Research on Task Allocation and Route Joint Optimization under Crowdsourcing Logistics

Pingfan Zhang

zhangpf10121122@163.com

Shanghai Maritime University, Shanghai, China

Abstract. This paper studies the crowdsourcing logistics problem of the combination of snatch and dispatch. First of all, based on the existing crowdsourcing tasks, this paper analyzes the task allocation mode of crowdsourcing logistics and the characteristics of crowdsourcing logistics subjects. Then, in view of the crowdsourcing task and the one-time arrival of the crowdsourcing couriers, the order grabbing process of the crowdsourcing logistics platform and the order scheduling and path planning process of the crowdsourcing logistics platform pushing the task are considered, and the model with the distribution cost and overtime cost as the optimization objective is constructed. The random rush rate is designed to control the number of orders. Then genetic algorithm is used to plan the delivery path of the crowdsourcing deliverer. Finally, the effectiveness of the model and algorithm is verified by numerical experiments, which provides reference and decision support for task allocation and route optimization of crowdsourcing logistics platform.

Keywords: Combination of order grabbing and order dispatching mode; Crowdsourcing logistics; Path optimization; Genetic algorithm.

1 Introduction

The concept of crowdsourcing was first proposed by Howe[1]in 2006. Crowdsourcing logistics is a logistics distribution mode that connects enterprises or individuals who have logistics distribution needs with idle people who voluntarily participate in distribution through the crowdsourcing logistics service platform, which should be undertaken by full-time distribution workers [2]. Mladenow A[3] believe that the crowdsourcing mode can enable logistics enterprises to obtain a large number of low-cost and flexible labor forces anytime and anywhere. Compared with the full-time distribution of logistics enterprises, the distribution cost using the crowdsourcing mode is lower. Devari A[4]. studied the use of friends or acquaintances in social networks to assist in last-kilometer delivery, which can effectively reduce delivery costs and total emissions while ensuring delivery speed and safety. Arslan [5]verified through experiments that the use of excess transport capacity in the journey, that is, temporary drivers, can make the last kilometer delivery more cost-effective and reduce the vehicle mileage. Varshney[6] built a mathematical model to solve the reliability and privacy protection problems that may exist when crowdsourcing platforms provide services. Liu Bochao[7]pointed out that crowdsourcing logistics can meet users' personalized needs in real time by mobilizing idle labor force in society, and solve problems such as high logistics cost, slow delivery speed and express delivery shortage. Xue Liang [8] divided the crowdsourcing logistics model into C2B and C2C, discussed

BDEDM 2024, January 12-14, Ningbo, People's Republic of China
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DOI 10.4108/eai.12-1-2024.2347290

the shortcomings of the development of crowdsourcing logistics in China, and put forward suggestions for the development of crowdsourcing logistics. Hu Feifan[9]constructed a crowdsourcing logistics platform service quality evaluation index system from five dimensions. Kung[10]and Wang Wenjie[11 12] studied the pricing strategy of crowdsourcing logistics platform. Estelles-Arolas [13]and Frehe[14]pointed out that crowdsourced workers are an essential part of the crowdsourced distribution process.At present, most of the logistics platforms adopt the mode of combining rush and dispatch to carry out task distribution, which is divided into two task distribution modes: rush before dispatch and rush after dispatch[15]. Although with the emergence and development of crowdsourcing logistics platform, it has made up for the deficiency of traditional logistics distribution to a certain extent, there are still some problems. On the one hand, due to the dispersed location and high randomness of the crowdsourcing personnel, it is difficult for task allocation and path planning; on the other hand, due to the high degree of freedom of the crowdsourcing mode, the delivery timeout sometimes occurs during the peak period of task arrival, resulting in low customer satisfaction and the quality of task completion cannot be guaranteed. Therefore, under the distribution mode of crowdsourcing logistics participation, how to reduce costs, improve distribution efficiency and customer satisfaction is an urgent problem to be solved.

2 Problem description and model building

2.1 Problem description

The crowdsourcing task assignment and path joint optimization under the combination of rush dispatching can be described as follows: suppose there are n crowdsourcing task sets N= 1,2... t... n, each crowdsourcing task t contains the pick-up $t_1$and the delivery t_2, and the pick-up point and the delivery point are delivered by the same crowdsourcing deliverer, which needs to consider the unilateral soft time window constraint of the delivery point, and there are m crowdsourcing deliverers M= 1,2... , k... m,distributes n crowdsourced tasks. Therefore, the solution goal of the crowdsourcing logistics optimization research considering the combination of rush dispatching is to find the matching set of crowdsourcing tasks and crowdsourcing deliverers and the distribution path order of each crowdsourcing deliverer's pick-up and delivery points, so as to minimize the cost of the crowdsourcing platform.

2.2 Model Building

2.2.1 Model assumptions

1. The crowdsourcing tasks have all arrived.2. The crowdsourcing deliverers are all driving at a constant speed.3. The delivery time of the crowdsourcing deliverer only refers to the distance travel time. 4. Crowdsourcing deliverers are equally skilled.5. The maximum load capacity of the crowdsourcing deliveryman is the same, and the driving cost per unit distance is fixed.6. The unit distance travel cost of the crowdsourcing deliveryman is fixed.7. The crowdsourcing deliveryman visits each customer only once, and each customer is only visited by one crowdsourcing deliveryman.8. The number of crowdsourcing deliverers to meet the delivery needs of the crowdsourcing platform.9. Penalty costs are only related to time Model assumptions.

2.2.2 Parameter setting

N: A collection of crowdsourced tasks$\{1, 2, \dots, t, \dots, n\}$

M: A collection of crowdsourced deliverers$\{1, 2, \dots, k, \dots, m\}$

Q: The maximum number of orders for crowdsourcing deliverers is limited

V: The average travel speed of crowdsourced deliverer k

$d_{u,v}$: The delivery distance from u to v

t_1: The pick-up location of the crowdsourced task t

t_2: The delivery location of Crowdsourcing Mission t

r_T: Push radius of crowdsourced tasks

b: The deadline for the crowdsourcing task t match

B_t^k: Matching time between the crowdsourcing deliverer k and task t

A_u^k: The time when the crowdsourced deliverer k arrives at point u is considered if and only if k delivers point u

s_t^k: The crowdsourcing platform specifies the estimated delivery time of the delivery task t by the delivery k

S_t^k: The actual delivery time of the crowdsourced deliverer k's delivery task t

k_0: Crowdsourcing deliverers are located at regional central points

k_1: The starting position of the crowdsourcing deliverer

k_2: The end point of the crowdsourcing deliverer

P_N: A collection of pickup and delivery points for all crowdsourced tasks

P_M: A collection of the starting point locations of all crowdsourced deliverers

c_1: Distribution cost coefficient

c_2: Overtime cost factor

x_{kt}^q: Variable 0-1, when the delivery agent k grabs the order t delivery, $x_{kt}^q = 1$, or=0

x_{kt}^p: Variable 0-1, when public delivery agent k is assigned to order t delivery, $x_{kt}^p = 1$, or =0

2.2.3 Objective function

The goal of this paper is to minimize the route cost and minimize the time-out cost

$$\min z = \min (z_1 + z_2) \tag{1}$$

$$z_1 = \sum_{k\in M} \sum_{u\in P_M \cup P_N} \sum_{v\in P_N} c_1 x_{u,v}^k d_{u,v} \tag{2}$$

$$z_2 = \sum_{k\in M} \sum_{t\in N} x_{kt}^q max\left(0, c_2\left(S_{t^2}^k - s_{t^2}^k\right)\right) + \sum_{k\in M} \sum_{t\in N} x_{kt}^p max\left(0, c_2\left(S_{t^2}^k - s_{t^2}^k\right)\right) \tag{3}$$

2.2.4 Constraint condition

1. Task assignment constraints

$$\sum_{k\in M} x_{kt}^{q} + \sum_{k\in M} x_{kt}^{p} = 1, \forall t \in N \tag{4}$$

$$\sum_{k\in M} x_{kt}^{q} \leq 1, \forall t \in N \tag{5}$$

$$\sum_{k\in M} x_{kt}^{p} \leq 1, \forall t \in N \tag{6}$$

2.The maximum task quantity constraint

$$\sum_{t\in N} x_{kt}^{q} + \sum_{t\in N} x_{kt}^{p} \leq Q, \forall k \in M \tag{7}$$

3.Crowdsourcing task scope constraints

$$x_{kt}^{q} \in \{0,1\}, \forall t \in N, k \in \left\{k \mid d_{k_1,t_1} \leq r_T \cap d_{k_0,t_2} \leq r_M, k \in M\right\} \tag{8}$$

$$x_{kt}^{q} = 0, \forall t \in N, k \notin \left\{k \mid d_{k_1,t_1} \leq r_T \cap d_{k_0,t_2} \leq r_M, k \in M\right\} \tag{9}$$

$$x_{kt}^{p} \in \{0,1\}, \forall t \in N, k \in \left\{k \mid d_{k_0,t_1} \leq r_T \cap d_{k_0,t_2} \leq r_M, k \in M\right\} \tag{10}$$

$$x_{kt}^{p} = 0, \forall t \in N, k \notin \left\{k \mid d_{k_0,t_1} \leq r_T \cap d_{k_0,t_2} \leq r_M, k \in M\right\} \tag{11}$$

4.Task assignment deadline constraints

$$B_t^k \leq b, \forall t \in N, k \in M \tag{12}$$

5. Distribution constraint

(1) Task point constraints

$$\sum_{u\in\{k_1\}\cup P_N} x_{u,i}^{k} - \sum_{v\in P_N\cup\{k_2\}} x_{i,v}^{k} = 0, \forall i \in P_N, k \in M \tag{13}$$

(2) Paired constraints

$$\sum_{v\in P_N} x_{t_1,v}^{k} - \sum_{u\in P_N} x_{u,t_2}^{k} = 0, \forall t \in N, k \in M \tag{14}$$

(3) Formula of estimated delivery time at delivery point

$$s_{t_2}^{k} = B_t^k + \frac{|T|}{|M|}\alpha + \left(d_{k_1,t_1} + d_{t_1,t_2}\right)\beta, \forall t \in N, k \in M \tag{15}$$

(4) Actual arrival time

$$S_v^k = A_u^k + \frac{d_{u,v}}{v}, \text{ when } x_{u,v}^{k} = 1, \forall k \in M, u \in P_N \cup \{k_1\}, v \in P_N \cup \{k_2\} \tag{16}$$

3 Model solving and algorithm design

3.1 Coding

In this paper, integer coding is used to design chromosomes in the way of task assignment and path combination. $t$represents the number of the crowdsourcing task, k represents the number of the crowdsourcing deliverer, $(t,\ t+n)$ represents the pick-up point$t_1$and delivery point$t_2$of the crowdsourcing task, and n represents the number of the crowdsourcing task. This coding method can ensure the pair constraints of the pick-up and delivery of the crowdsourcing task. The chromosome length is 3n, the first n genes of the chromosome represent the crowdsourcing deliverer $k$matched by the crowdsourcing task t and the last 2n genes represent the path planning of the pick-up and delivery points of the n tasks.

3.2 Random order grabbing algorithm

Firstly, the crowdsourcing task set T_k of each crowdsourcing deliverer$k$can grab orders is generated, and n time points obeying Weber distribution are ordered from small to large. Then randomly select a crowdsourcing dispatcher k that meets the maximum task quantity constraint and the task set T_k is not empty from the task set T_k, assign a value to B_t^k after success, and delete the tasks that have been ordered from all the sets. Repeat the above operations. Until the maximum number of orders is reached or the matching time between the next task and the crowdsourcing deliverer exceeds the task assignment deadline.

3.3 Genetic Algorithm

3.3.1 Generate initial population

(1) Task assignment section allocates unmatched tasks.

(2) The route planning part plans the delivery sequence path.

3.3.2 Select Operations

The roulette method is adopted for selection, and the distribution path cost and timeout cost are the minimum targets in this model, so the fitness value is set as the reciprocal of the total cost.

3.3.3 Design crossover and mutation probability

3.3.4 Cross operation

(1) Task assignment cross operation. An integer is randomly selected between 1 and 6, such as 3. Only 1-3 genes are crossed, and 4-6 genes are retained in the corresponding position of the offspring.

(2) Path crossing operation. By adopting the pre-order preserving cross operation[16], this method can ensure that the delivery sequence of the pick-up and delivery point of the crowdsourcing task does not change.

(3) Recalculate fitness.

3.3.5 Mutation operations

(1) Task assignment variation operation. Single point variation is used.

(2) Path variation operation.

4 Numerical experiments

4.1 Parameter settings

(1) The number of crowdsourcing tasks is $n = 60$.

(2) The number of crowdsourcing deliverers is $m = 20$.

(3) v=20km/h; r_M=5km; r_T=3km; Q=5; c_1=1.5yuan/km; c_2=0.5yuan/min; α=10; β=3; Random order ratio ρ=0.6; Proportional parameter λ=0.5; Shape parameter μ=0.5.

(4) Population size is 100; Crossover probability p_c=0.9; Variation probability p_m=0.1; Iteration times 800 generations.

4.2 Result analysis

When the above parameters are substituted into the algorithm, the number of iterations is 800 generations, and the change of the objective function value with the number of iterations is shown in the Figure1. From the Figure1, it can be seen that the algorithm of this model has convergence, and the optimal solution is obtained in about 450 iterations, with the objective function value of 227.34, the delivery path length of 151.23km, and the timeout time of 0.00min, and the delivery effect is good. The calculation results of the model are shown in the Table 1, and the path planning results are shown in the Figure2.

As can be seen from Table 1 and Figure2, there are a total of 19 crowdsourcing deliverers participating in the distribution. Timely delivery of orders by the platform can, to a certain extent, send the tasks on the way to the crowdsourcing deliverer for distribution. Effectively combining the crowdsourcing deliverer's order grabbing with the crowdsourcing logistics platform's order dispatching, and planning the distribution path, can obtain better distribution results.

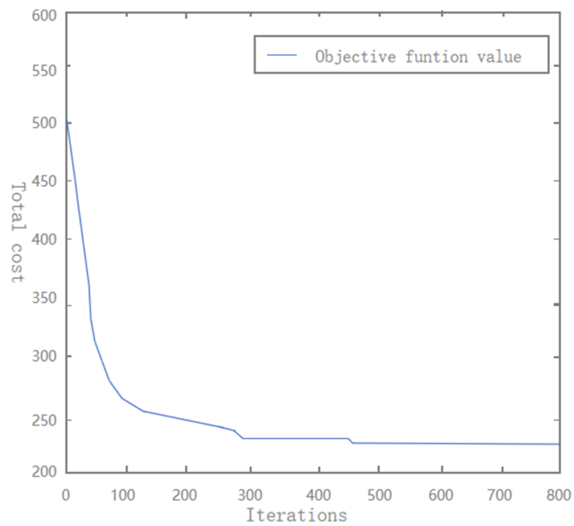

Figure 1. The change of the objective function value with the number of iterations.

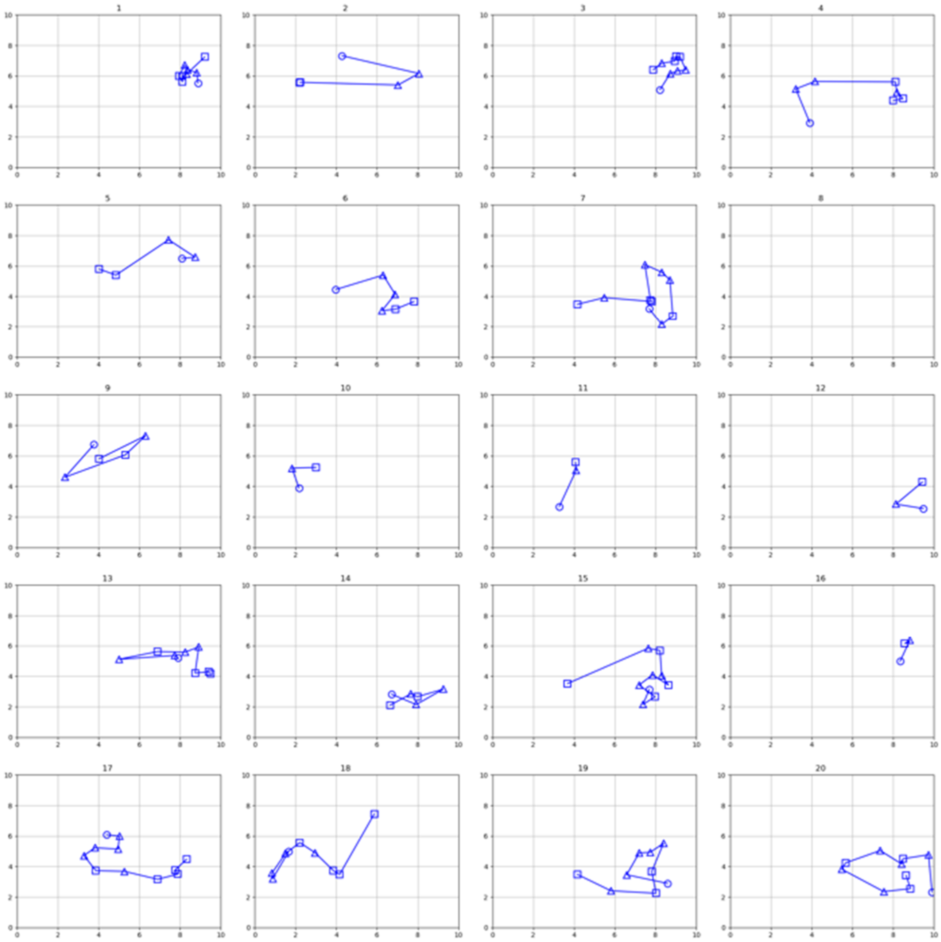

Figure 2. Path planning result.

Table 1: Model matching set and delivery path order.

k	t	Delivery path sequence
1	25, 32, 43, 55	32-43-55-92-115-103-25-85
2	12, 29	12-29-89-72
3	13, 35, 37, 39	13-35-37-95-97-73-39-99
4	2, 7, 20	7-20-67-2-62-80
5	1, 17, 23, 41, 54	41-101-17-1-54-77-114-61-23-83
6	5, 26, 51	26-51-5-65-86-111
7	27, 56	27-56-116-87
9	6, 11	11-71-6-66
10	58	58-118
11	10, 16, 46, 48	16-48-76-46-10-106-108-70
12	31	31-91
13	45	45-105
14	47, 57, 59	57-59-119-117-47-107

15	3, 4, 19, 38, 52	19-3-38-52-112-4-98-64-79-63
16	34	34-94
17	28, 30, 36, 40, 42	30-90-28-36-96-42-88-40-102-100
18	14, 15, 22, 49	14-49-22-109-15-74-82-75
19	8, 18, 21, 44, 60	21-8-18-44-81-104-68-78-60-120
20	9, 24, 33, 50, 53	24-84-9-33-69-53-50-93-110-113

5 Conclusion

Based on the crowdsourcing task existing in pick-up and delivery pairs, this paper studies the crowdsourcing logistics task allocation and path joint optimization under the combination mode of rush and dispatch, so as to improve the distribution efficiency of the crowdsourcing logistics platform and reduce the phenomenon of timeout. Subsequently, numerical experiments prove that the proposed algorithm has convergence, and can effectively solve the task allocation and path joint optimization problem of crowdsourcing logistics under the combination mode of rush and dispatch, and obtain a good distribution effect .Finally, an example is introduced to verify the effectiveness of the model and algorithm through numerical experiments, which provides reference basis and decision support for task allocation and route optimization of crowdsourcing logistics platform.

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