Maritime Routing and Speed Optimization with Emission Control Area Regulations

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1 Abstract

Shipping is the single most important mode of transportation when it comes to global trade, and around 80 percent of the total trade volumes and 70 percent of the total trade values are transported by vessels (UNCTAD, 2012). Although shipping is the most environmentally friendly mode of global cargo transportation it is still responsible for significant emissions of both traditional air pollutants (e.g. SO_x and NO_x) and greenhouse gases due to the size of the shipping operations. As a measure to reduce these emissions the International Maritime Organization (IMO) has introduced restrictions on emissions to air in certain areas of the world seas. These areas are called Emission Control Areas (ECA), see Figure 1.

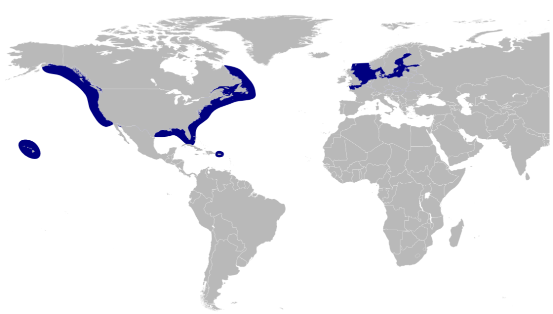

Figure 1: Emission control areas.

In the ECAs the restrictions on emission are primarily achieved by limiting the maximum content of different substances in the fuel oils loaded, bunkered, and subsequently used on-board. As a result the vessels equipped with dual fuel engines will use cheap and "dirty" fuel oils outside, and more expensive and cleaner fuel oils inside the ECAs. For shipping companies this may lead to choosing different sailing paths and speeds than it would have done without the ECAs in order to minimize the total fuels costs. These new sailing paths and speeds might actually lead to higher global emissions of certain gases, and less effective shipping. Abatement technologies are available to allow vessels to use the same fuel both inside and outside ECAs,

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but they include major modifications of the vessels and they demand investments of both money and time. Some vessels may also be deemed unfitted for such modifications. As a result of this it is unlikely that all vessels operating in the ECAs will have abatement technologies installed in the near future. In the the remainder of this work the focus will be on the case where vessels switch fuel types when entering/leaving EACs.

The problem studied consists of finding the optimal route between a set of customers ports that may or may not have time windows for start of service, decide the optimal sailing legs, and the speeds along these legs under the objective of minimizing fuel costs. A sailing leg is defined as a connection between two ports and optimizing the speed used when sailing this is becoming an increasingly important problem in shipping due to high bunker prices and emission reduction, see for instance Fagerholt et al. (2010) and Psaraftis and Kontovas (2013). However, because of ECAs, a shipping company might decide to increase the total length of a sailing leg in order to reduce the distance traveled within the ECA(s), or the speed may differ on the stretch inside and outside the ECA. In the literature, a sailing leg is usually considered a fixed distance or duration between two ports and there is only one possible connection between two ports. Due to the need to select different sailing legs and speeds between ports based on cost and speed choices, a sailing leg is in this work considered to be a sequence of one or more stretches, or parts, with fixed distances. This is to separate the distance sailed within ECAs from other. The rationale for this is that you might want to increase speed when using heavy fuel oils in order to slow down when switching to more expensive fuel oils. Speed optimization under ECA regulations was also studied in Doudnikoff and Lacoste (2014), but there the authors assumed a fixed route with given sailing legs. We present mathematical models for number of scenarios where routes and speed for a single vessel must be decided. The models have been solved using a commercial solver, and the results and their implications are discussed.

References

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