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An utility-based decision support sustainability model in slow steaming maritime operations

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ABSTRACT

This paper analyses slow steaming sustainability initiatives and generalizes the traditional discrete cost-based decision support model into novel continuous utility-based models. Two models based on logarithmic and linear utility functions are developed for risk-averse and risk-neutral decision makers respectively. The models, considering fuel consumption, carbon emission, and on time delivery, are applied to a Trans-pacific trade service route. A sensitivity analysis is conducted on parameters of sailing distance, expected transit time, quantity, and emission policies. The model contributes to ship liners on the optimal speed decisions in continuous utility-based slow steaming operations.

1. Introduction

1.1. Decarbonisation in maritime transportation

Carbon dioxide (CO_2) is the primary greenhouse gas emitted through the human activities. The highest percentage of the greenhouse gases (GHG) emitted by human activities is CO_2, comprising 82% of the total GHG, with a 5% increase along the previous five years. Over 70% of the CO_2 are primarily from the use of fossil fuel. Followed by CO_2, the next highest GHG are Methane (CH_4) with 9%, Nitrous oxide (N_2O) with 6%, and Fluorinated gases (F-gases) having 3% (EPA, 2014; Metz et al., 2007; IPCC, 2007). Over the decades, the global carbon emissions from fossil fuels have increased significantly, with over 16 times from 1900 to 2008 (Boden et al., 2010). The global greenhouse emission in 2010 is estimated to be 48,629 Metric tons of carbon dioxide equivalent ($MtCO_2Eq.$) (Ecofys, 2013). Leading countries have established goals to reduce emissions. U.S. revealed the energy-related CO_2 emissions in 2013 are expected to be 2% above the 2012 level (Antypas and Brown, 2014). U.S. Energy Information Administration reflected the emissions in 2013 are slightly more than 10% below 2005 levels and indicated that it is a significant contribution towards the goal of a 17% reduction in emissions from 2005 level by 2020 (US EIA, 2014). There is still a high sense of urgency as the world carbon emission has been increased significantly as indicated in Fig. 1, showing the carbon emission of 223 countries in the recent three decades. The two countries with the highest carbon emission are China and U.S., as shown in Fig. 2. China is the highest emitter in the world in 2011 with a five-times increase compared to 1980 while U.S. is the second highest emitter contributing 17% emission of the world (EIA, 2012). There is a vital need to reduce the carbon emission in these two countries in various sectors including manufacturing industries,

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construction, electricity and heat generation, and transport. Among the sectors, electricity and heat generation as well as transport produced nearly two-thirds of global CO_2 emissions in 2011, with the former one accounted for 42% and transport account for 22% (IEA, 2013).

The reduction of the carbon emission in the transportation and logistics industry has been emphasized in the World Economic Forum in July 2013 (Doherty et al., 2013; Doherty and Hoyle, 2009). The U.S. Environmental Protection Agency (EPA) reported that carbon emission in transportation accounts for 31% of the total U.S. emissions in 2011 (EPA, 2013). International Maritime Organisation (IMO) carried out a comprehensive and authoritative assessment of the level of GHG emitted in the global shipping industry. Shipping is estimated to have emitted 949 million tonnes of CO_2 and 972 million tonnes CO_2e for GHGs including CO_2, CH_4 and N_2O. International shipping operations are estimated to have emitted 796 million tonnes of CO_2 and 816 million tonnes of CO_2e in 2012, which is 2.1% of the global emissions of CO_2 in the same year (IMO, 2014; Wong et al., 2013). Container ships remain the highest in CO_2 emissions in international shipping, up to 205 million tonnes in 2012, followed by bulk carrier and oil tanker, with 166 and 124 million tonnes of CO_2 emissions respectively. IMO stressed the importance to carry out immediate actions on mitigating the emission growth. Statistics in the Global carbon budget 2014 indicates that global carbon emissions reached a new record of 36 billion tonnes of CO_2 in 2013, and are predicted to increase by a further 2.5% in 2014. The increase in consumption-based fossil fuel emissions from shipping should be addressed. The biggest emitters from a consumption-based perspective were China (23% of the global total), U.S. (16%), EU (13%), and India (6%) in 2012 (Le Quéré, 2014). With China and U.S. being the biggest emitters in the world, there is urgency for ship liners, especially in Trans-pacific Trade services, to exercise measures to mitigate carbon emissions in the ship operations.

The continuous increase in marine fuel oil consumption and bunker price brings urgent need of ship liners to seek ways to minimize the use of fuel consumption. The world fleet of ships, including cargo, non-cargo, and military vessels is estimated consuming 280 million tonnes of fuel per year, with more than 200 million tonnes required for cargo ships (Corbett and Winebrake, 2008). In 2007, the global merchant marine fuel oil consumption was in the range of 369 million tonnes. It is estimated that the consumption will increase to 486 million tonnes (IMO, 2007). The increase in bunker price, from USD110 per metric ton (pmt) in the first quarter of 2010 to USD470 pmt in the last quarter of 2012, has pushed pressure on shipper companies to minimize the operating cost in the daily operations (Yang et al., 2013). Companies are reported paying an average of USD630 pmt for bunkers in the third quarter of 2013. Alternative energy source for vessels has always been one of the agendas of ship liners. The use of other energy source will bring changes to the bunker costing and emission level of the company. The use of fuel-cell technology in vessel design and operations has moved forward to minimize greenhouse gas emission. Nippon Yusen Kabushiki Kaisha (NYK Line) has designed the concept of ship NYK Super Eco Ship 2030 by using an alternative energy source – fuel cells. Hetland and Mulder (2007) assessed the role of natural gas as a real option in transport and reviewed the new generation LNG-fuelled platform support vessel operating in the North Sea by Eidesvik in Norway. The vessel is quoted with emission reductions of 84% less NOx and 20% less CO_2 than conventional diesel engines.

1.2. Slow steaming development

One of the recent common ways to minimize fuel consumption to reduce operation cost and carbon emission is slow steaming. The practice of slow steaming emerged during the financial crisis in 2009 due to the soared bunker price and the increase in awareness of decarbonisation. The sudden drop in international trade and the low utilization of vessels push the ship liners to evolve the initiatives of slow steaming strategy. Maersk is one of the earliest shipping lines that successfully implemented slow steaming with fuel savings and carbon reduction in 2009. With adjusted network and engine settings, Maersk saved 22% bunker fuel in 2010. Other ship liners started to implement slow steaming speed reduction to save fuel consumption with the consideration of continuous increase in bunker costs. The Shipping Corporation of India, the largest Indian shipping company, announced the adoption of slow steaming as their standard operations in 2012. Vessel speed

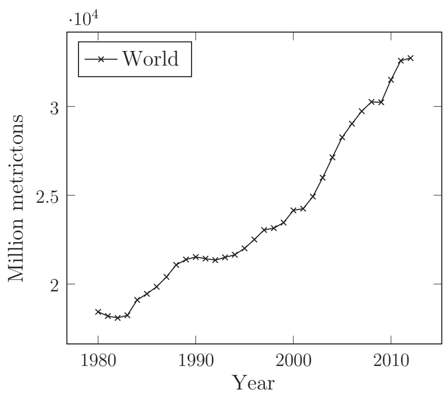

Fig. 1. Total carbon emission from 1980 to 2012 in the world. (Energy Information Administration, 2012).