Modeling challenges in maritime fleet renewal problems

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The task of renewing the fleet of a shipping company is one of the most important strategic decisions in maritime transportation. Fluctuations in demand, ageing of vessels, and the development of new and more efficient technologies force shipping companies to decide whether, when and how to renew its vessel fleet. We refer to this as the *maritime fleet renewal problem* (MFRP). Basically, the MFRP is that of deciding how many and what types of ships to operate in each time period, as well as when and how to provide (or dispose of) ships in order to efficiently meet the future (uncertain) demand. The main emphasis is on fleet modification decisions that must be made here-and-now decisions taking into account the future evolution of the market (and consequently of the fleet). Since the problem is faced each time strategic planning is performed, future decisions are only meant as supporting information for the here-and-now fleet modification decisions.

Several alternatives are available when ships are to be provided. Ships can be built or can be bought in the second-hand market. Ships can also be chartered in on time or voyage charters. A number of disposal alternatives are also available. Ships can be sold in the second-hand market or scrapped. Furthermore, ships may be chartered out or be set on lay-up time, which consists of stopping the ship at a port with crew and engine activity reduced to safety levels.

To meet demand, the shipping company has to deploy its ships in order to transport the appropriate amount of cargo from origin to destination. The routing or deployment depends much on the transportation mode of the company, i.e. industrial, tramp or liner. We will refer to the Roll on – Roll off (RoRo) shipping case, which can be categorized as liner shipping, without much loss of generality. When solving the MFRP, we are not really interested in the routing or fleet deployment decisions in themselves. However, in order to find good estimations of the amount of transport work a fleet is able to perform, one also needs to model the deployment of the ships, at least at some high level.

The costs shipping companies meet are due to both providing and operating the fleet of ships. When ships are added to the fleet, costs for buying new or second-hand ships or chartering in ships are met. The value of ships depends on many factors including the state of the freight market. Similarly, also building prices and charter rates depend highly on the market. Fixed operating costs are paid for all the owned ships and consist mainly of manning, insurance, stores, maintenance and repairs, and administrative costs. These costs typically increase with age and are met even if the ship does not sail. When ships are set on lay-up time, fixed operating costs are reduced due to reduced crew and stores and the engine kept on a low regime. Fixed operating costs are paid also for the ships chartered out but not for those chartered in. Finally, variable operating costs are met when a ship sails, and consist of fuel costs, port and canal fees. Revenues are generated by the remuneration for the transportation services provided, coming either from long-term contracts or from spot cargoes. Additional revenues come from selling, scrapping or chartering out ships.

When shipping companies are to renew their fleets, only the current values of demand, new building and second-hand prices, and charter rates are known for sure. The future values of these elements are likely to be uncertain. Similarly, the future travel costs and scrapping values are also uncertain, being mainly dependent on bunker and steel prices, respectively. As far as fixed operating costs are concerned, their main driver is the crew cost whose value is still uncertain but somewhat more easily predictable and under the shipping company's control.

In order to explicitly handle the uncertainty regarding prices and market development, we have proposed a multi-stage stochastic programming model for the MFRP. The model's objective is to minimize the expected cost, while satisfying the shipping company's (uncertain) demand on each trade. The main decision variables represent how to renew the fleet. However, as mentioned above, we must also include variables for how to deploy the ships in the fleet.

We investigate whether uncertainty matters and what problem characteristics that strengthen or weaken the role of uncertainty. Results show that the benefits of using stochastic programming are tangible compared to solving a deterministic model using expected values of the uncertain parameters. We also analyze and discuss the trade-offs between the levels of detail in the modeling of the fleet deployment and the quality of the fleet renewal decisions obtained.