Route optimization of container water-rail combined transportation under uncertain environment

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ABSTRACT

Considering the optimization of container multimodal transport under uncertain conditions, it has been defined as a chance-constrained programming problem in this paper. Firstly, a multi-objective optimization model has been established by using the triangular fuzzy number method. And then, the vessel waiting time was added into constraint conditions, and carbon emissions were calculated by introducing the forest accumulation conversion factor method. Finally, the improved ant colony algorithm was used to calculate the weight coefficient of each element. The results show that the route optimization method exhibits the excellent performance of convergence and provides a theoretical basis for transport scheming.

KEY WORDS: Multimodal transport; route optimization; uncertain conditions; ant colony algorithm; Triangular fuzzy numbers method.

INTRODUCTION

With the rapid development of global trade, in the inland area, it is far from enough to rely on railway transportation or inland waterway transportation for bulk goods. As an important organizational form of modern logistics transportation, the Water-Rail combined operation can make use of the advantages of waterway and railway transportation to provide more flexible and reliable options for cargo transportation, so it has attracted widespread attention.

In recent years, domestic and foreign scholars have mainly studied the multimodal transport route optimization problem. The establishment of multimodal transport route selection models is generally optimized from the aspects of the objective function, constraint conditions, and random factors. Ji et al. (2017) considered carbon emission factors, reloading time, and cost, and established an optimization model to minimize the total transportation cost and time. Cheng et al. (2019) established a multimodal transport route selection model under four carbon emission policies (mandatory carbon emissions, carbon tax, carbon trading, and carbon compensation). Wang et al. (2017) took transportation time, cost, carbon emissions, and comprehensive energy consumption as targets, and determined the final weights of the four objective functions with an entropy weight-analytic hierarchy process. Marjani et al. (2015) considered the mixed time window as a constraint condition and converted the time window into penalty cost. Wang et al. (2019) established a multi-task container transportation scheme optimization model with time and capacity constraints. Chen et al. (2020) considered the receiving time window as the soft constraint of the model. Martin et al. (2015) considered the uncertainty associated with travel time. Zhen et al. (2018) optimized the model for the uncertainty of transportation time and carbon emissions. Jiang et al. (2020) established a mathematical programming model based on demand uncertainty and used robust optimization to deal with constraints. For multimodal transport route selection, commonly used algorithms include the Dijkstra algorithm (Zhang et al., 2015), the genetic algorithm (Xiong et al., 2014; Yuan et al., 2021), the ant colony algorithm (Goel et al., 2019), particle swarm algorithm (Yu et al., 2019; Deng et al., 2021) and the hybrid algorithm of the above algorithms (Wan et al., 2019; Liu et al., 2020).

In the process of establishing the route optimization model, the waiting time of ships is hardly considered. Previous studies only considered carbon emissions and regarded railways and waterways' transportation speed and risk as a definite value. In response to the above problems, this paper introduces the waiting time of ships to establish an optimization model for container water-rail combined transport in an uncertain environment with the goals of the total cost, total time, greenhouse gas emissions, and risks. The improved ant colony algorithm selects the route of water-rail intermodal transportation.

1 Problem Description

Assuming that a batch of goods needs to be delivered from the departure city to the destination city, for the water-rail combined transport operator, it is necessary to consider the existing cargo volume, starting and ending locations, and service quality in terms of economy, timeliness, environmental protection, safety, etc. Factors to choose the optimal combination of transportation route and transportation mode, to achieve the result of customer satisfaction. This question assumes the following:

1) There is at least one mode of transport on any section of the path of the container water-rail intermodal transport network.
2) Only one mode of transport can be selected for the same batch of goods on the known intermodal route.
3) Goods are only transferred at nodes, and each node can only be transferred once.
4) The capacity of each node and each path is much larger than the cargo volume.