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Research on Takeaway Distribution Path under Multiple Constraints

Aifang Yang

School of Economics and Management, Xidian University, Xi'an 710126, China.

aifang_yang@163.co

Abstract

After a lot of research, it is found that domestic and foreign scholars have not done much research on take-out delivery paths in specific scenarios, so this paper proposes a new take-out delivery model. The model combines the existing research on VRP issues, analyzes the current problems in the takeaway distribution industry, and aims at the lowest cost and highest customer satisfaction. At the same time, based on the consideration of time window, vehicle load and other constraints, the time-varying road network environment is introduced, and the security of the distribution section is considered. It is expected that while reducing costs and improving customer satisfaction, it can also effectively mitigate the security problems in the take-out distribution process, and also provide a new direction for future take-out delivery path research.

Keywords

WVRP; Takeaway distribution; Time windows; Security.

1. Introduction

With the acceleration of the pace of life and the expansion of domestic demand proposed by the Chinese government, dining out and food delivery will gradually become the dining habits of more and more users in China, and the transaction scale of the food delivery market will also maintain a high growth rate. When collecting takeaway information, it was found that there was very little research on takeaway abroad, and the research direction was mainly on the health and security of takeaway catering. In China, the focus is on the study of takeaway operation models, platform construction, and market research. The service system of individual needs of consumers, the competition relationship between takeaway platform companies, the characteristics and applicable conditions of distribution models, and the research on customer satisfaction in the takeaway industry have been widely concerned. Domestic and foreign scholars have not done much research on specific delivery scenarios. Regarding the take-out distribution path, scholars have studied it as a typical VRP problem. As one of the basic businesses of take-out, it has a great impact on reducing costs and improving consumer satisfaction. And the distribution path is one of the most important links in takeaway distribution business. Therefore, it is necessary to design a reasonable distribution route plan, which can reduce the distribution cost and maximize customer satisfaction, while also alleviating the security problem of distribution.

2. Current Research Status

The Vehicle Routing Problem (VRP) was first proposed by Dantzig and Ramser in 1959, and has been continuously extended by scholars. The VRP problem goes through three stages. The first stage is the Traveling Salesman Problem (TSP), which is characterized by one car traversing all points; the second stage is the classic vehicle routing problem, which adds multiple vehicles to traverse all points;

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the third and current stage of research focuses on VRP with constraints. Design a suitable route for a series of customer demand points to allow vehicles to pass in an orderly manner while meeting certain constraints (such as vehicle load, customer time window, Vehicle mileage limit, etc.), to achieve certain optimization goals (such as shortest mileage, lowest cost, maximum customer satisfaction, high vehicle utilization, etc.).

The general model of VRP usually includes a starting point (end point) and N customers and K vehicles. The vehicle is required to start from the starting point and serve all customer points before returning to the warehouse point. The goal is usually the lowest total toll for transportation. Based on the basic vehicle routing problem, the vehicle routing problem has produced many different extensions and changes in academic research and practical applications. Including vehicle routing problems with time windows (VRPTW), vehicle routing problems in pursuit of the best service time (VRPDT), fleet size and mix vehicle routing problems (FSVRP), vehicles routing problems with multiple use of vehicle (VRPM), vehicle routing problems with backhauls (VRPB), vehicle routing problem with stochastic demand (VRPSD), etc. The classification of VRP is actually adding different realistic constraints to this model.

This paper will consider the four constraints of vehicle volume, time windows, time-varying road network environment, and security of the distribution section to build the model.

• Vehicle load: The vehicle load of each vehicle is limited.

• Time windows: The service time required by each customer is an interval, and penalty cost will occur earlier or later than the interval.

• Time-varying road network environment: In order to make the model simple and feasible, this paper agrees that there is only one road between each customer point. On these roads, there may be road conditions such as driving peaks, sudden maintenance of power and gas, traffic accidents, etc., and the road conditions of each road are different, so the speed of the delivery staff is different at different times on different roads. Because the scope of takeaway distribution is small, this article does not consider speed changes on different roads for the time being; only the different speeds in different periods are considered.

• Security of the distribution section: Similar to distance, danger values between two points are given in advance. And the danger values are based on the attributes of the road between the two customers (main road, side road, etc.), the frequency of traffic accidents, etc. Set a maximum danger value. When the sum of the danger values is greater than this value, the route is not selected.

3. Model Building

3.1 Related variables

K : number of vehicles in the restaurant;

n : number of customers in the restaurant;

Q : maximum load of the vehicle;

q_i : customer’s demand;

d_{ij} : distance between customer points;

r_{ij} : danger values between customer points;

$R_{\max}$: maximum danger values for the entire journey;

$[e_i, l_i]$: time windows;

ELT_i : The latest time the customer can accept;

$v_{ijk}(t)$: speed of vehicle k at time t ;

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t_{ijk} : time taken by vehicle k from point i to point j ;

t_i : time of vehicle arrival at point i ;

t_{re} : time interval from the current moment to the moment of speed change;

d_{re} : the distance traveled from the current moment to the moment of speed change;

λ_1 : unit time penalty cost of the vehicle reaching the point i before e_i ;

λ_2 : unit time penalty cost of the vehicle reaching the point i after l_i ;

C_{ij}, C_k : the distribution cost of each order, the labor cost of the delivery man;

C_c, C_s :fixed cost, penalty cost;

D, R : total distance and total danger values of one distribution;

3.2 Model assumptions

In order to better define the scope of this study, the following assumptions are made:

- Distribution center: The distribution center is a self-operated restaurant with coordinates (X_0, Y_0). The restaurant is the start and end of each journey for each delivery person.
- Delivery men and delivery vehicles: There are K delivery men corresponding to K delivery vehicles of the same size, same model and sufficient power, there will be no re-ordering during delivery. Incurred, the loss cost of the vehicle is relatively small and can be ignored.
- Vehicle load: The vehicle load of each vehicle is limited, denoted as Q, and the demand of each customer is represented by q_i .
- Time windows: The service time required by each customer is an interval, expressed by $[e_i, l_i]$, e_i is the earliest acceptable delivery time, and l_i is the latest acceptable delivery time.
- Customer: Each customer is equally important to the restaurant, and each customer is served by only one delivery man. Coordinates (X_0, Y_0), time windows $[e_i, l_i]$ and demand q_i are known.
- Vehicle speed: Road conditions, weather, and traffic accidents have an impact on the speed of electric vehicles. Speed is a step function, and the speed is different in different periods.

3.3 Objective function

3.3.1 Fixed costs

It considers the distribution costs per order (C_{ij}) and the labor costs (C_k). The total costs are equal to the sum of the two, recorded as C_c .

$$\min C_c = \sum_{k=1}^{K} c_k + \sum_{k=1}^{K}\sum_{i=0}^{n}\sum_{j=1}^{n} c_{ij} x_{ijk}$$

3.3.2 Penalty costs

By comparing the delivery time and time windows, the customer's satisfaction can be calculated. Delivery before or after the time windows will affect customer's satisfaction. Here it is converted into a calculable value, called the penalty costs and recorded as C_s .

$$C_s = \lambda_1 \sum_{i=1}^{n} \max\{e_i - t_i, 0\} + \lambda_2 \sum_{i=1}^{n} \max\{t_i - l_i, 0\}$$

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3.4 Mathematical model

$$\min Z=\sum_{k=1}^{K}c_k+\sum_{k=1}^{K}\sum_{i=0}^{n}\sum_{j=1}^{n}c_{ij}x_{ijk}+\lambda_1\sum_{i=1}^{n}\max\{e_i-t_i,0\}+\lambda_2\sum_{i=1}^{n}\max\{t_i-l_i,0\} \tag{1}$$

$$x_{ijk}=\begin{cases}1,\ \text{vehicle k travels from i to j}\\ 0, otherwise\end{cases} \tag{2}$$

$$\sum_{j=1}^{n}x_{0jk}=1, i\in z \tag{3}$$

$$\sum_{i=1}^{n}x_{i0k}=1, j\in z \tag{4}$$

$$\sum_{i=0}^{n}\sum_{j=0}^{n}x_{ijk}=1, i\neq j, i, j\in z \tag{5}$$

$$\sum_{k=1}^{K}\sum_{i=0}^{n}\sum_{j=1}^{n}x_{ijk}=1, i\neq j, i, j, k\in z \tag{6}$$

$$\sum_{i=0}^{n}\sum_{j=1}^{n}q_i x_{ijk}\le Q, i\neq j, i, j, k\in z \tag{7}$$

$$R=\sum_{k=1}^{K}\sum_{i=0}^{n}\sum_{j=1}^{n}x_{ijk}r_{ij},\ i\neq j, i, j, k\in z\ \&\ R<R_{\max} \tag{8}$$

$$t_i\le ELT_i, i=1,2,\ldots n \tag{9}$$

$$t_{ijk}\left(d_{ij},t_i\right)=\begin{cases}\dfrac{d_{ij}}{v_{ijk}(t_i)}, no\ change\ inspeed\ from\ i\ to\ j\\ t_{re}+t_{ijk}\left(d_{ij}-d_{re},t_i+t_{re}\right), otherwise\end{cases} \tag{10}$$

$$d_{re}=t_{re}v_{ijk}(t) \tag{11}$$

$$x_{ijk}(t_i+t_{ijk}(d_{ij},t_i)-t_j)\le 0, i\neq j \tag{12}$$

Formula (1) is the objective function; Formula (2) is the decision variable; Formula (3) means the vehicle starts from the restaurant; Formula (4) means the vehicle returns to the restaurant; Formula (5)means that all customers will be served; Formula (6) means that each customer is served only once by a delivery man; Formula (7) represents the limit of vehicle load; Formula (8) represents the limit of danger values; Formula (9) expresses the limitation of the latest delivery time; Formula (10-12) states the calculation of time and the continuity of delivery.

4. Conclusion

After comprehensively considering the actual situation of takeaway distribution, this paper takes the lowest cost as the goal, and considers the four constraints of vehicle load, customer time windows, time-varying road network environment, and security of the distribution section to establish the model. The treatment of constraints follows the methods of previous scholars, which can be solved using classic sub-heuristic algorithms, such as genetic algorithms and ant colony algorithms.

The continued popularity of the delivery industry has led to more and more types of delivery workers appearing on the road. While satisfying human convenience, the accompanying safety issues have become increasingly apparent, and even traffic accidents have occurred frequently. The state has also issued a number of related policies to restrict the takeaway, but there are still insufficient human resources on the monitoring side to cause inadequate supervision. The study of takeaway distribution

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paths considering security is a missing part of previous research and can be used as an extension of previous research. This paper hopes that while reducing distribution costs and maximizing customer satisfaction, it can also alleviate some of the security issues caused by the delivery industry and improve the acceptance of customers and the general public. If you follow the “checklist” your paper will conform to the requirements of the publisher and facilitate a problem-free publication process.

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