

School Bus Routing Considering Operation and Travel Costs

Kailei Li¹, Han Bai^{1,*}, Xiang Yan¹, Manxi Zhu¹ and Xiuguang Wang¹

¹ School of Transportation and Logistics Engineering, Shandong Jiaotong University, Jinan 250357, China

Abstract. In order to solve the problems of high operating cost and poor service quality of school bus due to the scattered distribution of bus stops in rural areas, multi-objective SBRP (School Bus Routing Problem) models were developed for the mixed-load and non-mixed-load scenarios. In the non-mixed-load scenario, a model of the SBRP was developed to optimize the students' travel cost and school operating cost, while in the mixed-load scenario, another model of the SBRP was developed to consider the input cost and operation cost of the school bus. Several heuristic algorithms were compared, based on which the simulated annealing algorithm was selected to solve the models, and the horizontal comparison of the solution results based on genetic algorithm were determined. Tests were conducted on an international bench mark case and the constructed models were solved by introducing different search operators into the simulated annealing algorithm, then the proposed approach was applied to the optimal design of school bus routes in Wulian county, Rizhao, Shandong province. The results showed that in the non-mixed-load scenario, compared with the original school bus operation mode, the school bus input, mileage and travel cost were reduced by 28.6%, 37.8% and 35.6%, respectively, and students' travel cost was reduced by 4.3% considering the students' perception of school bus service. While in the mixed-load scenario, the proposed approach reduced the school bus input, mileage and travel cost by 37.5%, 42.0% and 35.8%, respectively; due to the complexity of the mixed-load scenario, it is difficult to take the travel cost into account, thus the students' travel cost was increased by 0.5%. The proposed SBRP models were verified to be effective and the simulated annealing approach can optimize service quality and reduce operation cost of rural school bus to a greater extent than the genetic algorithm.

AMS subject classifications: 91B32, 90C29

Key words: Highway transportation management, School Bus Routing Problem (SBRP), Mixed-load, Simulated annealing, Multi-objective, Travel cost.

Translated from *Journal of Nanjing University of Information Science & Technology*, 2023, 15(3): 293-303.

*Corresponding author. Email addresses: likailei2021@163.com (K. Li), gushantraffic@163.com (H. Bai).

©2023 by the author(s). Licensee Global Science Press. This is an open access article distributed under the terms of the Creative Commons Attribution (CC BY) License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

1 Introduction

At present, the development of rural traffic in our country is generally backward and the school bus service is not perfect in rural areas. Different from the short-distance line length and high-density station coverage mode of urban school bus stations, rural school bus stations mostly show the demand mode of longitudinal extension and scattered distribution, and rural school bus route planning needs to be improved. School Bus Routing Problem (SBRP) is a combinatorial optimization problem that can reasonably plan school bus routes to send students from bus station to school (or return from school to bus station) and achieve specific goals under the constraints of school bus capacity and time window. Since Newton et al. [1], the author of the multi-school SBRP problem, generated school bus routes and schedules based on heuristic algorithms and used quadratic programming to plan school bus network, many scholars have been exploring relevant mathematical models, optimization algorithms and their applications. In order to solve the problem of school bus routing, Jaradat et al. [2] adopted Intelligent Water Drops (IWD) algorithm to optimize and solve the problem by targeting school bus capacity, maximum ride time and school time window. Calvete et al. [3] proposed a local assignment local search algorithm to solve the school bus routing problem with parking space selection. Gao Wei et al. [4] focused on the problem of the minimum number of operations of school buses, defined and described the problem of school buses, and divided the problem into limit case and general case. The SBLS (School Bus Limit Situation) algorithm and SBGS (School Bus General Situation) algorithm are designed for different situations. Regarding mixed-load SBRP, Hargroves et al. [5] pointed out the research direction, but did not build relevant models and algorithms to solve it. Hou et al. [6] constructed a hybrid iterative local search (ILS) meta-heuristic algorithm that can be used for SBRPS with multiple planning scenarios, including homogeneous or heterogeneous fleets, single-load or mixed-load operating modes. Park et al. [7] proposed a new mixed-load improvement algorithm that decomposed the multi-school SBRP problem into a single-school SBRP problem, used a scanning algorithm to optimize the single-school route, and then merged the optimized single-school route results. Semba et al. [8] used three meta-heuristic algorithms, Simulated Annealing (SA), Tabu Search (TS) and Ant Colony Optimization (ACO), to solve the model of multi-calibrated SBRP problems. The performance of the three algorithms is compared empirically.

The above literature has studied the multi-school SBRP, but the school bus service in rural areas pays too much attention to the cost of the school bus operator, and the service quality is not deeply discussed. Aiming at student travel cost, that is, students' perception of school bus service, this paper establishes an immixed school bus network layout model based on student travel cost and service coordination. Under the condition of ensuring school bus service quality, school bus routes can be optimized to reduce school bus operating mileage, thereby reducing school operating costs. Under the mixed-