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Research on Crowd-Sourcing Distribution Path Considering Real-Time Customer Demand

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ABSTRACT

With the rapid development of crowd-sourcing distribution, most of the existing researches focus on the path optimization of single distribution, and few consider the dynamic customer demand. Based on this, under certain assumptions, fuzzy time window is introduced to express customer satisfaction, which is constrained by achieving the expected customer satisfaction of the platform. On the basis of static model, considering the characteristics of real-time order generation, the dynamic model is built by delay processing. Through the example analysis, the dynamic model uses the way of delay processing and inserting orders to carry out the order integration distribution, solves some problems in the distribution network under the crowd-sourcing mode, effectively reduces the number of crowd-sourcing distributors, and reduces the overall distribution cost. The validity of the model is verified.

Keywords: *Crowd-sourcing distribution, path optimization, real-time customer demand, differential evolution algorithm*

1. PROBLEM BACKGROUND

At present, there are some problems in the way of crowd-sourcing distribution: On the one hand, the quality of distribution services is uneven; on the other hand, the situation of crowd-sourcing distribution staff blindly grabbing orders leads to unreasonable order distribution route and waste of social resources[1]. These problems limit the development of crowd-sourcing model to a large extent. At present, many experts and scholars carry out macro qualitative analysis on the crowd-sourcing mode[2]. There are few researches on the optimization of the crowd-sourcing distribution path. Most of the literature only study the static path optimization.However, in practice, customer needs are generated in real time, and the production of new orders in distribution process must be considered. When dealing with orders, we can use the delay insertion method in DVRP problem for reference[3]. This article takes crowd-sourcing platform as the main body, on the premise of satisfying the customer satisfaction of the platform's expectations, merges the delivery demand orders and researches on the optimization of the distribution path, so as to minimize the platform distribution cost.

2. PROBLEM DESCRIPTION

The process of crowd-sourcing distribution can be described as: There are m crowd-sourcing distributors in the current area, their starting position has n customer orders, each order has an order start and end point and customer order delivery time limit[4].Distribute n orders to the appropriate crowd-sourcing delivery staff and optimize the delivery path of each delivery staff, so that the cost of completing all orders under the constraints of reaching the platform's expected customer satisfaction is minimized.

In order to describe customer satisfaction quantitatively, this paper introduces fuzzy time window of customer order[5]. For the fuzzy time window construction function, $T_{i^-}^k$ indicates the arrival time of the crowd-sourcing distributor k to the customer i,the expected delivery time window of the customer is[ET_{i^-}, LT_{i^-}], the tolerable delivery time of the customer is [EET_{i^-}, ELT_{i^-}], and the customer satisfaction is λ_i. When $L_{i^-}^k = T_{i^-}$, the highest customer satisfaction is 1. Suppose that the customer satisfaction under the ideal condition is subject to the piece-wise function shown in the following formula:

$$\lambda_i = \begin{cases} 0 & 0 \le T_{i^-}^k < EET_{i^-}, \quad T_{i^-}^k > ELT_{i^-} \\ \dfrac{T_{i^-}^k - EET_{i^-}}{ET_{i^-} - EET_{i^-}} & EET_{i^-} \le T_{i^-}^k < ET_{i^-} \\ 1 & ET_{i^-} \le T_{i^-}^k \le LT_{i^-} \\ \dfrac{ELT_{i^-} - L_{i^-}^k}{ELT_{i^-} - T_{i^-}^k} & LT_{i^-} < T_{i^-}^k < ELT_{i^-} \end{cases} \quad (1)$$

It can be seen that under the fuzzy time window, when the order is delivered in the customer's expected time window, the highest satisfaction is 1. As the delivery time exceeds or the customer's expected time in advance increases, the customer satisfaction also decreases,until it drops to 0.

3. MODEL BUILDING

3.1 Dynamic Order Information Processing Strategy

The crowd-sourcing platform is set to update the order information every t time. The new orders generated in the t time period are allocated and route optimized as static orders,including at the end of the t time period and unfinished orders in the previous time period. For the orders that have been picked up but not delivered, only the distribution path is optimized, and the crowd-sourcing distributor remains unchanged. In the system, after the position coordinates and the remaining order receiving quantity of each crowd-sourcing distributor are defined, the crowd-sourcing platform allocates orders and optimizes the distribution path according to the static processing strategy.

As shown in Figure 1, orders generated in the 0-t time period are refreshed and allocated at time t.At the same time,orders generated from time t to time 2T are processed at time 2T, and so on, (n-1) orders generated from time t to time NT are processed at time NT.

At the time of the r-th order update, the orders in the crowd-sourcing platform can be divided into four categories: new orders generated at the update time of the r-th and the old order that has been previously generated. Among them, the old orders include completed orders and unfinished orders.The unfinished order also includes the order that has been picked up but not delivered and the unfinished order . Therefore, at the time of order update, there may be four types of orders in the system: newly generated orders, old orders that have completed distribution, old orders that have not been taken but not distributed, and old orders that have been taken but not distributed.

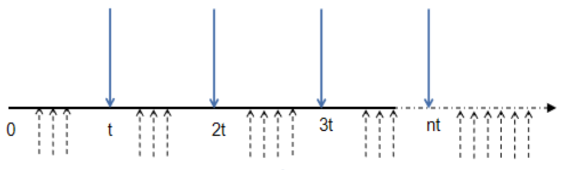

Figure 1 Order delay processing strategy

3.2. Model Description

Based on the predecessor's static model construction foundation, at the r update time, considering the undelivered orders and new order information conditions, with the r-th distribution route cost, personnel operating cost and overtime penalty cost as the optimization goals, build customers that meet the platform's expectations A dynamic model that minimizes platform costs under satisfaction constraints[6]. Based on the static model, we suppose:

O_r The order collection that needs to be considered at r update times. O_{nr} The new order set at the r update time. $O_{wr}=\{i\mid T_{i^+}^k>rt, i\in O_{r-1}, k\in M\}$:The collection of uncollected orders at the r update time. $O_{qr}=\{i\mid T_{i^+}^k<rt, T_{i^-}^k>rt, i\in O_{r-1}, k\in M\}$ The collection of orders that have been picked up but not delivered at the time of update. I_r :The collection of all order points that need to be considered at the r update time. M_w^r :The crowd-sourcing delivery personnel who have been dispatched at the r update time gather. M_n^r :R crowded delivery personnel who have not been dispatched at the r update time. $M=M_n^r\cup M_w^r$ is all crowd-sourcing distributors in the platform. Q_r :The number of crowd-sourcing delivery personnel newly added to the distribution task at r update times. N_{cr} : $N_{cr}=\{k_r^+\mid k\in M_w^r\}$ The crowd-sourcing delivery personnel who have been dispatched at the time of r times of the update will gather the temporary delivery starting point. $N_{wr}=\{k_0^+\mid k\in M_n^r\}$ The starting position of the delivery person who has not been dispatched at the r update time. H_r^k :The number of unfinished orders delivered by the delivery staff k at the time of r updates, excluding the newly generated orders for the r updates.

The dynamic model of crowd-sourcing distribution route optimization problem can be described as:

$$\min \sum_{k\in M_w^r}\sum_{g\in I_r}\sum_{j\in I_r} c_1(x_{k_r^+,g}^k d_{k_r^+,g}^k + x_{j,g}^k d_{j,g}^k) + \sum_{k\in M_n^r}\sum_{g\in I_r}\sum_{j\in I_r} c_1(x_{k_0^+,g}^k d_{k_0^+,g}^k + x_{j,g}^k d_{j,g}^k) + \sum_{k\in M_n^r}\sum_{i\in O_{nr}} c_2 x_{k_0^+,i^+}^k + \sum_{k\in M}\sum_{i\in O} c_3 \max(T_{i^-}^k - LT_{i^-}^k, 0) \qquad (2)$$

constraint:

$$\Lambda \geq \mu \qquad (3)$$

$$\sum_{k\in M}\sum_{g\in I_r} x_{i^+,g}^k = 1, \quad \forall i\in O_n^r \qquad (4)$$

$$\sum_{g\in I_r\cup\{k^+\}} x_{k_r^+,g}^k = 1, \quad \forall k\in M_w^r \qquad (5)$$

$$\sum_{j\in I_r\cup N_{cr}} x_{j,k^-}^k = 1, \quad \forall k\in M_w^r \qquad (6)$$

$$\sum_{g\in I_r\cup\{k^+\}} x_{k_0^+,g}^k = 1, \quad \forall k\in M_n^r \qquad (7)$$

$$\sum_{j\in I_r\cup N_{wr}} x_{j,k^-}^k = 1, \quad \forall k\in M_n^r \qquad (8)$$

$$\sum_{g\in I_r\cup N_{cr}\cup N_{wr}} x_{j,g}^k - \sum_{g\in I_r\cup\{k^-\}} x_{j,g}^k = 0, \quad \forall j\in I_r, \quad \forall k\in M \qquad (9)$$

$$\sum_{g\in I_r} x_{i^+,g}^k - \sum_{g\in I_r} x_{g,i^-}^k = 0, \forall i\in O_{nr}\cup O_{wr}, \quad \forall k\in M \qquad (10)$$

$$H_r^k = \sum_{g\in R_r^k}\sum_{i\in\{i\mid T_{i^-}^k>rt\}} x_{g,i^-}^k, \quad \forall k\in M \qquad (11)$$

$$H_r^k + \sum_{g\in I_r}\sum_{i\in O_{nr}} x_{i^+,g}^k \leq q, \quad \forall k\in M \qquad (12)$$

$$T_g^k = T_j^k + \frac{d_{j,g}}{v}, \forall k\in M, \text{且} x_{j,g}^k = 1, \forall j\in I_r\cup N_{cr}\cup N_{wr}, \forall g\in I_r\cup\{k^-\} \qquad (13)$$

$$T_{i^+}^k \leq T_{i^-}^k, \forall i\in O_{nr}\cup O_{wr}, \forall k\in M \qquad (14)$$

$$x_{j,g}^k = 0 or 1, \forall k\in M, \forall j\in I_r\cup N_{cr}\cup N_{wr}, \forall g\in I_r\cup\{k^-\} \text{且} j\neq g \qquad (15)$$

$$Q_r = \sum_{k\in M_n^r}\sum_{i\in O_{nr}} x_{k_0^+,i^+}^k \qquad (16)$$

Equation (1) is the objective function, which means to minimize the platform cost considering all unfinished orders at the time of r-update;Equation (2) is the customer satisfaction constraint expected by the platform, which means that the average customer satisfaction expected by the platform is greater than a fixed value;Equation (3) means that new orders generated at the time of r-update can only be accessed once by a crowd-sourcing distributor;Equation (4) and (5)indicate that the process of crowd-sourcing distributor who has been previously assigned orders starts from his current position, finishes all the order delivery and finally ends the delivery at the destination;Formula (6) and (7) indicate that after the order is refreshed, the crowd-sourcing deliverer who has not been dispatched has a starting point and an end point in his distribution route, that is, each crowd-sourcing deliverer starts from his current position and finishes the distribution of all orders and ends the distribution; Formula (8) indicates that the crowd-sourcing deliverer arrives at the order task point After the operation is completed, he will leave the point and continue to the next position; Equation (9) indicates that the order at the time of r-update exists in pairs and can only be accessed by the same crowd-sourcing distributor; Equation (10) indicates the number of unfinished orders of distributor K at the time of r-update, excluding the newly generated orders; Equation (11) represents the sum of the number of unfinished orders of delivery staff k at the time of r updates and the newly dispatched orders Less than the one-time maximum order quantity, that is, restrict the number of new orders distributed by delivery staff k; Formula (12) indicates the time when the crowd-sourcing distributor K arrives at point G; Formula (13) indicates that the order task point has the order of access, that is, for the merchant and customer location points in the order, the crowd-sourcing distributor must first arrive at the merchant location , then to the customer location;Formula (14) represents the decision variable, $x_{j,g}^{k}$ = 1 represents the crowd-sourcing distributor K from point J to point G, otherwise it is 0;Formula (15) represents the number of crowd-sourcing distributors newly added to the distribution task at the time of R update.

3.3 Crowd-Sourcing Delivery Scheduling Method Based on Differential Evolution Algorithm

The real number coding method is used to express the solution of the current distribution scheduling problem:Given the total number of orders n and the total number of delivery personnel m , the solution to this problem is represented by a n dimensional array, and the range of the code for each dimension is $[1,1+m)$, where the i dimensional code is used to determine the order of order i to take and deliver meals.

Decoding process: first, the dimension codes are divided into three parts: the integer part value of the code, the decimal part of the first part of the code and the decimal part of the second part of the code, The minimum number of decimal places is $[\log_{10}^{m}]$; second, According to the integer part of the code, the order is distributed to each delivery person; finally, the order sequence is determined by the corresponding two parts of the decimal value.

4. EXAMPLE SOLUTION

40 orders from 12:00 to 12:30:30 of crowd-sourcing platform are selected for research.. During this period, in this area,the location coordinates of the free crowd-sourcing distributors who have access to the platform are known.

The parameters are set as follows: the unit distribution cost c_1 is 0.4 yuan / km, the unit personnel operation cost c_2 is 30 yuan / person, the unit overtime penalty cost c_3 is 0.5 yuan / min, the average distribution speed of the crowd-sourcing distribution personnel v is 0.2km/min, the maximum one-time order receiving quantity of the crowd-sourcing distribution personnel q is 0.7, the average customer satisfaction expected by the five platforms μ is 0.7, and the customer expected delivery time is 30-40min after the order is placed.

In the dynamic scenario model, the crowd-sourcing distributor does not know all the order information.At the same time, there will be new orders in the process of distribution. According to the establishment of the dynamic model in Chapter 3, the crowd-sourcing platform needs to allocate the dynamic orders and plan the distribution route. In this section, our study object is still 40 orders which selected from 12:00 to 12:30. And the production time of each order is also listed in the table. Orders are continuously generated from 12 o'clock. Instead of processing orders immediately, the platform processes orders in the previous stage in a ten minute interval. The location point and number of crowd-sourcing distributors on the access platform are remain the same as the static model, so are the other parameters of the algorithm. The platform is updated 3 timesat 12:10, 12:20 and 12:30 respectively for optimization. Use matlab to solve the problem, and the iterative process is shown in Figure 2:

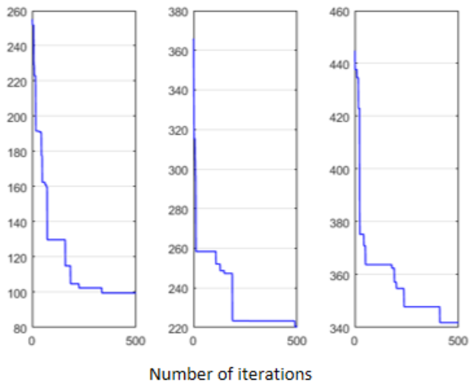

Figure 2 Solve iterative process

It can be seen from the figure that in the solution process, the three updates are iterated 500 times. The first update tends to be stable around 3500 times.The second update tends to be stable around 200 times. And the third update tends to be stable around 450 times.Finally, eight shippers are needed to deliver these orders. After three order updates, the minimum distribution cost of the objective function is 341.85 yuan, including 84.18km of distribution path length, 33.67 yuan of distribution path cost, 240 yuan of personnel operation cost, and 68.18 yuan of total overtime penalty cost. At this time, the average customer satisfaction of all orders is 0.7318, and the specific distribution path of each distributor is shown in Table 1:

Because the dynamic model processing process is to divide the time period into several static models of the same time for processing, using delay processing and order insertion to decompose the dynamic model orders, for the impact analysis of different parameters, refer to the static model analysis in the previous section. This section mainly analyzes the process of dynamic order processing to verify the validity of the model.

(1) Take the crowd-sourcing distributor K30 as an example, the condition of the distributor at the time of three order updates is as follows:

As can be seen from the figure, for the delivery staff K30, the platform is refreshed for the first time at 12:10. Orders from 12:00 to 12:10 are uniformly allocated and planned at 12:10. The distribution route of K30 is planned to be 6+→11+→12+→6—→11—→12—.The second refresh is carried out at 12:20 platform, and the orders from 12:10 to 12:20 are uniformly processed. At this time, K30 has completed the order 6 acquisition but the goods have not been delivered yet. Take the pick-up point of order 11 as the temporary delivery starting point of K30 to join the platform order pool for re-route planning. After the second update, the distribution route of K30 is 6+→11+→12+→19+→6—→11—→12—→19—, compared with the first update route, order 19 is inserted after the pick-up of order 12. Similarly, the platform is refreshed for the third time at 12:30. After the third update, the distribution route of K30 is 6+→11+→12+→19+→6—→32+→35+→11—→12—→19—→32—→35—.

(2) For order 12, the platform first refreshes and assigns order 12 to crowd-sourcing distributor K30 for distribution. At this time, the distribution path of distributor K30 is6+→11+→12+→6—→11—→12—.According to the planned path and estimated time of the platform,it is estimated that the distribution of order 12 will be completed at 50.44 (overtime).And the customer satisfaction of order 12 is 0.9035.There will be new orders in the distribution process of the dispatcher K30. At the second update time of the platform (20), the platform inserts new order 19 based on the original distribution route of K30.So the distribution route of K30 is 6+→11+→12+→19+→6—→11—→12—→19— .After the second update, the delivery clerk K30 is expected to complete the delivery of order 12 at 50.78 (overtime), which is slightly delayed. At this time, the customer satisfaction of order 12 is 0.8811.At the third update time (30), the platform inserts new orders 32 and 35 on the basis of K30 path. At this time, the delivery path of K30 is 6+→11+→12+→19+→6—→32+→35+→11—→12—→19—→32—→35—.After the third update, the distributor K30 is expected to complete the distribution of order 12 at 53.08 (overtime), which is also slightly delayed. At this time, the customer satisfaction of order 12 is only 0.7282.

According to the analysis of the change of customer satisfaction with order 12, we can know that in the process of the platform's processing and path optimization of dynamic orders,the platform, as the main body of coordinating all orders and distributors, needs to consider the distribution cost and average satisfaction. Although the insertion of new orders in the original distribution path leads to inevitable delay of some orders' distribution, so that the satisfaction of these orders will continue to drop. However, to a certain extent, order insertion can improve the average satisfaction of the overall order and minimize the distribution cost

Table 1 Distribution route

Delivery person	Order delivery route
K1	$1^{+}\to 3^{+}\to 5^{+}\to 8^{+}\to 13^{+}\to 1^{-}\to 3^{-}\to 5^{-}\to 8^{-}\to 13^{-}\to 18^{+}\to 23^{+}\to 18^{-}\to 23^{-}\to 38^{+}\to 38^{-}$
K6	$28^{+}\to 37^{+}\to 37^{-}\to 28^{-}\to 40^{+}\to 40^{-}$
K7	$26^{+}\to 20^{+}\to 17^{+}\to 26^{-}\to 20^{-}\to 17^{-}$
K8	$15^{+}\to 14^{+}\to 21^{+}\to 25^{+}\to 34^{+}\to 34^{-}\to 25^{-}\to 15^{-}\to 33^{+}\to 21^{-}\to 33^{-}\to 14^{-}$
K12	$4^{+}\to 2^{+}\to 7^{+}\to 7^{-}\to 22^{+}\to 22^{-}\to 10^{+}\to 30^{+}\to 4^{-}\to 2^{-}\to 9^{+}\to 9^{-}\to 30^{-}\to 10^{-}$
K21	$24^{+}\to 16^{+}\to 27^{+}\to 16^{-}\to 27^{-}\to 24^{-}\to 29^{+}\to 29^{-}$
K24	$36^{+}\to 31^{+}\to 39^{+}\to 36^{-}\to 39^{-}\to 31^{-}$
K30	$6^{+}\to 11^{+}\to 12^{+}\to 19^{+}\to 6^{-}\to 32^{+}\to 35^{+}\to 11^{-}\to 12^{-}\to 19^{-}\to 32^{-}\to 35^{-}$

For order 4, the platform first refreshes and assigns order 4 to distributor K12 for distribution. At this time, the distribution path of K12 is 4+→2+→7+→7—→10+→4—→2—→9+→9—→10—. According to the planned path and estimated time of the platform, the distributor K12 is expected that the distribution of order 4 will be completed at 31.93 (in advance), at which time the customer satisfaction of order 4 is 0.9312.In the process of distribution, there will be new orders generated by the dispatcher K12. At the second update time (20), the platform inserts new order 22 on the basis of the original distribution route of K12, at which time the distribution route of K12 is4+→2+→7+→7—→22+→22—→10+→4—→2—→9+→9—→10—. After the second update, the delivery clerk K12 is expected to complete the delivery of order 4 at 33.88 (in advance), at which time the customer satisfaction of order 4 is 0.9960.At the third update time (30), the platform inserts a new order 30 based on the K12 path, at which time the delivery path of K12 is4+→2+→7+→7—→22+→22—→10+→30+→4—→2—→9+→9—→30—→10—. After the third update, the delivery clerk K12 is expected to complete the delivery of order 4 at 34.92 (within the time window of customer satisfaction).At this time, the customer satisfaction of order 4 is 1.

It can be seen from the analysis of customer satisfaction change of order 4 that in the process of platform's processing and path optimization for dynamic orders, some order customer stores are too close to the merchants, which leads to the early arrival of orders in the process of platform's dispatch and route planning.Further lead to the decrease of customer satisfaction. Actually the insertion of new dynamic orders can delay the dispatch time of these orders, so we can delivery the products on time to improve customer satisfaction.

Based on the analysis of order 4 and order 12, the platform delays the processing of orders and adopts the method of inserting orders to process dynamic new orders, which will delay the delivery time of some orders in the original delivery path and may delay the orders that have arrived early. Until the time window for customer satisfaction arrives, improving customer satisfaction; it may also cause late orders to arrive later, reduce customer satisfaction, and increase the cost of overtime penalties. This is the result of the platform's overall planning and scheduling based on all orders. Although individual orders may be delivered later, they can minimize delivery costs and achieve an optimal state under the condition that the platform expects the lowest customer satisfaction. . By substituting the calculation example into the dynamic model for solving, the validity of the model is verified.

5. CONCLUSION

Considering the order generation time based on the static model,and the order is updated every 10 minutes. The order is processed separately but effectively combined.The number of delivery personnel is reduced, and the distribution path is optimized. In the dynamic model, the platform coordinates planning and scheduling based on all order conditions. There are cases where individual orders are delivered later and orders that should have arrived early which are delivered on time. This can minimize delivery cost and achieve an optimal state under the condition of ensuring the minimum customer satisfaction.Through empirical analysis, the validity of the model is verified.

REFERENCES

[1] Aashwinikumar Devari, Alexander G. Nikolaev, Qing He, crowd-sourcing the last mile delivery of online orders by exploiting the social networks of retail store customers[J], Transportation Research Part E , 105 (2017) 105-122.

[2] Zhao Jianjun, Yang Weinan, Yu Yunze et al. Crowdsourced task pricing model design based on K-means clustering algorithm [J], Modern Information Technology, 3(12) (2019) 72-74.

[3] Zhang Huanqing, Xu Qinghao, Pan Yifan, Research on crowd-sourcing Task Pricing Model Based on Objective Optimization Algorithm [J], Electronic Testing, 11 (2018) 60-61.

[4] Ichoua S, Gendreau M, Potvin J Y, Exploiting knowledge about future demands for real-time vehicle dispatching[J], Transportion Science, 40(2) (2006) 211-225.

[5] Kergosien Y, Lente C, Piton D, et al. A tabu search heurist for the dynamic transporation of patients between care units[J], European Journal of Operational Research, 214(2) (2011) 442-452.

[6] Wang Jun, Li Bo, Dynamic management of fuzzy demand VRPTW based on multi-objective optimization[J], Journal of Management, 10(2) (2013) 238-243.