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Research on the Location Optimization of Intelligent Express Self Delivery Cabinet on Campus——Take Chongqing University of Posts and Telecommunications as an Example

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Abstract

A multi-objective programming model is used to study the location problem of intelligent express delivery cabinet on campus. Specifically, through the establishment of three objective functions of the minimum operation cost, the shortest distance of customers and the highest score of alternative points, the comprehensive evaluation method is used to establish the evaluation index system of campus intelligent express cabinet surrounding environment satisfaction as the basis of alternative points scoring, and the weight assignment method is used to find the Pareto optimal solution of the model. On this basis, the relevant data of express delivery construction of Chongqing University of Posts and Telecommunications were investigated, and the model was verified by a case study. The location scheme of intelligent express cabinets of Chongqing University of Posts and Telecommunications was obtained, which has reference value for promoting the construction of the intelligent delivery cabinet of the university campus.

Keywords

Multi-objective planning; Comprehensive evaluation method; Self-extraction; Site selection.

1. Introduction

In recent years, domestic e-commerce platforms like Taobao, Jingdong and pinduoduo have risen rapidly, and online shopping has become one of the main channels for people to shop. The rapid development of e-commerce has also led to the rapid growth of express industry. According to the statistics of the State Post Office, in 2019, China's express business volume reached 63 billion, a year-on-year increase of 24%. The daily average express processing volume was 180 million, and the per capita express usage was 45. At the same time, the stepped growth of express delivery volume also makes the terminal distribution face unprecedented pressure. In this context, all kinds of self delivery methods are born, mainly including post station self delivery, convenience store collection, self delivery cabinet and so on. Self delivery mode effectively improves the efficiency of distribution, optimizes the allocation of resources, and reduces the cost of distribution. However, in real life, especially in Colleges and universities, there are many express delivery points of different companies, which are difficult to find and have short business hours. The existence of these problems not only makes the end outlets of express delivery unable to reduce costs and increase efficiency, but also greatly affects the satisfaction of customers' pick-up. However, due to the restriction of campus environment, customers cannot give up the self delivery mode and choose to deliver goods to their

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home because of their dissatisfaction with the self delivery mode. In this context, how to reasonably layout the campus self raised points has become an urgent problem to be solved.

At present, many scholars have discussed the layout of express delivery terminals. For example, based on the gradual coverage theory, Chen Yiyou, a domestic scholar, uses the concave convex function to measure consumer satisfaction, conducts a numerical example verification, and compares it with the traditional coverage model [1]. Chen Jingyu studies the layout of cold chain logistics self extracting points of fresh agricultural products, considering the convenience of consumers and the distribution cost of enterprises, divides the regions through cluster analysis, establishes the hierarchy evaluation index system of fixed region self extracting points, evaluates the alternative fixed region self extracting points by fuzzy comprehensive evaluation method, and selects the optimal scheme [2]. Considering the different needs of customers, Han Xun divides customers into three levels, establishes three levels of self-contained network structure, constructs a multi-objective location model considering customer utility and enterprise cost, and uses particle swarm optimization algorithm to verify and solve the model [3].

In the specific setting of the model, some scholars take the cost minimization as the goal, for example: Shi Shubiao and others take the distribution cost, rental cost and penalty cost minimization as the goal [4], and use qualitative and quantitative research methods to locate the location of express cabinets. Li Jingxuan et al. Aimed at minimizing the cost of loss [5], used the 0-1 programming model to find the shortest path between the alternative point and the demand point, and used the cluster analysis method to determine the service scope of the express delivery cabinet and get the optimal solution. Wang Yong takes the minimum transportation cost and construction cost as the goal [6], uses ant colony algorithm to take the candidate distribution center that has been assigned the supply point as the cluster center, and finds the distribution scheme with the lowest distribution cost, so as to select the location of multiple logistics distribution centers.

Some scholars take the maximization of customer benefit as the objective condition: Based on the theory of gradual coverage, Xiao KaFei et al. Considered the maximization of coverage and location benefit [7], established the location model of self extracting cabinet based on the gradual service radius, and designed the Lagrange relaxation heuristic algorithm to solve the model. Chen Yiyou constructs the utility function of customer to self extracting point based on the goal of maximizing the total amount of self extracting, constructs the optimal selection model based on the demand elasticity function, and uses immune algorithm to verify the important influence of customer selection behavior. Liu Hui pointed out the shortcomings of the traditional coverage model, and established a joint coverage model with the service level as the constraint condition and the location benefit maximization as the objective function [9]. Zhou Xiang et al. Established the objective function with the largest customer satisfaction based on the main consideration of the pickup distance and distribution time, designed the clustering algorithm to determine the number and location of alternative points, and solved the model by using the center offset secondary clustering algorithm and the minimum spanning tree algorithm [10].

However, the previous research only focused on the single factor of enterprise cost and customer benefit, which is often lack of feasibility in practical application. If only considering the dimension of construction cost and neglecting the satisfaction of students, students will be dissatisfied with the intelligent express cabinet mode, which is not conducive to the promotion of intelligent Express cabinet in Colleges and universities; if only considering the dimension of student satisfaction, it will allow It is easy to make the cost out of control, which is not conducive to the rapid development of express enterprises. Therefore, some scholars also consider the demands of these two aspects: tanzhuge uses the set coverage model to get the alternative plan of intelligent express delivery cabinet in Colleges and universities, and considers the construction cost, logistics benefit, customer satisfaction and traffic conditions, uses AHP to compare the four set coverage plans, and obtains the final delivery plan [11], but in the express cabinet construction cost and service There is no basis for the quantification of the level. According to the heterogeneity of customer demand, Han Xun

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designed the corresponding self extracting points, built a multi-level self extracting network, and established a multi-objective location model considering customer utility and enterprise cost [3]. Zhang Jingrong describes the service satisfaction, takes the minimization of construction cost and the maximization of service level as both objectives, establishes a multi-objective optimization model [12], but transforms the cost objectives into constraints when solving, and simplifies the problem.

According to the above literature, we can see that the establishment of intelligent express cabinet is an effective way to alleviate the bottleneck problem of terminal distribution. The self location problem is the primary problem for express delivery enterprises to satisfy customer needs and quickly occupy the market. At home and abroad, most of the researches on self-service focus on the operation mode of self-service, the composition of customer self-service satisfaction, how to use the existing resources and so on. There are few researches on the location of self delivery outlets, especially on the intelligent express cabinets. At present, the main factors affecting the site selection of self extracting outlets are: equipment distance, pick-up time, cargo volume, safety, return and exchange difficulty, construction cost, pick-up cost, etc. Among them, cost and distance are the primary concerns of enterprises and customers respectively.

In this paper, a multi-objective model is established based on the comprehensive consideration of the three objectives of the intelligent express cabinet, i.e. the minimum operating cost, the shortest distance for customers to pick up items and the highest score for alternative points. Combined with the specific characteristics of the campus environment of Chongqing University of Posts and telecommunications, the comprehensive evaluation index of the alternative address of the intelligent express cabinet on the campus is established. The AHP method in the comprehensive evaluation method is used to score different types of alternative points, and the actual calculation example is brought in to solve the model with the weight assignment method and lingo software, and the best scheme is obtained.

2. Construction of site selection model of self delivery cabinet

2.1 Problem Description

In this paper, the problem of location selection is to plan the best layout scheme of self extracting cabinets in a university campus. As a public welfare organization, the university needs to coordinate the needs of express enterprises and teachers and students in the campus. The self extracting mode led by the university should not only consider the cost, the distance of taking items, but also consider the impact of pick-up point construction on the surrounding environment. Therefore, the main goal is to select a reasonable scheme to minimize the cost, the shortest walking distance and the highest score of pick-up points when the number and scale of alternative points are determined. On the basis of the established alternative address and the score of alternative points, according to the site selection principle of being close to the reality, feasibility and economy, combined with the actual situation of the region where the self extracting network is located, the following assumptions are made:

(1) Suppose that each customer only goes to one pick-up point to pick up express delivery;

(2) It is assumed that the customer will pick up the express within 24 hours after the express is put into the cabinet;

(3) Regardless of the influence of the shopping festival on the number of daily express delivery in the campus, the self delivery order quantity of each demand point is fixed;

2.2 Model Construction

Suppose a university campus has i locations with express delivery demand, and the aggregate demand of i locations is I, and the demand of i locations is D_i; at the same time, suppose that there are j locations in the campus that meet the alternative requirements of express delivery terminals, and the aggregate demand of j locations is J, and the alternative location j can accommodate at most p_j sets of self delivery cabinets, and the rent and management cost of each set of equipment is C, and the point j will construct n_j sets of self delivery cabinets, and the comprehensive evaluation

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of alternative location j is expressed as Z_j, and the maximum express delivery cabinets Express delivery capacity is B; the actual distance between alternative point j and demand point i is expressed as r_{ij}; if alternative point J is selected as the construction location of self delivery cabinet, x_j = 1, if it is not selected, x_j = 0; if alternative point j provides self delivery service at demand point I, y_{ij} = 1, otherwise y_{ij} = 0.

$$Minf_1 = \sum_{j=1}^{m} C\, x_j n_j \tag{1}$$

$$Minf_2 = \sum_{i=1}^{n} \sum_{j=1}^{m} r_{ij}\, y_{ij} \tag{2}$$

$$Maxf_3 = \sum_{j=1}^{m} Z_j\, x_j \div \sum_{j=1}^{m} Z_j \tag{3}$$

s.t.

$$\sum_{j=1}^{m} y_{ij} = 1 \tag{4}$$

$$y_{ij} \leq x_i \tag{5}$$

$$\sum_{i=1}^{n} D_i \leq \sum_{j=1}^{m} n_j B \tag{6}$$

$$n_j \leq p_j x_j \tag{7}$$

$$x_i \in \{0,\ 1\}\ ;\ y_{ij} \in \{0,\ 1\} \tag{8}$$

Among them, the objective function (1) indicates that the total operation cost of the established intelligent express cabinet network is the smallest; (2) indicates that the total distance of all customers to pick up parts is the shortest; (3) indicates that the weighted average value of environmental satisfaction around the self lifting point is the highest; the constraint condition (4) indicates that each demand point can only be provided by one express cabinet construction equipment selection point; (5) indicates that the demand point can only be allocated to the final On the alternative points selected, (6) the total capacity of the self extracting cabinet constructed can meet the total demand of the demand point; (7) the number of construction units at point J does not exceed the local volume; (8) the value range of the decision variable.

2.3 The establishment of evaluation index of surrounding environment satisfaction

According to the characteristics of campus environment, there are three factors that affect the location of pick-up points of express cabinets, which are geographical environment, infrastructure and social factors. Among them, geographical environment factors include terrain conditions and easy to find, infrastructure factors include public facilities, traffic conditions and security, social factors include the impact on the surrounding and environmental protection.

The weight of each index can be obtained by establishing the judgment matrix, and then the evaluation score of surrounding environment satisfaction can be calculated by the detailed score of each terminal.

Table 1 Comprehensive evaluation of intelligent express cabinet on campus

Target layer	criterion layer	measure layer
Comprehensive evaluation index a of express service terminal	Geographical environment factor	Topographical conditions
		Easy to find
	Infrastructure factor	public facilities
		Traffic conditions
	Social factors	Security
		Impact on surroundings
		Environmental protection

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3. Example

3.1 Determination of demand point and alternative point

Taking Chongqing University of Posts and Telecommunications as an example, this paper finds that the demand for express delivery mainly comes from students' dormitory building and teachers' apartment building. The total number of express delivery is about 6000 per day, the total demand point is 40, each self delivery cabinet can hold 100 express delivery, and the demand for students' dormitory and teachers' apartment is about 165 and 50 respectively. At present, the express terminal mainly considers the form of intelligent express cabinet. The use cost of express cabinet is 0.3 yuan / slot, and the maximum number of construction units is shown in Table 2. The actual distance between the demand point and the alternative point is shown in the appendix.

Table 2 Location and capacity of alternative points

Alternative point number	Location	Maximum construction quantity
1	Space between building 3 and building 5	12
2	Northwest side open space	12
3	Space under building 9	12
4	Stores under building 15	12
5	Space between buildings 18 and 19	16
6	Space between building 22 and building 23	16
7	Space between buildings 27 and 28	16
8	Stores under Qianxihe	12
9	Space under building 32	16
10	Shop near sunshine pictures	12
11	Residential houses near cherry garden	12
12	Teachers' Apartment	12

3.2 Score of alternative points

Through the questionnaire survey, the teachers and students in the school and the express delivery employees in the campus are invited to score the indicators. The judgment matrix is shown in Table 3 to Table 6. The weights calculated by the sum product method are 0.087, 0.017, 0.194, 0.065, 0.356, 0.224, 0.057 respectively, and pass the consistency test.

Table 3 Comprehensive evaluation judgment matrix A of alternative points

Judgment matrix A	Geographical environment factors	Infrastructure factors	Social factors	Relative weight	CR
Geographical environment factors	1	1/3	1/5	0.10	0.0332<0.1
Infrastructure factors	3	1	1/3	0.26	
Social factors	5	3	1	0.64	

Table 4 Comprehensive evaluation judgment matrix B1 of alternative points

Judgment matrix B1	Topographic condition	Easy to find	Relative weight	CR

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Topographic condition	1	5	0.83	0
Easy to find	1/5	1	0.17	

Table 5 Comprehensive evaluation judgment matrix B2 of alternative points

Judgment matrix B2	Communal facilities	Traffic condition	Relative weight	CR
Communal facilities	1	3	0.75	0
Traffic condition	1/3	1	0.25	

Table 6 Comprehensive evaluation judgment matrix B3 of alternative points

Judgment matrix B3	Safety guarantee	Impact on surroundings	Environmental protection	Relative weight	CR
Safety guarantee	1	2	5	0.56	0.0462<0.1
Impact on surroundings	1/2	1	5	0.35	
Environmental protection	1/5	1/5	1	0.09	

After the weight of each evaluation index is obtained, the index will be subdivided into specific scores, as shown in Table 7, and the candidate points will be scored in turn and multiplied by the corresponding weights. The comprehensive evaluation scores of 12 candidate points are 8.39, 8.90, 8.30, 7.82, 7.85, 7.85, 8.10, 8.35, 8.10, 8.29, 8.13, 7.68, respectively.

Table 7 Scoring criteria for alternative points

Evaluating indicator	llustration	Full marks	Evaluating indicator	llustration	Full marks
Topographic condition	Slope <25 degrees	3	Safety guarantee	Equipped with camera	3
	The road surface is flat without ponding	3		Street lighting	3
	Space greater than 32 square meters	4		There is a security booth nearby	4
Easy to find	Nearby teaching buildings or canteens and other places with high popularity	5	Impact on surroundings	Do not affect normal road traffic	4
	Stand out and not hide	5		Does not affect the teaching order	3
Communal facilities	Power supply facilities nearby	5		DB less than 50dB	3
	Nearby receiving network	5	Safety guarantee	There are garbage cans nearby	5
Traffic condition	Close to the road	5		Recyclable cartons	5
	Less traffic flow	5			

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3.3 Model solution

This model includes three objectives: the lowest cost, the shortest journey and the highest comprehensive evaluation of alternative points. Considering some constraints, it is a multi-objective planning problem. The solution of the multi-objective optimization problem needs to balance each contradictory sub-objective, and the solution of the multi-objective optimization problem is not unique, but there is a group of Pareto optimal solutions or non inferior optimal solutions, and too many non inferior solutions can not be applied to the actual problems, so it is necessary to find a final solution in the solution process.

The solution of multi-objective programming mainly includes constraint method and efficiency coefficient method. The constraint method is to transform the constraint value set by some objectives into a constraint condition, and make it a single objective solution. In this way, the size of the constraint value has subjective factors, so it is difficult to set accurately, so there are certain limitations. The power coefficient method needs to give corresponding weight to each goal according to its different importance degree in the solution process, and then calculate the sum of each goal multiplied by its corresponding weight as a single goal problem. The specific distribution of weight can be given by the decision-maker according to the importance degree of the goal function, or by specific calculation method. With the change of weight coefficient, the solution A series of Pareto optimal solutions can be obtained, which meet the requirements of empirical solution in this paper.

First of all, the efficiency coefficient method needs to dimension f_1, f_2, f_3, and convert it into F_1, F_2, F_3. The results show that the maximum and minimum values of f_1 are 1800 and 4680 respectively, the maximum and minimum values of f_2 are 2310 and 32160 respectively, and the maximum and minimum values of f_3 are 7.68 and 8.90 respectively.

$$F_1 = \frac{f_1 - 1800}{4680 - 1800} \tag{9}$$

$$F_2 = \frac{f_2 - 2310}{32160 - 2310} \tag{10}$$

$$F_3 = \frac{8.895 - f_2}{8.90 - 7.68} \tag{11}$$

Then, F_1, F_2, F_3 are transformed into single objective functions:

$$MinF = a_1 F_1 + a_2 F_2 + a_3 F_3 \tag{12}$$

A represents the weight of each objective function, and the result of different weight proportion is different. Take a1=a2=a3 as an example. At this time, according to the above data, lingo17 is used to program and run the program, x1,x2, x3, x5, x8, x9 are 1, and the other decision variables are 0. It can be seen from the operation results that the outlets of intelligent express cabinets should be set up at alternative points 1, 2, 3, 5, 8 and 9 respectively, and the corresponding demand locations are shown in Table 8.

Table 8 List of service scope of self-delivery location

pick-up point	Corresponding demand point	Number of cabinets
1	3,4,5,6,15,16	10
2	1,2,11,12	7
3	8,9,10,13,38,40	6
5	14,17,18,19,20,21,22,23	12
8	7,24,25,26,27,28,29,	11
9	30,31,32,33,34,35,36,37,39	15

Fig. 1 Schematic diagram of site selection scheme

3.4 Effect analysis

From the perspective of pick-up distance, under the current mode, since customers want to pick up items in each express store, the sum of daily average walking distance from each demand point to pick-up point is 19204m. After the relocation, customers only need to go to a fixed place to pick up the parts, the walking distance is 4690 meters, and the average distance from each demand point to the corresponding pick-up point is 117 meters. Compared with the pre optimization, the optimized mode greatly reduces the customer's walking distance, that is, customers no longer need to pay extra time cost for picking up express delivery. This can greatly improve customer satisfaction, flexible pick-up time, and improve efficiency.

In terms of cost, the daily average cost of the pick-up point under the current mode is 2400 yuan, including the rent of 9 self delivery outlets, full-time staff salaries and operating expenses, which do not include part-time staff salaries and other off campus express delivery expenses. After the relocation, the total daily cost of 61 sets of intelligent express cabinets in 6 pick-up points is 1830 yuan, which can be used in the construction of campus common sorting system.

In addition, due to the short opening time and remote distance, the existing mode leads to the problem of low pick-up rate and occupying inventory. The shelf utilization rate of that day is not high, while the comprehensive utilization rate of the intelligent express cabinet after the site selection is as high as 98%.

This plan integrates cost, distance and comprehensive evaluation points. Except for No. 13 and No. 14 demand points, all demand points are no more than 300 meters away from the corresponding pick-up points. The reason is that these two demand points are located in the apartment of teachers' families. Most of the residents here are the elderly and postgraduate students. The noise and environmental pollution of self lifting cupboard students will have a great impact on their quality of life, so the nearby alternative points The lower score resulted in the unselected alternative 10 and 11, which resulted in the demand point being assigned to other alternative points. Therefore, the site selection scheme is reasonable and acceptable.

4. Summary

Aiming at the location problem of intelligent express self delivery cabinets in university campus, this paper also considers three objectives: the minimum operating cost, the shortest distance for customers, and the highest comprehensive evaluation score for alternative outlets, and establishes the distribution terminal layout optimization model. By using the method of weight assignment, the three targets are de dimensioned, so that the multi-target problem can be transformed into a single target problem. At the same time, taking Chongqing University of Posts and Telecommunications as an example, the comprehensive evaluation index of alternative points is established. Combined with the specific data, lingo17 is used to solve the model, and the best location and service scope of self extracting cupboard are obtained. It shows that the location model established in this paper can solve the layout problem of self extracting cabinet in university campus, and has certain reference value for the construction of self extracting cabinet in university campus. In the actual construction and promotion of intelligent express cabinets in university campus, it is necessary to further combine the actual situation, define the construction subject, confirm the responsibility object of each service link, and also consider the special period such as shopping festival, large-scale logistics, cold chain transportation and the storage location of special goods, so as to better improve the service quality of express terminal distribution in university campus.

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