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Research on VRP Model Optimization of Cold Chain Logistics Under Low-Carbon Constraints

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ABSTRACT

The research in this article aims to consider low-carbon factors, through reasonable vehicle allocation and optimization of distribution routes, to achieve high satisfaction and low total cost, and to provide an optimized solution for fresh food distribution companies. In this article, cargo damage cost, energy cost, and carbon emission cost are added to the total cost, and customer satisfaction constraints based on time and quality are added, respectively, to construct a multi-vehicle cold chain VRP model under the low-carbon perspective. In order to obtain a good initial path method, a good chromosome is generated and added to the initial chromosome population according to the constraints of the vehicle type and time window, and the local elite retention strategy is combined to speed up the population convergence. Finally, taking the data of A Fresh Food Company as an example, the MATLAB software is used to realize the programming, which verifies the validity and superiority of the multi-vehicle cold chain VRP model under the low-carbon perspective.

KEYWORDS

Cold chain logistics, low-carbon environment, multi-vehicles, partheno genetic algorithm, VRP optimization

INTRODUCTION

In recent years, cold chain logistics has developed rapidly. As a representative industry for consumption upgrades in the logistics industry, it has received extensive attention (L. Zhang et al., 2019). China's aquatic product market, meat product market, agricultural product market, quick-frozen food market, and dairy product market all have broad development prospects. According to statistics, in 2017, the total demand for cold chain logistics in China reached 147.5 million tons, an increase of 22.5 million tons over the previous year. The total value of currency in circulation reached four trillion yuan, an increase of 18% year-on-year. The total revenue of the logistics industry was 255 billion yuan, a year-on-year increase of 13.3% (Y. Zhang et al., 2020).

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The low-carbon concept advocated by the Chinese government continues to deepen, and cold-chain logistics distribution companies are gradually integrating low-carbon in the distribution process, comprehensively considering economic and environmental benefits (Chaudhuri et al., 2018). In the field of cold chain distribution, some experts and scholars have put forward corresponding suggestions for the low carbon emission of cold chain logistics (Rahmani et al., 2018). In order to enable cold chain distribution companies to achieve the goal of energy saving and emission reduction (Li et al., 2022), many scholars take carbon emission factors into consideration when studying the path optimization problem of a single distribution center and the path optimization problem of multiple distribution centers (Behzadi et al., 2013).

Taking into account the insufficient capacity of a single distribution center, scholars have gradually shifted from the study of single distribution center path optimization to multi-distribution center path optimization, taking carbon emission factors into consideration (Azad et al., 2022). However, this kind of research is relatively rare (Tan et al., 2006). Based on the concept of green logistics development (Kainuma & Tawara, 2006), some scholars have cost carbon emissions and proposed a cold chain distribution path optimization problem in which enterprises have multiple distribution centers (Gunasekaran & Ngai, 2012). Some scholars have proposed a multi-park green vehicle routing problem (Rabbani et al., 2018), constructed a multi-objective mathematical model that maximizes revenue (Lai et al., 2004), minimizes cost, minimizes time, and minimizes emissions and uses an improved ant colony optimization algorithm to effectively solve it (Jayaram & Tan, 2010). Some scholars have studied the multi-park vehicle routing problem with time windows (Chen, 2021). Under the constraints of time windows, vehicle capacity, fleet size, etc., they have constructed a multi-objective mathematical model with minimum total cost, fuel consumption, and carbon dioxide emissions as the optimization goals (W. Wang et al., 2021). A meta-heuristic algorithm based on ant colony algorithm is proposed to solve the problem (Ren et al., 2020).

In summary, domestic and foreign scholars have conducted certain research on the optimization of ordinary cold chain logistics (Obi et al., 2020), semi-open multi-distribution center cold chain logistics distribution path optimization, and cold chain distribution path optimization considering carbon emissions (Liu et al., 2021). However, in studying the optimization of the cold chain joint distribution route considering carbon emissions (Borumand & Beheshtinia, 2018), the related solving algorithms mainly focus on basic heuristic algorithms (Xiao & Konak, 2017), and there may be problems that consider the related costs in the distribution process (Bai et al., 2022). Cost benefit analysis is crucial in the optimization of cold chain joint distribution paths considering carbon emissions. The cost mainly includes direct costs, indirect costs, and carbon emission costs. The direct costs include direct expenses such as labor, vehicles, fuel, and maintenance. Indirect costs include such expenditures as management expenses, warehousing costs, etc. Carbon emission costs are typically used to measure environmental impacts. This may include government mandated carbon taxes or carbon trading costs. Optimizing distribution routes can reduce transportation mileage, fuel consumption, transportation costs, and reduce traffic congestion. Moreover, optimizing delivery routes can also reduce carbon emissions, improve air quality, and have a positive impact on the environment. In this paper, cargo damage cost, energy consumption cost, and carbon emission cost are added to the total cost (Wang & Wen, 2020), and customer satisfaction constraints based on time and quality are added to construct a multi-vehicle cold chain VRP Model under a low-carbon perspective (S. Zhang et al., 2019).

MATERIALS AND METHODS

VPR Basic Theory

VRP refers to formulating distribution rules for distribution vehicles, specifying optimization goals (such as minimum cost), and meeting corresponding constraints (such as not exceeding in terms of vehicle load and minimum delivery vehicles) (S. Wang et al., 2017). The delivery route and