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A Collection of Literature Review on Vehicle Routing Problem and Reflections

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Abstract: As a variation of vehicle routing problem whose objective is to determine the subset of nodes to be visited, and the order in which they should be visited, in order to maximize the profit collected within a given time, team orienteering problem has received a lot of attention in the last decades. With the growing interest in the logistics community in using electric vehicles as an alternative to conventional fuel vehicles, academic research on electric vehicle problem is increasing. However, there is still a paucity of research on the use of electric vehicles in team orienteering problem. This paper reviews the existing literature on electric vehicle routing problems and team orienteering problems to identify the feasibility of innovations that propose the use of electric vehicles to replace conventional fuel vehicles in team orienteering problems to complete deliveries, and briefly outlines future research plans.

Keywords: Vehicle Routing Problem; Team Orienteering Problem; Electric Vehicle.

1. Introduction

In February 2019, the Opinions on Promoting High-quality Development of Logistics and Forming a strong Domestic Market jointly issued by 24 ministries and commissions including the National Development and Reform Commission pointed out that it is necessary to speed up the development of green logistics, continue to promote pollution control efforts of diesel trucks, and encourage enterprises to use low-carbon and environmentally friendly distribution vehicles that meet standards. In order to actively respond to the national call for green logistics and low-carbon life, various logistics and express delivery enterprises have integrated the concept of green development into the actual distribution field.

As the logistics community shows growing interest in using electric vehicles as an alternative to traditional fuel vehicles, academic research on electric vehicle projects is increasing (Kucukoglu et al. 2021). The electric vehicle routing problem (E-VRP) is an extension of the traditional vehicle routing problem (VRP), taking into account the battery restraint and charging operation, finding optimized routes specifically for electric vehicles.

Team orienteering problem (TOP) is a special class of logistics distribution vehicle routing problem. In this problem, a limited number of vehicles provide services for a group of customers with a certain reward under certain constraints. Due to time or travel cost constraints, each location can be visited at most once, and the distribution path of these vehicles needs to be optimized to maximize the total profit of the fleet. It is often used in tourist attraction planning, post-disaster rescue and other scenarios.

This paper will sort out and analyze the existing research results at home and abroad on the two major variants of the vehicle routing problem, electric vehicle routing problem and team orienteering problem, find out the innovation points, propose that electric vehicle replace the fuel vehicle used in the team orientation problem as the goal of future research work, establish the corresponding mathematical model, and briefly describe the solution algorithm planned to use.

2. Literature Review

2.1. Related Research on Electric Vehicle Routing Problem

(1) Electric vehicle routing problem with full recharge

Conrad and Ryan（2011）replaced the fuel vehicle used in the VRP problem with a charging vehicle and proposed the Recharging VRP (R-VRP) problem, which only allows the vehicle to be charged at the customer node. The green vehicle routing problem (G-VRP) proposed by Erdogan and Miller-Hooks (2012) is considered to be the origin of the electric vehicle logistics routing problem (E-VRP). They built a mixed integer linear programming model considering charging stations and used the improved Clarke and Wright saving algorithm and density-based clustering algorithm. On this basis, Schneiders et al. (2014) added vehicle load and customer time window as model constraints, namely, E-VRP with time windows and recharging stations (E-VRPTW) for electric vehicle routing problem considering customer time window. Each customer node is given a time window, and the vehicle can only serve the customer within the time window. If the vehicle arrives early, it needs to wait; otherwise, it cannot be served. A hybrid meta-heuristic algorithm combining variable neighborhood search algorithm and tabu search algorithm is used to obtain an approximate solution. Hiermann et al. (2016) and Jie et al. (2016) considered the use of different vehicles and established a hybrid fleet EVRPTW (Heterogeneous EVRPTW, HEVRPTW). The differences in vehicles used were reflected in the maximum load capacity, maximum battery capacity, power consumption rate, charging rate and so on. Hiermann et al. (2016) used branch and price algorithm and hybrid heuristic algorithm combined with adaptive large neighborhood algorithm, embedded local search and labeling program. Jie et al. (2016) proposed to use the method of generating lower bound value to preprocess the vehicle type, and formulated the strategy of generating integer solution to compress the solution space, in order to speed up the solution speed, and use the branch and price algorithm to find its optimal solution. Guo et al. (2018) incorporated the

battery loss cost into the objective function and established a mathematical model to consider the minimization of the overall operating cost. In this problem, the battery charging rate is no longer a constant value, but is affected by the state of the battery at that time; The charging time depends not only on the state of charge, but also on the tradeoff between the cost of charging time and the opportunity cost of deep discharge driving. Pelletier et al. (2019) proposed an EVRP with energy consumption uncertainty (E-VRP with Energy Consumption Uncertainty, E-VRP-ECU), and established robust mixed integer linear programming for it. First, robust optimization technology was used to solve the optimal solution of a small example. And then a two-stage heuristic algorithm based on large neighborhood search is used to solve a large number of examples. Bruglieri (2019) proposed the green path optimization problem with limited charging facilities of charging station (GVRP with Capacitated Alternative Fuel Stations, G-VRP-CAFS). A single charging station has only *n* charging facilities. That is, only *n* vehicles can be charged at the same time, which may cause vehicles to wait in line for charging, thus prolonging the transportation time. MILP models are established based on arc variable and path variable respectively. In order to reduce the operation time of solving the problem, two variants of cut plane method are used. Sadati et al. (2022) proposed EVRP with Flexible Delivery (E-VRP-FD), in which customers can specify different delivery locations at different time Windows; A mathematical model is established with the goal of minimizing the total driving distance and the number of vehicles in use, and a hybrid algorithm combining variable domain search and tabu search is used to solve the problem.

(2) Electric vehicle routing problem with partial recharge

Felipe et al. (2014) proposed the problem of green vehicle routing problem with partial recharge (G-VRP with Partial Recharges (G-VRP-PR), that is, it is necessary to consider not only the charging time and location of the vehicle, but also the charging amount, and solve the problem by using the local search algorithm within the framework of non-uncertain simulated annealing. Keskin and Catay (2016, 2018) proposed the electric vehicle routing problem with partial recharge (E-VRPTW-PR), and used three charging stations with different charging rates, namely slow normal and fast charging; The higher the charging rate, the vehicle gets the same amount of power for less time, but at a higher cost. In addition, using an adaptive large neighborhood algorithm that introduces new insertion and removal operators, they demonstrate that the solution using a partial recharge strategy is superior to full charging. Desaulnier et al. (2016) consider four different scenarios (single/multiple charging stations and partial/full charging on each path) for an EV routing problem with time window (E-VRPTW); For each case, a precise branch, price and cut algorithm relying on customized one-way and two-way labeling algorithms was used to generate viable vehicle routes. Experimental results show that multi-facility partial charging is more helpful to reduce route cost and number of vehicles than full charging at a single charging station. Montoya et al. (2017) divided the charging process of electric vehicles into two stages. In the first stage, the charging rate is the same, and the charge increases linearly with time until the terminal voltage of the battery increases to a specific maximum value. In the second stage, the current drops exponentially, the terminal voltage remains the same, and the battery charge increases in a concave shape over time. Based on the partial charging method, a mixed integer linear programming problem for nonlinear electric vehicle routing problem (E-VRP with nonlinear charging functions (E-VRP-NL) is established and solved by a hybrid meta heuristic algorithm. Froger (2019) proposed two new MILP models for E-VRP-NL. The first was to modify the node-based time and charge in Montoya's model to one based on arcs; The establishment of the second model can avoid the duplication of the node of the charging station. Zuo et al. (2019) established a model considering concave nonlinear charging function for electric vehicle with time window (E-VRPTW considering concave nonlinear Charging Function, EVRPTW-CNCF). And this model is not replicated using charging station nodes; The charging mode in this model is replaced by a set of linear constraints with controllable precision to constrain the nonlinear relationship between the charging amount, charging time and charge level. Lin et al. (2021) proposed the E-VRPTW under time-variant electricity prices problem (EVRPTW-TP), that is, the electric vehicle is charged according to the price at the time of use, and the electric vehicle can also reverse discharge the electricity to the charging station. In order to obtain profits, Lagrange relaxation method and hybrid heuristic algorithm combining variable neighborhood search and tabu search are used to obtain high-quality lower bound and feasible solution respectively. On the basis of nonlinear partial Charging, Froger (2022) proposed the E-VRP problem with nonlinear charging function and limited charging station capacity (E-VRP-NL with Capacitated Charging Stations, E-VRP-NL-CCS), taking into account the constrained limitation of the limited charging station facilities. The biggest difference between this problem and G-VRP-CAFS (Bruglieri, 2019) is that the amount of charge in this problem is a decision variable, and the charging time depends on SoC and the amount of charge.

2.2. Related Research on Team Orienteering Problem

(1) Orienteering problem

The orienteering problem (OP) is a variant of the vehicle routing problem that aims to maximize profit for a single vehicle by choosing to visit customer nodes, within a specific time and/or distance limit. The single vehicle orienteering problem can be thought of as a combination of the backpack problem and the traveling sales problem.

(2) Team orienteering problem

The team orienteering problem (TOP) using multiple vehicles is an important variant of the orientation problem, first proposed by Chao et al. (1996). The difference between TOP and VRP is that (1) not every given customer node needs to be accessed, (2) the vehicle load does not need to be considered, and (3) the optimization goal is to maximize profit rather than minimize cost. The solution of this problem by Chao et [20] al is regarded as the benchmark example of the team orientation problem. Ke et al. (2016) used the Pareto simulation algorithm, which uses a new imitation operator to generate a new solution by imitating an existing one. In order to improve the quality of the feasible solution, it also adopts a new swallowing operator, which swallows (or inserts) an infeasible node to repair the infeasible solution. Hammami et al. (2020) proposes a hybrid adaptive large neighborhood search (HALNS) to solve this problem, combining the exploration capabilities of the adaptive large neighborhood search algorithm with a local search and an optimization phase using set packing problems to further improve the

solution.

Several scholars have studied and analyzed the team orienteering problem considering time window (TOPTW), and solved it with different algorithms. Vansteenwegen et al. (2009) designed iterative local search algorithm (ILS) to solve this problem quickly (Vansteenwegen, 2011). Gunawan (2017) extended ILS by introducing more local search operators and perturbed exchange path strategies; and also proposes a hybrid algorithm that combines iterative local search and simulated annealing, using simulated annealing to avoid early termination of the iteration when it is locally optimal. Yahiaoui (2022) proposes a hybrid heuristic consisting of a greedy random adaptive search program (GRASP) combined with iterative local search (ILS) and set coverage formulas.

Yu et al. (2019) proposed TOPTW and time-dependent scores (TOPTW-TDS) with profit changing over time, that is, different profits can be obtained when visiting customer points in different periods. The authors propose a hybrid artificial bee colony algorithm (HABC) to find optimal solutions for small instances and approximate optimal solutions for larger instances. Hanafi et al. (2020) studied the multi-visit TOP with precedence constraints (MTOP-PC) problem, where each customer point has a set of pre-arranged ordered tasks that require different vehicles to complete. To solve this problem, the authors introduce a new variant of the kernel search framework. The method is based on two different sorting strategies to identify feasible variables and construct subproblems on them; After that, we extend a branch-cutting method that can dynamically separate different valid inequalities, and use a reduced iterative kernel search (IKS) using local LP relaxation information as the original heuristic. Yu et al. (2020) combines the nonlinear time-varying profit function with the team orientation problem (TOP with service- and arrival-time-varying profit (TOP-TTP)) under the incentive of search and rescue operations. In order to solve this problem accurately, the authors propose a Benders branch and cut algorithm, which is able to deal with non-concave parts efficiently. In addition, the authors propose an efficient hybrid heuristic algorithm that integrates the improved coordinate search into the iterative local search, which can quickly produce high-quality solutions to this complex problem.

2.3. Electric Vehicle Team Orienteering Problem

There are few researches on the electric vehicle team orientation problem, and most of the existing literatures focus on the team orienteering of unmanned aerial vehicles (UAVs) and electric vehicle tourism problem.

Rubiano et al. (2018) studied a random team orientation problem, in which a group of UAVs need to visit a series of customers, the reward obtained by visiting customers is a random variable, and the service time of each customer depends on the reward obtained. The goal is to find the optimal set of customers that each UAVs must visit without violating the driving range constraints. Saeedvand et al. (2020) consider the application of TOPTW problem in the humanoid robot disaster relief scenario, where each robot has a limited amount of power, and it can obtain profits by visiting the task within the time window. The problem aims to optimize five different objectives: task profit, task finish time, total energy, maximum energy consumption of a single robot, and penalty for missing the time window.

Wang et al. (2018) combined the orienteering problem considering the time window with range limited electric vehicles to propose the electric vehicle tourist trip design problem with time windows (ETTDPTW). In addition, the authors introduce a model that can simulate the change of battery power state at various points along the route to check whether the next arc of the trip is feasible. Chen et al. (2020) studied the problem of electric vehicle travel planning, aiming to maximize profitability and minimize energy anxiety within prescribed limits; In addition, two scenarios of full charging and partial charging are considered. In order to solve this problem, the authors establish a bi-objective mixed integer model and use an interactive branch-and-bound algorithm based on non-dominated sets to solve it, so as to obtain the optimal solution under different charging strategies. Karbowska-Chilinska and Chociej (2020) investigate the multistage travel design problem, considering an itinerary composed of multiple connected trips, i.e., the multistage strategy. Therefore, this set of connected trips can be viewed as a "team" trip, i.e., a team orienteering problem.

3. Summary of Research Status and Innovation Points

Through the review and analysis of the existing literature, it can be seen that at present, domestic and foreign scholars have relatively rich research results on the electric vehicle routing problem and team orienteering problem. In terms of solving algorithms, no matter it is exact algorithm or heuristic algorithm, there are also rich theoretical results. However, in terms of electric vehicle routing problem, most domestic and foreign researches focus on minimizing driving distance, distribution time or operating cost, but seldom consider the team orienteering problem aiming at maximizing profit.

Therefore, the future research work will be based on the mathematical model and optimization algorithm theory and research results of the existing electric vehicle routing problem and team orienteering problem, combined with constraints such as charging time and customer time window that need to be considered in the actual distribution situation. After constructing a 0-1 mixed integer linear programming mathematical model for the team orienteering logistics distribution problem of electric vehicles with a time window, it is planned to design an adaptive large neighborhood search algorithm or deep reinforcement learning to solve the problems in this paper.

The core of the next research work is to set the maximization of collection profit as the objective function, consider the profits obtained by serving each customer point, and take the nonlinear charging process, charging time and customer time window of the distribution vehicle as the constraint conditions to ensure that the model is more practical. For the established mathematical model, it is planned to use an improved adaptive large neighborhood search algorithm to solve it, and verify the feasibility of the algorithm for the model.

All in all, the innovation points of future research are as follows: (1) A new problem of electric vehicle routing problem, that is, electric vehicle team orientation problem, is essentially a combination of electric vehicle routing problem and team orienteering problem. (2) The more practical partial nonlinear EV charging process is considered, thus saving charging time and power. (3) An adaptive large neighborhood search algorithm suitable for solving the problem model is designed and developed.

4. Conclusion

Under the influence of national policy incentives and environmental awareness, the use of electric vehicles has become an inevitable trend of future social development. By combing the existing research results of E-VRP, this paper finds that the application trend of electrification of urban delivery vehicles has been widely recognized in the academic fields at home and abroad. However, team orienteering problem, as a variant of vehicle routing problem, is rarely considered to be combined with electric vehicles. Therefore, based on the analysis of the domestic and foreign research status of E-VRP and TOP, the future research work will consider combining E-VRP and TOP to form an E-TOP problem and establish the corresponding mathematical model.

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