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The fleet renewal problem with regional emission limitations: Case study from Roll-on/Roll-off shipping

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ABSTRACT

In this paper, the maritime fleet renewal problem (MFRP) is extended to include regional limitations in the form of emission control areas. The motivation for including this aspect is that strengthening of emission regulations in such areas is expected to be challenging for deep sea shipping in the years to come. In the proposed model, various means to cope with these stricter emission regulations are evaluated for new vessels, and the possibility of upgrading existing vessels with new emission reduction technology is introduced. We consider future fuel prices to be important for the problem, and have chosen to treat them as uncertain, and thus, a stochastic programming model is chosen. A fleet renewal problem faced by the liner shipping operator Wallenius Wilhelmsen Logistics, concerning whether to use low sulphur fuel or have an exhaust gas scrubber system installed to comply with sulphur regulation in emission control areas from 2015, is used as a case study. Furthermore, tests show that the savings from including the aspect of emission control areas in the MFRP are substantial.

1. Introduction

In 2006, the first emission control area (ECA) was implemented in the Baltic Sea, enforcing a strict limit on SOx emissions from ships in this region (International Maritime Organisation (IMO), 2014a). Since then, more regions have been added to the list of ECAs, such as the North Sea and English Channel, and the North American and US Caribbean coast. In 2012, the global limit was reduced from 4.5% to 3.5% corresponding to emission levels resulting from regular combustion of fuel with a sulphur content of respectively 4.5% and 3.5%. As illustrated in Fig. 1, both the global limit and the ECA limit will be even stricter in the future (IMO, 2014b). The largest immediate concern is the reduction being effective from 1 January 2015, when the maximum level of sulphur content in the fuel within ECAs was reduced from 1.0% (current limit) to 0.1%. Obviously, this is a major challenge for many shipping companies, and will call for changes both regarding operation and composition of the fleet.

To comply with the 0.1% sulphur limit in ECAs after 2015 there are basically three alternatives; switch to low sulphur fuel when entering an ECA (so-called fuel-switching); install an exhaust gas scrubber and continue operations using heavy fuel oil (HFO) as usual; or, install LNG (gas) compatible machinery. In this paper, fleet renewal issues related to emission

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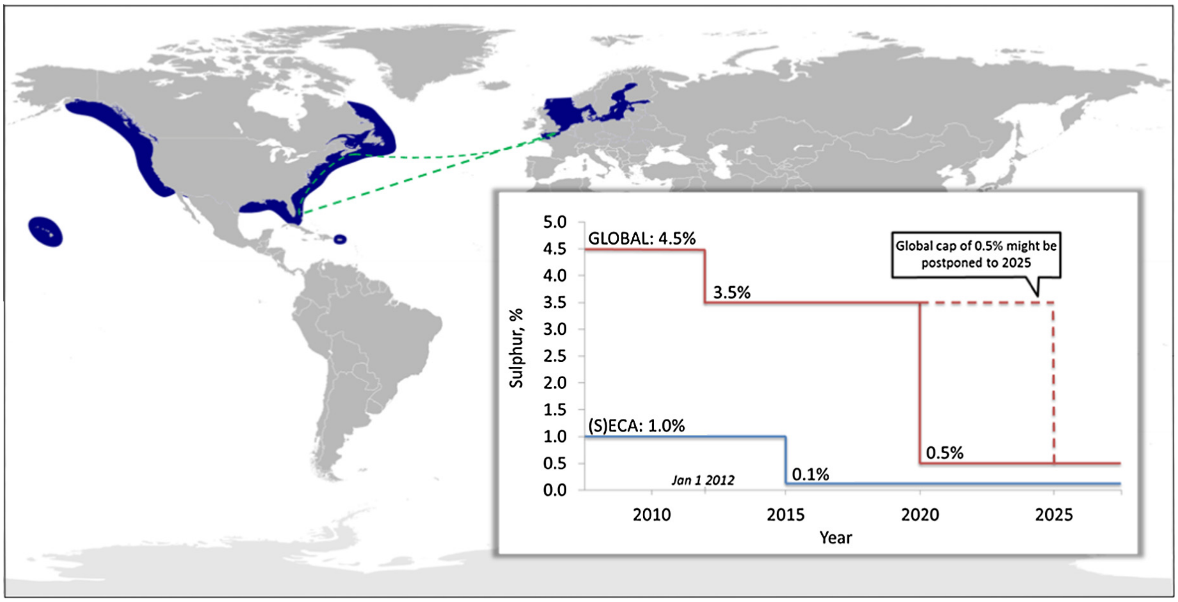

Fig. 1. SOx limits globally and in ECAs and illustration of ECAs.

regulation compliance and various machinery concepts will be addressed in terms of a model for the maritime fleet renewal problem (MFRP) with regional emission limitations.

1.1. The maritime fleet renewal problem

The composition of vehicles in a fleet is an important strategic problem in many transportation segments. In Operations Research (OR) literature, the problem of renewing or adapting an existing fleet is commonly referred to as the fleet renewal problem (FRP). For the maritime sector this is particularly important, due to the long life expectancy of ships, large investment costs, and considerable uncertainty in demand, freight rates and operational costs. In addition to these factors, environmental changes, the natural ageing of vessels, new regulations, and the development of new and more efficient technologies force market players to have their fleet of vessels up to date. In particular, decisions related to replacement (which to replace, replace with what, and when) and upgrading (which vessels should be upgraded, what upgrade is favourable, etc.) are fundamental. In essence, the fleet capacity and characteristics should be adapted to new market requirements. We will refer to the maritime counterpart of the FRP as the MFRP, which will be the basis for the model presented in this paper.

The traditional FRP is a combination of strategic fleet composition decisions (fleet size, and mix of vehicles) and the vehicle routing problem (VRP) in order to minimize lifecycle costs. Clearly, there is a strong dependency between a fleet composition problem and the routing or deployment of the vehicles in the fleet. Important aspects linking deployment and the vehicles are physical dimensions, compatibility and costs. For routing of vessels, examples of such dependencies are length, beam and draft, compatibility aspects such as loading/un-loading facilities and product types, while also variable sailing costs strongly influence the routing, and thus potentially also the fleet composition. As these aspects strongly limit the deployment of the vessels, the fleet composition is undoubtedly of importance when costs are to be minimized in the long run.

Typically, decisions to be made in a MFRP are regarding acquisition, selling, scrapping, chartering out, and chartering in vessels, in addition to the routing decisions made in the underlying deployment problem. Acquisition can be to order newbuilds, buy second hand, or engage in long-term charter contracts. Disposal of vessels can be relevant in various settings; tactical investments can lead to sales in the second hand market; outdated and old vessels can be scrapped; lay-up of vessels can be relevant if the market is poor; charter out is an option if demand (for the company) is low for a shorter period; and, if a vessel is on a long-term charter, the vessel will leave the fleet when the contract expires (if it is not renewed). In addition to these traditional fleet renewal decisions, the strategic aspect of upgrading of existing vessels can in many cases also be relevant, and thus, this is included as a fleet renewal decision in this paper. Reconfigurations can involve making the vessel longer (increasing cargo capacity), retrofit a bulbous bow (to reduce resistance), replace machinery, or retrofit vessels by installing emission reduction technology, to mention some.

Deployment decisions are mainly concerned with what vessels to service what trades to satisfy demand (usually long-term contracts). However, speed, short term chartering, docking (mandatory classing surveys), and spot cargo (the possibility of transporting additional non-contracted cargo) are aspects that often also are considered for the deployment. Revenues