The last-mile distribution of fresh e-commerce logistics: Case Study in Guiyang, China

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Abstract
As the market scale of fresh food e-commerce continues to expand and people's demand for various fresh foods increases, the last-mile distribution is the key point for the development of fresh food e-commerce. This paper would like to analyze 5 factors that affect the last-mile distribution of fresh e-commerce and to provide suggestions for the last-mile distribution of fresh food e-commerce enterprises and to propose optimization suggestions to help fresh food e-commerce enterprises adjust their future logistics development strategies in time, also to promote the stable development, including consumer experience, warehouse operation, costs, waste, transportation and distribution. The results showed that the main criteria affecting the last-mile distribution of fresh food e-commerce is costs, and its average weight is 0.420, which indicates that the costs is the most important to promote the development of fresh food e-commerce. The weight of transportation costs in sub-criteria is 0.240, which indicates that the transportation costs of fresh food is important.

Keywords
Fresh Food E-commerce, The Last Mile Distribution, Customer Experience, The Last Mile Operation, Analytic Hierarchy Process (AHP),

1. Introduction
In recent years, the fresh food retail market has been growing. People have a rigid demand for fresh food as one of the basic consumer goods, and with the increase of disposable income and consumer spending in life, the fresh food retail market is also expanding. Currently, with policy support, China has introduced a series of policies to encourage the development and innovation of fresh food e-commerce, especially to deal with the shortcomings of the "initial and last mile cold chain logistics", providing a clear direction for the development of the fresh food e-commerce industry. For example, the Chinese Ministry of Transport issued "Implementation Opinions on Promoting High-Quality Development of Cold Chain Logistics Transportation" in 2022, which aims to innovate transportation service models,

improve logistics transportation efficiency, and promote the safe planning and development of logistics transportation.

The new crown epidemic period accelerates the formation of fresh-to-home consumption habits, and consumer habits have changed so consumers are putting forward higher requirements for buying fresh foods online, leading to increasingly fierce competition in fresh e-commerce. This paper analyzes the fresh food e-commerce distribution by using AHP with five factors: consumer experience, warehouse operation, costs, transportation and distribution, waste, aiming to provide reference for fresh e-commerce companies to choose distribution modes and giving targeted optimization suggestions to help fresh e-commerce companies adjust their future logistics development strategies in a timely manner to provide reference, which in turn leads to long-term development.

2. Literature Review

The post-epidemic era has accelerated the formation of fresh-to-home consumption habits. Changing consumption habits and higher consumer demands for online freshness have led to increasingly fierce competition in fresh food e-commerce. Zhu, Huiqi, et al. (2019) the key point to improve the core competitiveness of fresh food e-commerce is the last-mile distribution, and the important opportunities and challenges are established in five factors, such as consumer experience, warehouse operations, cost, waste, transportation and distribution.

2.1. The fresh food in e-commerce

Fresh e-commerce refers to commercial transactions of fresh fruits and vegetables, fresh meat and other fresh agricultural foods on the Internet relying on a network platform, including fruits, vegetables, meat, poultry, eggs, dairy products, aquatic products, and other products in e-commerce mode. Fresh foods are characterized by their freshness, nutrition, diversity, seasonality Dolat Abadi (2021). Business-to-customer (B2C) is a kind of e-commerce model, which refers to the direct-to-consumer e-commerce transaction mode of enterprises. Fresh food has high shelf life and freshness requirements and is the carrier for fresh food e-commerce to achieve business closure Yi Jiang (2021). With the widespread use of electronic payments, the flexibility and convenience of distribution forms and the reliability of contactless shopping, it has brought a huge change to the way most consumers shop, and fresh food e-commerce is gradually integrating into people's lives.

In addition, online sales of fresh food are different from traditional e-commerce because it must be stored and transported using cold chain logistics to maintain freshness He et al. (2019). However, under the impact of the global COVID-19 pandemic, the structure of the global economy has changed, and humans are faced with new and unknown situations Sousa Jabbour et al. (2020). Without experience, decision makers face many challenges of uncertainty when making decisions in such situations Altig, Dave, et al., (2020).

2.2. The challenge of LMD for fresh food e-commerce

Wang, Shenxiang (2022) mentioned that for fresh food e-commerce, logistics is an important factor affecting customer satisfaction. The following are five operations of fresh food e-commerce: 1) Transportation, lack of strict quality inspection implementation standards, informal cold chain transportation tools are widely used, lack of professional transportation route optimization talents and unreasonable transportation routes increase transportation costs. 2)

Loading and unloading, companies do not have the protection of low-temperature environment, handling equipment backward, extending the handover time in and out of the warehouse (Lingyu, Meng, et al. 2019). 3) Warehousing, the uneven geographical distribution of cold storage, items pre-cooling set low, temperature control and regulation violations (Lim, Stanley Frederick W. T., et al. 2016). 4) Distribution processing and packaging, the circulation processing equipment is lagging the processing defective rate is high, and the waste is serious, the standardization of packaging is low, the packaging materials are not conducive to recycling. and the environment is polluted. 5) Delivery, the information of the distribution process is low, and the value-added business of the logistics distribution center is low (Yu, Xiaobing, et al. 2020).

2.3 Comments and discussion on criteria

There are many factors that affect the last mile distribution of fresh food e-commerce, and the most common variables that have a direct impact on the structural form of the LMD distribution of fresh food e-commerce are listed below with 5 main criteria, including waste, costs, warehouse operation, transportation and distribution, and consumer experience. Additionally, 13 sub-criteria have been established within these five mains criteria. Table 1 summarizes the comments on them.

Table 1. Criteria affecting the last-mile distribution of fresh food e-commerce

Main criteria	Sub-criteria	Comments and discussion on criteria	Title	Author(year)
Consumer Experience	Response time	The time difference between order placement and order delivery. Localized operations have short response times and are more efficient. In addition, the response time increases with the number of additional nodes in the LMD network.	Consumer-driven e-commerce: A literature review, design framework, and research agenda on last-mile logistics models	Stanley Frederick W.T. Lim (2018).
			Determinants of Customer Satisfaction with Parcel Locker Services in Last-Mile Logistics	Lai et al. (2021)
	Product freshness	The freshness of the food from the time it is completely manufactured to the time it reaches the point of consumption. This variable is governed by two factors: the distance of transportation and the indirectness of transportation.	Consumer-driven e-commerce: A literature review, design framework, and research agenda on last-mile logistics models	Stanley Frederick W.T. Lim (2018)
			The Effect of Product Freshness on Consumer Perception, Purchase Intention, and Actual Purchase Behavior: A Literature Review	Smith, J., Johnson (2020)
	Customer Information Security	Privacy security is an important driver of last-mile fresh food distribution models in terms of the sensitivity and importance of the information collected from individuals' residences in the last mile distribution.	Consumers' perceptions of last mile drone delivery (Leon et al. (2021))	Charlie Chen (2021 □
			Determinants of Customer Satisfaction with Parcel Locker Services in Last-Mile Logistics	Lai et al. (2021)

Warehouse Operation	Capacity of cold storage	Cold storage capacity refers to the internal volume of cold storage (boxes, warehouses, barrels, etc.). Full use of cold storage space, reasonable equipment configuration, energy saving and power saving.	Study on Cold Chain Logistics Operation and Risk Control of Fresh E-Commerce Products	Shenxiang Wang (2022）
			Multi-warehouse, multi-product inventory control model for agri-fresh products – A case study	Paam et al. (2022)
	Intelligent temperature control facilities	Intelligent temperature control is a fusion of artificial intelligence and automated equipment to achieve a seamless connection between cold chain information and physical objects in the warehouse.	Study on Cold Chain Logistics Operation and Risk Control of Fresh E-Commerce Products	Shenxiang Wang (2022）
			A hybrid sustainability performance measurement approach for fresh food cold supply chains	Liao et al. (2023)
	Warehousing operation standard	Warehouse operation standards refer to the receiving process, shipping process, inventory management, daily management of the warehouse, storage principles of the warehouse.	Study on Cold Chain Logistics Operation and Risk Control of Fresh E-Commerce Products	Shenxiang Wang (2022）
Costs	Distribution center costs	Distribution center cost includes fresh food circulation cost, distribution management fee, information circulation cost.	The Optimization of Distribution Path of Fresh Cold Chain Logistics Based on Genetic Algorithm	Bochao Zhang (2022）
			A distribution center location optimization model based on minimizing operating costs under uncertain demand with logistics node capacity scalability	Cui et al. (2023)
	Transportation costs	The total cost of transportation is the cost of completing the entire production process of fresh food displacement (including origination, operation, transit, arrival, etc.). The cost of each unit of transportation (tonne-kilometer, person-kilometer) is called the cost of transportation.	Logistics Path Decision Optimization Method of Fresh Product Export Cold Chain Considering Transportation Risk	Lifu Chen (2022)
			CFD analyses for the development of an innovative latent thermal energy storage for food transportation	Calati et al. (2023)
	IT cost	Fresh food storage and transportation throughout the information process using temperature, humidity, light, air oxygen content and other sensors as well as the Global Positioning System (GPS), BeiDou satellite navigation and positioning system to achieve rapid, non-destructive, real-time monitoring and detection of the cost incurred by the implementation and operation and maintenance of fresh foods.	Blue/red dual emission based ratiometric fluorescent intelligent labels for real-time food freshness monitoring	Shuo Yang (2023)
			Electronic-free and low-cost wireless sensor tag for monitoring fish freshness	Gopalakrishnan et al. (2023)

Transportation and Distribution	Model of transportation	The model of transportation includes road cold chain transportation, railroad cold chain transportation, waterway cold chain transportation, airline cold chain transportation, or it can be a comprehensive transportation consisting of various transportation methods.	In-store, pre-warehouse, or store-and-warehouse integration: Strategic analysis for neighborhood fresh product retail modes	Qiuxia Chen (2023)
			Bi-Objective Multi-Period Vehicle Routing for Perishable Goods Delivery Considering Customer Satisfaction	Liang et al. (2023)
	Transportation route	It is a process of continuous optimization of the overall operation mode based on a point (refrigerated) and line (refrigerated line), guided by refrigerated and frozen technology to improve distribution efficiency, strengthen service quality, and ensure the quality of fresh food.	The Optimization of Distribution Path of Fresh Cold Chain Logistics Based on Genetic Algorithm	Bochao Zhang, (2022)
			Bi-Objective Multi-Period Vehicle Routing for Perishable Goods Delivery Considering Customer Satisfaction	Liang et al. (2023)
Waste	Transportation and storage waste	In the process of fresh foods handling, ingredients that are not resistant to preservation, transportation and distribution links to cold chain transportation, storage should also maintain low temperatures to slow down the oxidation and decay of food.	Study on Cold Chain Logistics Operation and Risk Control of Fresh E-Commerce Products	Shenxiang Wang (2022)
			CFD analyses for the development of an innovative latent thermal energy storage for food transportation	Calati et al. (2023)
	Package waste	When fresh foods are left on the shelves or in the warehouse for too long, the loss of moisture and freshness will be very fast, and fresh foods that are not fresh will eventually be difficult to sell, and eventually can only be treated as loss.	Study on Cold Chain Logistics Operation and Risk Control of Fresh E-Commerce Products	Shenxiang Wang (2022)
			The Impact of Green Labels on Time Slot Choice and Operational Sustainability	Agatz et al. (2021)

3.Method

In this paper, the Krejcie and Morgan methods were used for sample collection of fresh e-commerce logistics in the last-mile distribution, and pairwise comparisons are presented to experts in the questionaries based on Saaty 9 Quantitative Scale and then the AHP method for consistency analysis.

3.1 Sample and data collection

From our research findings, due to the large number of people eligible for participating in the survey, Krejcie and Morgan table was used to determine the proper sample size (Esfahani et al. 2022). Based on the method to calculate the target population which is an effective method for determining the sample size needed to represent a specific population and this paper focuses on Guiyang City in Guizhou Province, which is one of the important central cities in southwest China. A total of 120 fresh food e-commerce companies were identified in Guiyang City based on Google Maps data. The sample size was calculated using the Krejcie and Morgan method sampling formula, and the sample size is equal to 91 participants.

Population Size Known:

$$SIZE = \frac{x^2 Np(1-p)}{e^2(n-1) + x^2 p(1-p)}$$

x^2 = table value of Chi-Square @ d.f= 1 for desired confidence level

.10=2.71, .0.5=3.84, .0.1=6.64, .0.01=10.83

N = population size

P = population proportion (assumed to be .0.5)

e = degree of accuracy (expressed as a proportion)

Therefore, our sample size is equal to 91 participants (SIZE)

3.2 Preparing Questionnaires

Based on Saaty 9 Quantitative Scale to design a questionnaire. The survey population focuses on fresh food related e-commerce in Guiyang, the capital of Guizhou Province, which is one of the important central cities in southwest China. The questionnaire covers 21 questions to assess the indicators affecting the last-mile distribution of fresh food e-commerce.

3.3. Analytic Hierarchy Process (AHP)

The hierarchical analysis method (AHP) is one of the multi-criteria decisions making (MCDM) methods. It was proposed and developed by Thomas L. Saaty. Mishra, D., & Rana, N. P. (2021). AHP measures the relative importance of the elements contained in each level of the hierarchy by pairwise comparisons and evaluates options at the lowest level of the hierarchy to make the best decision. In short, the results of AHP are verified by executing a rigorous mathematical theory with the ability to judge the consistency ratio. Thus, AHP is the best decision method when decision makers need to make judgments about multiple criteria. The step are as follows:

Step1: Structure a hierarchy, define the problem, determine the criteria, and identify alternative.

Step 2: Make a Pairwise comparison, Rate the relative's importance between each pair of decision alternative and criteria.

Step 3: Develop a Normalized Matrix

Divide each number in a column of the pairwise comparison matrix by its column sum.

Step 4: Develop the Priority Vector

Average each row of the normalized matrix. These row averages form the priority vector of alternative preferences with respect to the criterion. The values in this vector sum to 1.

Step 5: Calculate a Consistency Ratio

The consistency of the subjective input in the pairwise comparison matrix can be measured by calculating a consistency ratio. A consistency ratio of less than 0.1 is good. For ratios that are greater than 0.1, the subjective input should be re-evaluated.

Step 6: Develop a Priority Matrix

After steps 2 through 5 has been performed for all criteria, the results of step 4 are summarized in a priority matrix by listing the decision alternatives horizontally and the criteria vertically. The column entries are the priority vectors for each criterion.

Step 7: Develop a criterion pairwise development matrix

This is done in the same manner as that used to construct alternative pairwise comparison matrices by using subjective ratings (step 2). Similarly, normalize the matrix (step 3) and develop a criteria priority vector (step 4).

Step 8: Develop an overall priority vector

Multiply the criteria priority vector (from step 7) by the priority matrix (from step 6).

How to determine the Consistency Ratio

Step 1: For each row of the pairwise comparison matrix, determine a weighted sum by summing the multiples of the entries by the priority of its corresponding (column) alternative.

Step 2: For each row, divide its weighted sum by the priority of its corresponding (row) alternative.

Step 3: Determine the average, λmax, of the results of step 2.

Step 4: Compute the consistency index, CI, of the n alternatives by: CI = (λmax - n)/ (n - 1).

Step 5: Determine the random index, RI, as follows:

Table 2. The random index RI

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45
n	10	11	12	13	14	15			
RI	1.49	1.51	1.53	1.56	1.57	1.59			

Step 6: Determine the consistency ratio, CR, as follows: CR = CI/RI

4. The factors affecting the last mile distribution of fresh food e-commerce

The impact factors of the last mile of fresh food e-commerce are a complex multi-indicator process. In this paper, the Analytic Hierarchy Process (AHP) is chosen to analyze the impact factors, AHP is a method created by Thomas L. Saaty and a method of decision analysis by differentiating levels and calculating weights (Mishra, D., & Rana, N. P. 2021).

4.1 Build hierarchy

Based on the above analysis, a fresh food e-commerce last-mile distribution model index system is developed, as shown in Table 3, where A is the target layer, B is the main criteria, C is the sub-criteria.

Table 3. Assessment indicators affecting the last mile distribution of fresh food e-commerce

Assessment indicators affecting the last mile distribution of fresh food e-commerce(A)	Consumer experience(B1)	Response time(C1)
		Product freshness(C2)
		Customer Information Security(C3)
	Warehouse operation(B2)	Capacity of cold storage (C4)
		Intelligent temperature control facilities(C5)
		Warehousing operation standard(C6)
	Costs (B3)	Distribution center costs(C7)
		Transportation costs(C8)
		IT cost(C9)
	Transportation and distribution (B4)	Model of transportation(C10)
		Transportation route (C11)
	Waste(B5)	Transportation and storage waste(C12)
		Package waste(C13)

4.2 Construction of the judgment matrix and the solution of the weights

This paper takes Guiyang, one of the important central cities in southwest China, as a case study. At the stage, pairwise comparisons are presented to experts in questionaries and pair comparisons are based on Saaty 9 Quantitative Scale. The results are as shown in Table 4:

Table 4. Relative weights of A to the main criteria B

A	B1	B2	B3	B4	B5	W
B1	1	1/2	1/7	1/3	1/5	0.051
B2	2	1	1/5	1	1/2	0.109
B3	7	5	1	4	1	0.420
B4	3	1	1/4	1	2	0.188
B5	5	2	1	1/2	1	0.232
λmax	5.409		CR	0.091		
CI	0.102		RI	1.120		

The results of the calculation are as follows:

First, $\lambda max = 5.409$. Then, a consistency check is performed, and the consistency index (CI):

$$CI = \frac{\lambda max - n}{n - 1} = \frac{5.409 - 5}{5 - 1} = 0.102$$

The random index is used to calculate the consistency index RI=1.12. The consistency ratio is calculated as:

$$CR = \frac{CI}{RI} = \frac{0.102}{1.12} = 0.091 < 0.10$$

Since CR < 0.10, it can be considered that the construction of the judgment matrix is reasonable. Therefore, the weights of the criteria are calculated as shown in the table 4.

Relative weights of B for layer C, as shown in Table 5:

Table 5. Relative weights of B for layer C

B1	C1	C2	C3	W
C1	1	1/5	1/3	0.110
C2	5	1	2	0.581
C3	3	1/2	1	0.309
λmax	3.004	CR	0.004	
CI	0.002	IR	0.520	
B2	C4	C5	C6	W
C4	1	1/3	2	0.239
C5	3	1	4	0.623
C6	1/2	1/4	1	0.137
λmax	3.018	CR	0.018	
CI	0.009	IR	0.520	
B3	C7	C8	C9	W
C7	1	1/2	2	0.286
C8	2	1	4	0.571
C9	1/2	1/4	1	0.143
λmax	3.000	CR	0.000	
CI	0.000	RI	0.520	

The results of the calculation are as follows:

CR<0.10, which is consistent with the consistent with the consistency test, which proves that the expert scoring results are credible and valid, and That is, the final weighting coefficient table is also scientifically reliable.

Table 6. Relative weights of B for layer C

B4	C10	C11	W	B5	C12	C13	W
C10	1	2	0.667	C12	1	1/2	0.333
C11	1/2	1	0.333	C13	2	1	0.666
λmax	2.000	CR	0.000	λmax	2.000	CR	0.000
CI	0.000	RI	0.000	CI	0.000	RI	0.000

The results of the calculation are as follows:

CR<0.10, which is consistent with the consistent with the consistency test, which proves that the expert scoring results are credible and valid, and That is, the final weighting coefficient table is also scientifically reliable.

4.3 Analysis result

Integrate the calculation results and analyze the data of each matrix, the weight table of quasi-measurement layers B-C, as shown in Table 7:

Table 7. The weights of sub-criteria lay B-C

Main criteria	W	Sub-criteria	W	Wi
B1	0.050	C1	0.110	0.006
		C2	0.581	0.030
		C3	0.309	0.016
B2	0.109	C4	0.239	0.026
		C5	0.623	0.068
		C6	0.137	0.015
B3	0.419	C7	0.286	0.120
		C8	0.571	0.240
		C9	0.143	0.060
B4	0.188	C10	0.667	0.125
		C11	0.333	0.063
B5	0.232	C12	0.333	0.077
		C13	0.667	0.155

According to the research, the factors influencing the last-mile distribution in fresh e-commerce have been identified through literature review and in-depth interviews with relevant experts. The five main criteria affecting the last-mile logistics distribution in fresh e-commerce are waste, costs, warehouse operation, transportation and distribution, and consumer experience. Additionally, 13 sub-criteria have been established within these five main dimensions.

Based on the AHP method, the survey results reveal that the costs (0.419) are the most important factors influencing the last-mile distribution in fresh e-commerce and the second is waste (0.232). Within the sub-criteria of costs, transportation costs rank highest (0.240), followed by distribution center costs (0.120) and IT cost(0.060). Within the sub-criteria of waste, package waste rank highest (0.155), followed by transportation and storage waste (0.077).

Next in importance is transportation and distribution (0.181). Within transportation and distribution, the sub-criteria of model of transportation (0.125) and transportation route (0.063) rank highest. Within warehouse operation, the sub-criteria of capacity of intelligent temperature control facilities (0.068) rank highest, followed by capacity of cold storage (0.026) and warehousing operation standard (0.015).

Lastly, consumer experience (0.050) is the least important factor, with product freshness (0.030) ranking highest within its sub- criteria, followed by customer information security (0.016) and response time (0.006).

In summary, considering the comprehensive weights, the ranking of the 13 sub-criteria indicates that transportation costs (0.240) are the most important factor influencing the last-mile distribution in fresh e-commerce, followed by distribution package waste (0.155) and model of transportation (0.125). Response time (0.006) is the least important factor. The rankings of the other factors are shown in the Table 7.

5. Conclusion and Suggestion

This paper focus on the last mile distribution of fresh food e-commerce, divides the factors affecting the last mile of fresh food e-commerce into five factors: consumer experience, warehouse operation, costs, waste ,transportation and distribution, establish a risk index system for the last mile distribution of fresh food e-commerce, and evaluate the influencing factors through AHP method, which can provide target optimize and development suggestions for the last mile distribution of fresh food e-commerce. The results show that cost and waste are the most important factors in the last mile distribution. The following suggestions based on the factors in the last mile distribution are as follows:

1) Improve consumer experience, innovate delivery methods, and shorten delivery time. The decentralized and special nature of fresh food makes consumers demand more from fresh food e-commerce distribution. Lingyu, Meng, et al. (2019) it is imperative to create a targeted and innovative distribution model by relying on intelligent networking to accurately identify user needs and purchasing habits.

2) Increase self-built warehouses to achieve the integration of warehouse and distribution. Take goods close of consumers, improve the speed of logistics, effectively reduce costs, and achieve a positive cycle (Wang Shenxiang 2022). The larger the scale, the lower costs, the more value of logistics to society. At present, JD self-owned logistics according to the platform transaction data, doing the ultimate consumer experience in one day and the next day of efficient delivery, greatly improving the consumers experience, and Internet + logistics has unlimited potential.

3) Construction of fresh food standardization, to satisfy the personalized needs of consumers. Fresh food e-commerce focus on "fresh", consumers not only require fresh and delicious foods, but also constantly have new and personalized requirements. Therefore, we should focus on the advantages of efficient order response, timely return and exchange, low logistics costs, etc., and accelerate the development of safety and health standards to improve the quality of service, so that to stimulate consumer desire.

4) Implementation of "replacement packaging" of green self-operated logistics, develop the concept of green development. In the last mile of fresh food distribution, mostly the packaging is the low-cost, convenient plastic bag, it will cause white pollution, is not good to protecting the environment (Arkadiusz Kawa, Bartłomiej Pierański 2021). The implementation of "replacement packaging" green self-operated logistics, the system sets and recommends the packaging recycling option, and issues the brand of last-mile distribution packaging containers for recycling and promotes the replacement of disposable ice bags with recyclable ice boxes for effectively reducing packaging costs.

In summary, the last-mile distribution in fresh e-commerce is influenced by multiple factors, including costs, waste, transportation and distribution, warehouse operation, consumer experience. Fresh e-commerce can customize the last-mile distribution by combining the mentioned methods or adopting a combination of multiple delivery approaches, aligning with their own circumstances and market demands. This approach aims to provide a superior consumer experience and ensure food freshness.

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