



A Cross-Temporal Comparative Study on the Consumer Acceptance Mechanism of Drone-Based Last-Mile Delivery

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Abstract. Against the backdrop of the rapid development of the low-altitude economy and instant retailing, whether drone-based last-mile delivery can gain consumer acceptance has become a key issue for its commercial promotion. Based on an extended UTAUT model, this study constructs a structural equation model using 2025 sample data and conducts a cross-temporal comparison with findings from an existing 2023 study. The results show that performance expectancy and time constraints exert significantly positive effects on behavioral intention in both periods, constituting stable core drivers of consumers' adoption of drone-based last-mile delivery technology. Effort expectancy and service responsiveness shift from insignificant to significantly positive influences, indicating that consumers' evaluation focus has gradually expanded from outcome benefits to a comprehensive assessment of performance, convenience, and reliability. The effect of delivery mode expectancy changes from significant to insignificant, suggesting that the marginal influence of delivery touchpoints and receiving modes has weakened. Further analysis shows that these changes are closely associated with the improvement of policy regulation, the enhancement of technological maturity, deeper market penetration, and the expansion of instant consumption demand. Based on these findings, this paper proposes managerial implications and policy recommendations at the levels of enterprises, government, and scenario stakeholders, so as to provide references for the promotion of drone-based last-mile delivery services and the development of low-altitude logistics.

Keywords: drone-based last-mile delivery; consumer acceptance; cross-temporal analysis; extended UTAUT model; structural equation modeling (SEM)

1 Introduction

The sustained rapid growth of e-commerce and the surge in demand for instant delivery have posed unprecedented challenges to the quality of last-mile delivery services^[1,2]. Drone-based last-mile delivery is regarded as a potential solution capable of improving the efficiency, accessibility, and sustainability of the "final mile"^[3,4]. At the national level, policies such as the Implementation Plan for the Innovative Application of General Aviation Equipment (2024–2030) have been introduced to promote the construction of drone delivery networks. However, the successful deployment and widespread application of drones in last-mile delivery depend not only on policy promotion and technological maturity but also on public acceptance, which constitutes a critical constraining factor^[5]. Therefore, systematically identifying the key factors influencing consumers' adoption of drone-based last-mile delivery services, and further analyzing the evolution of these pathways across different developmental stages, is of great significance for facilitating the implementation and sustainable development of such services.

Existing research has produced a range of findings regarding public acceptance of drone-based last-mile delivery technology. Studies generally indicate that consumers hold a relatively positive attitude toward drone delivery^[6]. Perceived usefulness^[7,8], perceived ease of use^[9], and perceived environmental benefits^[10] significantly promote consumers' adoption intentions. Other positive factors include compatibility with lifestyle, facilitating conditions, service reliability, and service interaction quality^[11]. Meanwhile, concerns about privacy leakage, perceived delivery risks, and governance ambiguity in complex airspace environments^[12] may reduce consumers' willingness to accept. While the existing literature provides a foundation for understanding the acceptance mechanism of drone-based last-mile delivery, several limitations remain. First, most relevant studies are situated in foreign contexts, with respondents confined to local populations, and the findings cannot be generalized to other countries. Systematic empirical research targeting Chinese consumers' acceptance of drone-based last-mile delivery technology remains relatively scarce. Second, the majority of scholars have confined their investigations to a single cross-sectional time period, focusing on the significance of influencing factors, but lack systematic studies that identify whether each pathway evolves over time and explain the changes in consumer perceptions in response to multiple external environmental shifts.

During the period from 2023 to 2025, China's low-altitude economy and drone logistics have been undergoing a critical transition from pilot exploration to standardized development. At the national level, institutional arrangements concerning flight management, industrial development, and application demonstrations have been successively introduced, markedly enhancing the policy certainty of the low-altitude economy. Concurrently, relevant enterprises have continued to make progress in aircraft performance, operational systems, delivery networks, and scenario coverage, gradually bringing drone-based last-mile delivery technology toward maturity. In this process, consumers' cognitive structures regarding drone-based last-mile delivery are likely to undergo phased changes. If research remains confined to a single temporal

cross-section, it becomes difficult to accurately capture the dynamic characteristics of the acceptance mechanism for emerging technologies.

Against this backdrop, this study adopts an extended UTAUT model as the analytical framework, employs structural equation modeling with Chinese sample data from 2025 to empirically test the consumer acceptance mechanism of drone-based last-mile delivery, and conducts a cross-temporal comparison with the findings of an existing 2023 study. We identify stable and evolving pathways in the formation of behavioral intention, explain the phased differences in key pathways in light of changes in policy, technology, market penetration, and demand contexts, and subsequently propose corresponding managerial implications and policy recommendations.

2 Theoretical Model and Research Hypotheses

2.1 Extended UTAUT Model

The Unified Theory of Acceptance and Use of Technology (UTAUT) synthesizes eight classic theories and models in the field of technology acceptance, systematically elucidating the mechanisms through which performance expectancy, effort expectancy, social influence, and facilitating conditions affect individuals' behavioral intentions and subsequent usage behavior. Numerous scholars have incorporated factors such as perceived privacy risk, social anxiety, and price sensitivity into the UTAUT framework to investigate the drivers of consumers' willingness and behavior in adopting emerging technologies in organizational contexts^[13]. This study adopts an extended UTAUT model to examine consumers' behavioral intentions toward adopting drone-based last-mile delivery.

The behavioral intention model for drone-based last-mile delivery employed in this paper comprises six latent variables: performance expectancy, effort expectancy, service responsiveness, time constraints, delivery mode expectancy, and behavioral intention. The relationships among these variables are depicted in Figure 1. We choose to retain this model for two primary reasons. First, existing research has already validated the measurement reliability and structural validity of this model in similar application scenarios. Second, to enable a dynamic comparative analysis between the 2023 and 2025 periods, using a consistent variable system and item settings helps reduce measurement errors across dimensions and enhances the explanatory power of cross-temporal comparisons. Furthermore, given that the actual utilization rate of drone-based last-mile delivery in the broader society remains limited, with a relatively low proportion of respondents having real usage experience, this study does not introduce moderating effects of individual differences such as gender, age, education, or occupation at the model level. These demographic characteristics are used only as background information for sample description and discussion.

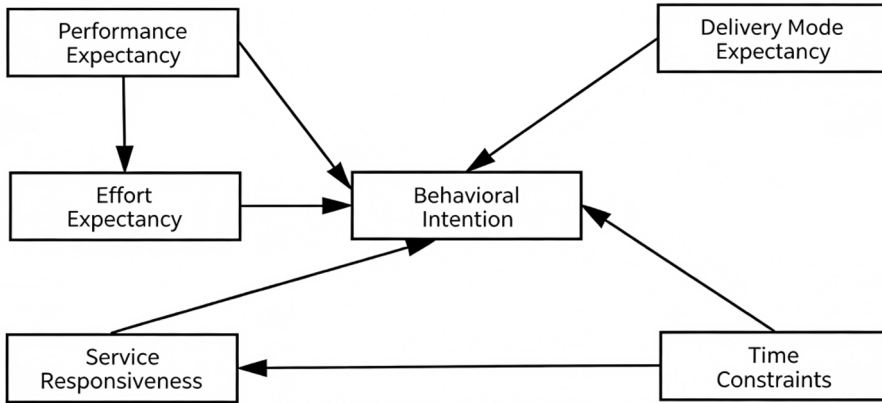


Fig. 1. Behavioral Intention Model for Drone-Based Last-Mile Delivery.

2.2 Research Hypotheses

In the UTAUT model, performance expectancy refers to the degree to which an individual believes that using a technology will enhance efficiency, improve outcomes, or generate benefits, while effort expectancy reflects subjective perceptions of learning costs, operational difficulty, and ease of use. The model posits that individuals' usage intentions are primarily influenced by performance expectancy and effort expectancy, leading to hypotheses H1 and H2. Higher expectations of technological benefits typically weaken the subjective perception of learning and operational costs, thereby improving evaluations of ease of use^[14], leading to hypothesis H3. Drone-based last-mile delivery is not only a technological application but also a service form that heavily relies on fulfillment timeliness, process information, and delivery assurance. Consumers' evaluations of service responsiveness dimensions—such as information availability, delivery timeliness, and service reliability—significantly affect their adoption decisions, leading to hypothesis H4. Moreover, last-mile delivery possesses a pronounced time-sensitive nature, particularly in scenarios such as instant retail and emergency delivery, where consumers tend to prefer delivery modes with stronger timeliness^[15,16]. Time constraints also amplify consumers' attention to service process responsiveness, because under greater time pressure, the importance of information transparency and fulfillment controllability further increases, leading to hypotheses H5 and H6. Compared with traditional express delivery, drone delivery often entails changes in delivery touchpoints and receiving methods. Consumers' subjective expectations regarding the convenience of delivery modes and the additional effort required may influence their acceptance, leading to hypothesis H7. The specific hypotheses are stated as follows:

- H1: Performance expectancy positively affects behavioral intention.
- H2: Effort expectancy positively affects behavioral intention.
- H3: Performance expectancy positively affects effort expectancy.
- H4: Service responsiveness positively affects behavioral intention.

H5: Time constraints positively affect behavioral intention.

H6: Time constraints positively affect service responsiveness.

H7: Delivery mode expectancy positively affects behavioral intention.

3 Analysis of the Behavioral Intention Model for Drone-Based Last-Mile Delivery

3.1 Questionnaire Design and Administration

Questionnaire Design. Based on the mature scales of the UTAUT model, this study adapted and revised the measurement items to fit the context of drone-based last-mile delivery, resulting in the final questionnaire. The questionnaire employed a Likert scale (1 to 5 points) for measurement and consisted of two parts: the first part covered basic demographic information (gender, age, education, occupation, and consumption and delivery preferences, etc.); the second part comprised latent variable measurement items, encompassing six dimensions with a total of 16 items.

Questionnaire Administration. The questionnaire was distributed through the Wenjuanxing platform from July 1, 2025, to July 10, 2025, and sample collection was conducted via social media channels. A total of 883 responses were received. After excluding 57 questionnaires with abnormally short response times or obviously consistent answers, 826 valid responses were obtained, yielding an effective response rate of 93.54%.

3.2 Statistical Analysis of the Data

Descriptive Statistics of the Data. The sample exhibits a balanced demographic structure. The age distribution is predominantly young (18–40 years old), with a relatively high proportion holding a bachelor's degree or above. The occupational categories are broadly covered, which adequately reflects the basic characteristics of the potential user group.

Consumers' demanded items are diverse, with items required in instant scenarios constituting the mainstream. Shopping preferences manifest a "coexistence of centralized and fragmented" pattern. Regarding delivery mode preferences, "door-to-door delivery" stands out as the primary choice. In terms of delivery time preferences, a considerable majority of consumers favor "immediate delivery" and "delivery within the desired time window."

Reliability Analysis. Based on the sample data (N=826), this study tested the reliability and validity of each variable and the overall scale. The reliability test results show that the Cronbach's Alpha coefficients for the overall scale and the four variables—performance expectancy, effort expectancy, service responsiveness, and behavioral intention—all exceed 0.7. The Cronbach's Alpha coefficients for the time

constraints and delivery mode expectancy variables range between 0.6 and 0.7, which falls within an acceptable range, indicating that the scale has good internal consistency (see Table 1).

Table 1. Reliability Test Results.

Variable	Item	Cronbach's Alpha	Cronbach's Alpha for the overall scale
Performance Expectancy	PE1	0.843	0.878
	PE2		
	PE3		
Effort Expectancy	EE1	0.804	
	EE2		
	EE3		
Service Responsiveness	SR1	0.833	
	SR2		
	SR3		
Time Constraints	TC1	0.695	
	TC2		
Delivery Mode Expectancy	DE1	0.693	
	DE2		
Behavioral Intention	BI1	0.817	
	BI2		
	BI3		

Validity Analysis. Validity encompasses both content validity and construct validity. The scale was adapted from established research scales and revised according to the specific context, thus demonstrating sound content validity. The construct validity test results show that the standardized loadings for all variables exceed 0.5, all AVE (Average Variance Extracted) values surpass 0.5, and all CR (Composite Reliability) values are above 0.7, indicating good convergent validity (see Table 2). Additionally, the square roots of the AVEs for each latent variable are greater than the correlation coefficients among the latent variables, satisfying the criterion for discriminant validity (see Table 3). In summary, the overall scale exhibits good reliability and validity, rendering it suitable for subsequent structural equation modeling analysis.

Table 2. Convergent Validity Test Results.

Variable	Item	Standardized Loading	AVE	CR
Performance Expectancy	PE1	0.843	0.642	0.843
	PE2	0.85		
	PE3	0.847		
Effort Expectancy	EE1	0.851	0.573	0.798
	EE2	0.694		
	EE3	0.811		
Service Responsiveness	SR1	0.76	0.638	0.840
	SR2	0.869		
	SR3	0.854		
Time Constraints	TC1	0.83	0.534	0.706
	TC2	0.775		
Delivery Mode Expectancy	DE1	0.799	0.531	0.703
	DE2	0.763		
Behavioral Intention	BI1	0.672	0.604	0.819
	BI2	0.714		
	BI3	0.812		

Table 3. Discriminant Validity Test Results.

	Performance Expectancy	Effort Expectancy	Service Responsiveness	Time Constraints	Delivery Mode Expectancy	Behavioral Intention
Performance Expectancy	0.801					
Effort Expectancy	0.253	0.757				
Service Responsiveness	0.180	0.330	0.799			
Time Constraints	0.198	0.376	0.370	0.731		
Delivery Mode Expectancy	0.250	0.462	0.384	0.459	0.728	
Behavioral Intention	0.493	0.482	0.441	0.465	0.452	0.777

Note: The diagonal values are the square roots of the AVEs for each latent variable, while the off-diagonal values are the correlation coefficients among the latent variables.

3.3 Structural Equation Model Fitting

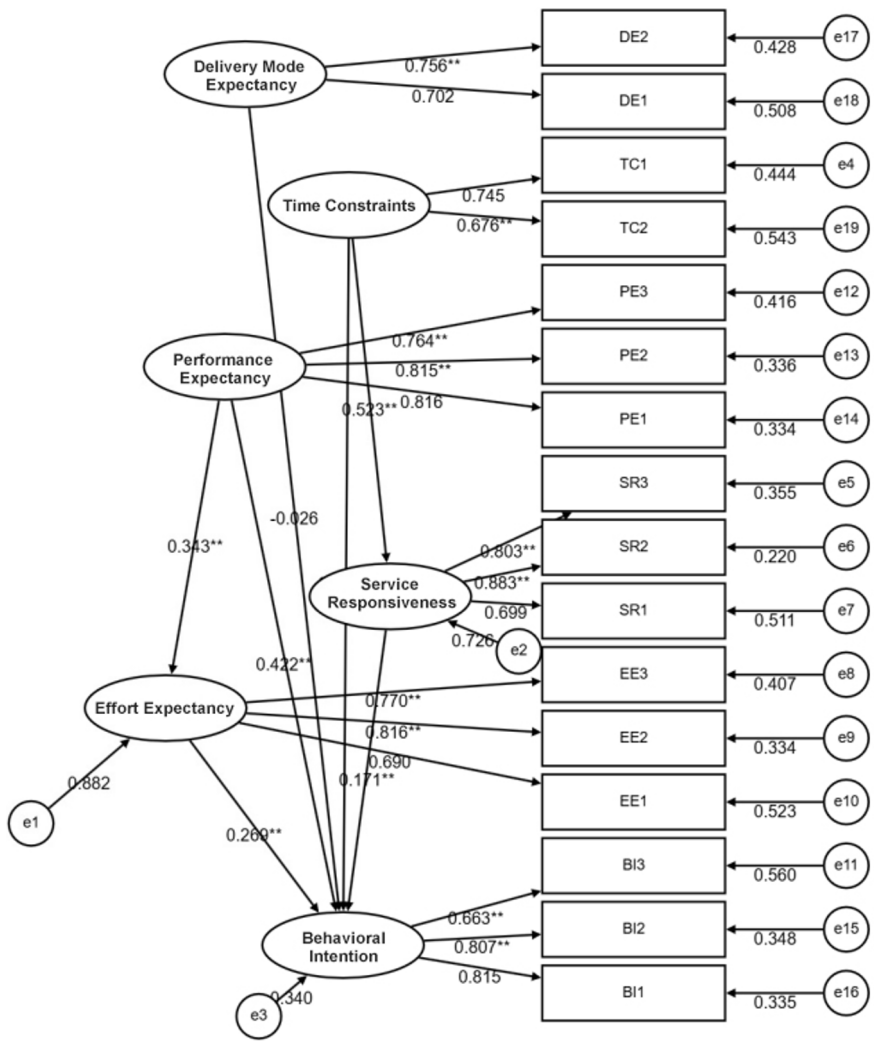


Fig. 2. Structural Equation Model Fitting Results for Behavioral Intention of Drone-Based Last-Mile Delivery.

This study comprises 16 observed variables with an effective sample size of 826, satisfying the requirements for structural equation modeling estimation. The model estimation was performed using the maximum likelihood estimation method. As shown in Figure 2, all fit indices meet accepted criteria, indicating good model-data fit.

3.4 Path Analysis Results

The significance test results of the model paths (Table 4) show that only Hypothesis H7 is not supported, while all other hypotheses are supported. Specifically, performance expectancy and time constraints are the primary drivers of behavioral intention, with effort expectancy and service responsiveness playing complementary roles, whereas delivery mode expectancy has no significant effect on behavioral intention. Performance expectancy significantly and positively affects effort expectancy, and time constraints significantly and positively affect service responsiveness.

In the 2025 context, consumers' adoption of drone-based last-mile delivery depends primarily on their comprehensive evaluation of service performance and timeliness fulfillment capabilities. Meanwhile, system ease of use and service responsiveness also provide supporting effects in shaping their intentions, while the delivery mode itself no longer constitutes a critical decision-making factor. Furthermore, the stronger consumers' perceived benefits, the more positive their evaluations of system ease of use; and the greater the time constraints they face, the higher their attention to information availability, fulfillment responsiveness, and arrival assurance during the delivery process.

Table 4. Path Estimates and Test Results of the Structural Equation Model.

Path	Standard- ized Path Coeffi- cient	S.E.	C.R.	P	Sup- ported?
H1: Behavioral Intention <--- Performance Expectancy	0.422	0.034	10.67 2	***	√
H2: Behavioral Intention <--- Effort Expectancy	0.269	0.038	7.507	***	√
H3: Effort Expectancy <--- Performance Expectancy	0.343	0.035	7.916	***	√
H4: Behavioral Intention <--- Service Responsiveness	0.171	0.042	4.278	***	√
H5: Behavioral Intention <--- Time Constraints	0.353	0.077	4.638	***	√
H6: Service Responsiveness <--- Time Constraints	0.523	0.048	10.50 5	***	√
H7: Behavioral Intention <--- Delivery Mode Expectancy	-0.026	0.068	-0.392	0.69 5	×

4 Cross-Temporal Replication Results and Discussion of Influence Mechanisms: A Comparative Interpretation Based on 2023 – 2025

4.1 Comparability of the Cross-Temporal Study

To ensure the comparability of the research results between 2023 and 2025, this study maintained consistency in the theoretical framework, variable settings, and measurement items to the greatest extent possible, thereby minimizing comparison errors caused by differences in variable definitions or scale specifications. Both samples passed the reliability and validity tests, and the main fit indices of the structural equation models for both periods reached acceptable or above standards.

To identify the phased differences in the consumer acceptance mechanism, the comparison between the 2023 and 2025 results in this paper is primarily based on the significance and effect sizes of paths across the two independent samples. It should be noted that the concepts of "stable paths" and "differential paths" discussed below are not directly equivalent to strictly tested between-group differences. Future studies may employ multiple-group structural equation modeling and measurement invariance tests to more rigorously identify cross-temporal differences.

4.2 Key Path Comparisons Between 2023 and 2025 and Phased Characteristics

To reveal the stability and phased differences in the acceptance mechanism of drone-based last-mile delivery across different temporal cross-sections, this study presents a parallel comparison of the path test results from the 2023 and 2025 structural equation models (see Table 5). Overall, the core structure of the extended UTAUT model is well supported in both samples; however, the effect sizes and significance patterns of different influencing factors on behavioral intention exhibit a certain degree of evolution.

Table 5. Comparison of Path Results Between 2023 and 2025.

Path	2023β (p-value)	2025β (p-value)	2023 Supported?	2025 Supported?	Type of Change
H1: PE→BI	0.278*	0.422***	√	√	Stable and significant
H2: EE→BI	-0.025 (p=0.841)	0.269***	×	√	Insignificant → Significant
H3: PE→EE	0.830***	0.343***	√	√	Stable and significant
H4: SR→BI	-0.440 (p=0.567)	0.171***	×	√	Insignificant → Significant

H5: TC→BI	0.436***	0.353***	√	√	Stable and significant
H6: TC→SR	0.982***	0.523***	√	√	Stable and significant
H7: DE→BI	0.690***	-0.026 (p=0.695)	√	×	Significant → Insignificant

Regarding the stable paths, performance expectancy and time constraints consistently exert significantly positive effects on behavioral intention across both periods, constituting the stable core driving mechanisms for consumer adoption. Meanwhile, two mechanistic paths also exhibit strong stability across the temporal dimension: the more consumers recognize the value of drone-based last-mile delivery technology, the more positively they perceive the learning and operational difficulty; and the greater the time pressure, the more consumers attend to information feedback, response speed, and assurance capabilities during the delivery process.

Regarding the differential paths, three main types of changes occurred during the 2023–2025 period. First, the effect of effort expectancy on behavioral intention shifted from insignificant to significantly positive, indicating that ease of use has now become an important factor driving adoption intentions. Second, the effect of service responsiveness on behavioral intention also shifted from insignificant to significantly positive, reflecting that consumers have devoted greater attention to the stability and certainty of the delivery process. Third, the effect of delivery mode expectancy on behavioral intention shifted from significantly positive to insignificant, suggesting that consumers' subjective emphasis on delivery modes has noticeably diminished.

4.3 Interpretation of the Evolution of Influence Mechanisms Through Changes in the External Environment

Policy and Regulatory Environment. From 2023 to 2025, China's policy support and regulatory frameworks concerning the low-altitude economy and drone operation management have been continuously improved, providing an institutional background for the phased evolution of consumers' acceptance mechanisms for drone-based last-mile delivery. At the national level, the Special Development Plan for General Aviation during the 14th Five-Year Plan Period proposed strong support for the development of drone logistics delivery; the Action Plan for Upgrading Equipment and Promoting Consumer Goods Replacement through Standards Enhancement encouraged drone flight tests and the formulation of airworthiness standards for (logistics) drones; and the Implementation Plan for the Innovative Application of General Aviation Equipment (2024–2030) encouraged the launch of application demonstrations for drone-based last-mile delivery in key regions. At the local level, documents such as the Guiding Opinions of the General Office of the People's Government of Sichuan Province on Promoting the Development of the Low-Altitude Economy and the Regulations of Guangzhou Municipality on the Development of the Low-Altitude Economy all identified the application of drone-based last-mile delivery as a priority. Meanwhile, the Safety Management Rules for Civil Unmanned Aircraft Operations

and the Interim Regulations on the Flight Management of Unmanned Aircraft established a full-chain regulatory framework for the safe operation of drones, aiming to safeguard public safety while promoting the healthy development of the drone industry.

These changes in the policy and regulatory environment, on the one hand, have signaled to the public the sustainable development of drone-based last-mile delivery technology, thereby enhancing the stability of consumers' expectations regarding service performance fulfillment. On the other hand, the regulatory oversight and safeguards applied to service operations have alleviated consumers' concerns about safety and stability, further facilitating the formation of adoption intentions.

Technology and Infrastructure. Continuous advances in technology and infrastructure for drone-based last-mile delivery have also exerted a significant impact on consumers' behavioral intentions. In terms of aircraft performance, companies such as Meituan, Fengyi Technology, and DJI have successively launched new-generation models since 2023, featuring visual perception systems and multiple safety mechanisms, with notable improvements in complex-environment adaptability and payload capacity. In terms of intelligent route operations, Meituan Drone has introduced three core products—the smart docking airport M-Port 3, the intelligent dispatch system M-DaaS 3, and the long-range version M-Drone 4L—capable of automated cargo loading/unloading, automated route planning, and nighttime lightless operation. In terms of infrastructure, the 2024 Construction Plan for the Longhua District Low-Altitude Economy Pilot Zone, for example, proposed adding over 40 low-altitude aircraft takeoff/landing platforms and last-mile delivery facilities by the end of 2024, striving to open more than 35 intra-district drone routes, while simultaneously advancing the construction of supporting facilities for communication, navigation, and meteorology.

Technological breakthroughs and infrastructure improvements primarily affect the consumer acceptance mechanism by enhancing the feasibility and reliability of services. First, upgrades in aircraft performance make stable drone-based last-mile delivery a viable option, strengthening consumers' judgments about its use value and fulfillment capabilities. Second, service intelligence has gradually made delivery modes a basic configuration, which also helps explain the shift in consumers' focal concerns.

Market Penetration and Social Cognition. As industry leaders such as Meituan, SF Express, and JD.com have rapidly expanded their drone-based last-mile delivery route networks and service coverage over the past two years, consumers' exposure to and perceptions of the service have markedly increased. By the end of December 2024, Meituan Drone had opened 53 routes in cities including Shenzhen, Beijing, and Shanghai, with cumulative orders exceeding 450,000; SF Fengyi Drone had opened 645 routes nationwide, transporting over 7.39 million cargo items. The normalized operation of drone-based last-mile delivery has led consumers to no longer view the technology as an inaccessible high-tech product. The convenience of delivery modes,

as a determinant of whether services can operate on a routine basis, has ceased to be a significant factor affecting adoption. Instead, the ease of use in actual operations and service responsiveness during service execution have become focal points for consumers before they gain firsthand experience.

Demand Structure and Consumption Context. The Instant Retail Industry Development Report (2025) issued by the Chinese Academy of International Trade and Economic Cooperation indicates that China's instant retail market reached RMB 781 billion in 2024, representing a year-on-year growth of 20.15%. Combined with the descriptive statistics of demand preferences from the 2025 sample, consumer demand exhibits pronounced immediacy: in terms of product categories, food and beverage products account for the highest proportion (64.77%); in terms of shopping preferences, the proportion of consumers favoring "instant purchase" is as high as 70.34%; and in terms of delivery time preferences, 47.58% choose "immediate delivery." This undoubtedly sustains the critical influence of time constraints across different years. Moreover, as timeliness requirements intensify and delivery time windows compress, the cost of delays increases, amplifying consumers' demand for delivery time controllability and rendering service responsiveness a necessary constraint. Additionally, in terms of delivery mode preferences, 59.93% of consumers favor "door-to-door delivery," contributing to the overall decline in the marginal explanatory power of delivery modes.

4.4 Managerial Implications and Policy Recommendations

The cross-temporal empirical findings of this study indicate that the acceptance mechanism for drone-based last-mile delivery technology exhibits a structural configuration characterized by "benefits and timeliness remaining core, ease of use and process responsiveness gaining weight, and delivery modes marginally weakening." Combined with the pronounced demand characteristics of "instant consumption and door-to-door delivery" observed in the survey sample, the following implications and recommendations are proposed for enterprises, government, and scenario stakeholders.

Emphasize Value Delivery and Responsiveness. Enterprises should focus the large-scale promotion of drone-based last-mile delivery on high-timeliness-demand scenarios and value-incrementally clear contexts, quantifying value indicators such as "time savings and certainty enhancement" to form performance advantages perceptible to consumers. Platforms should strengthen full-chain visualization capabilities and establish standardized customer service and operational mechanisms to enhance consumers' sense of security during the service process. Platforms should also simplify operational procedures to reduce consumers' learning costs.

Improve the Regulatory System and Evaluation Standards. While strengthening infrastructure construction to enhance service accessibility, the government should further refine drone operation regulatory mechanisms, reinforcing process traceability and loss compensation capabilities to lower public risk perceptions of uncertainty. The government should also introduce sound and standardized service evaluation criteria, prioritizing indicators such as on-time rate, information availability, and exception-handling efficiency as key assessment metrics.

Optimize Scenario Collaboration and Service Touchpoint Design. Stakeholders in scenarios such as communities, industrial parks, and commercial districts should establish more standardized collaboration mechanisms with operating platforms, focusing on critical links including takeoff/landing site placement, pickup process integration, peak-hour order maintenance, and exception handling to enhance the stability and smoothness of the service process, thereby reducing consumers' additional time and learning costs during actual deliveries.

5 Conclusion

Based on the extended UTAUT model, this study employed structural equation modeling with survey data collected in 2025, and combined with the findings of an existing 2023 study, conducted a cross-temporal comparative analysis of the consumer acceptance mechanism for drone-based last-mile delivery technology. The results indicate that performance expectancy and time constraints exert significantly positive effects on behavioral intention in both periods, constituting the stable core driving factors for consumer adoption. Effort expectancy and service responsiveness shifted from having insignificant to significantly positive effects, suggesting that ease of use and service process reliability have been incorporated into consumers' comprehensive evaluation framework. The effect of delivery mode expectancy shifted from significant to insignificant, indicating that the marginal influence of delivery touchpoints and receiving modes has diminished. Overall, the acceptance mechanism of drone-based last-mile delivery technology exhibits a phased evolutionary pattern characterized by "stable core drivers, shifting focal concerns, and upgrading evaluation structures."

The theoretical contributions of this study are mainly reflected in two aspects. On the one hand, this paper introduces a cross-temporal comparative perspective into the study of the acceptance mechanism for drone-based last-mile delivery technology, identifying both stable and evolving pathways influencing behavioral intention, thereby extending the understanding of the dynamic nature of emerging technology adoption in relevant research. On the other hand, this paper provides a structured explanation of the drivers of path evolution by integrating four major dimensions of change—policy, technology, market penetration, and demand context—offering theoretical guidance for promoting the diffusion and application of emerging technologies.

The findings of this study suggest that the current promotion of drone-based last-mile delivery should place greater emphasis on value delivery, service responsiveness, and scenario implementation. For enterprises, efforts should focus on high-timeliness-demand scenarios to accentuate performance advantages, while enhancing consumers' positive perceptions of the service process through streamlined operating procedures, improved information transparency, and enhanced exception response capabilities. For the government, regulatory frameworks and evaluation standards related to low-altitude logistics should be further refined to strengthen service standardization and traceability. For scenario stakeholders such as communities, industrial parks, and commercial districts, collaboration with operating platforms should be intensified in aspects such as site placement, process integration, and order management to facilitate the further normalization of drone-based last-mile delivery.

Admittedly, this study has certain limitations. First, the cross-temporal comparison is primarily based on path test results from two independent samples and has not yet employed multiple-group structural equation modeling or measurement invariance tests to more rigorously identify between-group differences. Second, this study focuses on the effects of five variables—performance expectancy, effort expectancy, service responsiveness, time constraints, and delivery mode expectancy—on behavioral intention, without incorporating factors such as risk perception, trust, and technology accessibility into the model. Future research may integrate actual user usage data, include more potential influencing factors, and conduct comparative studies across specific application scenarios such as instant retail, emergency delivery, community delivery, and remote-area delivery, to examine differences in consumer acceptance mechanisms under varying contexts.

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