energies

MDPI

Article

Optimization of Inventory Routing Problem in Refined Oil Logistics with the Perspective of Carbon Tax

Songyi Wang [1], Fengming Tao [1,2,*] and Yuhe Shi [3]

[1] College of Mechanical Engineering, Chongqing University, Chongqing 400044, China; songyi_wang@cqu.edu.cn
[2] School of Economics and Business Administration, Chongqing University, Chongqing 400044, China
[3] School of Transportation and Logistics, Southwest Jiaotong University, Chengdu 610031, China; SHI681242@163.com
* Correspondence: taofengming@cqu.edu.cn; Tel.: +86-185-8070-7012

Received: 12 May 2018; Accepted: 28 May 2018; Published: 4 June 2018

Abstract: In order to solve the optimization problem of the refined oil distribution system from the perspectives of low-carbon and environmental protection, this paper focuses on the characteristics of the secondary distribution of refined oil and combines it with the integrated optimization concept of refined oil distribution network, where a low-carbon inventory routing problem (LCIRP) model is constructed with the minimum total costs as the objective function on the basis of considering carbon emissions. An adaptive genetic algorithm combined with greedy algorithm is designed to solve the model, and an example is given to verify the effectiveness of the algorithm. Then, this paper solves the model with two parts by introducing a practical numerical example: in the first part, the LCIRP models with different carbon tax values are solved, which verifies the effectiveness of the model and proves that carbon tax policies can effectively reduce the carbon emissions in the secondary distribution network of refined oil; in the second part, the LCIRP models with the different maximum load capacity of oil tank trucks are solved, which provides the economic and environmentally friendly distribution schemes for refined oil distribution enterprises under the premise of carbon tax policies and load limitation. Finally, the emission reduction proposals that take into account both economic and environmental benefits are given respectively from the aspect of government environmental protection agencies and from the aspect of refined oil distribution enterprises.

Keywords: refined oil distribution; inventory routing problem; hybrid genetic algorithm; carbon emissions; carbon tax

1. Introduction

As a special energy commodity, petroleum plays a decisive role in the national economy and people's livelihood in a country [1]. The distribution of refined oil refers to the entire logistics process of transporting refined oil from the oil refinery to consumers, which connects the oil refining company, distribution oil depots and sales outlets (gas stations). In addition, the distribution of refined oil can be divided into two stages: primary distribution and secondary distribution. A primary distribution refers to the process of transporting refined oil from the refinery to distribution oil depots, and secondary distribution refers to the process of transporting refined oil from a distribution oil depot to gas stations [2]. The secondary distribution of refined oil has the characteristics of small quantity and multiple batches. With the intensification of global market competition, the importance and necessity of a highly efficient distribution network integration strategy have begun to become prominent. How to achieve the reduction of transportation costs and the improvement of distribution efficiency in the

inventory routing problem (IRP) of gas stations in a region has gradually become a core problem in corporate distribution management. At the same time, the combinatorial optimization research on the IRP of refined oil secondary distribution has also become the focus of many scholars.

In order to meet the needs of economic development, gas stations need a continuous supply of refined oil, but the transport of small quantity and multiple batches poses a series of threats to the ecological environment. The transportation of petrochemical products will generate a large amount of carbon emissions, which will lead to the increase of greenhouse gases, exacerbating air pollution and the greenhouse effect [3,4]. With the continuous promulgation of the carbon tax and other regulatory policies, the low-carbon transportation is imperative [5]. Therefore, it is necessary to optimize the design of the refined oil distribution network while considering the constraints of efficiency and environment, thus reaching a balanced state of economic efficiency and environmental benefits to achieve a win-win situation.

The remaining parts of this paper are organized as follows. In the next section, a literature review on the refined oil distribution optimization problem, as well as the balance between carbon reduction and cost optimization, is presented. Section 3 discusses the construction of the low-carbon IRP (LCIRP) model. The hybrid genetic algorithm is introduced to solve the model in Section 4. Section 5 gives a numerical experiment and results analysis. Finally, Section 6 concludes this paper and presents expectations for future work.

2. Literature Review

Since the main idea of the current research is to balance carbon emission reduction and cost optimization in IRP of refined oil logistics. We review the studies in two fields: refined oil distribution optimization and the balance between carbon reduction and cost optimization.

2.1. Refined Oil Distribution Optimization

Federgruen and Zipkin [6] first explicitly proposed the inventory routing problem (IRP) in 1984. They optimized the inventory routing scheme of the supply chain through scientifically making decisions about retailer's order quantity, order cycle, and route arrangement. In the same period, Golden et al. [7] also made a similar study. The ratio of the current inventory level to the storage capacity was used to describe the urgency of distribution demands, and a heuristic algorithm was designed to solve the problem.

With the improvement of the research level, the research of IRP has shown a trend of increasing complexity of the problem, and the depth and breadth of the problem have been extended. Avella et al. [8] studied the oil transportation problem with limited distribution resources (limited vehicles and limited drivers). A heuristic algorithm combined with the branch pricing algorithm was designed, which can be solved quickly. Moreover, they illustrated the effectiveness of the algorithm by multiple sets of real-world examples. Cornillier et al. [9–11] has been devoted to the study of IRP. They constructed mathematical models from the perspectives of multi-period distribution, distribution with time windows, multiple oil depot distribution and so on, and designed efficient algorithms to solve them. For the vehicle routing problem in the distribution of refined oil, Dai et al. [12] designed a human–computer interactively solving method based on a two-phase heuristic algorithm. Ma et al. [13] proposed a mathematical model with the shortest driving path and high full load rate as the optimization goals for the secondary distribution of refined oil, and the improved genetic algorithm was used to solve the model. Bocto et al. [14] designed several heuristic algorithms to solve the mathematical model for the problem of replenishment at gas stations, the simulation and real data were applied to verify the effectiveness of the algorithms respectively. Zhen et al. [15] studied the distribution of refined oil from the perspective of third-party logistics and introduced a combinatorial auction mechanism to construct a mixed-integer programming model with the objective of minimizing costs. A heuristic algorithm was devised to solve the problem. Popovic et al. [16] aimed at IRP in the refined oil logistics. An improved variable neighborhood search algorithm was introduced to solve the