



Research on Functional Restructuring of Waterfront Spaces Driven by the Low-Altitude Economy: A Case Study of the Nanjing "Jiangyida" Low-Altitude Flight Base

Zhengbo Huang

College of Civil Aviation, Nanjing University of Aeronautics and Astronautics, Nanjing, 210000, China

2324753411@qq.com

Abstract. With the low-altitude economy being elevated to a national strategic emerging industry development plan, the "two-dimensional plane" urban space will transform into a "three-dimensional space." This article uses the Nanjing "Jiangyida" low-altitude flight base as a case study, demonstrating how low-altitude infrastructure promotes the functional upgrading of waterfront spaces. This demonstrates that the low-altitude economy can bring about three-dimensional development and functional enhancement of waterfront spaces. However, it also presents challenges such as technological and institutional friction and social acceptance. The proposed "double-helix reconstruction model of low-altitude waterfront spaces" reveals the coupling relationship between technological application and institutional adaptation, providing theoretical support and practical reference for the development of the low-altitude economy in waterfront cities.

Keywords: Low-altitude economy, Waterfront space, Spatial restructuring, Nanjing, Urban planning

1 Introduction

The global low-altitude economy has experienced explosive growth in recent years, coinciding with the Chinese government's inclusion of it in its 2024 strategic emerging industries development plan. Across the country, various regions are seeking their own unique application areas and development models. Waterfront areas are typically complex urban spaces, facing significant challenges in transformation and upgrading due to their ecological fragility, functional diversity, and mixed ownership. Nanjing, a pioneer in China's low-altitude economy, has taken the lead in practicing "integrated waterfront low-altitude development" by utilizing the Yangtze River's golden waterway.

In August 2025, the "Jiangyida" low-altitude flight base in Gulou District officially began operation. It is China's first intelligently interconnected low-altitude flight center integrating land, water, and air, handling an average of 150 drone delivery missions daily, connecting 15 kilometers of the Yangtze River waterway, and filling service gaps

© The Author(s) 2026

L. Trajkovic et al. (eds.), *Proceedings of the 2026 2nd International Conference on Data Mining and Project Management (DMPM 2026)*, Advances in Economics, Business and Management Research 390,

https://doi.org/10.2991/978-94-6239-689-0_2

along the river. Its model can serve as an "ideal testing ground" for observing and studying the reconstruction of waterfront spaces under the influence of the low-altitude economy.

This paper proposes a "double-helix reconstruction model for low-altitude waterfront spaces" to explore the mechanism by which low-altitude infrastructure, through technological embedding, institutional innovation, and spatial response, promotes the functional reconstruction and value enhancement of existing waterfront spaces. Taking Nanjing as an example, the analysis aims to provide a reference model for the low-carbon and intelligent renewal of waterfront areas in similar cities.

Furthermore, the literature review also focuses on logistical efficiency and environmental issues. This indicates that in developing low-altitude logistics, in addition to pursuing faster and more reliable delivery services, it is also necessary to consider equity and the quiet and pleasant landscape environment of waterfront walkways.

Recent studies have mainly focused on drones themselves and airspace management issues, but have rarely discussed the actual impact of these technologies on waterfront spaces, especially those areas primarily used for walking and leisure activities. This paper attempts to address this deficiency by integrating drone flight paths with urban human activity spaces for analysis. In this way, while assessing the system's operational efficiency, it is also possible to consider potential social problems and new opportunities in spatial design.

2 Literature Review

In addition to Chinese literature, more and more international studies have begun to focus on the governance, safety and logistical support of low-altitude operations. NASA's Unmanned Aircraft Systems Traffic Management (UTM) project has described the concept and field trials of large-scale integrated low-altitude operations and provided a general governance and data exchange template for cities [1]. As for Europe, the U-space regulatory scheme ((EU) 2021/664-666) defines services such as networked remote identification, geofencing and dynamic capacity management, which can be directly applied to waterfront areas [2]. Many past studies have focused on the logistics perspective, summarizing the optimization models and route policies for drone delivery [3,4], while past energy-environment related studies have quantified topics such as noise that are less discussed in low-altitude waterfront area research [5,6].

The integration of low-altitude economy and waterfront space, as a three-dimensional extension of smart cities, is essentially a product driven by "technology-space-institution". A review of relevant Chinese and foreign literature in the past five years reveals that the existing research results are mainly characterized by two aspects of "disconnection". One is that technology is emphasized while space is neglected. Too much research focuses on improving UAV performance, flight path algorithms, and airspace management, with less attention paid to the impact of these technologies on the urban built environment [7]. Most of these studies consider the engineering aspects without addressing spatial morphology, functional organization, and social impact.

Secondly, there is a disconnect between industry and human factors. While domestic reports provide detailed descriptions of the low-altitude economic industrial chain and market size, they often neglect humanistic issues such as social acceptance and spatial equity [8]. Social research on the low-altitude economy, especially surveys on people's acceptance of new technologies, benefit sharing, and risk awareness, is clearly insufficient.

Besides the inherent limitations of the theories themselves, previous work also has certain limitations in practical application. Spatial production theory can be used to explain the phenomenon of airspace resource utilization, but it does not address specific governance mechanisms [9]; the three-dimensional smart city theory focuses on airspace resource attributes but does not consider the special characteristics of waterfront environments [10]; the ecosystem service theory focuses on ecological impacts but does not consider the characteristics of the low-altitude economy [11].

Furthermore, existing research lacks information on the special characteristics and governance mechanisms of waterfront areas. Most low-level studies focus on general transportation or logistics and do not consider the special ecological constraints of waterfront areas (such as bird migration corridors and river wind disturbance); at the same time, although the Nanjing model adopts a government-enterprise joint approach, it has not formed a standard interface, making it impossible to imitate.

3 Research Method and Design for Low-Altitude Waterfront Space

In the core waterfront area, several low-altitude unmanned aerial vehicle (UAV) service nodes can be set up, along with a unified data interface and dynamic geofencing system. Simultaneously, noise level (L_{den}), delivery reliability ($R(u)$), and spatial accessibility indicators (A_i) can be incorporated into monthly operational monitoring for continuous system performance evaluation. Furthermore, small-scale pilot projects can be conducted initially in areas such as medical transportation and emergency delivery, accumulating experience for subsequent large-scale deployment through gradual testing and adjustments.

This study employs an embedded single-case study design, using the Nanjing "Jiangyida" base as the core case unit. Qualitative and quantitative methods are used to triangulate the research conclusions to ensure the reliability of the study. The "Jiangyida" base is China's first intelligent interconnected low-altitude flight hub integrating land, water, and air. This case was chosen because of its typical representativeness and pioneering nature, highly condensing the basic characteristics of waterfront low-altitude spatial reconstruction.

3.1 Data Sources

This study employs a relatively simple and reproducible methodology. First, potential UAV take-off and landing points are identified. Then, the service capacity and opera-

tional reliability of each node are estimated based on recent flight mission data. Subsequently, the overall travel cost is calculated by considering flight time and the additional costs associated with airspace complexity, and a spatial accessibility distribution map is drawn based on this. All parameter settings are described in the study to ensure the method can be applied and validated in other similar waterfront areas.

This study primarily utilizes various publicly available data, including land use planning maps and urban public facility distribution maps of the riverside area published by the Nanjing Municipal Planning and Natural Resources Bureau; the "Jiangyida Low-Altitude Logistics Operation White Paper (2025)" published by the Yangtze River Logistics Group; shipping statistics published by the Nanjing Municipal Transportation Bureau; and relevant policy documents, development plans, and management methods related to the low-altitude economy issued by the Jiangsu Provincial Government and the Nanjing Municipal Government [6–8].

3.2 Analysis Methods

In GIS, a route centerline is buffered into B_r (radius= 20–60 m) and overlaid with sensitive waterfront polygons S (viewing decks, promenades, schools, etc.) to obtain intersections

$$I=B_r \cap S \tag{1}$$

For each conflict unit $u \in I$, the study defines a risk score:

each potential conflict unit is scored by combining crowding degree $D(u)$ (*persons/100m²*), complaint heat $H(u)$, and adverse-wind conditions $W(u)$ (all normalized to 0–1) with transparent weights(β); high scores $R(u) \geq \tau$ trigger rerouting and time-window control.

To comprehensively consider service effectiveness, an accessibility evaluation model for low-altitude services was established based on three dimensions: spatial distance, time cost, and operational capacity. The low-altitude service accessibility for any demand location i is defined as:

$$A_i = \sum_j \frac{w_j \cdot k_j}{c_{ij}} \tag{2}$$

Accessibility is computed as a simple ratio that increases with service capacity and reliability and decreases with generalized travel cost.

Where w_j : Service capacity weight of takeoff/landing point j , calculated by weighting the 75th quantile of daily sorties in the past 7–30 days (balancing stability and timeliness);

k_j : Operational reliability coefficient of takeoff/landing point j , defined as $k_j = 1 - \text{failure rate}$ (data from the Jiangyida Low-Altitude Logistics Operation White Paper (2025));

c_{ij} : Generalized travel cost from location j to takeoff/landing point j , calculated as

$$c_{ij} = t_{ij} \cdot \alpha(z_{ij}) \tag{3}$$

where t_{ij} is flight time (in minutes) and $\alpha(z_{ij})$ is an airspace complexity adjustment factor (incorporating wind speed, corridor crossing, and geofencing detours, with a value range of 1.0–1.8).

For a riverside demand point i with three sites $J = \{A, B, C\}$: $k_A=0.95$, $c_{iA}=8$; $w_B=2.0, k_B=0.90$, $c_{iB}=6$; $w_C=1.0, k_C=0.85$, $c_{iC}=5$.

Calculation:

$$\begin{aligned} A_i &= \frac{w_A \times k_A}{c_{iA}} + \frac{w_B \times k_B}{c_{iB}} + \frac{w_C \times k_C}{c_{iC}} \\ &= \frac{3.0 \times 0.95}{8} + \frac{2.0 \times 0.90}{6} + \frac{1.0 \times 0.85}{5} \\ &= 0.356 + 0.300 + 0.170 \\ &= 0.826 \end{aligned} \quad (4)$$

Normalization (to $[0,1]$):

If $\max(A_x) = 1.12$, then $\tilde{A}_i = 0.826 / 1.12 = 0.738$.

Operational efficiency metrics:

On-time performance:

$$OTP = \frac{\text{Number of on-time missions}}{\text{Total missions}} \times 100\% \quad (5)$$

mean mission duration

$$\mu = \frac{\sum_{k=1}^N t_k}{N} \quad (6)$$

with standard deviation

$$\sigma = \sqrt{\frac{\sum_{k=1}^N (t_k - \mu)^2}{N-1}} \quad (7)$$

For $N \geq 30$, a 95% confidence interval for $\mu \pm 1.96 \cdot \frac{\sigma}{\sqrt{N}}$.

Example: $N = 200$, $\mu = 23.5 \text{ min}$, $\sigma = 6.2 \text{ min}$, $CI = [22.64, 24.36] \text{ min}$.

Stratify by weather (clear/rain/fog/high-wind) and assess stability of OTP using a Cochran–Mantel–Haenszel framework; report the pooled odds ratio and its confidence bounds to evidence robustness under operational conditions.

GIS spatial analysis techniques, including buffer zone and overlay analyses, were employed to quantify the service coverage range of low-altitude facilities and identify spatial conflict points. Specific operations included: using UAV takeoff and landing points as centers to establish service buffer zones of different radii; performing overlay analysis of route data and land use maps to identify areas of spatial use conflict.

The core of spatial analysis involved using GIS to simulate quantitative dynamic interactions between low-altitude routes and waterfront activities. Beyond static buffer and overlay analyses to map service coverage and identify geometric conflict points (e.g., flight paths over platforms), the study analyzed temporal patterns in UAV trajectories. It enables diagnosis of complex time-based usage conflicts, such as peak flight hours coinciding with high tourist activity at the Riverside Happy Stage.

Relative time saving: If traditional access takes T_0 and low-altitude service takes T_1 , then:

$$\theta = \frac{T_0 - T_1}{T_0} \times 100\% \quad (8)$$

When the service radius expands from 0.5 km to 15 km, the number of vessels served increases from

$$N_0 \text{ to } N_1 \approx 3.2 \times N_0 \quad (9)$$

if the average value per service is v , the potential output increment is

$$\Delta Y \approx (N_1 - N_0) \cdot v. \quad (10)$$

In addition to calculating the mean and confidence interval, this study further analyzes the tail distribution of the data. Specifically, empirical quantiles (Q05 and Q95) are used to observe extreme cases, and the runs test is used to determine whether there is serial correlation in the data. If significant autocorrelation is detected, the Newey-West method is used to correct the standard errors.

Where, A_i represents the accessibility level of low-altitude service at spatial location i ; W_j represents the service capability weight of takeoff and landing point j ; C_{ij} represents the comprehensive cost from spatial location i to takeoff and landing point j , which takes into account factors such as flight time and airspace complexity; O_j represents the operational capability coefficient of takeoff and landing point j . The relevant parameters are mainly estimated based on the actual daily average flight data published in industry white papers.

This study also conducts a comparative case analysis, comparing the Nanjing model with relevant practices in Shanghai North Bund and Shenzhen Talent Park. A unified evaluation index system was established, encompassing operational scale, service type, technological level, and policy environment.

It should be noted that this study primarily focuses on operational indicators, with less consideration given to policy guidance and market maturity; therefore, the depth of comparative analysis remains somewhat limited.

4 In-depth Description and Analysis of the Nanjing Case

4.1 Operational Efficiency Analysis

Time-value benefit: Let c_t be the hourly time value per vessel

$$\Delta T = \sum(T_0 - T_1) \quad (11)$$

the total hours saved; the time-value benefit is

$$TB = c_t \times \Delta T \quad (12)$$

Fuel and carbon emissions: If conventional docking avoided saves $\Sigma\Delta f$ tons of fuel with emission factor EF , the gross carbon reduction is $EF \times \Delta f_k$. The net climate benefit accounts for UAV energy consumption:

$$\Delta CO_{2,net} = EF \cdot \Sigma\Delta f_k - E_{uav}. \quad (13)$$

The report analyzed both gross profit and net profit. The study found that the economic benefits brought by the system were most obvious in areas with a high concentration of mixed functions. This is mainly because the shorter response time can support more practical application scenarios, such as rapid replenishment, facility inspection and timely delivery of key materials.

From the perspective of spatial operation, the function of waterfront areas is changing. In the past, these areas mainly served relatively simple service functions, but with the support of low-altitude logistics, they have gradually formed a more three-dimensional service network. In this way, the connection between ships and shore facilities can be faster and more stable, thereby improving the overall user experience and alleviating the congestion problem of fixed docks to a certain extent.

Data shows that, relying on the low-altitude logistics service of Jiangyida Base, about 20,000 cargo delivery missions were completed during the trial operation from January to July 2025; after the base was put into use, the average daily delivery missions reached about 150, indicating that the base has entered a period of large-scale operation[12]. In terms of delivery weight, a total of 285 tons of supplies were delivered, with an average delivery weight of 6.7 kg per flight. The proportion of heavy-duty drones (with a payload of ≥ 20 kg) increased from 15% in the early stage to 35%. The on-time rate of this route reached 92.7%, and the average delivery time was only 23.5 minutes, which is about 75% less than the time spent on traditional ship-to-shore berthing and resupply. According to the drone operation under different weather conditions, the drone operation rate reached more than 95% under wind conditions below level 7[13].

4.2 Spatial Restructuring Effects

This estimate is primarily used for budgeting and also serves as a reference for cost-sharing between the public sector and private service providers. To translate improved operational efficiency into quantifiable economic indicators, this study estimates the time efficiency gains for shipping and shore-side facilities, while also calculating reduced fuel consumption. To avoid exaggerating low-carbon benefits, the study deducts the energy consumed by drone operations in its calculations and addresses uncertainties in key parameters.

Traditional access takes $T_0 = 45\text{min}$ while low-altitude service takes $T_1 = 12\text{min}$, the relative saving

$$\theta = \frac{T_0 - T_1}{T_0} \times 100\% = 73.3\% \quad (14)$$

Formalizing the double-helix: Let the technology state

$T(t) \in \{\text{pilot}, \text{iteration}, \text{scale} - \text{up}\}$

and the institutional $stateS(t) \in vacuum, sandbox, codified$. Using a semi-Markov approximation:

$$PT_{t+\Delta} = \tau' | T_t = \tau, S_t = s = f_{\tau}(demand, cost, reliability; s), \quad PS_{t+\Delta} = s' | S_t = s, T_t = \tau = g_s \text{ (risk incidents, public acceptance, data availability; } \tau).$$

The joint evolution over (τ, s) yields transition matrices enabling policy scenarios (e.g., a sandbox raises the probability of transitions from sandbox to codified).

Cost structure. UAV operating costs are composed into energy, amortized hardware, maintenance, and airspace/compliance service fees. The benefit ledger includes time value, avoided fuel, and avoided berth occupancy; all items are reported with uncertainty bands.

GIS spatial analysis revealed the spatial restructuring effect of the low-altitude economy: the service radius of the waterfront area expanded from a ground service radius of 500m to an air service radius of 15km, and the number of boats receiving this type of service within this range increased by 3.2 times; at the same time, accessibility analysis showed that low-altitude services could reduce the average travel distance along the riverbank to 12min, from the original 45min to 12min, reducing the time cost by 73.3% [14].

According to the drone trajectory monitoring results released by the Nanjing Low-Altitude Traffic Management Center, analysis of the drone flight trajectory heat map revealed three hotspot areas: the main channel from the Yangtze River Bridge to the Second Yangtze River Bridge (62%), the riverside wharf area (25%), and the sightseeing area (13%). There were four flight paths that overlapped with the viewing platform, most of which were located around the riverside entertainment stage.

Land use impact studies show that low-altitude facilities have increased the functional mix of the waterfront area, increasing the density of commercial service facilities by 35% and the completeness of public service facilities by 28% within a 1km radius of the site; however, they have also led to an increase in noise complaints, with complaints occurring in the morning (6:00-8:00) and evening (18:00-20:00) accounting for approximately 72% of the total complaints.

4.3 Economic Benefit Assessment

It is worth noting that the double helix framework was used as a governance compass rather than a mathematical calculation. In practice, the sandbox mechanism reduced the uncertainty of innovative operations; standardized data sharing increased trust and reduced coordination costs. This framework clarified the city's current situation and the next prudent direction for action.

Economic benefit analysis shows that the low-altitude economy brings significant economic benefits to Gulou District. In terms of direct economic benefits, it generated RMB 18.5 million in direct operating revenue from January to August 2025 and created 235 jobs in related industries. In terms of indirect economic benefits, by shortening travel time, it reduced shipping companies' travel time costs by approximately RMB 32 million and reduced ship fuel consumption by approximately 850 tons.

The number of low-altitude drone manufacturing and related supporting enterprises in Gulou District increased from 12 in 2024 to 28 in 2025, an increase of 133.3%. The

low-altitude drone economy has initially formed a complete industrial chain based on drone research and production, extended by operation and services, and supported by related industries such as data processing and maintenance.

This study sets up three policy scenarios for comparative analysis. Scenario S1 represents maintaining existing policies and operating methods; Scenario S2 involves piloting under a regulatory framework and introducing dynamic geofencing for management; Scenario S3 establishes a unified data interface and allows different agencies to share relevant data services. During the analysis, the study calibrated the scenario transition matrix based on problems encountered in actual operation and interviews with relevant stakeholders to better reflect changes in system operation under different policy scenarios.

4.4 Comparative Analysis Results

Table 1. Comprehensive Comparison of Low-Altitude Economy Modes in Three Regions

Evaluation Dimension	Nanjing Mode	Shanghai Mode	Shenzhen Mode
Operational Efficiency (2025)	7.2 sorties/aircraft/day	5.8 sorties/aircraft/day	6.3 sorties/aircraft/day
Service Diversity	6 service types	3 service types	2 service types
Policy Support	Government-enterprise collaboration	Market-oriented	Market-oriented
Social Acceptance (Full marks: 100 points)	72 points	80 points	85 points

Comparing the Nanjing model with those of Shanghai's North Bund and Shenzhen's Talent Park (see Table 1), it can be seen that in terms of operational efficiency, Nanjing's average daily takeoffs and landings per aircraft is 7.2, higher than Shanghai's 5.8 and Shenzhen's 6.3. Regarding service diversity, Nanjing offers six types of services (e.g., logistics and distribution, emergency rescue, and shoreline inspection), surpassing Shanghai's three and Shenzhen's two. In terms of policy support, Nanjing has established a complete government-enterprise collaborative governance system.

The above comparison shows that due to different development strategies and urban environments, Nanjing, Shanghai, and Shenzhen have significantly different development directions. Nanjing's development model primarily serves the needs of its rapidly developing shipping industry and enhanced maritime public safety management. This explains why Nanjing offers a more diversified range of services, such as heavy-duty cranes and fleet tracking drones. In contrast, Shanghai's North Bund, as the largest financial and tourism center, prioritizes the safety and experience of high-end tourism,

neglecting its logistical value. Similarly, the Shenzhen-Hong Kong model, based on a technologically advanced consumption environment, focuses on improving the "last mile" efficiency of urban delivery within a high-density urban fabric. Therefore, Nanjing's higher daily flight frequency is not merely an operational result, but a direct integration with the high-frequency demand for river logistics, which is distinctly different from Shanghai's more fragmented tourist flights or Shenzhen's concentrated parcel delivery peaks.

5 Theoretical Model Construction and Policy Implications

5.1 Model Construction

This study uses the Nanjing case as an empirical analysis to construct a "double-helix reconstruction model of low-altitude waterfront spaces" (as shown in Figure 1) to explain the evolutionary mechanism of low-altitude waterfront spaces. The driving forces behind the development of low-altitude waterfront spaces are summarized as the joint driving forces of the "technology application spiral" and the "institutional adaptation spiral."

Based on the empirical analysis of the Nanjing case, this study constructs a "double-helix reconstruction model of low-altitude waterfront spaces" (as shown in Figure 1) to explain the evolutionary mechanism of low-altitude waterfront spaces and summarizes the joint driving forces of the "technology application spiral" and the "institutional adaptation spiral" in promoting the development of low-altitude waterfront spaces. The "double-helix reconstruction model" is inductively developed based on the empirical patterns observed in the Nanjing case study. The core logic of this model is as follows: each advancement in one spiral creates conditions and requires a response from the other spiral.

The Technology Application Spiral: This refers to the interaction between technology and the market. It begins with the needs of specific application scenarios (such as refueling on ships), promoting technological development and adaptation (e.g., developing a drone capable of tracking moving vessels and providing wind resistance), which in turn opens up new markets and applications and drives further technological iteration.

The Institutional Adaptation Spiral: This reflects the interaction between government regulation and institutional innovation. The application of new technologies generates new risks and uncertainties, disrupting existing institutional and regulatory systems and prompting government policy responses and institutional innovation. The new institutional environment, in turn, influences and constrains the technological development process.

These two spirals intertwine and propel each other. Technological innovation drives institutional change, while institutional reform opens up safer boundaries for technology use. These two spirals ascend in tandem, jointly "encoding" and constructing the functions, spatial forms, and governance methods of low-lying waterfront areas.

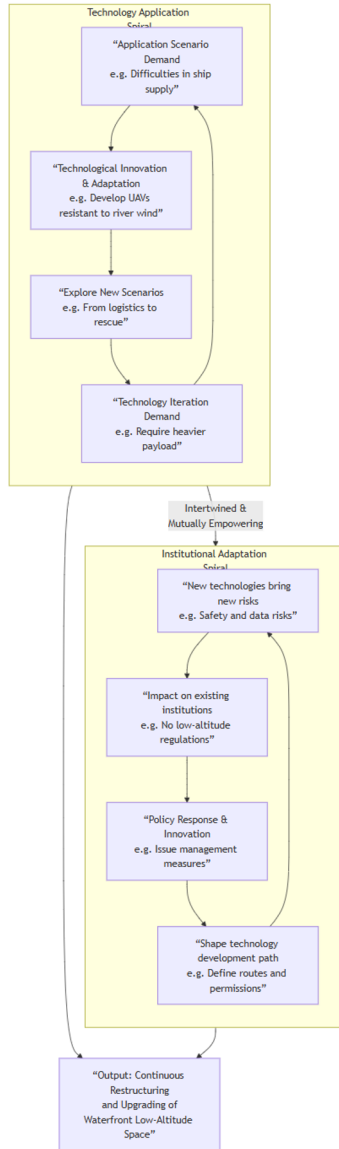


Fig. 1. Double Helix Restructuring Model for Low-Altitude Waterfront Space.

5.2 Policy Recommendations and Future Directions

Based on the above analysis, this paper proposes several policy recommendations to address different types of institutional friction. For situations where technological development outpaces institutional adjustments, demonstration applications of manned unmanned aerial vehicles (UAVs) for medical flights can be conducted, and a "regulatory sandbox" mechanism can be introduced to provide a testing environment for new

technologies. Regarding the issue of institutional restrictions on technological applications, a new generation of intelligent dynamic electronic fence systems can be developed to achieve more scientific and flexible airspace management. For friction related to social acceptance, public participation and compensation mechanisms can be established to ensure that relevant development achievements are more widely shared by society.

At the specific policy level, progress can be made in the following three aspects: Planning level: Incorporate low-altitude infrastructure into the urban planning and management system, and formulate planning and design guidelines for waterfront low-altitude infrastructure. Governance level: Establish a hierarchical data authorization mechanism between the government and enterprises to promote data sharing while ensuring security. Industry level: Strengthen the integrated development of the low-altitude economy and local advantageous industries.

5.3 Ethical, Environmental and Social Considerations

Noise: According to psychoacoustic studies, at the same sound pressure level, small-scale drone noise is more disturbing than road vehicle noise due to its tonal characteristics [6]. On densely populated waterfront promenades, this means that drones need stricter time and location restrictions and adaptive route planning to avoid peak hours.

Carbon Emissions and Energy: From a life cycle perspective, drones can reduce greenhouse gas emissions compared to vehicle delivery for short-distance lightweight cargo delivery. However, as payload and delivery distance increase, their advantages disappear or even become disadvantages under high-carbon emission power sources [5]. For Jiangyida Base, this forces us to develop dispatch rules based on different payloads and to procure clean energy.

Social Aspects: Establish a public participation platform (such as an APP or WeChat mini-program) for low-altitude waterfront applications, regularly communicate with the public about drone flight plans and social impacts, and promptly provide feedback on public opinions.

6 Conclusion

This paper takes the Nanjing "Jiangyida" low-altitude flight base as a case study to analyze the functional reconstruction path, impact, and governance dilemmas of low-altitude economic development on waterfront spaces. The main conclusions are as follows: First, the low-altitude economy enhances the value of waterfront spaces through three-dimensional expansion and multi-functional utilization; second, the development of low-altitude waterfront spaces is significantly constrained by technological-institutional frictions; finally, collaborative governance between government and enterprises is a feasible path to solve the governance challenges of the low-altitude economy. In addition, this paper constructs a "double-helix reconstruction model of low-altitude waterfront spaces," demonstrating the dual impact of technology use and institutional adjustment on spatial production.

Finally, in practical terms, the measures proposed in this paper, such as incorporating low-altitude facility construction into urban planning and establishing a hierarchical data authorization system between government and enterprises, have practical guiding value for the low-altitude economic development of waterfront cities. However, the analysis in this study has certain limitations: the application of drones in waterfront spaces is mainly concentrated in the urban area of Nanjing, and suburban waterways such as those in Jiangning are not fully covered; policies related to manned drones have not yet been relaxed, so the analysis is predictive. Future research could conduct more cross-case comparisons and explore the role of technologies such as digital twins in low-altitude governance.

References

1. Kopardekar, P., Rios, J., Prevot, T., Johnson, M., Jung, J., & Robinson, J. (2016). Unmanned Aircraft System Traffic Management (UTM) Concept of Operations. In AIAA Aviation.
2. European Union Aviation Safety Agency (EASA). (2021). U-space regulatory framework—Regulations (EU) 2021/664, 2021/665 and 2021/666.
3. Otto, A., Agatz, N., Campbell, J., Golden, B., & Pesch, E. (2018). Optimization approaches for civil applications of UAVs in logistics. *Networks*, 72(4), 411–458.
4. Dorling, K., Heinrichs, J., Messier, G. G., & Magierowski, S. (2017). Vehicle Routing Problems for Drone Delivery. *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, 47(1), 70–85.
5. Stolaroff, J. K., Samaras, C., O'Neill, E. R., Lubers, A. S., Mitchell, A. S., & Ceperley, D. (2018). Energy use and life-cycle greenhouse gas emissions of drones for package delivery. *Nature Communications*, 9, 409.
6. Christian, A. W., & Cabell, R. H. (2017). Initial Investigation into the Psychoacoustic Properties of Small Unmanned Aerial Vehicle Noise. NASA/TP-2017-219629.
7. Thipphavong, D. (2023). Urban Air Mobility Droneport Placement for Emergency Response. *Transportation Research Part C: Emerging Technologies*, 146, 103991.
8. Zhang, G., Yun, X. Y., Qin, X. W., Jiang, W. S., Fang, Z. B., & Zhu, C. Y. (2025). Low-altitude digital air route network: Methods, system, and verification—From "no path to follow" to "having a path to rely on". *Remote Sensing of Natural Resources*, 1-12.
9. Lefebvre, H. (1991). *The Production of Space*. Blackwell.
10. Hollands, R. G. (2008). *Intelligent Cities: Towards Interactive and Global Innovation Environments*. Routledge.
11. Liu, Q. H. (2025). Research on the evaluation of ecosystem service value and synergistic relationships in urban blue-green spaces: A case study of the Chan River and Ba River corridor in Xi'an. *Urban Observation*, (3), 144–164.
12. Changjianghui Group. (2025). *Jiangyida low-altitude logistics operation white paper*. Changjianghui Group.
13. Cao, D. R., Yang, X. L., & Shen, Z. (2025). Waterfront space accessibility in the old urban area of Nanjing based on multi-method coupling analysis. *Chinese Journal of Applied Ecology*, 36(9), 2836–2844.
14. Jiangsu Provincial Bureau of Statistics. (2025, September 15). The scale of Jiangsu's low-altitude economy reaches nearly 30 billion yuan, with comprehensive strength ranking among the top in China. Official Website of Jiangsu Provincial Bureau of Statistics. https://tj.jiangsu.gov.cn/art/2025/9/15/art_87245_11640943.html

Open Access This chapter is licensed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (<http://creativecommons.org/licenses/by-nc/4.0/>), which permits any noncommercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.

