Establishment of a Comprehensive Fleet Optimization Model for River -Sea-Going Ships under Low-Carbon Economy

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ABSTRACT

A comprehensive optimization model is set up to optimize the configuration and speed of river-sea-going fleet within specific transportation environment. This model aims at minimizing the fleet’s annual running cost and carbon emission under the condition of meeting the forecasted cargo demand. Genetic algorithm is applied to solve this non-linear problem with multi-variables and multi-restrictions. The best ship-type configuration and segmental speed of the fleet can be determined through this optimization, thus providing suggestions for the formation and operation of river-sea-going fleet under low-carbon environment.

KEY WORDS: River-sea-going fleet; fleet optimization; optimal speed; segmental research; carbon emission

INTRODUCTION

River-sea-going transportation is the transportation mode which ship sails directly from inland to sea area with cargo immediately transported from origin port to destination port. This kind of transportation way attracts more and more Chinese shipping enterprises by its advantage of saving delivery costs and laytime. After 20 years of development, river-sea-going transportation has become the fresh combatant of Yangtze shipping, but there are still many problems exist, which are mainly as follows: the technical level lags behind, and the ship types do not match the transportation environment. The capacities of river-sea-through container ships in Yangtze River are mostly less than 500 TEUs (20-foot equivalent units), which leads to the economic inefficiency and inconformity with the requirements of shipping market. In allusion to the problems mentioned above, the traditional fleet optimization methods mainly consists of linear programming and dynamic programming (Yang, 2010). John L Everett (1972) put forward a comprehensive fleet deployment model to optimize the composition of a newly-built American fleet in the next 10 years without considering the ships’ sailing speed. Powell and Perkins (1997) proposed a new computing model with the combination of linear planning and integer planning to ascertain the optimal configuration of the fleet in different routes. Yang (2010) fully summarized the research status and solving method of fleet planning. All these researches above didn’t mention the ship’s speed, which can dramatically affect fuel cost and carbon emission.

In allusion to the problems mentioned above, the traditional fleet optimization model is extended to optimize the configuration and speed synchronously in this paper. The segmental research is applied to optimize the operation process of the newly-built fleet with the number of each ship type in different seasons (dry season and wet season) and the sectional speed taken as variables. Moreover, the carbon emission regulation under market mechanism is introduced to reduce the discharge of carbon while minimizing the running cost of the fleet. The remainder of this paper is organized as follows: (1) A thorough description of the comprehensive optimization model is given, including the exposition of the segmental research and the forecast of cargo volume. (2) The mathematical formulation for the problem is presented with a special focus on the modeling of the ships’ speeds. (3) Describe the self-programmed genetic algorithm proposed for solving the problem. (4) A computational study is performed, while concluding remarks are given in the final section.

PROBLEM DESCRIPTION AND ASSUMPTIONS

The configuration and speed of the ships are the main decision variables for a newly-built fleet with a determined route. Let $S = \{S_1, S_2, ..., S_n\}$ be the set of ship types to be selected for the fleet. They have different cargo capacities, sailing speed ranges and fuel consumption profiles separately. When establishing the fleet, we should choose the ship which can match the transportation demand and reduce...