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Research Article

Reduction of Ship Based CO_2 Emissions from Container Transportation

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Abstract:

Today, with the globalization of the world, traders have almost removed the borders. Therefore, there has been a considerable increase in demand for people to reach each other. This also led to the increase in maritime transport which has approximately 80% of the volume of worlds' freight load and also is the most economical mode of transportation. Despite being the most environmentally friendly transport system, the current CO_2 emission rate due to sea transport is 2.5%. Also, 26% of CO_2 emissions and energy consumption resulting from maritime transportation is caused by container ships which only generate 16% of world fleet. In this context, container transport has been examined in terms of CO_2 emissions. Slower steaming requires less bunker consumption and fewer bunkering port calls thus lowering CO_2 emissions compared to steaming at normal speeds. However, it takes more navigation time and vessels to meet the vessel-routing schedule but it can also reduce fuel cost. This study investigates CO_2 emissions responsible for a container ship to determine bunker fuel saving and CO_2 reduction strategies for container shipping lines. A case study was carried out using the real shipping data of a container ship with a capacity 1880 TEU between Ambarlı and Savannah ports. Additionally, two different scenarios have been proposed to reduce the emission of a real container ship in operation.

1. Introduction

International shipping trade is vital for the global economy. It is responsible for more than 80% of world trade. Seaborne trade volume increased by 2.6% from 2015 to 2016 and reached 10.3 billion tons [1]. Maritime transport system is the most environmentally friendly among other transportation systems. Nevertheless it gives off around 1000 million tons of CO_2 per year and is account for approximately 2.5% of global greenhouse gas emissions [1,2]. Growing emissions of greenhouse gases cause of negative impacts on human health and the climate change [3]. Container shipping is the fastest growing segment of marine transportation by about 5% growth. One of the reasons for this increase is that container transportation can easily be integrated with other transportation modes. In addition, container transport has vital importance to supply chains with short transit time ability.

Bunker fuel costs comprise of a large part of the operating costs of container shipping line. Ronen emphasizes that bunker fuel costs are responsible for around 75% of the operating costs of a large container ship [4]. In this context, in order to save fuel consumption and to decrease the amount of emission, a case study was made. The case study was implemented utilization the real shipping data of a container ship with a capacity 1880 TEU between Ambarlı and Savannah ports. Two different scenarios have been suggested to reduce the emission of a real container ship in operation.

1.1. Literature Review

The sailing speed is the main criterion that determines the fuel consumption of a ship. There are many studies in the literature that deal with speed optimization to reduce fuel consumption and emissions. Fagerholt et al. addressed the problem of determining the optimal speed on a particular route [5]. Carlou analyzed effects of relation of CO_2 emission and reducing of speed in the container ship [6]. Kim et al. investigated amount of fuel and optimum ship speed for a fixed ship route [7]. Notteboom and Cariou researched the effects of slow sailing on BAF charge paid by shipper as well as fuel consumption at the ship [8]. Khor et al. implemented a software program to optimize the speed of large container ships. As a result the optimum speed was found to be 19.5 knots [9]. Sheng developed a mathematical model that takes into account the size and optimum speeds of container ships. The model cannot be used for vessels higher than 16,000 TEU [10]. Doudnikoff et al. investigated differences speed between inside and outside SECA which amount of CO_2 emissions and the total transit time [11]. Meng et al. used a mathematical model to investigate the fuel efficiency of container ships [12]. Mao et al. established a model for ship's speed prediction by using two statistical approaches [13]. Tai and Lin analysed possible changes main routes in the container shipping as a result of the Panama canal expansion. These changes on emissions was examined [14]. There are studies in the literature that focus on emissions in certain regions and ports such as sea of Marmara sea [15], Candarli Gulf Turkey [16], United States ports [17], Taiwan ports [18].

2. Calculation of Emission

The ship emission is influenced by fuel type, engine type, fuel consumption, operation mode, time period in operation mode, emission factors and weather conditions. The amount of shipping emissions between Turkey and USA is calculated for a container ship. Additionally, in this study, real data obtained from a container ship with a capacity of 1880 TEU was used. The emission amounts emitted by sailing ship are calculated as follows [16, 19]:

$$E^e = E^e_S + E^e_M + E^e_P \quad (1)$$

$$E^e_S = T_S \times F^0_t \times K^0_{S,e} = \frac{D_{i\sim j}}{V} \times F^{h0}_t \times K^{h0}_{S,e} + \frac{D_{i\sim j}}{V} \times F^{d0}_t \times K^{d0}_{S,e} \quad (2)$$

$$E^e_M = T_M \times F^0_t \times K^0_{M,e} = T_M \times \left(F^{h0}_t \times K^{h0}_{M,e} + F^{d0}_t \times K^{d0}_{M,e}\right) \quad (3)$$

$$E^e_P = T_P \times F^0_t \times K^0_{P,e} = \frac{Q_i}{EF_i} \times F^{d0}_t \times K^{d0}_{P,e} \quad (4)$$

2.1. Case Study

In the study is utilized case study of a real container ship from a global shipping. The transit time of the selected ship in the case study is 25 days between Ambarlı and Savannah ports. The container ship has been standing on the port for about 9 days for loading and unloading operations and sailing for 15 days on sea. In the study, firstly the emission amount for a specific route was calculated. The total CO_2 emissions of the ship are calculated 7.46 tonnes CO_2 per specific route. Then, daily amount of emissions per TEU are found. The daily CO_2 emission for the dry container is 0.15 kg and the reefer container is 0.22 kg.

Two different scenarios have been proposed to reduce the emission of a real container ship in operation. In the first scenario, the ship speed is reduced by 0.5 knots from the speed value in the actual scenario. Reduced fuel consumption of the ship is calculated. The total CO_2 emissions of the ship is found 6.62 tonnes CO_2 per route for first scenario. The daily CO_2 emission for the dry container is 0.13 kg and the reefer container is 0.20 kg. Reduced ship speed causes the transit time to increase. As a result the transit time between Ambarlı and Savannah ports is increased by 10 hours. However, this situation has led to a decrease in the amount of fuel consumed. The amount of emissions generated by the container ship has decreased. In scenarios first a reduction of 11.27% was calculated for the CO_2 emission amount from the container ship per a specific route.

In the second scenario, the ship speed is reduced by 1.0 knots from the speed value in the actual scenario. Reduced fuel consumption of the ship is found. The total CO_2 emissions of the ship is found 5.90 tonnes CO_2 per route for second scenario. The daily CO_2 emission for the dry container is 0.12 kg and the reefer container is 0.19 kg. Reduced ship speed causes the transit time to increase. As a result the transit time between Ambarlı port and Savannah port is increased by 21 hours. However, this situation has led to a decrease in the amount of fuel consumed. In Figure 1 show that the fall in speed has an effect on fuel consumption.

The amount of emissions generated by the container ship has decreased. In scenarios second a reduction of 20.84% was calculated for the CO_2 emission amount from the container ship per a specific route. Not only the carbon footprint of the ship but also the carbon footprint per container is calculated in the study. Figure 2 shows reducing a container ship' speed is decreased amount of emissions per container.

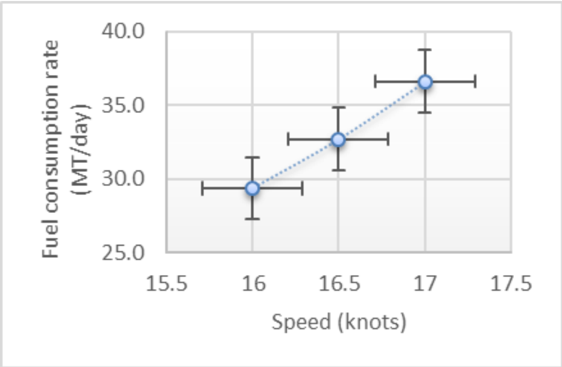

Figure 1. *Fuel consumption rates of container ship at different speeds.*

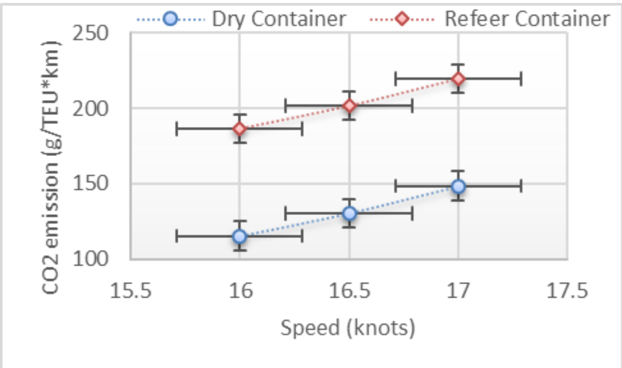

Figure 2. *CO_2 emissions of per container at different speeds.*

3. Conclusion

This study researches CO_2 emissions responsible for a container ship to determine bunker fuel saving and CO_2 reduction strategies for container shipping lines. A case study was carried out using the real shipping data of a container ship with a capacity 1880 TEU between Istanbul Ambarlı port and Savannah port. The emission amount of the container ship was calculated during the route. The total CO_2 emissions of the ship are calculated 7.46 tonnes CO_2 per specific route. This research also involves carbon footprint calculation per dry container and reefer container. A container ship accounts for daily CO_2 emission for the dry container is 0.15 gr and the reefer container is 0.22 kg.

Two different scenarios have been proposed to reduce the emissions of the container ship. In the first scenario shows that reducing the container ship's speed form 17 knot to 16.5 knot has decreased CO_2 emissions by around 11.27% between Istanbul Ambarlı port and Savannah port. In the second scenario indicates that reducing the container ship's speed form 17 knot to 16 knot has decreased CO_2 emissions by around 20.84% for the same route.

Positive impact of slow steaming provides that emission reduction from ship and fuel consumption saving. Bunker fuel costs also comprise of a large part of the operating costs of container shipping lines. The slow steaming strategy is crucial in terms of fuel and emissions reduction for container shipping industry. Global container companies should adopt a variety of technological and operational strategies to reduce bunker consumption, such as lower ship speeds, energy-saving and low-carbon power and drive systems, better body designs, voyage optimization systems and renewable energy sources.

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