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# Competitive location problem of multi-level pickup point considering cooperative coverage

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**Abstract:** To occupy a greater market share in terminal distribution, companies are urged to make full use of cooperative coverage formed with brand effect and information sharing in the layout of pickup points. Based on the diversity of pickup points, the piecewise function, signal intensity function and probability function are introduced. Meanwhile, considering the effect of distance satisfaction and cooperation coverage on customer behavior, the location model of the pickup point under competitive environments is established. The genetic algorithm is used to solve the problem, and the effectiveness of the model and algorithm is verified by a case. The results show that the sensitivity of weighted demand coverages to budget decreases gradually. The maximum weighted demand coverage increases at first and then decreases with the increase of the signal threshold, and there is a positive correlation with the change of the actual demand coverage to the senior customers, but it is negatively related to the intermediate and primary customers. When the number of high-level pickup points in a competitive enterprise is small, the advantage of the target enterprise is more significant. Through comparison, the cooperative coverage model is better than the non-cooperative coverage model, in terms of the weighted demand coverage, the construction cost and the attention paid to the important customers.

**Key words:** pickup point; cooperative coverage; multi-level facility layout; competitive conditions; genetic algorithm
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The rapid spread of e-commerce has stimulated a sharp increase in residents' demand. Shoppers in non-first-tier cities have become the mainstay of online consumption. The strong demand for express delivery has brought tremendous pressure on the terminal distribution. Thus, utilizing pickup mode shall become the main method to solve the "last mile" problem. However, the shortage of pickup points is prominent. It greatly reduces distribution efficiency, restricts the improvement of consumption experience, and inhibits consumer's willingness to consume. Therefore, accelerating the construction of pickup points and expanding the coverage of the network are the most important issues.

The existing research on the location of pickup points is based on the assumption of single, undifferentiated points, which cannot accurately depict the diverse point in real operation. For a multi-type or multi-level facility location, we can employ the achievements of domestic and foreign scholars, whose research objects are mostly concentrated in shelters, distribution centers and other public service facilities[1-2]. As for the research of a multi-type or multi-level terminal delivery system, Chen et al. [3] took into consideration the customer's pick-up distance and the attractiveness of different types of pickup points, reconstructed the customer's utility function, and established a pickup point location model based on customer bounded rationality. Based on the network composed of a pickup service center, pickup service point and pickup service station, Han et al[4]. established a two-stage location model for multi-level pickup points.

Concerning a real-life scenario, another important consideration would be the competitive environment. The layout and management strategy of the competitors will affect the customers' choice in the market. The research on competitive location is relatively developed[5-6]. The utility function is the main method to determine the choice of customers[7]. In the competitive location research based on the maximum coverage model, Plastria et al. [8] proposed a discrete competitive location problem for prediction, then came up with three competitive location models respectively by different strategies.

However, what contrasts the real situation is that, in the form of utility function, whether it is 0-1 coverage or gradual coverage, one important assumption is that customers are influenced by a single point, and only choose the facility with the largest utility. The cooperative coverage model describes the phenomenon that customers are affected by all the facilities within the service radius. It is suitable for layout optimization of chain facilities and emergency facilities. Berman et al. [9] proposed coopera-

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tive coverage model under continuous and discrete demand. In the case of alarm location, it was verified that the number of facilities needed under cooperative coverage was half of that under traditional single-point coverage. Li et al.[10] established the largest cooperative coverage location model with budget constraint, and compared the cooperative coverage with non-cooperative coverage models by some indicators. The former was superior in various scenarios.

To sum up, there are the following problems. First of all, most of the location models only consider a single-type point. The multi-level point is often ignored. Secondly, most of the location models are set with the background of a monopoly market, which ignore the competitors' influence on the enterprise's decision as well as customer behavior. Thirdly, these models deem that customer satisfaction is affected by distance, ignoring the general effect of signal intensity on their selection.

With the assumption that pickup points of the same company jointly affect the behavior of the customer, the level of supply and demand, distance of the single pickup point, and cooperative coverage of multiple pickup points on customer selection behavior are taken into consideration. This paper proposed a location model with the aim of maximizing weighted demand coverage in a competitive situation.

## 1 Model Establishment

### 1.1 Problem description

A competitive environment brings customers more choices. It also has an important effect on the location decision of the enterprise. On the basis of a multi-level pickup network[11], the attractiveness, the distance and the cooperative coverage of pickup points work together on customer selection behavior, which are depicted respectively by utility function, signal intensity function and probability function. A target enterprise can employ a multi-level location model to decide the number, level and location of pickup points, in order to hold more market share.

### 1.2 Customer satisfaction function

As a criterion of whether the customer chooses the pickup point and accepts service from one enterprise or not, the satisfaction function is introduced. Through demonstration, Morganti et al.[12] showed that customer accessibility had an important influence on the layout of facilities. Distance affects the accessibility and convenience of the customer receiving service. Attractiveness refers to whether the pickup point provides customers with the due service. Focused service, to a certain extent, can make up for the decline in satisfaction with distance. Distance and attractiveness both influence a customer's satisfaction.

Satisfaction of customer $i$ to single point $j$ in target enterprise is structured as

$$f(l_{ij}) = \begin{cases} A_{s_i t_j} & l_{ij} \leqslant L_{s_i}^{\bar{l}} \\ \left( \dfrac{L_{s_i}^{\bar{u}} - l_{ij}}{L_{s_i}^{\bar{u}} - L_{s_i}^{\bar{l}}} \right)^{\varepsilon_{s_i}} A_{s_i t_j} & L_{s_i}^{\bar{l}} < l_{ij} \leqslant L_{s_i}^{\bar{u}} \\ 0 & l_{ij} > L_{s_i}^{\bar{u}} \end{cases} \quad (1)$$

where $I$ represents the customers set, $i \in I$; $J$ is the candidate pickup points set, $j \in J$; $S$ is the customer level set, $S = \{1, 2, 3\}$, representing the junior, intermediate and senior customers; $T$ is the pickup point level set, $T = \{1, 2, 3\}$, representing the primary, secondary and tertiary points; $s_i$ is customer $i$ in level $s$, $s_i \in S$; $d_i$ is the demand volume of customer $i$; $t_j$ means pickup point $j$ in level $t$, $t_j \in T$; $A_{s_i t_j}$ means the attractiveness of pickup point $j$ in level $t$ to customer $i$ in level $s$; $L_{s_i}^{\bar{l}}$ or $L_{s_i}^{\bar{u}}$ mean the minimum or maximum critical distance of customer $i$ in level $s$; $l_{ij}$ means the distance between point $j$ in target enterprise and customer $i$; $\varepsilon_{s_i}$ represents the sensitivity coefficient to the distance of customer $i$ in level $s$.

Similarly, the satisfaction of a demand point to single point $h$ of competitor is calculated as

$$f(l_{ih}) = \begin{cases} A_{s_i t_h} & l_{ih} \leqslant L_{s_i}^{\bar{l}} \\ \left( \dfrac{L_{s_i}^{\bar{u}} - l_{ih}}{L_{s_i}^{\bar{u}} - L_{s_i}^{\bar{l}}} \right)^{\varepsilon_{s_i}} A_{s_i t_h} & L_{s_i}^{\bar{l}} \leqslant l_{ih} \leqslant L_{s_i}^{\bar{u}} \\ 0 & l_{ih} > L_{s_i}^{\bar{u}} \end{cases} \quad (2)$$

where $H$ is a competitor's pickup points set, $h \in H$.

### 1.3 Signal intensity function

Companies can occupy a larger market share by attracting customers through jointly influencing their decision-making with brand establishment and information exchange. In the cooperative coverage network of a pickup facility, customers can receive the signal from the corresponding level or higher-level pickup points in the maximum critical distance. Customers can be covered by these facilities if the signal intensity exceeds the predetermined threshold, that is, the lowest limit in the satisfaction level of the customer's acceptance service. The more expressive a facility is, the more likely customers will choose to attend. $v_i$ and $v_{0i}$ represent the signal volume that customer $i$ accepts from all the pickup points of the target enterprise and the competitor, respectively. $x_j$ is 0-1 variable, if pickup point $j$ is set up, $x_j = 1$; otherwise, $x_j = 0$.

Influenced by a corresponding level or higher-level pickup points in target enterprise or competitor, signal volumes that customer $i$ received are structured as

$$v_i = 1 - \prod_{j \in J} (1 - f(l_{ij}) x_j) \qquad \forall s_i \in S \mid t_j \geqslant s_i \quad (3)$$

$$v_{0i} = 1 - \prod_{h \in H} (1 - f(l_{ih})) \qquad \forall s_i \in S \mid t_h \geqslant s_i \quad (4)$$

### 1.4 Probability function

Since customers may be subject to external environment or psychological changes, their choices have certain probabilistic characteristics: They do not always choose the enterprise with the largest utility to accept services. Through the analysis above, the customer selection behavior is related to the received signal intensity from the enterprise. $\tilde{\omega}$ represents the signal threshold when the customer is covered. If $v_i$ is not less than the threshold $\tilde{\omega}$, while $v_{0i}$ is less than $\tilde{\omega}$, it indicates that the customer is only covered by the target enterprise, i. e., all of his needs are assigned to the target enterprise. Otherwise, all needs will be assigned to the competitor. If both $v_i$ and $v_{0i}$ are not less than $\tilde{\omega}$, the selection probability of customers can be described by the binary Logit model. If $v_i$ and $v_{0i}$ are both smaller than $\tilde{\omega}$, because there are only two enterprises providing the service in this region, the customer will also make the decision through the Logit model.

The probability of customer $i$ choosing target enterprise is structured as

$$p_i = \begin{cases} 1 & v_i \geqslant \tilde{\omega} > v_{0i} \\ \dfrac{e^{v_i}}{e^{v_i} + e^{v_{0i}}} & v_i,\ v_{0i} \geqslant \tilde{\omega} \text{ or } v_i,\ v_{0i} < \tilde{\omega} \\ 0 & v_{0i} \geqslant \tilde{\omega} > v_i \end{cases} \tag{5}$$

### 1.5 Multi-level pickup point location model under cooperative coverage

This section first introduces the customer satisfaction function and signal intensity function to describe the impact of facility distance, attractiveness and cooperative coverage on customers; and then describes the customer's selection behavior through the probability function. Considering the constraints such as customer's importance, the nested level of pickup points, budget and capacity of pickup points at different levels, with weighted demand coverage maximization as the goal, the specific model and constraints are as follows:

$$\max \sum_{i \in I} d_i p_i q_{s_i} \tag{6}$$

$$\text{s.t. (1) to (5)}$$

$$t_j \geqslant s_i \tag{7}$$

$$\sum_{i \in I} d_i p_i \leqslant \sum_{j \in J} Q_{t_j} x_j \tag{8}$$

$$\sum_{j \in J} c_j x_j \leqslant C \tag{9}$$

$$x_j \in \{0, 1\} \tag{10}$$

$$\forall\, i \in I,\ \forall\, j \in J,\ \forall\, t_j \in T,\ \forall\, s_i \in S,\ \forall\, h \in H,\ \forall\, t_h \in T \tag{11}$$

where $Q_{t_j}$ represents the maximum capacity of pickup point $j$ in level $t$; $q_{s_i}$ is the importance degree of customer $i$ in level $s$ for the enterprise; $c_j$ is the construction cost of pickup point $j$; $p_i$ is the probability of customer $i$ distributed to the target enterprise; $C$ is the budget to set up facilities. Eq. (6) represents the goal of maximizing weighed demand coverage by a target enterprise. Eq. (7) indicates that demand can be assigned to a pickup point with corresponding or higher service level. Eq. (8) means the capacity constraint of the pickup points. Eq. (9) is the budget constraint. Eq. (10) is the range of decision variables. Eq. (11) is the range of parameters.

### 1.6 Multi-level pickup point location model under non-cooperative coverage

Under non-cooperative conditions, each pickup point is treated as an independent individual to cover customer demand. The distance and attractiveness will affect customer $i$ accepting service from pickup point $j$ or $h$. Therefore, the probability that customer $i$ chooses the target enterprise is

$$p_i = \frac{\sum_{j \in J} e^{f(l_{ij}) x_j}}{\sum_{j \in J} e^{f(l_{ij}) x_j} + \sum_{h \in H} e^{f(l_{ih})}}$$

$$f(l_{ij}) > 0,\ f(l_{ih}) > 0 \tag{12}$$

Compared with Section 1.5, the objective function and the constraints of the multi-level pickup point location model under non-cooperative coverage are modified as

$$\max \sum_{i \in I} d_i p_i q_{s_i} \tag{13}$$

$$\text{s.t. (1), (2), (7) to (12)}$$

## 2 Algorithm Design and Comparison

In the layout model established above, $x_j$ is 0-1 variable. The genetic algorithm (GA) is a global search optimization algorithm, with a high search efficiency in solving 0-1 planning problems.

### 2.1 Algorithm design

GA is widely used in combination optimization, discrete optimization and other fields, and, therefore, GA is used to solve this model. Specific steps are as follows:

1) Set population size PopSize, maximum evolutionary times of population MaxGen, crossover and mutation probability $p_c$ and $p_m$. The initial population $P(t)$ is randomly generated, $t = 0$. The chromosome representation is explained by binary 0-1, and each chromosome is divided into $n$ genes, which means that there are $n$ pickup points. If the initial chromosome does not satisfy the constraint of the budget, a new chromosome will be randomly generated to replace the original infeasible chromosome generated in population initialization until each chromosome in the population is feasible.

2) On the basis of the initial population, the customers are allocated to calculate the fitness of the objective function. Customers with a higher level and larger demand will have priority for assignment. If one's demand exceeds the capacity of the pickup points with a corresponding or higher level in the target enterprise, this customer will be ignored. Next customer in the rank will be distrib-

uted.

3) Using the feasible chromosome in step 1) and the assignment in step 2), the fitness of the objective function (6) is solved.

4) Applying the roulette method, chromosomes which have better fitness are selected to form the next generation with a certain probability.

5) Two points are set randomly in chromosomes defined as pairs. Part of the genes between two intersections are exchanged to generate new chromosomes. The method of uniform mutation is then used. After generating a new chromosome, if all genes in the chromosome are zero, some genes will be randomly replaced by non-zero genes to form a new chromosome.

6) Make $t = t + 1$. If $t > \text{MaxGen}$, the algorithm terminates; otherwise, it jumps back to 2).

### 2.2 Algorithm comparison

In order to verify the effectiveness of GA in solving the model, six sets of randomized cases with different scales are designed. The authors ran each set 10 times, recorded the averages of the optimal value and running time, and then compared them with particle swarm optimization (PSO). The results are shown in Tab. 1. $a$ customers, $a = \{50, 100, 200\}$, and $b$ alternative points of the target company, $b = \{40, 80, 120\}$, are randomly generated. The demand volumes of junior, intermediate and senior customers are, respectively, subject to the Poisson distribution of $\lambda_1 = 20$, $\lambda_2 = 50$, $\lambda_3 = 120$. The locations of the customers and the pickup points are randomly distributed in the planar network of $[0, 10] \times [0, 10]$. The costs of the primary, secondary and tertiary alternative points in the target company are subject to uniform distributions, of $U_1(10, 40)$, $U_2(50, 80)$, $U_3(90, 120)$.

**Tab. 1** Comparison of different algorithms

| $a$ | $b$ | Average optimal value | | Average running time/s | |
|---|---|---|---|---|---|
| | | GA | PSO | GA | PSO |
| 50 | 40 | 2 623 | 2 601 | 12.6 | 12.1 |
| 100 | 40 | 4 587 | 4 415 | 35.4 | 30.2 |
| 100 | 80 | 4 986 | 4 634 | 59.5 | 42.6 |
| 200 | 40 | 9 004 | 7 577 | 67.4 | 49.8 |
| 200 | 80 | 9 872 | 8 094 | 100.2 | 56.6 |
| 200 | 120 | 10 069 | 8 421 | 132.8 | 64.1 |

It can be seen that as the scale of the solution increases, the computation time of the two algorithms also increases. When the calculation scale is small, the gap of running time between PSO and GA is small, and the optimal value of GA is slightly better. As the scale of calculation increases, PSO has shorter running time, and the GA's advantage in optimal value is more significant.

## 3 Case Introduction

### 3.1 Parameter setting

The residential areas in a business district of Chengdu can be clustered into 30 customers according to the district street administrative division. The demand and its level of each point are known. The customers numbered 1 to 5 are senior customers. The customers numbered 6 to 15 are intermediate customers and the rest are junior customers. The minimum and maximum critical distance for each level of customers are $L^{\bar{l}}_{s_i} = \{L^{\bar{l}}_1, L^{\bar{l}}_2, L^{\bar{l}}_3\} = \{1, 1, 1\}$, $L^{\bar{u}}_{s_i} = \{L^{\bar{u}}_1, L^{\bar{u}}_2, L^{\bar{u}}_3\} = \{3, 4, 5\}$. The attractiveness of pickup points by all levels to customers are

$$A_{s_i t_j} = \{A_{11}, A_{12}, A_{13}, A_{21}, A_{22}, A_{23}, A_{31}, A_{32}, A_{33}\} = \{1, 0.8, 0.6, 0, 1, 0.8, 0, 0, 1\}$$

The target enterprise will layout pickup points in this district, totaling 15 options. The points numbered 1 to 3 are tertiary alternative pickup points; the points numbered 4 to 8 are secondary alternative pickup points, and the rest are primary pickup points. Restricted by the geographical environment, human resources and other factors, the construction costs of those alternative pickup points are $c_j = \{99, 102, 91, 79, 54, 70, 65, 43, 32, 12, 32, 13, 33, 21, 24\}$. The overall construction cost constraint is $C = 300$. The maximum capacities of the alternative points $j$ in level $t_j$ are $Q_{t_j} = \{Q_1, Q_2, Q_3\} = \{100, 250, 500\}$. The importance degrees of customer $i$ in level $s_i$ are $q_{s_i} = \{q_1, q_2, q_3\} = \{1.0, 1.5, 2.0\}$. The signal threshold of the covered demand is 80%. In addition, the competitor in the region layouts one tertiary pickup point, two secondary pickup points and two primary pickup points.

### 3.2 Calculation results

The specific parameters of the algorithm are set as follows: PopSize = 50, MaxGen = 400, crossover probability $p_c = 0.7$, mutation probability $p_m = 0.01$. With the continuous evolution of the algorithm, the fitness function value of the optimal solution increases before it eventually levels off. The optimal individual for the maximum weighted demand coverage of the target enterprise is (0 1 1 0 1 0 0 0 0 0 0 1 1 0 0), which means building 2 tertiary pickup points (numbered 2, 3), 1 secondary pickup point (numbered 5), and 2 primary pickup points (numbered 12, 13), with the cost being 293 units.

### 3.3 Sensitivity analysis

#### 3.3.1 The influence of budget on weighted demand coverage

As an important factor in the enterprise location decision, budget influences the number, level, and the position of pickup points. In order to analyze the influence of the budget, the authors use budget $C = \{150, 200, 250, 300, 350, 400, 450, 500, 550\}$ as examples to calculate weighted demand coverage under different budgets and their corresponding numbers of constructed pickup points at each level, as shown in Fig. 1.

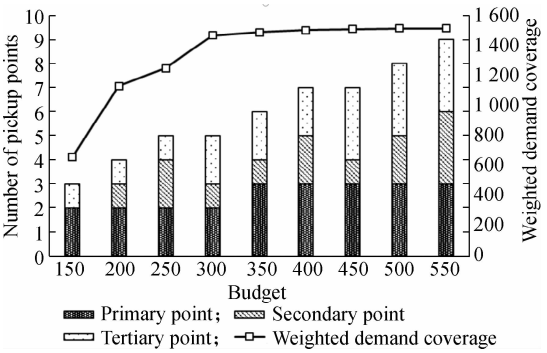


**Fig. 1** The influence of budget on weighted demand coverage

The following conclusions can be drawn. The weighted demand coverage rises with the increase of budget, but this growth gradually slows down. When the budget is at a low level, its 150 units increase brings a leap from 659 to 1 469 of the weighted demand coverage, showing significant marginal benefits. After the budget exceeds the critical point ($C = 300$), the competitive situation is basically stable due to the location, the demand level and demand volume of the customers in a specific area. The sensitivity of the weighted demand coverage to the budget is decreasing, and the increase of the budget cannot bring any positive effect. It reveals that the enterprise should invest moderately so as to obtain maximum return by the least investment. To avoid capital waste, it is not suggested to pursue the maximization of demand coverage.

### 3.3.2 The influence of signal threshold on weighted demand coverage

As an important parameter in the cooperative coverage model, the value of the signal threshold has a profound influence on the weighted demand coverage. In order to analyze it, the authors take the signal threshold $T = \{0.05, 0.1, 0.15, 0.2, 0.25, 0.3, 0.35, 0.4, 0.45, 0.5, 0.55, 0.6, 0.65, 0.7, 0.75, 0.8, 0.85, 0.9, 0.95\}$ as examples. The weighted demand coverage under different signal thresholds is calculated, as well as their corresponding coverage of customers at all levels. The results are shown in Fig. 2.

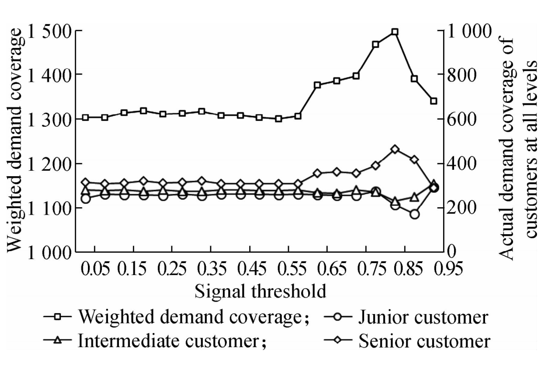


**Fig. 2** The influence of signal threshold on weighted demand coverage

The following conclusions can be obtained:

1) The weighted demand coverage tends to increase first and then decrease as the signal threshold grows. When the signal threshold is low, the weighted demand coverage is stable and there is a small range of fluctuation. When the signal value exceeds the critical point ($T = 0.6$), weighted demand coverage increases sharply, reaches the highest point and then decreases rapidly. The reason is that a low signal threshold means that the customer selection standard is relatively low. Most of the pickup points of the target enterprise and competitor are able to serve as the options for customers. The demand is met according to the probability. At this time, the competitive advantage of the target enterprise is relatively small. When the signal threshold increases, it means that the service satisfaction becomes higher, and customers can only be covered by the enterprise whose signal strength exceeds the threshold. Knowing the layout of a competitor, target enterprise can enhance signal intensity by a location decision to obtain all the needs of customers. When the signal threshold is too high, it is difficult for either the target enterprise or competitor to meet customer demand. Thus, the customers are still served according to probability, and the weighted demand coverage of the target enterprise decreases. It shows that, by thorough investigation, an enterprise should reasonably estimate the signal threshold of the customers in the market and the signal strength of competitors for making the best location decision.

2) The weighted demand coverage is positively related to the change in the actual demand coverage in senior customers, but is inversely related to the intermediate and junior customers. Due to the high weight of the senior customers in the enterprise decision-making, meeting the needs of senior customers can effectively improve the weighted demand coverage. In such cases, enterprises will tend to provide services for higher level customers. It is suggested that the enterprise should provide differentiated services for customers at different levels according to the signal threshold in the region.

3) When it comes to location in a competitive environment, the layout of the competitor's pickup points will have an important impact on the decision-making of the target company. Assume that the competitor has five points in the region with six different layout strategies, the location results and demand coverage of the target enterprise are solved as shown in Tab. 2.

The following conclusions can be obtained:

1) Due to budget restrictions, the number of high-level pickup points that the target company can establish is limited. When there are fewer high-level points in the competitive enterprise, the advantage of the target company in market share is more significant. When the quantity of the high-level points of the competitor increases, that is, in cases 4# to 6#, the target company will also adjust the layout of the points.

**Tab. 2** The influence of the competitor's layout strategy on weighted demand coverage

| Layout strategy | Point number of competitor | | | Point number of target company | | | Demand coverage of customer of each level | | | Actual demand coverage |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tertiary | Secondary | Primary | Tertiary | Secondary | Primary | Tertiary | Secondary | Primary | |
| 1# | 1 | 1 | 3 | 2 | 2 | 3 | 397 | 409 | 281 | 1 087 |
| 2# | 1 | 2 | 2 | 2 | 2 | 3 | 397 | 287 | 280 | 964 |
| 3# | 1 | 3 | 1 | 2 | 3 | 2 | 397 | 285 | 265 | 947 |
| 4# | 2 | 1 | 2 | 2 | 1 | 4 | 299 | 287 | 297 | 883 |
| 5# | 2 | 2 | 1 | 2 | 2 | 3 | 299 | 286 | 297 | 882 |
| 6# | 3 | 1 | 1 | 3 | 2 | 0 | 305 | 289 | 286 | 880 |

Within the budget, the secondary and tertiary points are increased by reducing the number of low-level points to attract more high-level customers. Therefore, it is necessary for the target company to pre-investigate the layout of other enterprises, establish more high-level points within the budget to capture more intermediate and senior customers, and also to form a more comprehensive coverage for junior customers.

2) The demand coverage of the target company decreases with the increase of high-level points in the competitor. From the changes of 1# and 2#, it can be seen that as the quantity of secondary points in a competitive company increases, the target company's demand coverage for intermediate customers decreases. Seen from the changes of 3# and 4#, the competitor has added one tertiary point, and the number of senior customers covered by the target company has increased. Due to the increase of high-level points in competitor, the target company needs to construct more high-level points. In addition, according to the principle of diminishing returns, when there are more high-level points in competitor, it is more difficult for target company to upgrade its coverage. It is more beneficial to control the construction scale for maintaining a certain market share, thus to avoid low input-output ratios and vicious competition.

### 3.4 Comparison with non-cooperative coverage model

The data of the cooperative coverage model will be compared with that of the non-cooperative coverage model. The weighted demand coverage of the non-cooperative coverage model is 1 270 units. The actual coverage demand is 830 units. Its corresponding optimal individual is (1 0 0 0 0 0 1 0 1 1 0 1 1 1 1) with the cost of 299 units. Compared with the cooperative coverage model, the weighted demand coverage in the target enterprise is reduced by 15.67%, while the cost is increased by 2.01%.

Under the two coverage models, the results of customer demand allocation are shown in Fig. 3.

Under cooperative coverage, the average coverage of the target enterprise for senior customers' needs reaches 69.3%, and those for intermediate and junior customers are 45.0% and 50.0%, respectively. Additionally, the average coverage of the target enterprise for senior, intermediate and junior customers is 50.7%, 47.0% and 53.9% under the non-cooperative coverage. Enterprises considering cooperative coverage are more pertinent.

They tend to maintain the interests of higher-level customers who can bring more value for the company.

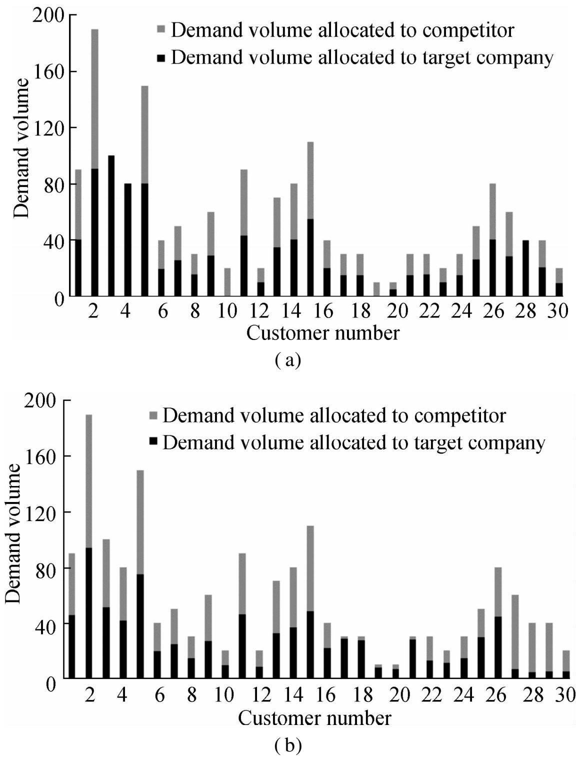


**Fig. 3** Customer demand allocation. (a) Cooperative coverage; (b) Non-cooperative coverage

It can be seen that the location model considering cooperative coverage is better than the non-cooperative coverage model in terms of the weighted demand coverage, the construction cost, and the attention paid to the important customers.

## 4 Conclusions

1) The sensitivity of weighted demand coverage to budget decreases gradually.

2) The maximum weighted demand coverage is positively correlated with the change of the actual demand coverage of senior customers.

3) The demand coverage of the target enterprise decreases with the increase of the high-level pickup points in a competitive enterprise. When the number of high-level pickup points in competitive enterprise is small, the advantage of the target enterprise is more significant.

4) The location model considering cooperative coverage is better than the non-cooperative coverage model in multiple indicators.

With the development of behavioral economics, the research objects are changing to non-rational people, which means that not all subjects will pursue the optimal results. Therefore, in the research of pickup network design, the influence of rationality on customer behavior can be taken into consideration. In future, the utility function involving endowment effect and psychological account can be constructed, and the customer selection probability function can be re-established to optimize the location model.

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# 基于合作覆盖的多级自提点竞争选址问题


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**摘要:**为了在末端配送中获取竞争优势,指导企业利用品牌作用和信息共享形成的联合覆盖进行自提点选址布局. 在考虑自提网点多样性的基础上,引入分段函数、信号强度函数和概率函数,同时考虑距离感知和联合覆盖对顾客行为的影响,建立竞争环境下自提点选址模型. 针对优化问题,采用遗传算法进行求解,并用算例验证了模型和算法的有效性. 结果表明,加权需求覆盖量对预算的敏感度逐渐减小;最大加权需求覆盖量随着信号量阈值的增加大体上呈现出先增后降的趋势,并与高级顾客实际需求覆盖量的变化呈正相关,而与中、初级顾客呈负相关;当竞争企业高等级网点较少时,目标企业占据市场份额的优势更显著. 通过模型对比,联合覆盖模型无论是在加权需求覆盖量、覆盖成本和对重要顾客的关注方面都优于非联合覆盖模型.



**关键词:**自提点;合作覆盖;多级设施选址;竞争环境;遗传算法

**中图分类号:**F270;F224.3;C931