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Research on the Spatial Layout Strategy of Freshippo Forward Warehouse in the Context of Instant Retail

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Abstract: This article focuses on the spatial layout strategy of Freshippo's forward warehouses in the context of on-demand retail, aiming to optimize warehouse location selection and distribution efficiency. Based on the analysis of the current development status of domestic and foreign forward warehouses and the characteristics of instant retail, a layout model considering population distribution, order density, transportation convenience and inventory management was constructed. Through the simulation and comparison of specific urban cases, this paper verifies the advantages of the hybrid layout strategy combining core warehouses and micro-warehouses in improving distribution efficiency, reducing warehousing costs and enhancing inventory turnover rate. The research results provide a theoretical basis and practical reference for Freshippo and similar enterprises in the layout of forward warehouses in the urban instant retail scenario.

Keywords: Fresh e-commerce; Front storage; Front warehouse; Instant retail; Micro-warehouse; O2O retail

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1. Introduction

With the rapid growth of the demand for on-demand retail and "last mile" delivery, the forward warehouse has become an important means for fresh food and fast-moving consumer goods enterprises to improve logistics efficiency [1]. As a leading retail enterprise in China, Freshippo's layout of its forward warehouse network directly affects delivery timeliness, inventory management and operating costs [2]. This paper takes the Freshippo forward warehouse as the research object, combines urban consumption demands and logistics characteristics, and explores the design strategies of the forward warehouse from the perspective of spatial layout optimization. Through theoretical analysis and case simulation, this paper strives to propose a scientific and operational layout plan, providing references for enterprises to optimize their supply chains in the context of instant retail.

1.1. Analysis of the scenarios of pre-positioned warehouses and instant retail

1.1.1. The concept and development of the forward warehouse

A pre-positioned warehouse is a small-scale warehousing model set up around consumers in the on-demand retail system, specifically designed to facilitate the rapid fulfillment of online orders [3]. Its core features lie in "proximity" and "speed". By setting up small warehouses of several hundred square meters in high-density urban communities, the inventory is brought infinitely close to consumers, shortening the traditional long link of "central warehouse-consumer" to an extremely short link of "forward warehouse-consumer", thereby achieving minute-level response and delivery of orders. Compared with large supermarkets or traditional warehouses, its SKUs have been carefully selected, focusing on high-frequency and essential fresh food products. Its operation is highly dependent on data algorithms for product selection and replenishment decisions.

In terms of the current development status, the paths at home and abroad are different. With the rise of the new retail wave, the domestic pre-positioned warehouse model has gone through various explorations and competitions, from pure pre-positioned warehouses (such as MissFresh and Dingdong Maicai) to "store-warehouse integration" (such as Freshippo), and has now entered a stage of refined operation and profit breakthrough. The foreign market is represented by American Gopuff and others, but its product structure is more inclined towards instant convenience goods. Moreover, due to differences in population density and consumption habits, the warehouse network density and business model are different from those in China [4].

1.1.2. Analysis of instant retail scenarios

Instant retail refers to a retail model where consumers place orders through online channels and the platform delivers the goods within an extremely short period of time (usually 30 to 60 minutes). Its market characteristics are distinct:

(1) It is time-sensitive, with delivery speed being the core competitive element;

(2) The scenario-based consumption, as orders mostly stem from immediate and specific life needs, such as running out of vegetables when cooking or urgent needs at the last minute, with a short decision-making chain;

(3) There is a focus on product categories, mainly featuring high-frequency and short-shelf-life goods such as fresh produce and fast-moving consumer goods;

(4) It is the integration of all channels, with traffic entry points widely distributed in independent apps, platform mini-programs, etc.

In this scenario, consumer behavior exhibits high-frequency and fragmented characteristics [5]. The user stickiness is high, but the average transaction value is relatively low. The shopping habit has changed from "weekly shopping spree" to "buy as needed". Its preference for delivery not only demands "fast", but also "accurate" (on-time delivery) and "good" (standardized service and intact goods). In addition, there are differences in category preferences among different regions and groups of people, reflecting a common pursuit of convenience and a quality life.

This places extremely high demands on the supply chain for being "fast, accurate and flexible". The supply chain must have an extremely rapid response capability, with seamless connection from order receiving to picking, packaging and delivery. Precise demand forecasting and inventory management are needed to deal with the risk of high loss. At the same time, it must also have sufficient flexibility to smoothly handle the huge order fluctuations during daily and peak periods, which is completely different from the traditional retail supply chain model.

1.1.3. Current operation status of Freshippo forward warehouses

Freshippo (Hema)' s business model is centered on "store-warehouse integration", but its forward warehouses (such as Hema Xiaozhan and Hema Linli, etc.) serve as strategic supplements and form a key part of its intensive fulfillment network. These forward warehouses are smaller in size and more flexible in location selection. They mainly undertake the immediate fulfillment function of online orders, aiming to cover the niche markets that the main stores cannot reach or have insufficient penetration, and form a complementary and collaborative layout network with large stores.

In the urban distribution system, the Freshippo forward warehouse serves as the bridgehead for the "last mile". It takes over the goods transferred from the city center warehouse or "store warehouse", and is responsible for the final fulfillment of online orders within its coverage radius, including warehousing, sorting, packaging and delivery by riders. This makes it a key node connecting centralized supply chains with decentralized consumer demands, effectively enhancing the efficiency and response speed of the entire urban distribution network.

However, its current spatial layout is confronted with several major challenges as outlined:

(1) Site selection and density balance: If it is too dense, it will lead to the diversion of orders among warehouses and cost pressure; if it is too sparse, it will be impossible to achieve effective coverage;

(2) Inventory accuracy: The limited warehouse capacity requires that SKUs must be extremely matched with the surrounding demands. Prediction deviations will directly lead to stockouts or high losses;

(3) Capacity coordination: How to balance the fulfillment pressure during peak order periods and the idle resources during off-peak periods, and handle the potential competition and coordination relationship between the forward warehouse and the main store in business, is the key point of continuous optimization [6].

2. Influencing factors and model construction of the spatial layout of the forward warehouse

2.1. Theories and indicators related to spatial layout

The spatial layout decision of the forward warehouse is based on the classic warehouse location theory and modern logistics optimization principles [7]. The core theory mainly includes the trade-off between centralized and decentralized layouts. Centralized layout emphasizes setting up a small number of large warehouses in regional centers to reduce inventory and operating costs through economies of scale, but it is difficult to meet the timeliness requirements of instant retail. The essence of the pre-positioned warehouse model is the ultimate embodiment of decentralized (or networked) layout. By building high-density, small-unit network nodes to get close to consumers, it achieves the ultimate delivery speed and customer satisfaction at a higher warehousing cost. In addition, quantitative methods such as the center of gravity method and coverage models (such as the maximum coverage model and the set coverage model) also provide a scientific basis for site selection, aiming to find the optimal solution between service coverage and cost.

Evaluating the quality of a layout relies on a series of key indicators. The delivery radius and timeliness are the primary indicators. Generally, it is required that the coverage radius be within 1 to 3 kilometers to ensure that orders can be delivered within the promised time. Service coverage measures the proportion of the target population or region that the layout network can reach, and it is a direct manifestation of market penetration ability. Inventory turnover rate reflects the operational efficiency of warehousing. A high turnover rate means high efficiency in capital utilization and low loss of goods. In addition, average distribution cost per unit and floor efficiency (revenue generated per unit area) are also important financial indicators for measuring the health of a business model.

2.2. Influencing factors of the layout of the forward warehouse

The spatial layout of the forward warehouse is a complex decision-making process, influenced by multiple factors together. External environmental factors serve as the macro foundation for layout. Population density and customer group characteristics directly determine the potential order density and consumption capacity, and are the primary considerations for site selection. The heat of consumer demand, that is, the high-frequency order areas identified through data analysis, can precisely guide the location of warehouse points. The convenience of transportation and the road network are of vital importance as they directly affect the accessibility and efficiency of delivery. It is necessary to avoid areas with perennial congestion to ensure smooth cycling on manual lines. In addition, the competitive situation and property conditions (such as rent and hardware facilities) are also practical constraints that cannot be ignored.

Internal factors of an enterprise determine the feasibility of its layout and the quality of its operation. The storage capacity limits the SKU breadth and inventory depth of a single warehouse, which need to be matched with the estimated order volume. Inventory management strategies, such as whether to adopt a unified allocation of "one inventory" or operate independently in each warehouse, directly affect the replenishment frequency and cross-warehouse allocation capacity, and thereby influence the flexibility of the layout. Delivery capacity is the final link in order fulfillment, including the number of riders, the efficiency of the dispatching system, and the aggregation ability of a single delivery [8]. A strong delivery system can appropriately relax the strict requirements for the absolute distance between warehouses and points.

Among all the factors, the technical factor is playing an increasingly crucial role. Big data analysis can deeply integrate population data, historical orders, map information and even business district planning to build an accurate site selection prediction model. Intelligent dispatching systems (such as algorithm engines) dynamically optimize the matching of orders and warehouse points, plan picking routes and rider delivery routes. This is equivalent to superimposing a "digital twin" network on top of the physical network, greatly enhancing the operational efficiency of the existing layout. Its own capabilities have also become the core variables that need to be considered in a coordinated manner when making layout decisions.

2.3. Construction of Freshippo forward warehouse layout model

To optimize the spatial layout of the Freshippo forward warehouse, a decision-making model centered on multi-objective optimization can be constructed. The core objectives of this model typically include: maximizing distribution efficiency (such as minimizing the average order fulfillment time), minimizing operating costs (covering fixed warehousing costs, variable labor costs and last-mile delivery costs), and maximizing service coverage (ensuring that the vast majority of demands in the target area can be responded to within the standard time limit). There are often trade-offs among these goals. For instance, increasing coverage would raise costs, so the model needs to seek a Pareto optimal solution.

Before building the model, clear assumptions and parameter settings need to be made. Key assumptions may include: discretizing urban areas into several demand cells (such as community grids), assuming that the service capacity of each warehouse point has an upper limit, and setting a standard service time limit (such as 30 minutes). The parameters to be input are extremely rich, including: the predicted order volume of each demand community, the rent and operating costs of potential warehouse candidate locations, the path distance and travel time between each point, the average driving speed and single load volume of riders, as well as the inventory holding cost and loss rate of different goods, etc. [9].

Methodologically, GIS (Geographic Information System) spatial analysis can be adopted for initial screening. By superimposing layers such as population heat maps, traffic networks, and competing locations, unsuitable areas can be visually excluded. On this basis, integer programming or network optimization models can be used for precise calculation, aiming to determine the best combination of warehouse locations and the precise division of their service scope, so as to achieve the lowest total cost or the highest total service efficiency. For dynamic scheduling problems, simulation methods can be introduced to evaluate the robustness of layout schemes under different order pressures, thereby constructing a comprehensive layout optimization model integrating static location selection and dynamic operation.

3. Research on the spatial layout strategy of Freshippo's forward warehouse

3.1. Case background and site selection requirements analysis

With the rapid development of on-demand retail, the core business districts of cities have become the key areas for the layout of Freshippo's forward warehouses. This study takes Xuhui District in Shanghai as the case area and selects the main residential areas, commercial areas and transportation hubs in this area as the analysis objects to deeply explore the site selection strategy of the forward warehouse. Xuhui District has a high population density and strong consumption capacity. At the same time, it is close to multiple subway lines and major urban roads, featuring typical demand characteristics of instant retail.

Through the analysis of Freshippo order data in Xuhui District over the past year, it was found that the orders were mainly concentrated in five major blocks: Tianyaoqiao Road, Caoxi North Road, Zhaojiabang Road, Wanping South Road and the area around Hongqiao Road. **Figure 1** shows the order heat map of each block in Xuhui District, which can visually reflect the high-demand areas and the relatively low-demand areas. The proportion of orders from high-demand areas has reached 65% of the total orders, indicating that the forward warehouses should be prioritized to be located in these core areas to ensure distribution efficiency.

Figure 1. Order heat map of Xuhui District.

An analysis was conducted on the surrounding roads, subways, bus routes and peak traffic hours of the selected core blocks. It was found that the core blocks have convenient transportation, but some branch roads have congestion problems during peak hours. Combining the average delivery speed and delivery radius, the maximum coverage radius for delivery within 30 minutes is set at 3 kilometers to ensure the timeliness of instant retail. **Figure 2** shows the transportation network and distribution accessibility analysis of the core district, which can be used to assist in the site selection of the forward warehouse [10].

Figure 2. Schematic diagram of the transportation network and distribution accessibility in Xuhui District.

Through market research, the distribution of the forward warehouses of other fresh food e-commerce and retail enterprises in the surrounding area was statistically analyzed, including Hema, JD Daojia and local community fresh food stores. The analysis shows that there are layout gaps in some areas. Freshippo can give priority to these areas to gain market advantages and avoid excessive homogeneous competition at the same time.

Based on the above analysis, the objectives of this study in selecting a forward warehouse in Xuhui District are as follows:

(1) Ensure that orders in core consumption areas are delivered within 30 minutes;

(2) Reduce the number of warehouses and operating costs through reasonable layout;

(3) Optimize inventory allocation by integrating order heat maps with product categories to maximize inventory turnover.

In conclusion, through data-driven regional analysis, traffic accessibility assessment, and competitive layout investigation, this study provides a scientific basis for the subsequent spatial layout plan of the forward warehouse and lays the foundation for formulating optimization strategies.

3.2. Design plan for the spatial layout of the forward warehouse

After clarifying the consumption distribution and traffic characteristics of Xuhui District, in response to the demand of Freshippo's instant retail business, this paper designs three spatial layout schemes: core point centralized layout, decentralized micro-warehouse layout and mixed layout scheme. By simulating and analyzing the performance of different layout patterns in terms of cost, efficiency and coverage, the optimal strategy can be determined.

3.2.1. Option one: Centralized layout of core points

The core point centralized layout is based on the concept of "central warehouse", setting up 1 to 2 large forward warehouses in high-demand areas to serve the residents and business district orders within a 3-kilometer radius around. Each warehouse is responsible for inventory concentration, order sorting and rapid delivery (**Table 1**).

Table 1. Comparison of key parameters for centralized layout scheme

Indicator	Warehouse quantity	Average delivery radius	Average inventory
Centralized layout	2	3.0 km	15,000 SKU

This solution is suitable for areas with high order concentration and relatively stable delivery routes. Its advantages lie in concentrated inventory, high management efficiency and relatively low warehousing costs. However, due to the larger service radius, the delivery time for orders in edge areas may increase, affecting the user experience. The analysis results show that this scheme can effectively reduce warehousing and labor costs, and is suitable for pilot projects in high-density and high-demand urban core areas. However, it is difficult to cope with the situation of large order fluctuations.

3.2.2. Option two: Decentralized micro-warehouse layout

The decentralized micro-warehouse layout is characterized by flexibility and rapid response. Multiple small forward warehouses are set up in the hotspots of demand, with an average distance of 1 to 2 kilometers between them. Each micro-warehouse has an area of approximately 300 to 500 square meters and mainly stores high-frequency fast-moving consumer goods and immediate replenishment items. This layout can significantly shorten the distribution radius and enhance timeliness. The simulation results show that the average delivery time can be controlled within 20 minutes. However, due to the dispersion of inventory and the small storage area, inventory redundancy and management costs have increased (**Table 2**).

Table 2. Comparison of key parameters for decentralized micro-warehouse layout scheme

Indicator	Warehouse quantity	Average delivery radius
Decentralized micro-warehouse layout	6	1.2 km

From an economic perspective, the decentralized micro-warehouse model is more in line with the user demands in the instant retail scenario. However, in the long-term operation, it may face problems such as high inventory costs and insufficient warehouse utilization.

3.2.3. Option three: Hybrid layout (core + micro-warehouse)

The hybrid layout scheme integrates the advantages of the first two layouts and adopts a structure of "1 core warehouse + several micro-warehouses". The core warehouse is responsible for the overall inventory allocation, low-frequency SKU storage and commodity sorting within the urban area, while the micro-warehouse focuses on the immediate delivery of high-frequency goods, achieving hierarchical management and rapid response. The core objective of this plan is to build a multi-level warehousing system through inventory concentration in the central warehouse and efficient distribution in micro-warehouses, thereby enhancing system flexibility. The model simulation results show that under the hybrid layout, the average order delivery time of Freshippo has been shortened to 22 minutes, the delivery cost has decreased by approximately 15% compared to the core layout, and the inventory turnover rate has increased by 18% (**Table 3**).

Table 3. Comparison of key parameters for hybrid layout scheme

Indicator	Warehouse quantity	Average delivery radius
Hybrid layout (core + micro-warehouse)	1+4	1.8 km

From the comprehensive assessment results (**Figure 3**), the hybrid layout scheme performs the best in terms of timeliness, cost and coverage balance. This layout can flexibly adjust the number of micro-warehouses according to the fluctuations of on-demand retail, achieving dynamic spatial optimization. It is the most feasible layout strategy in the future urban on-demand retail system.

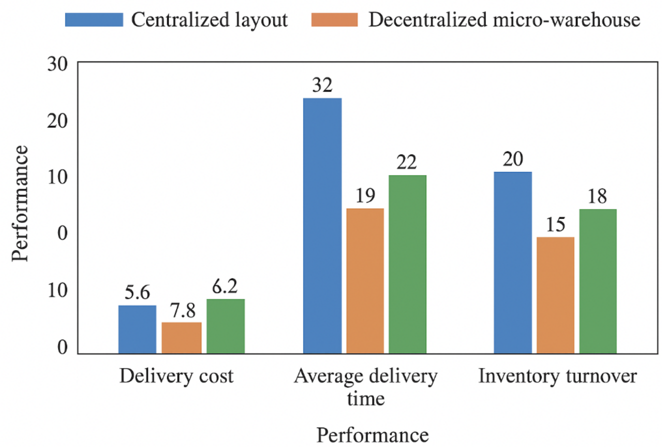

Figure 3. Performance comparison chart of three layout schemes (bar chart shows cost, timeliness and inventory turnover rate).

3.3. Simulation and analysis

Based on the historical order data of Freshippo in Xuhui District, Shanghai, distribution simulation and performance evaluation were conducted for three warehouse layout schemes (centralized core point type, decentralized micro-warehouse type and mixed layout type). The analysis indicators include unit order delivery cost, average delivery time and inventory turnover rate. The simulation results show that the centralized core point type has the greatest advantage in warehouse cost control, but due to the long distance, the delivery delay during peak hours is severe. The decentralized micro-warehouse type has a significant advantage in terms of timeliness, with the average delivery time shortened by approximately 41%, but the inventory pressure and management complexity increase. The hybrid layout type performs well in all three indicators, being able to control costs while maintaining a high distribution efficiency. The specific results are shown in **Table 4**.

Table 4. Comparison of layout types

Layout type	Average delivery cost (CNY)	Average delivery time (mins)	Inventory turnover rate/ month
Centralized layout	5.6	32	20
Decentralized micro-warehouse layout	7.8	19	15
Hybrid layout	6.2	22	

As seen above, the hybrid layout achieves the optimal balance between cost and efficiency, and has high implementability and scalability. It is suitable for the high-frequency and short-distance delivery scenarios of instant retail.

3.4. Suggestions for strategy optimization

Based on the simulation results, Freshippo should further optimize the layout strategy of the forward warehouse through dynamic and intelligent means. For instance:

(1) The inventory and replenishment cycles of micro-warehouses should be flexibly adjusted in accordance with seasonal fluctuations and holiday promotional activities to avoid excessive hoarding or inventory gaps;

(2) By integrating GIS data with real-time order distribution, the delivery routes are optimized to form a “multi-point shipping and intelligent dispatching” urban micro-logistics network;

(3) Big data and machine learning algorithms should be fully utilized to predict high-frequency consumption areas and dynamically update the location of micro-warehouses, achieving “self-evolution of the front-end warehouse network”;

(4) From a management perspective, the success of the hybrid layout model in the Xuhui District case indicates that this strategy can be replicated in other first-tier cities and provides a feasible path for digital warehouse layout for on-demand retail enterprises.

4. Conclusion

Through the research on the spatial layout of the Freshippo forward warehouse, this paper concludes that the hybrid layout strategy has obvious advantages in balancing delivery timeliness and operating costs. At the same time, the micro-warehouse positions can be dynamically adjusted according to the order distribution to improve the overall logistics efficiency. This study not only provides an empirical reference for Freshippo’s layout of forward warehouses in the urban instant retail scenario, but also offers methodical references for other retail enterprises to optimize their warehousing networks and supply chain management. In the future, big data prediction and intelligent scheduling technologies can be further integrated to achieve dynamic optimization and refined management of the layout of the forward warehouse.

Disclosure statement

The author declares no conflict of interest.

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