Research on Optimization Model of Dynamic Distribution Path Based on Intelligent Logistics

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Abstract. Compared with traditional logistics distribution, today's express delivery is more dynamic, increasing the difficulty of distribution path optimization. The application of intelligent logistics technology in dynamic distribution path optimization is a deep application of intelligent logistics technology and a major breakthrough in logistics distribution. This paper, aiming at minimizing the total cost, establishes the DVRP-TW model of distribution path optimization model based on dynamic traffic and uses improved Genetic Algorithm to solve it. A delivery network in Beijing is selected as an example, the optimization results of distribution path under dynamic traffic are obtained by MATLAB programming. Finally, by comparing and analyzing the results of distribution path optimization under static condition, it is concluded that it is very necessary to consider the influence of dynamic traffic on distribution path optimization, and the more accurate the road information processing is under intelligent logistics, the more scientific the design of distribution path is.

Keywords: Intelligent Logistics; Courier; VRP; Dynamic Traffic; Genetic Algorithm.

1. Introduction
In the era of intelligent logistics, the Internet of things, big data, cloud computing and other new generation of information technology rapid development, and gradually applied in various logistics links. At the same time, online shopping and new retail and other ways to create a huge express market, customers also put forward higher and more diverse requirements for express delivery. traditional static VPR problems can no longer be satisfied. how to establish a new model of practical problems based on the dynamic information obtained through intelligent logistics technology has become a hot spot for scholars at home and abroad to pay attention to and study.

The Vehicle Routing Problem (VRP) was creatively put forward by Dantzig and Ramser[1] in 1959. At present, the VRP has been applied in distribution center distribution plan, bus line formulation, newspaper delivery route arrangement and so on. As most of the researches for VRP are under static information, Psarafitis[2] first researched on the VRP under dynamic information (DVRP); Fleischmann studied the dynamic path planning problem under dynamic traffic information; Guo Yaohuang [3] team deeply studied DVRP under uncertain information; Malandraki[4] proposed the Time Dependent Vehicle Routing Problem (TDVRP), which establishes a vehicle path model with capacity constraints and time window constraints; Potvin[5] considered new customer orders and dynamic road travel time,
to establish a DVRP model with time window constraints. For solution algorithm, Malandraki[4] proposed greedy algorithm and dynamic programming algorithm; Gendreau[7] first proposed to use parallel tabu search algorithm to solve real-time demand model with soft time window; Wu Zhaofu [8] combined evolutionary algorithm with ant colony algorithm to solve multi-objective DVRP and so on.

Among the existing research, the DVRP problem of express delivery is less studied. Express delivery requires the combination of delivery and delivery, considering the time window, and is a real-time dynamic process, which belongs to the complex vehicle path problem. Based on the main distribution characteristics of express delivery, this paper uses intelligent logistics technology to obtain the latest dynamic information, takes the lowest total cost of distribution as the objective function, and establishes a real-time path optimization model based on dynamic traffic.

2. Intelligent Logistics and path optimization

2.1. Real-time distribution path optimization system

With the development of Internet of things, communication technology and so on, it is possible to obtain traffic information in real time, which also provides strong support for the study of DVRP. The distribution system can adjust the path according to the real-time information, achieve the goal of minimum cost or shortest time under the demand of customers, and improve the profit and service quality of enterprises. The function of real-time distribution path optimization system based on intelligent logistics is shown in Figure 1.

![Figure 1. Function of real-time distribution path optimization system](image)

The intelligent transportation system collects real-time traffic information and acts as an investigator; the intelligent decision-making system adjusts the distribution route according to the real-time road condition information, and completes the accurate docking between the distribution vehicle and the user, which is the core part and conductor of the whole system; the vehicle management system uses information technology such as Internet of things to display the location and status information of the distribution vehicle in real time, and is the executive of the system. The information in the execution process is fed back to the investigator and becomes part of the real-time information, and the three subsystems form a closed loop.

2.2. Dynamic traffic

The change of dynamic traffic is directly reflected in the change of road vehicle driving speed. The information of dynamic traffic mainly comes from intelligent transportation system (ITS). it monitors the traffic condition and weather condition of the road in the service area of the distribution center in real time, updates the information to the system every certain time, and completes the automatic collection, processing and transmission of the information.

In general, there are two ways to deal with dynamic traffic information, one is to use real-time information to replan the path, the other is to use big data technology to analyze and process the historical
traffic information, to calculate the traffic situation on the same day, and to optimize the distribution path one day on this basis. The first method can actively deal with any unexpected situation, but the process is complex and changeable, which is not conducive to the driver to carry out the task. Although the second method is not real-time data, but because the analysis and processing of historical data by big data system is very similar to the actual situation, and the processing process of this method is simple and easy to distribute the task execution, so this paper chooses the second method..

3. Distribution Path Optimization Model Based on Dynamic Traffic

3.1. DVRP-TW model building

For a distribution center to distribute parcels to multiple outlets, the geographical location, demand and time window of each network is certain, under the influence of dynamic traffic information, the distribution path is reasonably planned to achieve the goal of the lowest total cost of distribution. The total cost of distribution includes fixed cost, transportation cost and penalty cost that does not meet customer service time window. There are two decision variables:

\[ x_{ij}^k = \begin{cases} 1, & \text{car } k \text{ starts from } i \text{ to } j \\ 0, & \text{otherwise} \end{cases} \]

\[ y_k = \begin{cases} 1, & \text{the car } k \text{ is used} \\ 0, & \text{otherwise} \end{cases} \]

The fixed cost refers to the costs incurred in starting each vehicle, including the driver's salary, the cost of wear and tear resulting from the driving of the vehicle. The fixed cost is recorded as \( C_1 \), and the unit fixed cost is recorded as \( c_1 \).

\[ C_1 = \sum_{k \in K} c_1 y_k \]

The transportation cost of the vehicle includes the fuel consumption, repair and maintenance of the vehicle. The day is divided into four periods, which is recorded as \( [T_1, T_2], [T_2, T_3], [T_3, T_4], [T_4, T_5] \). And \( c_2 (N = 1, 2, 3, 4) \) is used to indicate the unit cost of the vehicle during the \( [T_N, T_{N+1}] \) period.

\[ C_2 = \begin{cases} \sum_{i, j \in N} \sum_{k \in K} c_{21} x_{ij}^k \frac{l_{ij}}{V_T}, & T_1 < T < T_2 \\ \sum_{i, j \in N} \sum_{k \in K} c_{22} x_{ij}^k \frac{l_{ij}}{V_T}, & T_2 < T < T_3 \\ \sum_{i, j \in N} \sum_{k \in K} c_{23} x_{ij}^k \frac{l_{ij}}{V_T}, & T_3 < T < T_4 \end{cases} \]

\( l_{ij} \) means travel distance from customer \( i \) to \( j \); \( V_T \) means the average speed at which the customer \( i \) to \( j \) during T period.

In the process of logistics distribution, often due to weather, traffic congestion and other reasons resulting in violation of customer time window constraints. According to the characteristics of express delivery, this paper adopts the soft time window limit, that is, it does not have to arrive in the time window, but the arrival outside the time window limit will cause the loss of waiting or delay. Assume that the penalty costs due to time window constraints are \( C_3 \), \( c_3^1 \) means unit wait time cost and \( c_3^2 \) means unit delay time cost. \( ET_i \) and \( LT_i \) indicate the earliest and latest time that the customer \( i \) receive the service.
To sum up, the construction of distribution path optimization model based on dynamic traffic is as follows:

\[
C_3 = \begin{cases} 
\sum_{i\in N} c_1 \max((ET_i - t_i), 0), 0 < t_i < ET_i \\
0, & \text{if } ET_i \leq t_i < LT_i \\
\sum_{i\in N} c_3 \max((t_i - ET_i), 0), & t_i \geq LT_i 
\end{cases}
\]

Formula (1) means that the vehicle \( k \) starts from distribution center and returns to it after completing the service; Formula (2) means that each customer has only one vehicle service; Formula (3) means that the number of vehicles used is less than total number of vehicles; Formula (4) means that when a vehicle \( k \) set off from the center, its load shall not exceed the maximum load of the vehicle. Formula (5) and (6) mean that when the vehicle leaves customers, its deadweight shall not exceed the maximum deadweight of the vehicle. Formula (7) means that the driving distance can’t exceed the maximum travel distance of the vehicle; Formula (8) represents the logical relation of service time of adjacent points.

3.2. Improved Genetic Algorithm

An improved genetic algorithm is proposed for the DVRP-TW model in this paper, which uses the nearest neighbor method to the initial population. Firstly, select the nearest customer point from the distribution center as the initial node, and find the nearest customer point as the suffix node which meets the vehicle load and distribution distance, so that the suffix node as the initial node, looking for the nearest customer point again. If the constraints are not met, insert 0 and repeat the above steps in the remaining customers until the last customer location is found. The initial population created in this way is optimized before the algorithm starts, which accelerates the convergence speed of the algorithm and the ability to find the optimal solution.

The improved genetic algorithm mainly includes the coding of genes, the generation of initial population, the establishment of fitness function and the design of genetic elements such as selection, crossover and variation.

4. Example Analysis

This paper chooses the actual problem of delivery from a logistics enterprise distribution center in Beijing to the surrounding 20 express outlets as an example, and combines the urban road condition to simplify the processing. These 20 express outlets fixed geographical location, the time window to
receive service, each network has a certain amount of goods and volume. According to the actual traffic flow survey and data access [9], the traffic data of a certain section of Beijing city are selected for one week, and the distribution time of one day is divided into four periods: 7:00-10:30, 10:30-13:00, 13:00-18:30 and 18:30-22:00.

Table 1. Parameters setting in the model

| Parameters                                      | Value |
|------------------------------------------------|-------|
| maximum vehicle load                           | 5 t   |
| maximum distance per vehicle                   | 500 km|
| unit wait time cost                            | 4 yuan|
| unit delay time cost                           | 12 yuan|
| unit fixed cost                                | 200 yuan|
| unit time cost in 7:00-10:00                   | 90 yuan|
| unit time cost in 10:30-13:00                  | 50 yuan|
| unit time cost in 13:00-18:30                  | 90 yuan|
| unit time cost in 18:30-22:00                  | 50 yuan|
| speed in 7:00-10:30                            | 30km/h|
| speed in 10:30-13:00                           | 80 km/h|
| speed in 13:00-18:30                           | 25 km/h|
| speed in 18:30-22:00                           | 75 km/h|

Combined with the example, the parameters of the improved algorithm are shown in Table 2.

Table 2. Parameters setting in Genetic algorithm

| Parameters                  | Value |
|-----------------------------|-------|
| population size             | 300   |
| cross probability           | 0.9   |
| variability probability     | 0.3   |
| termination algebra        | 400   |

According to the DVRP-TW model and the improved algorithm, using Matlab to carry out programming operations, the optimal distribution path scheme is obtained. Figure 2 shows the optimal distribution path scheme, and table 3 shows the distribution plan.
Table 3. Shows the distribution plan.

| Vehicle | Distribution path       | Cost    |
|---------|-------------------------|---------|
| 1       | 0-15-11-1-5-19-18-0     | 435.0yuan |
| 2       | 0-2-16-20-10-8-9-6-0    | 443.9yuan |
| 3       | 0-3-13-17-12-14-7-4-0   | 453.2yuan |

Then we establish the optimization mode of distribution path under static traffic and analyze the example. Figure 3 and table 4 show the results of distribution path under static traffic.

![Distribution path diagram under static traffic](image)

Table 4. Distribution schedule under static traffic

| Vehicle | Distribution path       | Cost    |
|---------|-------------------------|---------|
| 1       | 0-7-6-8-16-1-11-15-0    | 512.7yuan |
| 2       | 0-3-13-18-2-19-5-0      | 463.5yuan |
| 3       | 0-4-17-12-14-9-10-20-0  | 485.6yuan |

Compared with the dynamic results, it is concluded that the distribution scheme under dynamic traffic is different from the static traffic. The more accurate the road information processing by intelligent logistics technology, the more scientific the design of distribution path is.

5. Conclusion and Future Research

In this paper, we constructs the real-time distribution path optimization system, applies the intelligent logistics technology to the express delivery path optimization problem, not only satisfies the customer demand diversity, but also becomes the express delivery enterprise core competition factor. And then the distribution path optimization model ——DVRP-TW model based on dynamic traffic is established, and the importance of considering dynamic traffic is proved by an example. The following research will focus on the real-time path solution under a variety of dynamic information, that is, considering the influence of various uncertain factors, such as customers, roads, vehicles, etc., the system makes a rapid response to dynamic information.

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