Development Economics of China
2025, VOL. 9, NO. 9, 27-30
DOI: 10.47297/wspdecWSP2515-797306.20250909

The Bottleneck Problem of Low-altitude Economy Enabling Logistics and Innovative Solutions

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ABSTRACT
The low-altitude economy is reshaping logistics as a transformative force in modern transportation. Emerging as a key trend in logistics innovation, it is revolutionizing traditional supply chain models. The deployment of low-altitude aircraft—particularly drones and electric vertical takeoff and landing (eVTOL) systems—has introduced more efficient and flexible delivery solutions. However, the sector faces critical challenges including immature aircraft technology, safety concerns, and inadequate airspace management. To overcome these obstacles, three strategic approaches are essential: advancing aircraft technology, optimizing airspace management systems, and strengthening infrastructure development with enhanced network coordination. Looking ahead, the integration of low-altitude economy and smart logistics, coupled with cross-industry resource sharing and policy innovations, will unlock broader opportunities for the logistics industry, driving comprehensive improvements in operational efficiency and service quality.

KEYWORDS
Low-altitude economy; Logistics; Aircraft technology; Airspace management

1 Introduction

As an emerging economic sector, the low-altitude economy has gradually become one of the key directions for global technological innovation in recent years, particularly demonstrating tremendous potential in the logistics industry. With technological advancements in low-altitude aircraft such as drones and electric vertical takeoff and landing (eVTOL) vehicles, the low-altitude economy is poised to break through traditional logistics limitations in urban congestion, delivery efficiency, and cost control, bringing revolutionary changes to the industry. The empowerment of logistics through low-altitude technology not only enhances delivery efficiency but also expands service coverage, especially showing significant advantages in air transportation for remote areas and urban regions. However, despite the numerous conveniences it brings, the low-altitude economy still faces challenges in practical applications, including aircraft technology, safety, airspace management, and infrastructure. This paper aims to analyze the bottlenecks in leveraging low-altitude technology for logistics and explore innovative solutions and technical pathways, providing insights and references for further development of the low-altitude economy in the logistics sector.

2 Current Situation and Challenges of Low-altitude Economy Enabling Logistics

2.1 The Impact of Low-altitude Economy on the Logistics Industry

The booming low-altitude economy is creating new opportunities for the logistics industry. By utilizing low-altitude aircraft, particularly drones, it enables efficient and cost-effective short-distance cargo delivery. Traditional logistics models often struggle with urban congestion and traffic bottlenecks, while low-altitude logistics offers a more flexible urban distribution solution that breaks through ground transportation constraints and completes urban delivery tasks swiftly [1]. Particularly in remote or underdeveloped areas, this economic model can effectively reduce transportation time and expand logistics coverage. Simultaneously, it provides digital and automated transformation opportunities for the logistics sector, leveraging technologies like smart flight systems and IoT integration to enhance operational precision and efficiency. However, the application of low-altitude economy in logistics still faces challenges in technology, policy, and infrastructure. Balancing innovation with risk management has become an urgent challenge for the industry to address.

2.2 Main Bottlenecks in the Current Logistics Industry

While the low-altitude economy has brought new opportunities to the logistics industry, its practical implementation still faces multiple bottlenecks. Technical specifications such as aircraft flight capabilities, payload capacity, and endurance remain insufficient to meet the demands of large-scale commercial applications. Inadequate regulations governing airspace management and flight permits in logistics distribution have restricted aircraft operations, thereby affecting delivery efficiency. Meanwhile, the integration between ground logistics and air logistics remains unresolved, with

effective coordination and resource consolidation still requiring thorough exploration. The lack of widespread infrastructure development—such as charging stations and aircraft maintenance facilities—has constrained the coverage capacity of delivery networks.

2.3 Technical and Managerial Barriers In Low-altitude Economic Applications

The low-altitude economy faces dual challenges in technological and managerial implementation. Technologically, aircraft innovation and support systems require breakthroughs. Most commercially available aircraft still lack sufficient payload capacity, flight range, and stability for large-scale commercial operations. Autonomous navigation and obstacle avoidance capabilities in complex environments need enhancement, particularly regarding flight safety in densely populated urban areas. Critical supporting technologies like aircraft systems and airspace management require urgent development. Management-wise, the rapid growth of low-altitude economy demands timely policy updates, as current airspace management frameworks inadequately meet the requirements of low-altitude aircraft. Outdated flight permit policies and airspace usage regulations hinder low-altitude logistics applications. Furthermore, establishing comprehensive standards and procedures for flight safety, logistics coordination, and other management aspects is essential to ensure sustainable development of the low-altitude economy.

3 Bottleneck Analysis of low-Altitude Economy Enabling Logistics

3.1 The Maturity and Safety of Aircraft Technology

The current maturity of aerial vehicle technology remains the primary bottleneck constraining the development of low-altitude economy. While drones and electric vertical takeoff and landing (eVTOL) systems have achieved significant technological advancements, existing aircraft still fall short of fully meeting commercial logistics demands in terms of stability, payload capacity, and endurance. Equally critical are the adaptability and safety of these vehicles in complex environments, particularly for urban high-density airspace operations where precise autonomous navigation and obstacle avoidance capabilities are essential. This necessitates enhanced hardware durability and stability, coupled with continuous software improvements [2]. Furthermore, maintenance, charging, and repair processes pose operational challenges that increase costs and hinder the widespread adoption of low-altitude logistics.

3.2 Space Management and Policy and Regulatory Restrictions

Low-altitude airspace management and regulatory frameworks remain key constraints for the low-altitude economy. China's low-altitude airspace management is still in its exploratory phase, with policies and regulations governing aircraft flight permits, airspace demarcation, and flight path planning yet to be fully established. Conflicts persist between aircraft operations and existing aviation management systems, while airspace sharing and coordination mechanisms remain underdeveloped. Given the pressure on airspace and high flight volumes, maintaining safe distances between low-altitude logistics aircraft and other aircraft, along with rational scheduling of low-altitude flights across different airspace zones, still requires advanced regulatory oversight and intelligent management technologies. Meanwhile, challenges in public acceptance and safety concerns for low-altitude aircraft have prompted cautious policy implementation. Therefore, striking a balance between safety and innovation will be crucial for the sustainable development of the low-altitude economy.

3.3 Insufficient Logistics and Distribution Network and Infrastructure Construction

The effective implementation of low-altitude logistics depends not only on advancements in aerial vehicle technology, but more crucially on robust infrastructure and distribution networks. While some pilot cities have achieved initial applications of low-altitude logistics, nationwide development of supporting facilities—including aircraft charging stations, maintenance points, and material storage/distribution centers—remains underdeveloped. Particularly in remote areas, inadequate infrastructure prevents smooth implementation of low-altitude logistics. The distribution network for low-altitude logistics remains incomplete, with unresolved challenges such as seamless integration of aerial flight and ground delivery, and coordination between air logistics and traditional ground logistics. Currently, the informatization management, data sharing, and logistics scheduling of low-altitude logistics still face significant challenges, failing to fully realize its potential.

4 Innovative Solutions and Technical Paths

4.1 Improve the Technology and Intelligence Level Of Aircraft

The low-altitude economy empowers logistics through technological breakthroughs in aerial vehicles and advancements in intelligent systems. Current aircraft performance faces limitations in payload capacity, endurance, and flight stability, all requiring urgent improvements. Enhancing design innovation and R&D to boost flight capabilities and adaptability can effectively address existing technical bottlenecks. Elevating intelligence levels remains crucial for developing autonomous navigation and obstacle avoidance systems in low-altitude logistics [3]. Integrating big data, AI, and machine learning significantly enhances automation, reducing human intervention and flight risks. After completing logistics missions, real-time monitoring and intelligent scheduling enable precise flight path planning, obstacle avoidance, and emergency response. This approach not only improves delivery efficiency but also significantly enhances flight safety and accident prevention. The utility model further enhances battery endurance and charging speed, resolving range limitations and infrastructure gaps, thereby promoting low-altitude logistics adoption. Clustered operations of aerial vehicles are also highly anticipated, representing a strategic direction to boost logistics efficiency, enable coordinated complex delivery tasks, and strengthen market competitiveness in this sector.

4.2 Building a Sound Airspace Management System and Policy Support

The development of the low-altitude economy requires a robust airspace management system and supporting policies. While high-altitude airspace regulations are primarily established by aircraft operating at higher altitudes, low-altitude aircraft face challenges such as airspace resource constraints and outdated policies. To better promote the low-altitude economy, it is essential to establish an airspace management system tailored to low-altitude flight requirements. First, clear demarcation and allocation of airspace usage rights for low-altitude aircraft must be implemented to prevent resource conflicts. Second, efforts should be accelerated in issuing flight permits, planning flight routes, and establishing safety management standards for low-altitude aircraft. Specialized airspace management agencies should be established to oversee low-altitude economic operations. Airspace management must prioritize both aircraft safety and coordination with ground transportation systems to ensure seamless integration between low-altitude logistics and ground logistics networks. Continuous policy refinement is equally crucial for the sustainable development of the low-altitude economy. Governments should introduce innovation-friendly policies, provide fiscal subsidies, or offer tax incentives to attract more capital into the low-altitude logistics sector.

4.3 Strengthening Logistics Infrastructure Construction and Network Coordination

The rapid development of low-altitude economy relies on comprehensive logistics infrastructure and efficient network coordination. From an infrastructure perspective, low-altitude logistics requires urgent deployment of supporting facilities such as charging stations, maintenance sites, and distribution centers to support large-scale aerial logistics distribution. Charging stations should cover major delivery areas to meet aircraft charging demands, while maintenance sites need to be established in critical zones to ensure operational safety and convenient maintenance. The construction of distribution centers and hubs is equally crucial, as they enhance logistics efficiency and flexibility while reducing delivery costs. Beyond aircraft-specific characteristics, low-altitude logistics demands deep integration between ground and aerial logistics. Traditional ground logistics networks play a vital role in low-altitude logistics applications, and seamlessly connecting aerial flight with ground delivery is key to improving logistics efficiency [4]. In this context, logistics enterprises need to build smarter delivery networks and utilize big data, IoT, and AI technologies to optimize logistics scheduling and resource allocation, thereby achieving coordinated air-ground operations.

4.4 The Future Development Prospect of Low-altitude Economy Enabling Logistics

4.4.1 Cross-Industry Coordinated Development and Resource Sharing

The future development of the low-altitude economy hinges on cross-industry collaboration and resource sharing. As low-altitude logistics spans aviation, telecommunications, transportation, logistics, and information technology, intersectoral cooperation becomes crucial. To ensure sustainable growth, industries must break down barriers and forge close partnerships. For instance, airlines can provide aircraft technical support, telecom companies can offer real-time data transmission and navigation services, while logistics firms can optimize delivery networks. Through resource sharing, all stakeholders can leverage each other's strengths to maximize efficiency. Beyond industry collaboration, government-enterprise cooperation is equally vital. Governments should provide robust support through policy guidance and financial incentives. It is anticipated that the low-altitude economy will evolve into an interconnected, mutually beneficial ecosystem, where collaborative efforts drive low-altitude logistics into broader market opportunities.

4.4.2 The Driving Role of Policy Innovation and Government Support

Policy innovation and government support will serve as the primary drivers for empowering logistics through the low-altitude economy. As this sector rapidly develops, governments must refine relevant policies and regulations to ensure the safe and standardized growth of low-altitude logistics. In terms of policy innovation, authorities should establish management frameworks compatible with low-altitude aircraft, while creating more flexible and innovative flight permit systems and airspace management policies to streamline operations. Concurrently, governments should enhance R&D support for low-altitude technologies, encourage corporate technological innovation, and provide financial incentives and tax breaks to stimulate investments in aircraft development, safety management, and infrastructure. Collaborative efforts with industry stakeholders to advance standardization, facilitate technology sharing, and promote knowledge exchange will help propel the low-altitude economy toward greater maturity.

4.4.3 The Integrated Development of Low-altitude Economy and Intelligent Logistics

The integration of low-altitude economy and smart logistics is creating new prospects for the future of the logistics industry. With the advancement of artificial intelligence, big data, and the Internet of Things, low-altitude economy has evolved beyond mere air cargo delivery to become an integral component of the entire logistics system. Low-altitude aircraft can deeply integrate with ground transportation, warehouse management systems, and distribution networks, enabling intelligent scheduling and automated operations to monitor and precisely manage logistics processes throughout the entire workflow [5]. This convergence will drive leapfrog development in logistics efficiency, reducing delivery times, lowering costs, and enhancing process visibility and transparency. By collecting and analyzing real-time data, the low-altitude economy can also predict logistics demands more accurately and optimize delivery routes, further improving overall efficiency. The deep integration of low-altitude economy and smart logistics will serve as the core driving force for the intelligent transformation of the logistics industry and the comprehensive upgrading of the logistics sector.

5 Conclusion

The low-altitude economy is revolutionizing the logistics sector, yet unlocking its full potential requires overcoming critical challenges. Technologically, aircraft payload capacity, endurance, and stability demand urgent upgrades, while intelligent technologies need further development. Management-wise, rational airspace allocation and robust regulatory frameworks are imperative. Key solutions include advancing aircraft technology, refining airspace management systems, strengthening infrastructure, and fostering industry collaboration. Through policy innovation and cross-sector resource sharing, the deep integration of low-altitude economy and smart logistics will propel the industry toward a more efficient and intelligent future. In summary, the low-altitude economy holds vast potential for logistics empowerment. With policy support and technological innovation, it should be accelerated to deliver smarter, more precise solutions for the global logistics industry.

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