Location Selection of Fresh E-Commerce's Front Warehouse Under New Retail Model

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Abstract. In order to meet consumers' demand for instant ordering and instant enjoyment, the front warehouse has become a new metabolite. The rational location of the front warehouse is an important step in the operation of fresh e-commerce enterprises. This paper mainly studies the location of the front warehouse based on online sales, considering the type and rental costs of front warehouse. This paper constructs the maximum coverage location model (MCLP) aiming at maximizing the coverage demand. The greedy algorithm is used to select the appropriate number and type of front warehouse in the existing alternative front warehouse. Finally, an example is given to verify the effectiveness of the model.

Keywords: Fresh E-Commerce · The Location Of Front Warehouse · MCLP

1 Introduction

Covid-19 changed people's living and consumption habits, the "House Economy" is becoming the new normal, more and more users choose online shopping, new retail services are becoming a daily necessity, which requires efficient logistics distribution. The State Postal Bureau proposes new service models such as instant delivery, warehouse and distribution integration and 'supermarket + express'. At present, many fresh e-commerce enterprises have put forward the front warehouse mode to meet the immediate needs of consumers. Setting the front warehouse is to set up the warehouse closest to the consumer (within 3–6 km of the surrounding area) through the front-end supply chain, in order to facilitate the rapid arrival of goods. The front warehouse is used to further enter the user in a high-precision way with low cold chain logistics cost. How to layout the appropriate front warehouse to meet the requirements of consumers is particularly important.

The location of logistics facilities affects the operation cost and efficiency of enterprises, which belongs to the research problem of logistics management strategy layer. At present, there are many and perfect studies on the location of logistics facility nodes. As early as 1909, Weber published a location paper aiming at the shortest distance from a single warehouse to a customer. Then many experts and scholars began to conduct in-depth research on the location problem, for example, Tammy Drezner and Bagherinejad

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et al. studied the maximum coverage model to solve the location problem [1, 8]. Zhu Haipeng and Ding Huan focused on the location problem of distribution centers [3, 4]. Chen et al. constructed Bilevel Programming Model of Fresh Cabinet with the goal of minimizing the cost [2]. Qiu Li et al. used factor analysis and cluster analysis to analyze the location of logistics network nodes in Beijing-Tianjin-Hebei region [6]. Chen Gang et al. studied the location problem of emergency shelters [2]. The above studies mainly focus on the site selection of factory facilities, distribution centers, emergency facilities and regional logistics nodes, and use qualitative and quantitative methods to carry out research.

The front warehouse model is put forward in recent years. There are some differences between the factors considered in the traditional service facilities location and the front warehouse location. Heng used the K-means algorithm to study the location of the front warehouse [5]. Lu Yichen focused on the distribution system of the front warehouse mode [9]. Yang Zhenyu et al. mainly studied the location model of front warehouse of fresh chain retail enterprises [10]. At present, the research on the location of front warehouses is mainly based on experience, lacking scientific and systematic. Based on the characteristics of front warehouse mode, this paper constructs the maximum coverage location model to meet the needs of consumers in the maximum range with the minimum operating cost as the goal, and considers how to comprehensively consider the consumer structure and demand in different regions of the city in the existing alternative front warehouse.

2 Analysis on Influencing Factors of Front Warehouse Location

2.1 Geographic Position

Because of the characteristics of instant consumption of fresh products, and considering the positive correlation between consumption demand and population density, combined with the consumer structure and consumption level of the region, it is generally considered to be distributed in regions with dense population size distribution.

2.2 Market Positioning

In order to conform to the concept of new retail, the business goal of front warehouse is to achieve the best combination of time cost and commodity price for consumers.

2.3 Consumer Demand

According to the China Association of Online Consumers, the consumers are mainly young people. Taking daily freshness as an example, the users under the age of 24 accounted for 40%, and the cumulative proportion under the age of 30 accounted for more than 70%. It can be seen young people with faster pace of life and high timeliness requirements are the main consumers of the front warehouse. According to the statistics of relevant consulting agencies, nearly 90% of consumers are willing to purchase fresh food through the fresh e-commerce platform, and they pay more attention to the distribution speed, product quality and commodity prices. Therefore, fresh e-commerce enterprises must understand the local market demand and consumption demand in detail, including the age structure, purchasing ability and purchasing habits of local personnel when arranging the front positions.

2.4 Industry Competitive Factors

Before the location of the front warehouse, fresh e-commerce enterprises need to fully analyze the competitors of the industry including the analysis of consumer positioning, radiation range and company development strategy of the same type of industry, in order to minimize the impact of homogeneous competition.

3 Construction of Maximum Coverage Model

In this paper, we mainly consider the factors affecting the location of front warehouse in the early stage of the enterprise. After analyzing the regional consumption level and consumer structure, we use the qualitative analysis method to determine the alternative front warehouse outlets. At present, we mainly select the appropriate number of small and medium-sized front warehouses to serve the consumers in the corresponding region according to the development strategy of the enterprise. In the location of front warehouse, this paper only considers the logistics operation between the front warehouse and the customer (demand point), and doesn't analyze the transportation and construction between the distribution center and the front warehouse. When the location and demand of each customer (demand point) are known, how to select a location from a set of alternative point as the final warehouse, and assign the customer (demand point) to the open front warehouse nearby, so as to meet the needs of all customers (demand point) as much as possible is shown in Fig. 1.

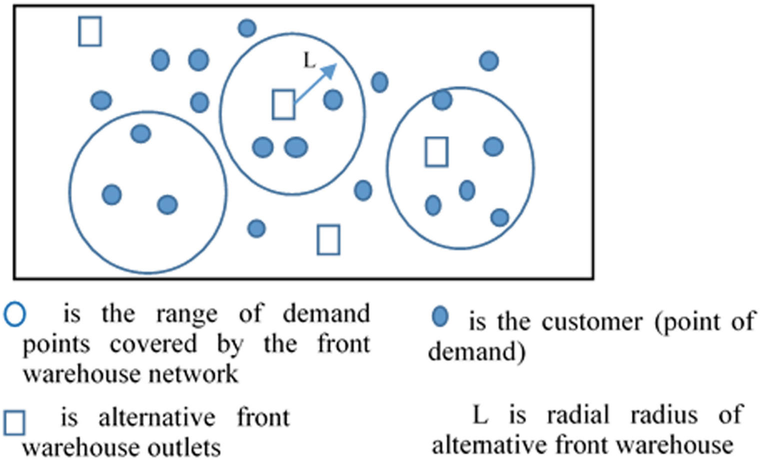

Fig. 1. Schematic diagram of network location of fresh e-commerce enterprise front warehouse

3.1 Hypothesis

Before constructing the mathematical model, in order to ensure the rationality and feasibility of the model, this paper gives the following assumptions:

The front warehouse is different from the traditional facility node location. Because consumers' need is instant and personalized, the front warehouse is mainly rent-based. Therefore, the front warehouse location mainly considers the rental cost and distribution time, and does not consider the distribution cost and cargo damage cost.

The distribution process of fresh products does not consider the impact of some irresistible force (such as road closure, bad weather, etc.).

In the early stage, the paper has investigated each demand point, collected relevant information such as consumer age structure, gender structure and income level, and used the demand forecast function to calculate the demand of consumers at each demand point.

Each front warehouse has no capacity constraint, which can meet the consumption demand of fresh products in the service area.

Each demand point can only have one front warehouse for distribution.

Do not consider the distribution of transport overload problem.

In order to meet the distribution service requirements of nearby demand points, according to the distribution of coverage radius and demand points, the paper constructs two types of front warehouses, medium front warehouse (large coverage radius) and small front warehouse (small coverage radius).

3.2 Variable

N: The set of customers (demand points) in the research object, N = (1, 2… n);

M: The set of front warehouse candidate points in the research object, M = (1, 2… m);

B: Type collection of front warehouses for fresh E-commerce enterprises, B = (1, 2… b);

h_i: Total demand of customers (demand points) i, $i \in N$;

d_{ij}: Distance from customer (demand point) i to alternative front warehouse j; $i \in N$, $j \in M$;

c_{jk}: The rent of type k front warehouse in alternative front warehouse j; $j \in M$, $k \in B$;

D_k: Coverage radius of type k front warehouse; $k \in B$;

P: Number of front warehouses to be opened;

T: Cost budget of front warehouse outlets;

A(j): The set of customers (demand points) i covered by the front warehouse node j;

B(i): $B(i) = \{j \mid i \in A(j)\}$ A set of front warehouse nodes j that can cover customer (demand point) nodes i;

$$x_{jk} = \begin{cases} 1, \textit{If the } k-\textit{type front warehouse open at} \\ \textit{the alternative front warehouse } j \textit{ point} \\ 0, \textit{If not} \end{cases}$$

$$y_i = \begin{cases} 1, \textit{If the customer (community) } i \textit{ is covered} \\ 0, \textit{If not} \end{cases}$$

3.3 Mathematical Model

According to the description of the problem, when the number of front warehouses is certain, it is necessary to find the best configuration to meet the needs of the most demand points. The locations of the alternative outlets and customers (demand points) are discrete, located on the network nodes, and the location of customers (demand points) is determined (Fig. 1), which belongs to the discrete location problem. Customer demand time is fixed, so it must be arranged within a specific distance from customers (demand points) to meet the special requirements of customers. Therefore, using the coverage model to solve this problem. However, this paper discusses that fresh e-commerce can meet the needs of all customers (demand points) without sufficient resources. The paper uses the maximum coverage location model to solve. The objective is to select the location of the limited front warehouse outlets and provide services for as many demand points as possible. The corresponding objective function can be expressed as:

$$\max \sum_{i \in N} h_i y_i \tag{1}$$

The constraint condition is:

$$\sum x_{jk} \leq 1, k \in B, \forall j \in M \tag{2}$$

$$\sum x_{jk} \times c_{jk} \leq T, j \in M, \forall k \in B \tag{3}$$

$$\sum x_{jk} \leq P, j \in M, \forall k \in B \tag{4}$$

$$x_{jk} \in \{0, 1\}, \forall j \in M, k \in B \tag{5}$$

$$y_i \in \{0, 1\}, \forall i \in N \tag{6}$$

Formula (1) is the objective function, requiring as much coverage as possible under the condition of limited warehouse;

Constraints (2) to ensure that only in the alternative front warehouse network to open medium-sized front warehouse or small front warehouse;

Constraint (3) ensures that the cost of opening front warehouse cannot exceed the budget of the enterprise;

Constraints (4) to ensure that the maximum number of front warehouses may be opened;

The constraint condition (5) is the 0–1 constraint of the decision variables, whether the type of warehouse is opened in the alternative warehouse, 1 is not opened;

Constraint (6) 0–1 constraints for decision variables, whether the customer (demand point) is covered, 1 covered, 0 not covered.

3.4 Solution Method for Model

Since the maximum coverage model belongs to NP-hard problem, using the greedy algorithm to solve which designed by Richard Church and Charles Re Velle. The specific steps are as follows:

1) *Initialization.* Let all xjk = 0, yi = 0, for each alternative front warehouse node j, the required points for coverage are determined by the given coverage radius Dk, and then set A(j) and the set B(i) are determined;

2) *Select the next facility node.* Select the front warehouse from M, which xjk = 0 and A(j) with the largest module point j′, that is |A(j′)|=max{ |A(j)|, j ∈ M}, let xjk = 1 and the node j′ is removed from the set M, that is M = M\{j′}.

3) *Determine the coverage of warehouse j′.* The demand points in A(j′) are assigned to j′ in the order of B(i) modules from large to small, until A(j′) is empty;

4) *Update set.* If the number of front warehouses selected is less than P and the cost of opening front warehouse xjk × cjk is less than T, update sets A(j) and B(i) and go move to step 2.

4 Analysis of Examples

A fresh e-commerce enterprise plans to carry out the layout of front warehouses in different regions of Wuhan. It is proposed to first set up warehouse outlets in a certain region, and all the demand points can be set up nearby. In the early stage, questionnaires are distributed to experts in related industries, and five alternative warehouse outlets are finally selected by using the analytic hierarchy process (AHP). By collecting the basic information of each enterprise's warehouse, this paper summarizes the size, service time and coverage radius of each type of warehouse as shown in Table 1, the specific rent of outlets is shown in Table 2. Because the limited funds of the enterprise, the paper considers the operating cost. It is decided to set up two front warehouses first, which can be medium-sized front warehouses and small front warehouses, mainly to meet the demand points in the service area as much as possible, and ensure that the monthly rent cost cannot exceed 60,000 yuan.

4.1 Determination of Demand

According to the analysis of consumer demand factors, the demand point's demand calculation formula is:

$$h_i = (s_i n_i m_i) r_i = \left(\sum_{k=1}^{4} p_i \alpha_k\right)\left(\sum_{s=1}^{2} q_i \beta_s\right) m_i r_i \tag{7}$$

Table 1. SCALE, SERVICE TIME AND COVERING RADIUS OF FRONT WAREHOUSE

Type	Area (sq.m)	Service Time	Covering radius
Large-scale	400–1000	Within 2 h	10 km
Medium-scale	100–400	Within 2 h	6 km
Small-scale	50–100	Within 30 min	3 km

Table 2. RENT OF ALTERNATIVE FRONT WAREHOUSE OUTLETS (YUAN/MONTH)

	Node 1	Node 2	Node 3	Node 4	Node 5
Small-scale	10000	11000	9000	8000	8000
Medium-scale	25000	26000	23000	21000	20000

Table 3. THE QUANTITY DEMAND AT EACH POINT OF DEMAND

	DP 1	DP 2	DP 3	DP4	DP 5	DP 6
QD	13455	12877	5387	9845	14898	7743

i: represents the requirement point;

s_i: represents consumer gender;

n_i: represents consumer age;

m_i: represents consumer income;

r_i: represents regional population density;

k: represents age structure (k = 1, 2, 3, 4, is divided into four ages (0–17 years old; 18 to 34 years old; 35–59 years old; above age 60)); p_i represents the proportion of each age group of demand point i;

q_i: represents the gender proportion of demand point i;

α_k: represents the age structure's impact factor;

β_s: represents the influence coefficient of gender structure.

According to the survey of some fresh e-commerce enterprises, if $k = 1$, $\alpha_k = 0.96$; if $k = 2$, $\alpha_k = 1.75$; if $k = 3$, $\alpha_k = 1.2$; if $k = 4$, $\alpha_k = 0.57$; the influence coefficient of male purchase is 0.94, and female's is 1.25; When consumer monthly income in 3000-6000yuan, impact coefficient is 2.5, in 6000–10000 yuan, it is 1.43.

Through research, there are 4354 persons in demand point 1, Average monthly income is 3000–6000 yuan, insert values into the formula (7), the demand of point 1 is 13455. Similarly, the demand of other points can be calculated, as shown in Table 3.

4.2 Computation

The distance between each alternative front warehouse and each demand point is calculated (Table 4). According to Table 1, the coverage radius of the medium-sized is 6 km, and small is 3 km.

According to the above conditions, N = (1, 2, 3, 4, 5, 6), M = (1, 2, 3, 4, 5, 6), P = 2, and $D_1 = 3$ km, $D_2 = 6$ km. Using the greedy algorithm to solve the model, the conclusion is to build a medium-sized front warehouse in the alternative point 1 and 4. The final total rent is 46,000 yuan per month, less than the cost budget of 60,000 yuan. It can serve the needs of all demand points in the region.

Table 4. DISTANCE BETWEEN EACH ALTERNATIVE OUTLET AND EACH DEMAND POINT

	AP 1	AP 2	AP 3	AP 4	AP 5
DP 1	3 km	6 km	8 km	7 km	9 km
DP 2	4 km	2 km	7 km	8 km	4 km
DP 3	5 km	4 km	4 km	4 km	7 km
DP 4	9 km	7 km	5 km	2 km	3 km
DP 5	8 km	3 km	3 km	5 km	5 km
DP 6	6 km	5 km	2 km	3 km	8 km

5 Conclusion

Through this study, it can be seen when fresh e-commerce enterprises implement the front warehouse model, they should focus on the location. When the service capacity and time satisfaction are not constrained, they can consider the medium-sized front warehouse to meet the needs of each demand point in a region. If an enterprise intends to increase its investment in front warehouses in the future, it can consider time satisfaction and service capacity as constraints, and use intelligent optimization algorithm to solve the location of front warehouses in all regions, which will be further discussed in the future.

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