Research on multi-rider collaborative dynamic scheduling model and algorithm of takeaway delivery

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Abstract. Aiming at the field of high-demand takeaway delivery, a dynamic scheduling strategy based on multi-rider collaborative delivery status is proposed, and the model implementation is obtained by constructing a collaborative dynamic scheduling optimization model and using the optimization TS algorithm to obtain a multi-rider scheduling scheme in a dynamic environment, so that the total delivery time is minimized. Finally, the experimental results show the effectiveness and feasibility of the model and algorithm implementation.

Keywords: Takeaway delivery; Multi-rider; Dynamic scheduling optimization model; TS algorithm.

1. Introduction

In order to make each takeaway service platform complete the work efficiently, ensure that user satisfaction continues to increase and improve the ability of real-time order distribution, many scholars continue to optimize the takeaway delivery plan, and the research is mainly divided into two categories: one is the optimization of order distribution. Literature [1]-[2] Realize order optimization through the combined order distribution of orders, and Literature [2]-[3] design OBA algorithm and ODSA algorithm respectively to solve the online scheduling problem. The other is the optimization of distribution routes, and the C-W saving algorithm, distribution optimization algorithm, online fleet scheduling algorithm and improved LNS algorithm are designed to solve the problem of vehicle distribution route optimization. Literature [9]-[10] Path optimization is achieved by optimizing and improving the time window constraint.

In general, most scholars will improve the algorithm and combine the algorithms according to the differences in the problems they study. Based on the background of takeaway delivery route optimization, this paper introduces dynamic factors in the delivery process, including order rollover and order transfer, into the research to provide a reasonable scheme and decision-making reference for takeaway delivery optimization.

2. Dynamic scheduling optimization model

2.1 Description of the problem

Dynamic scheduling initialization strategy in any scenario without considering cross-regional delivery and merchant refusal to accept orders (see Figure 1). Rules that trigger rolling optimization once at regular intervals. Set up an order buffer pool to store all allocated unpicked orders and newly generated orders, after each scheduling trigger, the picked orders gradually exit the order pool, the newly generated orders gradually accumulate in the order pool, after triggering the order rescheduling condition, start the rescheduling optimization calculation for all new orders before the decision point in the order pool and all allocated unpicked orders before the dispatch point, release a new scheduling plan after the calculation, and start the accumulation of the next wave of the order pool.
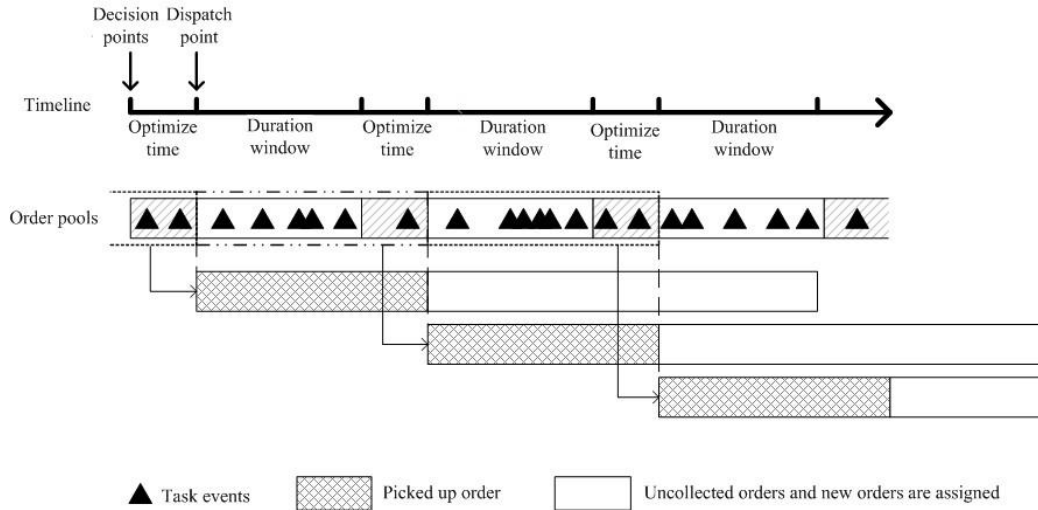
Fig. 1 Rescheduling optimization time flow chart

2.2 The dynamic scheduling optimization model is established under the condition of rolling optimization

Given a road traffic network diagram $G = (V, E)$,where vertex set $V = (v_1, v_2, ...v_n)$,edge set $E = (e_1, e_2, ...e_n)$, all orders that require service are generated in network diagram G , $l(v_m, v_n)$ representing the distance between v_m and v_n in the network diagram, all orders are generated in real time, there are a total of n orders, the order sequence is represented as $s = (O_1, O_2, ...O_n)$, the resulting order is represented as $O_i = (R_i, J_i, D_i)$, where R_i represents the order time of order i , $J_i \in V$ indicates the pickup point of the order is the location of the merchant node, and $D_i \in V$ represents the receiving point of the order is the location of the customer node, $i \in I = (1, 2, ...n)$. Consider multiple delivery personnel for delivery services, the vehicle capacity is Q .

The objective function is:

$$\min F = e^p \sum_{i \in I} (t_i - R_i) \qquad (1)$$

The constraints are:

$$\sum_{k \in K} x_{ikt} \le 1 \qquad \forall i \in I \qquad (2)$$

$$\sum_{i \in I} x_{ikt} \le Q \qquad \forall k \in K \qquad (3)$$

$$\sum_{c_n^k \in C^k} z_{c_n^k} = 1 \qquad \forall k \in K \qquad (4)$$

$$t_i \le T_{O_i} \qquad \forall i \in I \qquad (5)$$

$$y_{ic_n^k} \le \sum_t x_{ikt} \qquad \forall k \in K, i \in I \qquad (6)$$

$$t_{ic_n^k} \le y_{ic_n^k} \qquad \forall i \in I, c_n^k \in C \qquad (7)$$

$$t'_{ic_n^k} > R_i \qquad \forall i \in I, c_n^k \in C \qquad (8)$$

$$t'_{ic_n^k} > l'_{ic_n^k} / V \qquad \forall i \in I, c_n^k \in C \qquad (9)$$

$$t''_{ic_n^k} \ge l''_{ic_n^k} / V \qquad \forall i \in I, c_n^k \in C \qquad (10)$$

$$t'_{ic_n^k} < t''_{ic_n^k} \qquad \forall i \in I, c_n^k \in C \qquad (11)$$

$$t_i = \sum_{c_n^k \in C} z_{c_n^k} t''_{ic_n^k} \qquad \forall i \in I \qquad (12)$$

$$x_{ikt} \in (0,1) \qquad (13)$$

$$z_{c_n^k} \in (0,1)$$

（14）

Constraint (2) guarantees that each order is delivered by and only one rider; constraint (3) guarantees that the number of orders being delivered per rider at each moment does not exceed its maximum capacity Q; Constraint (4) ensures that each rider chooses only one delivery path; constraint (5) is an order time window constraint so that all orders do not break the time window as much as possible; constraint (6) ensures that order O_i will appear on the path of delivery person k only when order O_i is assigned to rider k; Constraint (7) guarantees only when order O_i is on the Nth path of the delivery person k; The completion time of order O_i in path c_n^k is not 0; Constraints (8) ensure that the pickup time of each order is later than the time when the order is placed; constraints (9) and (10) ensure that the pickup time and delivery time of order O_i in route c_n^k are not earlier than the earliest time when the rider can reach the merchant node where he picks up the goods and the customer node of the delivery when driving at speed V, and the rider may stay for a period of time due to external factors such as road section conditions during riding, so his arrival time may be later than his earliest possible arrival time; Constraint (11) ensures that the pickup time of each order is earlier than its delivery time, that is, the food delivery task is completed first; constraint (12) calculates the actual completion time of order O_i, and constraint (13) and constraint (14) are 0-1 decision variables.

3. Optimized design based on tabu search algorithm

*Step*1：First, the input data is processed, and then the algorithm parameters are set, the parameter set is determined, and the encoding operation is performed;

*Step*2：A part of the coding group is randomly selected, and a feasible initial solution is obtained after random screening, and the content of the initial taboo table is empty. Set the initial number of iterations $g = 0$;

*Step*3：The fitness function of the initial solution is calculated to liberate the relatively highest fitness function into the taboo table；

*Step*4：Among the remaining candidate solutions, neighborhood selection is carried out according to the best improved solution priority strategy;

*Step*5：The solution that does not meet the constraint condition in the neighborhood solution is deleted, and the fitness function of the solution that satisfies the constraint in the neighborhood is calculated, and the candidate solution is selected from it；

*Step*6：Calculate the fitness function of all solutions in the candidate solution, select the solution corresponding to the highest fitness function, put it into the tabu table, and replace the solution that entered relatively earlier in the current taboo table；

*Step*7：Determine whether the termination condition is met: compare g with the maximum iteration step G and return when $g < G$; When $g = G$, proceed to *Step*8；

*Step*8：Output the current taboo table and select the optimal solution as the global optimal solution。

Table 1. Algorithmic pseudocode

Algorithmic flow pseudocode
While i < iterations
NewStra = findNext(currentStra)
newCost = calObj(newStra)

If newCost < bestStra && not in tabeList currentCost = newCost
currentStra = newStra Insert newStra into tabe List
If not find better Stra in 50 times
Free a Stra from tabe List
Input currentStra and CurrentCost

4. Study simulation

After setting the basic parameters of the model, the results of the study are as follows：

(1) First scheduling

The first rolling dispatch target value is 127.4057 minutes, the orders involved are all orders within the order start time to 10.2 minutes, from Fig 6, it can be seen that the first dispatch order is order 1-7, the rider pickup delivery route chart and convergence curve are shown in Fig 5-6:
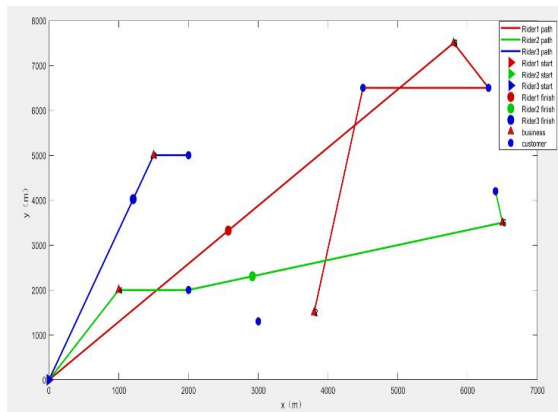
Fig. 5 The first dispatch pick-up delivery path can be viewed
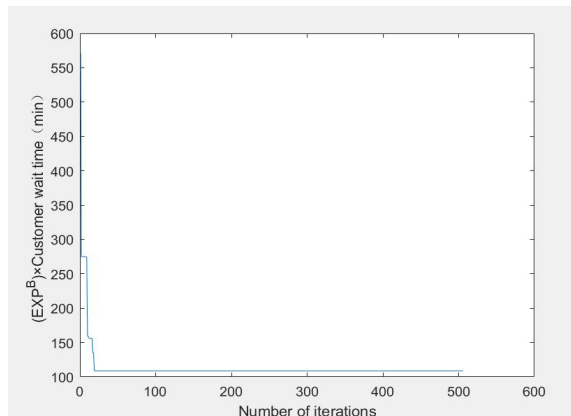

Fig. 6 First scheduling convergence graph

(2) Second scheduling

The target value of the second rolling dispatch is 279.8372 minutes, the new orders involved are all orders with an order start time of 10.2-20.2 minutes, the second dispatch of the new order is order 8-14, and the rider takes the delivery route chart and convergence curve after dispatch as shown in Fig7-8:
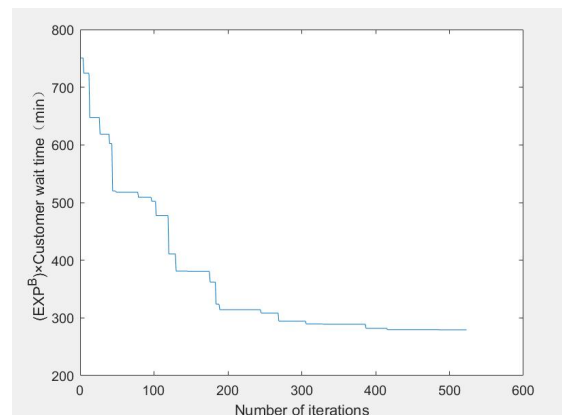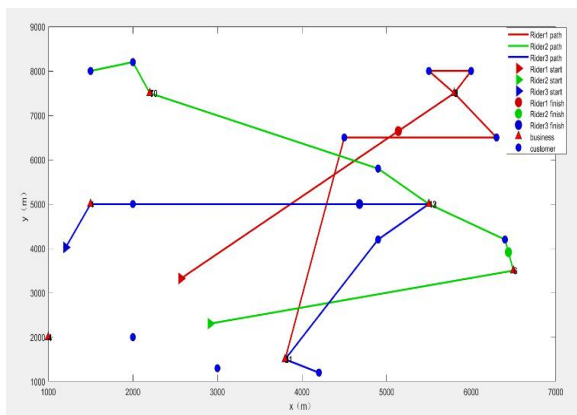
Fig. 7 The second dispatch pick-up delivery
path can be viewed

Fig. 8 Second scheduling convergence
graph

(3) Third scheduling

The target value of the third rolling dispatch is 334.3915 minutes, and the start time is 30.2 minutes and the end time is 40.2 minutes. The new orders involved are all orders with an order start time of 20.2-30.2 minutes, as can be seen from Fig 10, the second dispatched order is order No. 15-18, and the rider picks up the delivery route chart and convergence curve after the third dispatch as shown in Fig 9-10:
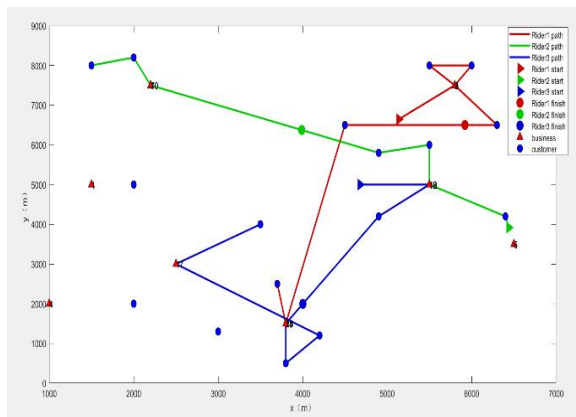

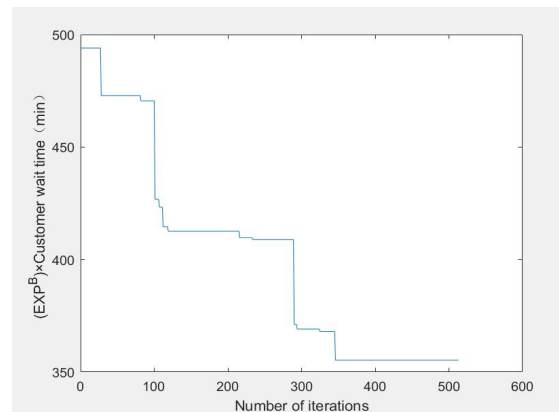Fig. 9 The third dispatch pick-up delivery
path can be viewed

Fig. 10 Third scheduling convergence
graph

(4) Fourth scheduling

The target value of the fourth rolling dispatch is 318.6818 minutes, and the start time is 40.2 minutes and the end time is 50.2 minutes. The new orders involved are all orders with an order start time of 30.2-40.2 minutes, as can be seen from Fig 12, the order of the fourth dispatch is order No. 19-20, and the rider picks up the delivery route chart and the convergence curve after the fourth dispatch are shown in Fig 11-12:
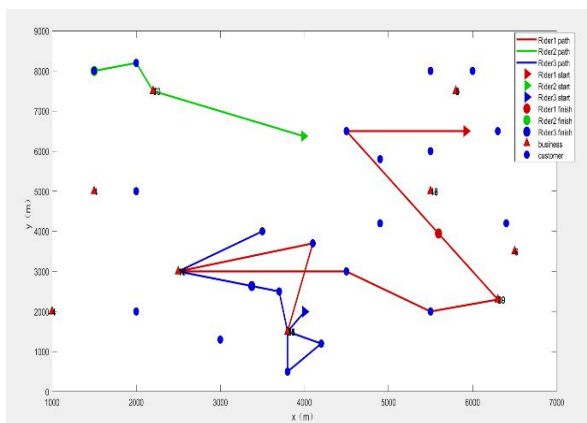

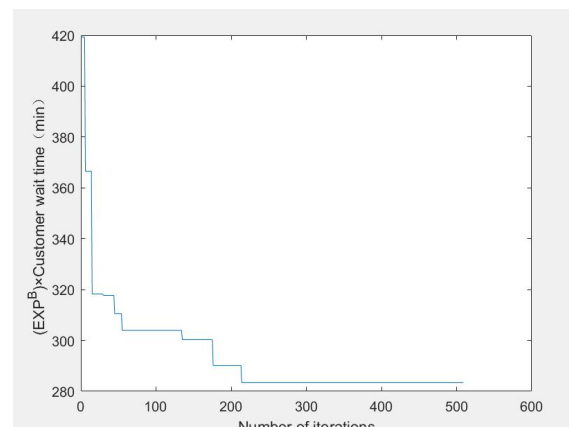Fig. 11 The fourth dispatch pick-up delivery
path can be viewed

Fig. 12 Fourth scheduling convergence
graph

5. Conclusion

Aiming at the problem of multi-rider delivery collaborative scheduling in dynamic environment, this paper starts from reducing the total waiting time of customers, establishes a single-target

multi-rider dynamic collaborative scheduling model, and optimizes the taboo search algorithm, which effectively solves the problem of completing the allocation and delivery of orders placed by customers within the specified time window as much as possible, and improves customer satisfaction. The numerical example experiments after programming show that the multi-rider dynamic collaborative scheduling model proposed in this paper is close to the ideal optimal value in terms of total customer waiting time, and to a certain extent, the economy and feasibility of the design are verified.

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