Proceedings of the 3rd International Conference on Functional Materials and Civil Engineering
DOI: 10.54254/2755-2721/2025.21253

Low-altitude Transportation Reshapes the Future of Urban Travel: Multi-dimensional Integration and Exploration of Sustainable Development Paths

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Abstract: Low-altitude economy has prompted low-altitude transportation, a new public transportation mode, to bring new changes to citizens' daily travel. Low-altitude transportation has broad prospects. In low-altitude airspace, aircraft are used as vehicles to cover low-altitude flight activities such as manned and cargo. It has the advantages of alleviating ground traffic congestion and improving travel efficiency. The development of low-altitude transportation faces many challenges, such as inaccurate airspace resource management and lack of coordination in the life cycle of the entire industrial chain. Therefore, it is crucial to promote the reform of the management system of the entire civil aviation industry, accelerate the implementation of airspace classification management, improve service guarantee quality, and improve the service system for low-altitude flight activities. And with the help of big data analysis and artificial intelligence technology, optimize flight paths, improve flight efficiency, and reduce operating costs. Although facing many challenges, with policy support, technological innovation, and management optimization, low-altitude transportation is expected to be widely used and developed, injecting new vitality into the public transportation system. This article mainly discusses the integrated development of low-altitude transportation in the public transportation system, analyzes its definition, characteristics, application status and proposes optimization strategies for airspace management, technical bottlenecks, laws and regulations, and other restrictive factors. This article provides theoretical basis and practical reference for the future development of low-altitude transportation, promotes the healthy and sustainable development of low-altitude transportation, and brings changes to urban transportation.

Keywords: Low-altitude traffic, low-altitude economy, public transportation, travel efficiency, data algorithm.

1. Introduction

Low-altitude economy refers to economic activities carried out in low-altitude airspace below 2,000 meters above the ground using drones, light aircraft and other aircraft. This concept covers multiple fields such as cargo transportation, air travel, and air tourism, and is an important branch of the aviation industry. With the continuous opening of the global aviation field and the rapid development of science and technology, the low-altitude economy is gradually becoming a new economic growth

DOI: 10.54254/2755-2721/2025.21253

point. Among them, low-altitude transportation, as a core element supporting the development of the low-altitude economy, has shown great potential in daily public transportation . As an important part of the urban transportation system, public transportation undertakes the important task of alleviating traffic congestion and improving travel efficiency. However, traditional ground transportation methods can no longer meet the growing travel needs, especially in large cities, where traffic congestion, air pollution and other problems are becoming increasingly serious. Therefore, exploring new public transportation methods and improving travel efficiency have become important directions for the current development of urban transportation. Low-altitude transportation, with its fast, flexible and efficient characteristics, provides a new solution for daily public transportation.

This study focuses on the integration of low-altitude transportation and public transportation systems, aiming to clarify its definition, aircraft types and airspace scope; analyze its characteristics, such as efficiency, flexibility, environmental protection and safety; and examine the current status and prospects of applications, such as drone delivery, air taxis and low-altitude tourism. At the same time, it deeply explores the constraints such as airspace management, technical bottlenecks, laws and regulations, policies and safety issues; explores their roots and industrialization obstacles, and proposes optimization strategies. Combining big data and artificial intelligence, it proposes innovative viewpoints, such as intelligent scheduling, multimodal transport and green and low-carbon development, and provides theoretical and practical references for the development of low-altitude transportation with the help of market scale forecasting, technical analysis and policy interpretation. The research not only enriches the theory of transportation disciplines and provides new ideas for urban transportation planning, but also helps the industrialization of low-altitude transportation, promotes the development of emerging formats, creates economic growth points and optimizes the economic structure.

2. The Connotation and Characteristics of Low-altitude Traffic

Low-altitude traffic refers to transportation activities carried out by various aircraft in airspace below 1,000 meters true altitude. This field covers many types of aircraft, including but not limited to fixed-wing aircraft, helicopters, drones, etc., which are used for various flight activities such as commercial, military, and rescue. First of all, its efficiency is particularly outstanding. It can cleverly avoid the congestion bottleneck of ground transportation, achieve fast and direct access from point to point, and greatly improve travel efficiency. It widely uses clean energy, such as electricity or solar energy to avoid the pollution and exhaust emissions caused by traditional fuel transportation, and has minimal impact on the environment. At the same time, the noise generated by low-altitude transportation is relatively small and will not cause interference or trouble to the daily life of urban residents. It can be called a model of green travel. Finally, safety is another important guarantee for low-altitude traffic. Advanced autonomous driving technology is widely used in it, which effectively avoids errors and negligence that may be caused by human operations and significantly improves operational safety.

3. Application of Low-altitude Traffic in Public Transportation

3.1. Drone Delivery

An important application of low-altitude transportation in public transportation is the deployment of drones. It can solve logistics problems in remote areas, improve distribution efficiency, and carry out logistics distribution through drones. Taking JD.com, SF Express and other companies as examples, they have begun to deploy drone delivery in the express delivery of remote areas such as rural and mountainous areas, and have successfully applied them in express delivery. Drone delivery provides

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a new solution for logistics distribution, with the advantages of fast speed, low cost and high flexibility.

3.2. Air Taxi

Air taxis are another innovative application of low-altitude transportation in the field of public transportation. The relief of urban ground traffic pressure and the improvement of travel efficiency can be achieved through air taxis. At present, many companies around the world are conducting research and development of air taxis, such as Volvo in Germany and Jobs in the United States. These companies are committed to developing safe, efficient and environmentally friendly air taxis that meet the needs of urban travel. The advent of air taxis will provide a more convenient and fast choice for people to travel.

3.3. Low-altitude Tourism

Low-altitude tourism is the application of low-altitude transportation in the tourism field. Aerial sightseeing through low-altitude aircraft allows people to overlook the beautiful scenery of the city and enjoy a unique tourism experience. Low-altitude tourism has the advantages of broad vision, unique experience and high safety, and has become a new hot spot in the tourism market.

4. Challenges and Countermeasures Faced by the Development of Low-altitude Transportation

4.1. Challenges

The development of low-altitude transportation faces many challenges, among which the problem of airspace management is particularly prominent. China's airspace resources are relatively tight, and the flight airspace of low-altitude aircraft is subject to many restrictions, which to a large extent restricts the rapid development of the low-altitude economic industry. On the one hand, limited airspace resources make it difficult to flexibly arrange the flight plans of low-altitude aircraft, increasing the difficulty and time cost of flight approval; on the other hand, the tense situation in the airspace has also led to an increase in the risk of potential conflicts between aircraft, requiring more refined airspace management and coordination mechanisms to ensure flight safety. In addition, technical bottlenecks are also a major obstacle to the development of low-altitude transportation. At present, low-altitude aircraft still have certain technical difficulties in terms of endurance, load-bearing capacity, and safety. Insufficient endurance limits the operating range and duration of the aircraft, affecting its application in long-distance transportation and long-time operation scenarios; limited load-bearing capacity limits the amount of cargo or the number of passengers transported in a single trip, reducing transportation efficiency and economic benefits; safety issues are even more related to the survival of low-altitude transportation.

In terms of laws and regulations, China's laws and regulations for the low-altitude economy are not yet sound, and the guidance and support for the development of the industry are obviously insufficient. The existing laws and regulations still have many gaps or ambiguities in the airworthiness standards, airspace use management, and operation qualification approval of low-altitude aircraft, which leads to many policy risks and uncertainties faced by enterprises when conducting low-altitude transportation business. For example, the management regulations for key elements such as the flight altitude, flight area, and flight time of low-altitude aircraft are not clear enough, which makes enterprises at a loss when planning flight routes and operation plans; at the same time, the lack of special support policies for the low-altitude transportation industry, such as tax incentives, financial subsidies, and scientific research investment, is not conducive to stimulating the

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innovation vitality and investment enthusiasm of enterprises, and slowing down the development of the low-altitude economic industry. Safety issues are an important link that cannot be ignored in the development of low-altitude transportation. During the operation of low-altitude aircraft, there are certain safety hazards due to their complex flight environment, high flight speed, and low flight altitude. Therefore, strengthening the safety management of low-altitude aircraft, establishing a sound safety supervision system, and improving the safety performance and reliability of aircraft are the keys to ensuring the healthy development of the low-altitude economy.

4.2. Coping Strategies

In order to promote the healthy development of low-altitude transportation, it is necessary to solve the current challenges from multiple aspects. First, in terms of airspace management, it is necessary to scientifically and rationally plan airspace resources and break the existing bottleneck of airspace restrictions. Simplify the flight approval process of low-altitude aircraft and reduce unnecessary cumbersome procedures, so as to increase the freedom of flight and enable low-altitude aircraft to perform flight operations more flexibly. At the same time, establish a refined low-altitude public route to provide a clear flight channel for low-altitude aircraft and ensure the safety and order of flight. Secondly, technology research and development investment is the key driving force for the development of low-altitude transportation. We must concentrate the efforts on breaking through the key technical difficulties of low-altitude aircraft, improve product performance and reduce costs through technological innovation, and then promote the innovative development of the entire industry. In the core technology fields of unmanned driving technology, air traffic management systems, communication and data processing, we should continue to increase research and development investment, enhance the core competitiveness of the industry, and lay a solid technical foundation for the long-term development of low-altitude transportation. In addition, a sound legal and policy system is a strong guarantee for the healthy development of the low-altitude economy. We should speed up the establishment of a complete set of laws and policies related to the low-altitude economy, clarify the regulatory framework of low-altitude transportation, standardize the market order, and provide clear guidance and support for the healthy development of the industry [1]. This will not only help guide enterprises to operate in compliance, but also effectively prevent market risks and promote the healthy development of the low-altitude transportation industry. Finally, safety management is the lifeline of the development of low-altitude transportation. We must attach great importance to the operational safety of low-altitude aircraft, establish a sound safety supervision system, strengthen the maintenance and overhaul of aircraft, and ensure that every aircraft is in good operating condition [2]. Through strict safety management measures, we can prevent and resolve various safety hazards, provide solid guarantees for the stable operation of low-altitude transportation, and allow the public to safely choose low-altitude transportation as a means of travel.

5. Cutting-edge Perspectives and Data Support for Low-altitude Transportation Development

5.1. Cutting-edge Perspectives

In the development of low-altitude transportation, intelligent dispatching based on data algorithms is playing a crucial role. By using cutting-edge technologies such as big data and artificial intelligence, the intelligent dispatching system for low-altitude transportation can accurately adjust the allocation of key resources such as routes and take-off and landing points in real time. This process relies on in-depth analysis of massive data such as traffic flow and aircraft status to achieve efficient planning and optimization of flight missions, significantly improve travel efficiency, ensure the smooth

DOI: 10.54254/2755-2721/2025.21253

operation of low-altitude traffic, and provide passengers with more punctual and convenient transportation. Travel services.

At the same time, the seamless connection of multimodal transport has become an important trend in the development of low-altitude transportation. This requires the promotion of the deep integration of low-altitude transportation with various traditional transportation modes such as ground transportation and rail transportation, and the construction of a diversified, coordinated and efficient transportation network. Through the construction of comprehensive transportation hubs, convenient transfers between different transportation modes can be achieved. Passengers can flexibly choose the most suitable transportation combination according to their travel needs. Whether they want to quickly reach remote areas from the city center or travel efficiently between different cities, they can enjoy the travel convenience brought by seamless connection [3]. This has greatly expanded people's travel options and improved the operating efficiency and service quality of the entire transportation system.

In addition, green, low-carbon and sustainable development is one of the core concepts for the future development of low-altitude transportation. In order to reduce the negative impact on the environment, the low-altitude transportation industry is actively taking a series of measures to achieve the goal of green and low-carbon development. This includes the widespread use of clean energy, such as electricity and solar energy, to replace traditional fuel power, thereby reducing carbon emissions; at the same time, through technological innovation, improving energy efficiency, reducing energy consumption, and further reducing pressure on the environment. These measures not only help protect the ecological environment, but also conform to the general trend of global sustainable development [4], enabling low-altitude transportation to occupy a more advantageous position in future market competition, providing people with more environmentally friendly and sustainable travel options, and promoting the entire society to develop towards a green and low-carbon future.

5.2. Data Support

The low-altitude transportation market has shown great development potential. According to market research institutions, by 2030, the global low-altitude transportation market is expected to reach hundreds of billions of dollars. This huge market prospect is impressive. Among them, drone delivery and air taxis will become the main driving force for market growth, showing a market potential that cannot be underestimated. Drone delivery, with its fast and flexible characteristics, can effectively solve the "last mile" problem in logistics distribution, improve delivery efficiency, and reduce logistics costs [5]; while air taxis are expected to provide a new solution to urban traffic congestion problems and provide people with more convenient and efficient travel options.

The continuous advancement of technology provides solid support for the development of low-altitude transportation. Technologies such as drones and air taxis have made significant progress in recent years. Taking drones as an example, a number of drone products have been commercialized. Their performance indicators, such as endurance and load capacity, have been continuously improved, and they can meet the needs of use in more scenarios. At the same time, the research and development of air taxis is also accelerating, and major companies have increased investment and are committed to overcoming key technical problems and improving the safety, comfort and economy of aircraft. It is expected that in the next few years, air taxis will achieve commercial operation, which will mark a new stage of development of low-altitude transportation and bring more diverse choices for people's travel.

Policy support has injected strong impetus into the development of low-altitude transportation. The Chinese government attaches great importance to the development of the low-altitude economy and has issued a series of policy documents to promote the application and development of low-altitude transportation and other fields. These policy documents cover a number of aspects, including

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simplifying flight approval procedures, expanding the opening of low-altitude airspace, and encouraging social capital investment, providing strong policy guarantees for the development of low-altitude transportation. Simplifying flight approval procedures will reduce the operating costs and time costs of enterprises and improve the efficiency of aircraft use; expanding the opening of low-altitude airspace will provide a broader development space for low-altitude aircraft and promote the prosperity of the low-altitude economy [6]; encouraging social capital investment will attract more funds and resources to the low-altitude transportation field and accelerate technological innovation and industrial upgrading [7].

6. Case Analysis

6.1. German Volokopt Air Taxi Project

Volocopter of Germany is a company that focuses on the development of air taxis. The VOLOCOPTER air taxi developed by the company uses zero-emission, low-noise, and high-efficiency electric vertical take-off and landing technology. Volocopter air taxis have been tested and tested in many cities and are expected to be put into commercial operation in the next few years [8]. The successful implementation of this project will provide a new solution for urban travel to ease ground traffic pressure and improve travel efficiency.

6.2. China Fengfei Aviation's eVTOL Aircraft Project

China Fengfei Aviation Company successfully finished the first flight of the world's first electric vertical take-off and landing aircraft cross-sea and cross-city air route (Shenzhen-Zhuhai). The way originally took 2.5-3 hours on the ground, it presently only takes 20 minutes in the air, considerably increasing travel efficiency [8]. The great execution of this project illustrates China’s inventive features in the area of low-altitude transportation with a technological level of use. At the same time, it also gives economical services for urban agglomerations and cities, aided to reduce land traffic jams.

6.3. Low-altitude Traffic Applications in Alaska, USA

Alaska is one of the states with the most developed general aviation in the United States. Due to the inconvenience of road, rail, and water transportation and the high construction costs, low-altitude transportation has become the main mode of public transportation in the region. The number of people taking general aviation commercial flights each year is several times the total population of the state [9]. Alaska’s successful experience shows that in areas with inconvenient ground transportation, low-altitude transportation can be used as an effective mode of transportation to meet people’s travel needs.

7. Conclusion

Low-altitude transportation, as an innovative model, has been integrated into the public transportation system, causing a huge change in daily travel. Its high efficiency, flexibility and environmental protection have great potential in improving travel efficiency, alleviating traffic congestion and promoting economic development [10].

In the field of low-altitude transportation, technological innovation is an inexhaustible driving force for development. We need to achieve a surge in the performance of new aircraft such as drones and air taxis, reduce costs, continuously expand the application boundaries, and integrate with cutting-edge technology fields such as big data and artificial intelligence, so that the intelligent dispatching system can improve operational efficiency and management level, laying a solid foundation for sustainable development.

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The perfection of policies and regulations is the key pillar for the steady development of low-altitude transportation. In the future, a complete legal and policy system will ensure the sustainable development of the escort industry and guide low-altitude transportation towards a new journey of standardization and order.

Multimodal movement and seamless communication include the two aspects of the increase in urban transportation efficiency: the reduction of low-level transportation and the acceleration of the use of a heterogeneous . The development of comprehensive transportation hubs has made the transportation system convenient for people to travel, so that they can have more travel decisions and also improve the comprehensive transportation service efficiency and realize the needs of the transportation demand of people's needs.

There has been increasing firmization of green concept practice in the environmental protection wave, which will help to achieve the goal of improving the economy by improving energy efficiency as well as the ability of green energy application and energy efficiency to reduce carbon emissions.

With the advancement of technology and support of policies, low-altitude transportation will reshape the urban transportation landscape, provide people with a more convenient, efficient and environmentally friendly travel experience, and usher in a new era of comfortable and fast travel.

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