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A decision support methodology for strategic planning in maritime transportation

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ABSTRACT

This paper presents a decision support methodology for strategic planning in tramp and industrial shipping. The proposed methodology combines simulation and optimization, where a Monte Carlo simulation framework is built around an optimization-based decision support system for short-term routing and scheduling. The simulation proceeds by considering a series of short-term routing and scheduling problems using a rolling horizon principle where information is revealed as time goes by. The approach is flexible in the sense that it can easily be configured to provide decision support for a wide range of strategic planning problems, such as fleet size and mix problems, analysis of long-term contracts and contract terms. The methodology is tested on a real case for a major Norwegian shipping company. The methodology provided valuable decision support on important strategic planning problems for the shipping company.

1. Introduction

The world economy is heavily dependent on maritime transportation, which is probably the most important mode of transportation. More than 7 billion tonnes annually are carried by ships, and this figure seems to increase every year [1]. A ship involves a major capital investment (usually millions of US dollars, tens of millions for larger ships) and a large long-term transport contract for a ship operator may span several years and require a considerable increase in fleet size. Proper planning of fleets and their operations has the potential of improving their economic performance and reducing shipping costs. Here we focus on the strategic decisions for a ship operator, ranging from fleet size and mix decisions to transport contract considerations. To ensure good long-term, strategic decisions we also consider a significant amount of details regarding short-term decisions.

Usually we distinguish between three general modes of shipping operations: *Industrial*, *tramp*, and *liner shipping* [2]. In industrial shipping, the cargo owner or shipper also controls the fleet of ships. Industrial operators try to ship all their cargoes at minimum cost. Tramp shipping is similar to a taxi operation, where the ships follow the available cargoes. A tramp shipping company often has a certain amount of contract cargoes that can be considered as mandatory. In addition, the company tries to maximize profit from optional spot cargoes. Liners operate similarly to a bus line, with published itineraries and schedules. The distinction between these modes is not always clear, and shipping companies may simultaneously operate their fleets in different modes. In this paper we limit ourselves to industrial and tramp shipping. Typical cargoes carried in these modes of operation include various dry and wet bulk products. For these two modes, there are a few references on routing and scheduling, see for instance [3–7] and [8]. However, all these studies involve short-term routing and scheduling, which can be considered as tactical/operational planning problems.

The literature is scarce considering studies of strategic planning problems in maritime transportation. We can find some contributions dealing with optimal fleet size and mix problems, see for instance [9] and [10]. However, most of the studies dealing with strategic maritime transportation problems are for liner shipping (including [9] and [10]). The few contributions that are also valid for industrial/tramp are developed to solve only very specialized problems. One exception here is [11], where a model is developed for evaluating the effectiveness of alternative policies regarding chartering out vessels on a long-term basis or operating in the spot/contract market.

For a review on the use of operational research (OR) in maritime transportation, we refer to [12,13] and [14]. Furthermore, in [15], a comprehensive survey of various planning problems in maritime transportation is given, together with a presentation of mathematical models and a discussion of solution methods for some of the problems.

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The objective of this paper is to present a new decision support methodology that is applicable to a wide range of strategic planning problems in industrial and tramp shipping. The methodology includes a Monte Carlo simulation framework built around an optimization-based tool for solving the underlying short-term routing and scheduling problem. The methodology can provide support for ship operators in decision problems related to for instance fleet size and mix and the evaluation of transport contracts.

The rest of the paper is organized as follows. Section 2 gives a thorough description of these focused strategic planning problems and of how they usually are or can be solved, both in practice and in the research literature. Section 3 presents the proposed decision support methodology for these problems. A case study where we have applied the decision support methodology to provide decision support for an industrial shipping company in a real setting is described in Section 4. Concluding remarks are given in Section 5.

2. Strategic planning in industrial and tramp shipping

Strategic planning in industrial and tramp shipping spans a large variety of problems. Since there is a strong interplay between strategic, tactical and operational planning levels, one often cannot provide valuable decision support for strategic problems without simultaneously considering the underlying routing decisions. This is also emphasised in the first review paper on ship routing and scheduling [14]. Therefore, we start in Section 2.1 by briefly describing the underlying short-term routing and scheduling problem in industrial and tramp shipping. Section 2.2 presents the most important strategic planning decisions on which we focus in this paper, while a discussion of various solution approaches is given in Section 2.3.

2.1. The short-term routing and scheduling problem

The short-term routing and scheduling problem in industrial and tramp shipping consists of optimally assigning cargoes to available ships in the fleet and simultaneously deciding the underlying routes and schedules for each ship. Each *cargo* consists of a pickup port, a delivery port, a quantity of a given product (can be given in an interval), and a time window (for loading and/or discharging) in which the loading/discharging must start. To service the cargoes, the ship operator controls a fleet of ships, each ship with a given capacity and service speed. In contrast to traditional Vehicle Routing Problem the ships do not return to a depot, and their initial and ending positions in a given planning problem can be any port or point at sea. The ship routing and scheduling problem is similar to a multi-vehicle Pickup and Delivery Problem with Time Windows, where pickups and deliveries can be combined and the ships may in principle never be empty, see [16]. However, in maritime transportation applications, there are often special additional constraints, like for instance ship-port compatibility (can be dependent on the load onboard the ship), ship-product compatibility and stowage constraints. There are often multiple time windows, since many ports are closed for service during nights and weekends and time windows usually span several days.

For an industrial shipping application, the objective is to service all (contract) cargoes while minimizing costs. In tramp shipping, the objective is to maximize profit. All contract cargoes must be serviced, while there may be some optional spot cargoes that may only be carried if there is enough fleet capacity and if they contribute positively to the profit. In both modes, the routing and scheduling will usually be performed by following a rolling horizon principle, where the plan is updated when new important information becomes available (e.g. new requests for spot cargoes or information about ship delays). For a further description, including mathematical models for different versions of the underlying short-term routing and scheduling problem in industrial and tramp shipping, we refer to [15].

2.2. Strategic planning problems

In this paper we focus on two important classes of strategic decisions for industrial and tramp shipping companies:

- Contract analysis
- Fleet size and mix

Contract analysis includes decisions such as whether to accept or reject a given long-term transport contract and analysis of negotiable terms in the contract. The most common long-term contract in industrial and tramp shipping is the so-called *Contract of Affreightment* (COA), which is a contract to carry specified quantities of a given product between specified ports within a specific time frame for an agreed payment per tonne. In each COA, the shipper or customer will specify cargoes (as described for the short-term routing and scheduling problem) to be lifted by the ship operator. Most often, these cargoes are agreed to be evenly spread throughout the contract period, specifying to some extent how the COA should be divided into cargoes with given quantities and time window widths throughout the year. In such a contract, negotiable terms, in addition to the income rate, might be

- width of the time windows of cargoes,
- flexibility in quantities for each cargo, and
- notice times, i.e. the time in advance the shipper must give a notice about the cargo.

All these terms can substantially influence the possibility the shipping company has to utilize the fleet effectively and improve profit. It is for instance obvious that increasing the width of the time windows can give the ship operator more possibilities to find better routing and scheduling decisions. The same is true when the ship operator is given more flexibility regarding cargo quantity. If the cargo quantity comes in an interval, for instance 10,000 ton $\pm$ 10%, instead of a single value, there may be more flexibility regarding which ship to use for the cargo. Also if the notice time increases, the planner gets more information earlier that can be utilized to find better solutions.

When a tramp shipping company that also operates in the spot market analyses whether or not a COA will be profitable, it has to make some assumptions about how the spot market will develop for the given contract period. Typically, if the shipping company anticipates low spot rates, it will prefer to have as large contract coverage as possible, or go 'short of tonnage' and vice versa.

Fleet size and mix problems aim at determining an optimal fleet for a given market situation. Only in rare situations is it relevant to determine a completely new fleet size and mix. In most practical industrial and tramp shipping problems, the fleet size and mix problem is more about adjusting or extending an existing fleet. Many shipping companies have fleet renewal programmes that run continuously. Often, the need for adjusting the fleet comes from the scrapping of old ships, while the need for extending the fleet often comes from new COAs or an increased focus on getting a higher share of the spot market.

Contract analysis and fleet size and mix decisions are strongly interrelated. For instance, if a shipping company gets a request for a new major long-term contract it may be necessary to extend or