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Maximizing the rate of return on the capital employed in shipping capacity renewal ☆

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ABSTRACT

Decisions regarding investments in capacity expansion/renewal require taking into account both the operating fitness and the financial performance of the investment. While several operating requirements have been considered in the operations research literature, the corresponding financial aspects have not received as much attention. We introduce a model for the renewal of shipping capacity which maximizes the Average Internal Rate of Return (AIRR). Maximizing the AIRR sets stricter return requirements on money expenditures than classic profit maximization models and may describe more closely shipping investors' preferences. The resulting nonlinear model is linearized to ease computation. Based on data from a shipping company we compare a profit maximization model with an AIRR maximization model. Results show that while maximizing profits results in aggressive expansions of the fleet, maximizing the return provides more balanced renewal strategies which may be preferable to most shipping investors.

1. Introduction

Among the most crucial decisions for a shipping company, the composition of the fleet of ships determines, to a great extent, the competitiveness of the company. Finding the best adaption of the fleet to volatile market conditions is the main scope of the Maritime Fleet Renewal Problem (MFRP), which consists of deciding how many and which types of ships to add to the fleet and which available ships to dispose of (see, e.g., [3,30,31]).

The MFRP can be considered a special version of the Capacity Expansion Problem (CEP) or of the Machine Replacement Problem (MRP). CEPs seek the best addition to available capacity in order to meet increasing demand, while MRPs seek the best substitution of available machines, induced by factors such as obsolescence [29], deterioration, and ageing. In CEPs and MRPs the terms "capacity" and "machine" generically refer to equipment of various types, such as, cables, pumps, computers, and vehicles [33], with differences in, for example, economic life, cost magnitude, and relevance for the core business.

CEPs and MRPs have received considerable attention by the operations research community, producing a plethora of models at increasing level of realism, and adapting to various operating configurations. For example, Fong and Srinivasan [12] consider multi-period capacity expansion and location, Li and Tirupati [22] focus on the trade-off between specialized and flexible capacity in multi-product production systems, Cormier and Gunn [10] consider warehouse capacity expansion under inventory constraints, Kimms [19] combines capacity expansion with production planning and lot sizing, van Ackere et al. [40] study the short-term problem of adjusting the capacity in reaction to the behavior of customers waiting in queues, while Ahmed et al. [2] and Bean et al. [4] study CEPs under uncertainty. The main issues faced in CEPs are related to expansion size, time, and location [24] and the option of replacing machines is typically ignored [33]. As far as MRPs are concerned, Sethi and Chand [37] consider the replacement of single machines with only one replacement alternative, while Chand and Sethi [6] allow the possibility of replacing available machines by any from a set of available alternatives. Goldstein et al. [14], Nair and Hopp [29], Hopp and Nair [16], and Adkins and Paxson [1] consider replacement decisions triggered by technological breakthroughs. Typically, MRPs do not consider the possibility of changes in the demand for equipment. Capacity expansions and replacements are however naturally tied decisions (see, e.g., [34,33,35,7]).

The problem of expanding/replacing transportation capacity takes on specific features due to the interplay between the investment in vehicles and their routing. Classical models focus

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mainly on the initial configuration of a fleet of vehicles (see, e.g., [11] and the surveys in [15,30]), rather than its evolution. However, the problem of renewing fleets of vehicles has recently received attention especially in the maritime literature, due to the volatile nature of the shipping business, and the consequent need to adjust shipping capacities in response to changes in the market. As an example, Alvarez et al. [3] and Pantuso et al. [31] consider multi-period renewal of a fleet of ships in order to cope with uncertain market developments. Examples can also be found for rail-road capacity expansions (see, e.g., [23]).

The studies mentioned above cover a wide variety of operating features and equipment types. However, relatively little attention has been paid by the operations research community to the financial aspects related to investments in capacity besides their technical fitness. Most of the models available seek minimum cost or maximum profit capacity expansion/replacement decisions with the Net Present Value (NPV) being the only metric used. However, financial and economic data related to an investment can be aggregated in a number of alternative ways, giving rise to different metrics often used in place of, or in conjunction with, the NPV for evaluating the profitability of capital asset investments (see, e.g., [36,27]). This is especially true for equipment with long economic life and a relevant capital magnitude, such as vehicles, buildings, and pipelines. As an example, Menezes et al. [28], pointing out that a mere attention to profit in facility location can lead to too high investments, include Return on Investment thresholds requirements in the corresponding models, and show that this leads to a higher utilization of the available facilities. Particularly, for the case of maritime shipping, Stopford [38] shows that investments can be evaluated by the ratio between the economic value added by the transportation services over the net asset value of the fleet.

In this paper, we consider the maximization of the *Average Internal Rate of Return* (AIRR) in the renewal of maritime shipping capacity. The AIRR [25] measures the return of multi-period investment projects which generalizes and solves a number of flaws of the well known concept of *Internal Rate of Return* (IRR) as explained by Magni [26]. It can be expressed as the ratio between the actualized returns generated by a stream of capital investments over the actualized sum of the investments. This metric is in line with the indicator used in Stopford [38]. The focus is on the MFRP as it well represents strategic CEPs and MRPs due to the long economic life of ships, their cost magnitude, and the high level of uncertainty. As an example, the second-hand price of a five year old 300 000 deadweight tons (dwt – a standard measurement unit for the ship carrying capacity) oil tanker, increased from 124 to 145 million dollars in 2008, and fell down again to 84 million dollars in 2009 as reported by the United Nations Conference on Trade and Development [39]. The contribution of this paper is therefore twofold: (1) we introduce a model for maximizing the AIRR for capacity renewal in shipping, and (2) we compare the results of the new model against that of a more classic model maximizing profits NPV in order to offer managerial insights by highlighting the economical and structural differences in the solutions obtained. In addition, we show how the resulting non-linear AIRR model can be reformulated in an equivalent linear model in order to ease computation. In order to account for market information being revealed at different points in time, both the AIRR and the profit maximization problems are formulated as multistage stochastic programs.

The remainder of this paper is organized as follows. In Section 2 we provide a thorough description of the MFRP. In Section 3 we introduce a mathematical model for the MFRP which maximizes the AIRR, as well as an alternative model which maximizes profits. In Section 4 we analyze the results and the solutions obtained by the two alternative models based on the case of a major liner shipping company. Finally, conclusions are drawn in Section 5.

2. The renewal of maritime shipping capacity

The MFRP is a special version of MRPs and CEPs due to routing constraints. The objective is to seek an investment mix which is sound in some economical sense (typically cost efficient) and respects operating constraints. In what follows, we sketch the main features of the problem, while a detailed description can be found in Pantuso et al. [31].

The MFRP consists of deciding, for each time period, how many ships of each type to add to or remove from the available fleet. Ships can be bought in the second-hand market, or built. In the former case, the company must choose from the ships available in the market but the ship is available in short time (typically weeks to months). In the latter case the ship can be built according to the company's specifics but the building process takes longer time (typically years). Ship prices depend, to a great extent, on the type of ship, its age, and on the market status. Ships can be disposed of by selling them in the second-hand market or scrapping (demolishing) them. In both cases the ship can be removed from the fleet in weeks to months. Scrapping rates depend to a great extent on the weight of the steel the ship is made of, and are therefore sensitive to changes in steel prices.

A necessary distinction must be made. In the shipping business there exist two broad types of players interested in investing in ships, which we will refer to as *speculators* and *ship operators*. Speculators see ships as an asset to trade. Their main scope is buying ships in order to sell them at a higher price when the market allows so. They do not necessarily have competencies in shipping operations, but see ships as a marketable asset. Ship operators, on the contrary, buy ships to operate them. Their business model consists of using ships to provide transportation services. Finer classifications, though possible, are beyond the scope of this paper. In what follows we refer to the ship operator type of player.

When deciding how to modify the available fleet, investors must take into account how the fleet is operated. This includes both the possibility of temporary adjustments to the fleet and the utilization (i.e., the sailing activities) of the available fleet. Temporary adjustments to the fleet are mainly done by means of *time charters*, which consist of hiring a ship and its crew for a period time (weeks to years). The charterer pays a (per day) fee as well as all sailing-related expenses, such as fuel and port fees. The owner of the ship bears the rest of the costs, such as capital cost, crew, and insurance. Any shipping company can, in general, act both as a charterer and a charteree, depending on the specific need. Fleets can also be temporarily scaled down by *laying-up* ships, which consists of stopping ships at port for a period of time, paying port fees but reducing operating expenses such as manning, storages, and, possibly, insurance.

The utilization of the ships depends on the shipping company's operation mode (see, e.g., [21,9]). In what follows we focus, without much loss of generality (see [31]) on liner shipping operations. Liner shipping companies *deploy* their fleets on a number of *trades*. A trade is a sequence of origin and destination ports in different geographic areas (e.g., Europe to U.S. and Asia to Europe). A ship deployed (i.e., assigned) to a trade (*servicing* the trade) visits some/all of the ports on the trade according to a pre-published schedule, picking up cargoes at origin ports and delivering cargoes at destination ports. Concluded the sailing on one trade, the ship is deployed on another/the same trade with, possibly, some empty (*ballast*) sailing to reposition the ship. Trades are separated into *contractual* and *optional* trades. On contractual trades the shipping company has contractual transportation

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