Ship Fuel Economy Estimate for a 7,000 TEU, 97,000 dwt Container Vessel

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Abstract

In order to maintain a healthy environment and clean air, it is necessary to assess the environmental impact of transportation, a major contributor to air quality degradation. With the rapidly increasing human population comes rapidly increasing numbers in vehicle population. As a result, air pollution levels rise. There will always be a need for transportation, and in particular, commercial goods transportation. The three most commonly used forms of transportation are trains, tractor-trailer trucks, and containerships. After determining the estimated fuel consumption per km for a containership carrying a known amount of cargo, the fuel economy and environmental impact of the containership can then be compared to that of trains and tractor-trailer trucks.

1. Introduction

Fuel consumption can be compared for different forms of freight transportation to assess environmental impact, since emissions and negative environmental impact are both products of fuel consumption. In this case, the comparison is being made of the estimated fuel consumption for three different forms of freight transportation; train, tractor-trailer truck, and containership, compared under the assumption that each is carrying a designated amount of cargo at a given speed. Based on the cargo, a calculation is made to estimate fuel consumption. Once an estimate is established, a comparison is made about the relative efficiency and environmental impact from each form of transportation.

For container vessels, fuel consumption per km is a function of deadweight tonnage (dwt) and cruising speed of the containership. Once the fuel consumption per km is calculated, dividing the answer by the number of twenty-foot equivalent unit (TEU) containers will determine fuel consumption per TEU. This equation can be used to estimate total fuel consumption at various speeds and with a range of engine sizes.

Fuel consumption estimates for commercial goods transportation are not only important when considering economic and financial efficiency, but also perhaps more importantly in assessing environmental impact. When approximate fuel consumption is established for several different forms of transportation, consensus can be realized about the most fuel-efficient form of transportation. This method can prove useful to many different agencies and companies dealing with importing and exporting goods using alternative transport modes, especially for determining the most cost-efficient form. For

example, if a large timber company exported their wood overseas by containership, it would prove useful to the company to know how much fuel would be consumed during the transportation of their wood products in order to evaluate cost efficiency and environmental impact. This knowledge is also useful for many different environmental agencies for representation and assessment of environmental impact and emissions. To evaluate environmental impact of trains, tractor-trailer trucks, and more specifically a given containership, observations and calculations must first be made to determine the approximate fuel consumption of each. At operating speeds of 30 knots or less, the containership consumes less fuel per TEU than the train or the tractor-trailer truck.

This paper will follow this organization: Section 2, "Transportation and Environmental Impact," discusses fuel consumption under current technology; Section 3, "Fuel Consumption of Containerships," will discuss in depth the method used to determine fuel consumption of the given containership; Section 4, "Assessing Environmental Impact," compares fuel consumption of the containership with that of tractor-trailer trucks and trains; finally, the "Conclusion," presents concluding comments.

2. Transportation and Environmental Impact

Environmental impact is directly related to fuel consumption. Diesel engines are used to transport a large portion of manufactured commercial goods around the world, and they are among the most efficient and economical ways. Also, vehicle inventories and miles traveled are expected to increase dramatically in the future. Diesel is used largely by tractor-trailer trucks, trains, and containerships for the transportation of goods, and the number of diesel engines in use is increasing. However, diesel happens to be one of the largest contributors to worldwide environmental pollution.

Obviously, as more fuel is being consumed by trains, tractor-trailer trucks, and containerships alike, more and more pollution is being released into the atmosphere as a result. Emissions from burning diesel fuel are large contributors to health effects such as cancer, cardiovascular, and respiratory problems. Air, water, and soil pollution are also big problems resulting from the consumption of diesel fuel. Particulate matter from diesel exhaust has the highest proportion of black carbon, which contains a complex mixture of carbon, sulfur, nitrogen, hydrogen, and oxygen. The amount and exact composition of diesel exhaust depends on a number of different variables, such as speed, motor load, engine and vehicle type, fuel composition, ambient air temperature, and relative humidity (Lloyd and Cackette, 2001, p. 813). To take environmental health into consideration, the amount of diesel fuel being consumed, as well as the amount of other fuels, must be measured or estimated.

3. Fuel Consumption of Containerships

The estimated fuel consumption per km for a given containership can be calculated as a function of deadweight tonnage (dwt) and speed in knots. As operating speed increases, fuel consumption increases exponentially, which not only means significantly higher fuel costs, but also significantly worse environmental impact. Once

the ship's fuel consumption in liters per kilometer travelled is known, the ship's fuel consumption per km is divided by the number of twenty-foot equivalent units (TEU) to determine fuel consumption in TEU-km, the amount of fuel in liters required to transport each TEU one km by ship. Sealed metal containers are used to transport high-value manufactured goods on containerships. A twenty-foot equivalent unit (TEU) is used to express containership cargo capacity. One TEU is equal to half a standard metal shipping container. An equation of fuel consumption for a containership where F is fuel consumption in liters, d is deadweight tonnage, and speed in knots is represented by s is shown as:

$$F=0.04857(d^{2/3}\, s^3)/(1.84s^2-139.96s+2791.50)$$

For a containership with 96,998 dwt and 7,000 TEU, all even speeds from 16 to 48 knots will be considered in the equation. Normal operating speeds for transoceanic shipping range from approximately 16 to 24 knots. The given speed is substituted for s, where d is 96,998 dwt throughout. After determining estimated fuel consumption in liters per km for various operating speeds, those figures are divided by 7,000 TEU to get fuel consumption per TEU-km. Once fuel consumption is determined for each operating speed, the results can be compared with the known fuel consumption of the tractor-trailer truck and the train to compare fuel consumption and efficiency. Results are shown in Table 1.

Table 1
Container Vessel Fuel Consumption

Operating Speed (knots)	*Fuel Consumption (liters per km)*	*Fuel Consumption (liters per TEU-km)*
16	**25.65**	**.0036 per TEU**
18	**38.26**	**.0055 per TEU**
20	**56.32**	**.0080 per TEU**
22	**82.31**	**.0118 per TEU**
24	**119.97**	**.0171 per TEU**
26	**174.87**	**.0250 per TEU**
28	**255.06**	**.0364 per TEU**
30	**371.06**	**.0530 per TEU**
32	**533.14**	**.0762 per TEU**
34	**741.29**	**.1059 per TEU**
36	**965.89**	**.1380 per TEU**
38	**1139.11**	**.1627 per TEU**
40	**1196.63**	**.1709 per TEU**
42	**1137.99**	**.1626 per TEU**
44	**1015.40**	**.1451 per TEU**
46	**879.19**	**.1256 per TEU**
48	**755.30**	**.1079 per TEU**

A distinct pattern in the fuel consumption for the containership can be seen in Table 1 above. The fuel consumption increases with each speed from 16 to 40 knots. After reaching 40 knots, the projections of fuel consumption show a decrease in each higher speed from 42 to 48 knots. This information suggests that perhaps the fuel consumption of the containership can be regulated or reduced by traveling at a particular speed, depending upon which speed is the most fuel efficient.

4. Assessing Environmental Impact

The results show how fuel consumption increases exponentially with speed, but also show a noticeable decrease after 40 knots. With this in mind, there must be a point of minimal fuel consumption at higher speeds, however, higher speeds than those presented above are unrealistic for large marine vessels transporting commercial goods. In this case, to consume the least amount of fuel possible, the traveling speed of the containership should be set at the speed that achieves the least amount of fuel consumption, that is, the lowest speed possible.

Containerships are powered by large diesel engines that consume significantly more diesel fuel than that of tractor-trailer trucks and trains. This is obviously because containerships used for the transportation of commercial goods are significantly larger and require a larger engine and more diesel fuel. Also, when transporting goods, especially across seas, containerships generally tend to travel longer distances at a time than tractor-trailer trucks and trains. Another consideration is that containerships carry a much larger load and weigh much more. However, when it comes to fuel consumption per TEU, the containership consumes less than the truck or train when traveling at 30 knots or slower.

The fuel economy comparison among the three forms of transportation in this case are made under the assumption that tractor-trailer trucks carry 2 TEU and burn 0.5880 liters of diesel fuel per kilometer, and trains carry 200 TEU and burn 14.7000 liters per kilometer. According to the results from the containership estimate, it consumed the least amount of fuel at 16 knots, and presumably would burn even less fuel at lower speeds. The fuel consumption increases for each higher speed until 40 knots. The fuel consumption then decreases from 40 to 48 knots. At 30 knots, the containership consumes .0530 liters per TEU, where the train consumes .0735 liters per TEU, and the truck consumes .2940 liters per TEU.

5. Conclusion

It will always be important and beneficial to be aware of certain environmental impacts, especially those on air quality. Determining the fuel consumption of transportation is essential in assessing environmental impact. With this knowledge, fuel can be used more efficiently and environmental problems can be minimized with careful planning and observation. The comparison of fuel consumption and load capacity among containerships, trains, and tractor-trailer trucks provides a good general idea of how much each one contributes to air pollution and climate change. It also presents projections of

fuel economy which can be incorporated in cost-benefit analyses for organizations using commercial transportation for goods. Many conclusions can be drawn from fuel consumption estimates, the most important being forecasts of environmental impact. This method of analysis should continue to inform business and policy decisions as long as the world continues to depend on fossil fuels for transportation, manufacturing, and the many other activities that consume fossil fuels.

Reference

Alan C. Loyd, Thomas A. Cackette (2001) Diesel Engines: Environmental Impact and Control. Retrieved March 8, 2008, http://hschang.yu.ac.kr/notes/data/AWMA/crit_2001_34.pdf.