Optimization of distribution path for community group buying considering customer satisfaction

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Abstract. Aiming at the problems of low efficiency, high cost and low customer satisfaction in the logistics distribution of community group purchase enterprises. In this paper, a VRP model with minimum total cost including fixed cost, transportation cost and penalty cost is established under the constraint of satisfaction function of distribution time window. The designed genetic algorithm is used to solve the model. Through the example verification, the total cost function designed in this paper can effectively reduce the cost and obtain good satisfaction. The algorithm is feasible and effective, providing a reference for enterprise decision-making.

1. Introduction

For community group purchase logistics distribution, it is quite different from the traditional B2B distribution mode. At present, there are few literatures about community group purchase, and community group purchase enterprises usually adopt rough methods for distribution. Vehicle routing problem (VRPTW) with time window is one of them. Discussed the establishment of mathematical models for vehicle routing problems with time Windows [1]. Due to the np-hard characteristic, many scholars use heuristic algorithms to solve such problems. Include genetic algorithm [2], particle swarm optimization [3], and hybrid heuristic algorithm [4]. Many domestic scholars have done in-depth research on the vehicle routing problem of customer satisfaction with time window. Proposed a VRP optimization model for multi-model cold-chain logistics under the constraint of satisfaction [5]. Therefore, this paper first establishes the customer satisfaction function with service time as the variable. Then the total cost model including fixed vehicle cost, transportation cost and penalty cost is established.

2. Mathematical model of community group buying based on customer satisfaction

2.1. problem description
The specific problem can be described as that in a distribution center, all vehicles start from the distribution centre on the same day, know the location of the community leader point. Build the model based on the following assumptions:
- The location of the distribution center is fixed and distribution vehicles of the same type.
- The total demand of customers shall not exceed the stowage capacity limit of vehicles.
- The distribution vehicles run at a certain speed and the traffic is smooth.
• Each community should be served and only receive one service. The geographical location, demand and time range of receiving distribution service of each community leader are known.
• All delivery vehicles have time constraints when they arrive at the community.

2.2. symbol description
N is the set of community heads; K is the collection of distribution vehicles; Q is the maximum load of the vehicle; V is the average speed of the vehicle; \( d_{ij} \) is the distance between the previous community point \( i \) and the next community point \( j \); \( p_c \) is the fixed cost of a car; \( p_r \) is the vehicle fuel cost per kilometer; \( \epsilon_1 \), \( \epsilon_2 \) are the costs of vehicle waiting and tardiness per unit time. Decision-making scalar:
\[
x_{ijk} = \begin{cases} 
1, & \text{Vehicle } k \text{ goes from } i \text{ to } j \\
0, & \text{Otherwise}
\end{cases} \\
y_{ik} = \begin{cases} 
1, & \text{Customer } i \text{ is delivered by vehicle } k \\
0, & \text{Otherwise}
\end{cases}
\]

2.3. satisfaction calculation
In this paper, the linear continuous time satisfaction function under the vehicle service time window is used to quantify customer time satisfaction \( CT_i \), as shown in figure 1. \( CT_i \) is customer \( i \) satisfaction, and \( t_i \) is the moment when the vehicle arrives at customer \( i \). The satisfaction function is expressed as

\[
CT_{i}(t_i) = \begin{cases} 
0, & t_i \not\in [E_i, L_i] \\
\frac{t_i - E_i}{E_i} - t_i \in [E_i, e_i] \\
\frac{L_i - t_i}{L_i - e_i}, & t_i \in (l_i, L_i] \\
1, & t_i \in [e_i, l_i]
\end{cases}
\] (1)

Figure 1. Time satisfaction

2.4. Mathematical model construction
Considering customer satisfaction, the distribution model is as follows:
\[
Max \frac{1}{N} \sum_{i=1}^{N} CT_i(t_i)
\] (2)
MinZ = \sum_{k=1}^{K} \sum_{j=1}^{N} x_{ijk} f_k + \sum_{k=1}^{K} \sum_{j=0}^{N} \sum_{i=0}^{N} d_{ij} x_{ijk} p_r + \epsilon_1 \sum_{i=1}^{N} \max \{E_i - t_i, 0\} + \epsilon_2 \sum_{i=1}^{N} \max \{t_i - L_i, 0\}
\] (3)
\[
\sum_{j=1}^{N} q_i y_{ik} \leq Q k = 1, 2, ..., K
\] (4)
\[
\sum_{k=1}^{K} y_{ik} = 1, i = 1, 2, ..., N
\] (5)
\[
\sum_{j=1}^{N} x_{ijk} = \sum_{i=1}^{N} x_{ijk} = 0, \forall k
\] (6)
\[
\sum_{i=0}^{N} x_{ijk} = y_{ik}, i = 1, 2, ..., N, \forall k
\] (7)
\[
\sum_{j=0}^{N} x_{ijk} = y_{jk}, j = 1, 2, ..., N, \forall k
\] (8)
equation (2) is the objective function to maximize the average customer satisfaction; Equation (3) is the objective function that requires the minimum of fixed cost, transportation cost and penalty cost; Formula (4) limits the maximum carrying capacity of distribution vehicles; Formula (5) ensures that each colonel
is served by only one vehicle; Formula (6) ensure that the starting and ending points of distribution vehicles are in the distribution center; Equations (7) - (8) ensure that each colonel is served only once.

3. Genetic algorithm design

3.1. Genetic manipulation

3.1.1. Chromosome coding. In this paper, chromosome coding is carried out by natural number coding.

3.1.2. Fitness function. In the genetic algorithm, the higher the fitness $f$, the better the chromosome, the smaller the total cost objective function $Z$. $Z_i$ will represent the total cost of the $i$-th subpath. $f(i) = 1/Z_i, i = 1, ..., N$.

3.1.3. Select operation. The parent generation of the cross was selected by the roulette wheel selection strategy. At the same time, elite reservation mechanism is adopted based on roulette.

3.1.4. Cross operation. In this paper, the partial matching crossover rule is used to prevent the genetic algorithm from getting into the local optimum and the result from getting the optimal value.

4. Analysis of examples

4.1. Initial data

The data in [6] are adopted in this paper. The parameters in the model are set as follows: the running speed of the vehicle $v=40km/h$, the vehicle unit distribution cost is $P_r=1.5$, the fixed cost of each vehicle is $f_k=85$, $e_1=50$, $e_2=100$, and the maximum load of the vehicle is 250 units. In the genetic algorithm, the population size is 150, the crossover probability is 0.9, the mutation probability is 0.05, and the maximum number of iterations is 200.

4.2. Analysis of results

The path obtained by using genetic algorithm in literature [6] is 0-7-13-14-15-0;0-11-9-1-6-10-0;0-12-3-5-4-8-2-0; As the path, the total cost is 499.8, the total path length is 163.2, and the average customer satisfaction is 0.813. We ran the optimal value of the objective function with a total cost of 476.3, a total path length of 141.5, and an average customer satisfaction of 0.805. The vehicle routes of the three vehicles corresponding are shown in figure 2.

![Image](image1)

Figure 2. Vehicle routing.

It can be seen that when the experimental data and parameters are set exactly the same, the path length obtained by establishing the model in this paper is reduced by 15% compared with the results in literature [6], the average customer satisfaction is slightly lower, and the total cost is even lower, reduced
by 5%.

5. Conclusion

In view of the problems existing in community group-buying logistics distribution, this paper, under the constraint of customer satisfaction function of time window, constructs a mathematical model of distribution cost for community group-buying logistics distribution, analyses in detail the fixed cost, transportation cost and time window penalty cost, and then designs a genetic algorithm to solve them. Through the example comparison, the community group purchase logistics distribution model obtains satisfactory solution and good satisfaction. This paper provides valuable reference for enterprises to improve user stickiness and customer service experience in the fierce competition.

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