA's) have the strictest rules on ship fuels and thus, ship flue gas emissions. Existing ECA's cover the majority of the USA and Canadian waters, the Baltic Sea and a partial region of the North Sea. While the USA and Canadian waters are prehibited for both nitrogen oxides (NO_x) and sulfur oxides (SO_x), the Baltic and North Sea can be identified as Sulfur Emission Control Areas (SECA's) in which onlu SO_x are monitored. Ships traveled into an ECA region have to switch its fuel from heavy fuel oil (HFO) to marine gas oil (MGO) in order to be sure to reduce the emission amounts.

In this study, the Marmara Sea and Turkish Straits are accepted as a potential ECA region and thus, in this case, fuel switching would be a mandatory application. First, the current emission estimation of ferry traffic in Bosphorus is realized. Then, the potential emission reduction is calculated by using fuel switching method. Finally, the total environmental impact and the total cost of fuel switching is investigated.

2. Materials and Methods

Estimations are made on 21 ferries that are actively operating in Bosphorus. 16 ferries were built before 2000 and thus, are subjected no regulations, which are developed by International Maritime Organization (IMO). 5 of the ferries were built after 2000, thus, are subjected Tier I of IMO regulations. IMO regulations were developed in order to reduce the specific ship flue gas emissions such as SO_2 and particulate matter (PM).

Various methods were developed in order to estimate ship-related flue gas emissions. In this study, Fuel Consumption (FC) method was used. The formula for FC method was offered by Trozzi, (2010) and presented below:

$$E_{Trip,i,j,m} = \sum_{p}(FC_{j,m,p} \times EF_{i,j,m,p}) \tag{1}$$

ETrip: Total emission (t)
FC: Fuel consumption (t)
EF: Emission factor (g/t fuel)
i: Pollutant type
j: Engine type
m: Fuel type
p: Voyage stages

Emission factors (CO_2, SO_2, carbon monoxide (CO), hydrocarbons (HC), PM and NO_x) are presented in Table 1 (Moldanová, J., (2010)).

Table 1. Emission factors for different pollutant and fuel types

Pollutant	Tier	HFO	MGO	Unit
CO_2		3,179	3,179	t/t fuel
SO_2		0,054	0,002	t/t fuel
CO		0,0051	0,0053	t/t fuel
HC		0,0009	0,001	t/t fuel
PM		0,00233	0,00098	t/t fuel
NO_x	No Tier	0,0617	0,0632	t/t fuel
	Tier I	0,0498	0,0549	t/t fuel

The ferries currently use HFO; however, if fuel switching would be mandatory in order to be in accordance with ECA regulations, the ferries should switch their fuels to MGO. The needed prices for HFO and MGO was obtained as 385 $ and 634.5 $ per tons for Istanbul, respectively (Web1).

3. Results and Discussion

Between 2011 and 2016, the ships consumed an average of 10452.6 tons of HFO, annually. The emission estimations are realized by multiplyling the emission factors presented in Table 1 and the fuel consumption data. While Table 2 presents the current situation, Table 3 shows the emission reduction in case the Bosphorus is declared as ECA. The estimations for Table 2 and Table 3 was realized with HFO and MGO, respectively.

Table 2. Annual average emission amounts in current situation

Pollutant	Annual Average Amount	Unit
CO_2	33,228.83	t
SO_2	564.43	t
CO	53.3	t
HC	9.4	t
PM	24.35	t
NO_x	609.83	t

Table 3. Annual average emission amounts in case of ECA

Pollutant	Annual Average Amount	Unit
CO_2	31,127.7	t
SO_2	19.58	t
CO	51.9	t
HC	9.78	t
PM	9.6	t
NO_x	595.9	t

As it can be seen in Table 2 and Table 3, declaring Bosphorus as ECA would be a significant reduction impact on especially SO_2 and PM emissions. Although the reduction seems to have a very positive impact on environment, the reduction issue needs to be examined in economical perspective. Thus, an economical analysis was made to calculate the cost of fuel switching. While the average annual cost for HFO is $ 4,024,251.0, the average annual cost for MGO is $ 6,632,174.7.

It is clear that fuel switching causes a remarkable additional cost for shipping operations. On the other hand, fuel switching is an effective method to reduce the shipping-related emisisons. Although the sanction power of international regulations plays an important role to reduce the emissions, economic concerns are still on the forefront. Thus, emission abatement issue should be considered as a holistic subject with both environmental and economic concerns.

4. References

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