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UAV Low-altitude Logistics Operation Mode and Deep Integration of Industry and Education from the Perspective of New Quality Productive Forces

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Abstract: Low-altitude economy is a representative of new quality productive forces, and UAV low-altitude logistics is an important field for developing low-altitude economy. Exploring the operational mode of UAV low-altitude logistics from the perspective of new quality productive forces, exploring the multi domain application scenarios of UAV logistics and the deep integration of industry and education, has important theoretical significance and practical guidance value. Firstly, the significant advantages of UAV low-altitude logistics were analyzed, and then its operation mode was discussed. The multi domain application scenarios of UAV logistics were analyzed, and the application trends and prospects of UAV low-altitude logistics were discussed. On this basis, specific strategies and implementation suggestions for the deep integration of industry and education have been proposed from multiple aspects, providing strong support for the sustainable development of the low-altitude logistics industry.

Keywords: New Quality Productive Forces; UAV; Low-altitude Logistics; Operation Mode; Deep Integration of Industry and Education

1. Introduction

The "new" and "quality" in the new quality productive forces are closely related to technological innovation represented by strategic emerging industries and future industries. The core essence of new quality productive forces is to integrate technological innovation resources, lead the construction of a modern industrial system, create strategic emerging industries such as low-altitude economy, commercial aerospace, advanced manufacturing, etc., thereby opening up new fields and tracks for development, shaping new driving forces and advantages for development. Among them, as a representative of new quality productive forces, low-altitude economy has become a new track for development, and UAV (unmanned aerial vehicle) low-altitude logistics is an important field for low-altitude economy.

In March 2024, the Civil Aviation Administration of China and four other departments jointly issued the "Implementation Plan for Innovative Applications of General Aviation Equipment (2024-2030)", which covers important fields such as logistics, transportation, and aviation. The "Plan" is of great significance for the challenges, opportunities, and development prospects of low-altitude flight applications in the future.

2. An Important Field of Typical Representative of New Quality Productive Forces: Low-altitude Logistics

Low-altitude economy is a typical strategic emerging industry with a long industrial chain and rich application scenarios. From the perspective of the industry chain, the low-altitude economy covers various industries such as aircraft research and development, low-altitude flight infrastructure construction and operation, and flight service support; From the perspective of application scenarios, the low-altitude economy includes both traditional general aviation formats and the integration of low-altitude production and service modes supported by UAVs. It has been widely used in industries such as industry, agriculture, and services, and plays an important role in building a modern industrial system, with extremely broad development space.

According to the "Research Report on the Development of China's Low-altitude Economy (2024)", the scale of China's low-altitude economy has reached 505.95 billion yuan in 2023, with a growth rate of 33.8%. It is expected that by 2026, the scale of low-altitude economy is expected to exceed one trillion yuan. From this, it can be seen that the low-altitude economy is a strategic emerging industry with broad prospects and a typical representative of new quality productive forces. [1]

Low-altitude economy empowers new quality productive forces, and UAV low-altitude logistics is an important field for the development of low-altitude economy, which will become an important engine for the growth of logistics economy. Actively and steadily promoting the development of low-altitude logistics is of great significance for cultivating strategic emerging industries and empowering the development of new quality productive forces. This study explores the operational mode of UAV low-altitude logistics from the perspective of new quality productive forces, providing theoretical references for enriching and improving the relevant theoretical system in China's low-altitude logistics field; On the other hand, exploring the application prospects of UAV logistics in the low-altitude economy field has practical guidance value for relevant enterprises and policy departments.

3. Current Research Status of UAV Logistics

UAV logistics has unique advantages in distribution and transportation, and more and more researchers are actively exploring the technology and applications of UAV logistics. Relevant research literature has been increasing in recent years.

Zhou [2], Xu and Li [3] conducted research on long-distance UAV logistics transportation. Overall, due to the limitations of UAV transportation capacity and incomplete management system, the technical research and application research on large load and long-distance branch line UAV transportation are still in the early exploration stage. Gu [4], Zhang et al. [5], Ghelichi et al [6], Dukkancl et al [7], Park et al. [8], Leon et al. [9] have conducted research on UAV logistics operation management. Overall, research on UAV delivery management is not comprehensive or systematic, but the importance of studying the quality and level of UAV delivery services is evident. Pan et al. [10], Lu et al. [11], Ruan et al. [12], Li et al. [13] conducted research on UAV warehouse management. At present, there is still a lack of practical technical methods for UAV warehouse management, and the modeling and positioning of warehouses need further research. There are still many limitations to the method of quickly calculating the volume of bulk materials based on UAVs. Ren et al. [14], Dorling et al. [15], Zhang et al. [16], Han and Zhang [17], Xu et al. [18], Arafat and Moh [19], Gonzalez-r et al. [20], Zhang et al. [21], Yi et al. [22] have conducted research on the design of UAV logistics networks. However, there is still limited literature on this topic, and in the future, it is necessary to combine it with the characteristics of UAV logistics to comprehensively optimize other transportation modes.

In summary, due to the broad development prospects of UAV logistics, the research and practical activities of UAV logistics technology development and application have become increasingly active in recent years, with an increasing number of research literature. However, in terms of the maturity of the UAV logistics system, research on UAV logistics is still in its early stages of development.

4. Significant Advantages of UAV Low-altitude Logistics

The application cases of UAVs in the field of low-altitude logistics are rich and diverse, covering UAVs, logistics distribution, low-altitude freight, and low-altitude logistics monitoring and management. With the continuous development of technology and the gradual improvement of policies, the application of low-altitude logistics in related fields will become more extensive, bringing new opportunities and development space to the logistics industry.

Low-altitude logistics based on UAV applications has significant advantages. UAVs can fly quickly, shorten delivery time, and improve logistics operation efficiency. UAV delivery does not require a large amount of manpower or transportation vehicles. Low-altitude cargo aircraft are suitable for

short distance and high-frequency cargo transportation, such as express delivery between cities, e-commerce cargo distribution, etc. This type of aircraft has the advantages of fast takeoff and landing speed, low noise, and low fuel consumption, which helps to improve the transportation efficiency of low-altitude logistics and reduce operating costs. UAVs can avoid congested roads, achieve straight-line flight, and improve the reliability of delivery. In the field of medical rescue, UAVs also play an important role. UAVs can transmit real-time medical data of the rescued person back to medical institutions, allowing doctors to understand the patient's condition at the first time and provide strong support for rescue.

In addition, UAVs can quickly deliver urgently needed supplies such as medical equipment and drugs to the rescue site, improving rescue efficiency. Logistics is the most widely used scenario for commercial applications of low-altitude economy. Enterprises in the logistics and aviation field have been laying out low-altitude economy for more than a decade and have achieved certain results. Expand the diverse scenarios of low-altitude applications, establish a low-altitude logistics service system, continuously explore the applicable scenarios of low-altitude products and services, promote UAV mainline logistics distribution, expand hub express transportation, half day delivery of fresh food, and explore potential application scenarios in the middle end of logistics. Carry out low-altitude transfer between primary and secondary logistics warehouses in the city to achieve delivery within 2 hours for express delivery within the city. Explore new business models for intercity connecting air traffic scenarios, promote the application of UAVs for delivery in rural and mountainous areas, and promote the integration of emerging aircraft applications into transportation scenarios. [23]

5. Operation Mode of UAV Low-altitude Logistics

5.1 Low-altitude UAV Logistics Distribution Mode for Cities

(1) UAV three-level logistics distribution network. In order to promote the landing of low-altitude logistics projects and advance the innovative development of low-altitude economy, more and more cities are actively developing UAV logistics, supporting contactless transaction services, and committed to building a three-level logistics distribution network based on unmanned systems that covers the entire city, including "hub-grid-terminal". To this end, relevant departments and logistics enterprises with experience in grid point and hub point planning are building a "end-to-end integrated" urban new logistics infrastructure network to further strengthen the inherent relationship between the logistics distribution system and urban living space. Through UAV intermodal transportation, the number of intermediate loops and transportation time are reduced, and logistics and express delivery efficiency are improved.

Build a three-level logistics distribution network for urban UAVs. Targeting cities, building a three-level logistics distribution network based on UAV applications, consisting of regional logistics hubs, community level grid points, and consumer terminals, to enhance the efficiency and quality of logistics services for urban residents. At the same time, based on UAV logistics network and logistics infrastructure, urban comprehensive distribution centers will be established around logistics hubs, such as e-commerce new retail, cold chain fresh food, central kitchen, pharmaceutical testing and other distribution centers, to serve people's daily lives. On the one hand, UAV logistics can generate billions of direct economic benefits, and on the other hand, it can drive innovation in other business models, achieving greater economic and social benefits.

(2) Design of UAV transportation scheme. A solution for air transportation technology based on UAV applications, including route planning, application approval, construction of takeoff and landing point engineering, route survey and pilot operation, deployment of ground personnel, and related training. Through UAV intermodal transportation, a low-altitude UAV logistics transportation network is established to reduce transit links and transportation time, optimize flight branch line planning, and improve urban logistics distribution efficiency.

Firstly, optimize the UAV operation route. Based on the airport airspace management regulations and the actual operating conditions of UAVs, the project team focuses on planning

and optimizing UAV transportation routes between remote network points and sorting and distribution points, improving the routes between distribution points and hubs, and enhancing the delivery efficiency of the area and the overall.

Secondly, enhance the configuration of UAVs and landing sites. The entire project will deploy a reasonable number of UAVs, with a maximum transport capacity of 100-120kg per UAV per day, and will use supporting take-off and landing platforms.

Thirdly, improve the management of supporting facilities. The UAV control center is equipped with a captain's operating room, and each takeoff and landing site and transit site is equipped with an equipment storage room for ground personnel's daily operations. It also has the functions of material storage, battery storage, and charging. At the same time, it is equipped with fire-fighting equipment and takeoff and landing site monitoring systems. The fire-fighting regulations, relevant operating norms, safety management systems, and other contents are hung prominently on the wall.

Fourthly, clarify the service targets and objectives. At present, the service mainly targets traditional logistics operators, instant delivery operators, ordinary end customers, and consumers. The service objectives mainly include: firstly, high-frequency transportation, determining the UAV flight frequency based on the daily transportation task volume, route conditions, and airspace conditions; The second is high timeliness, with the overall lifecycle of express delivery extended to within 2 hours; Thirdly, it has high flexibility and can respond to service needs at any time. Once there is an urgent need, it can take off within 3 minutes; The fourth is full monitoring. The operation control system comprehensively manages the five elements of UAVs, airspace, stations, personnel, and business to achieve full process monitoring of UAV flight tasks. The fifth is significant demonstration. Through the UAV logistics acceleration demonstration project, the operation mode will be quickly replicated from cities to other counties, towns and other places with conditions, and efforts will be made to achieve normalized operation and the current annual flight service target of 15000 to 20000 flights.

5.2 Multi Domain Application Scenarios of UAV Logistics

(1) Lifting and hoisting in special environments. UAV lifting and hoisting is a highlight of low-altitude economy and will become a standard configuration in the future logistics field. UAV lifting and hoisting will play an important role in alleviating urban traffic congestion and transporting emergency supplies. UAV lifting not only breaks the spatial limitations of traditional logistics transportation, but also achieves a qualitative leap in efficiency and safety. It transforms logistics transportation from traditional ground transportation mode to low-altitude rapid transportation. Whether it is the transportation of goods in the city or the urgent transportation of materials in special environments, UAV lifting and hoisting can be competent and become a powerful assistant in the era of low-altitude economy.

(2) Traffic monitoring. UAVs monitor traffic conditions in real-time over the road, transmitting video data back to the command center to help understand road conditions and achieve remote command and dispatch. During peak hours or major events, UAVs can provide real-time traffic flow information to help optimize traffic plans.

(3) Public safety. UAVs play a more important role in law enforcement in the field of public safety, such as monitoring and investigation, search and rescue, traffic management command, rapid deployment of emergency events, monitoring and patrolling border lines, providing evidence from a top-down perspective, monitoring network attacks and abnormal behavior, assisting in network security defense, counter-terrorism and security, ecological environment protection, natural resource protection, etc.

(4) Infrastructure maintenance. The application of UAVs can achieve rapid detection, analysis, efficient communication, remote inspection, image recognition, autonomous navigation, hovering function, relay transmission, fault finding and mapping application, flow velocity measurement, and engineering line installation of infrastructure, which helps to reduce costs and increase efficiency of infrastructure.

(5) Mountain transportation operations. UAVs with complete autonomous flight capabilities are suitable for mountain transportation operations. For example, the UAV of

Huaxiang General Motors is equipped with domestic aviation engines, adopts modular design, foldable rotor, high field deployment efficiency, maximum takeoff weight of 650 kilograms, maximum flight height of 6500 meters, maximum flight speed of 150 kilometers per hour, and control distance of ≥ 100 kilometers. This type of UAV has strong autonomous flight capabilities and can fully leverage its advantages in mountain transportation operations.

(6) Power grid infrastructure. The SG-400 helicopter used in power grid engineering utilizes reverse torque without tail rotor and longitudinal twin rotors, making it more suitable for complex terrain environments. It uses long rope slings to lift materials and tools, increasing efficiency by more than three times compared to traditional lifting methods.

6. Application Prospects of UAVs in Low-altitude Logistics from the Perspective of New Quality Productive Forces

6.1 Continuously Providing Development Momentum for Low-altitude Economy

It is expected that in the coming years, with the development of relevant policies and technologies, the low-altitude economy will make significant progress and achieve normalized operation. Looking ahead to the future, low-altitude logistics will provide new quality productive forces for the high-quality development of related industries. The technology, products, and industrial development prospects are broad and promising.

6.2 Profoundly Changing Traditional Logistics Models

Develop new business models and normalize UAV delivery. With the advancement of technology, the UAV delivery model will become more mature, enabling normalized operation and reducing traffic congestion and environmental pollution. With the development of electric vehicle technology and the improvement of battery energy density, electric vertical takeoff and landing vehicles (eVTOLs) have gradually become a reality. By constructing a low-altitude 3D digital airspace geographic information system, the position and status of aircraft can be monitored in real time, route planning can be optimized, and flight safety and logistics efficiency can be improved.

6.3 Exploring More Innovative Application Scenarios

Establishing a low-altitude cargo network with general aviation as its core can supplement or even replace some traditional land freight, especially in time sensitive cargo transportation, where low-altitude cargo demonstrates unparalleled advantages. With the further development of low-altitude economy, general aviation will integrate more with other fields such as agriculture, tourism, urban management, etc., and explore more innovative application scenarios. The relevant regulations and standard system will gradually improve, providing a clearer and more standardized operating environment for low-altitude logistics.

7. Deep Integration of Industry and Education in the Field of Low-altitude Logistics

With the vigorous development of low-altitude logistics industry, the deep integration of industry and education has become an important way to promote the sustainable development of the industry. This study proposes specific strategies and implementation suggestions from the aspects of base construction, long-term mechanism, structural adjustment, training mode, and achievement transformation, aiming to promote the innovative development of low-altitude logistics by deepening the integration of industry and education.

7.1 Building a Low-Altitude Logistics Industry-education Integration Base with Creating an Industrial Talent Highland

Low-altitude logistics, as an emerging industry, has broad development prospects and enormous market potential. However, its rapid development also faces problems such as talent shortage and insufficient technological innovation. The integration of industry and education, as an effective educational model, provides strong talent guarantee and technical support for low-altitude logistics by integrating educational resources with market demand. Therefore, strengthening the integration of industry and education and promoting the development of low-altitude

logistics are of great significance.

Universities and low-altitude logistics enterprises jointly establish a production education integration training base to provide students with real practical scenarios and equipment. Develop standards for the use and management of training bases to ensure their effective utilization. Carry out joint training programs between schools and enterprises, such as "modern apprenticeship system" and "order-based training". Develop implementation plans and evaluation criteria for joint training projects to ensure effective improvement in training quality. Establish a mechanism for sharing the achievements of school enterprise cooperation, such as jointly applying for patents and publishing papers, encouraging teachers, students, and technical personnel from enterprises to participate together and promote the widespread application of scientific and technological achievements.

7.2 Establishing a Long-Term Mechanism for Cooperation between Low-Altitude Logistics Enterprises and Promote the Integration of Industry, Academia, Research and Application

Establish stable school enterprise cooperation relationships between universities and low-altitude logistics enterprises, sign long-term strategic cooperation agreements, clarify the cooperation period, goals, rights and obligations of both parties, and ensure the long-term effectiveness of cooperation. Establish a school enterprise cooperation office or liaison mechanism to ensure timely and effective communication between both parties. Joint research and development of innovative projects, with both schools and enterprises jointly establishing research and development projects focusing on core technologies, key applications, and other areas of low-altitude logistics. Invest special funds and human resources to promote project research and implementation, ensuring the transformation and application of results. Build a technology exchange platform, establish online and offline technology exchange platforms, such as regularly holding technical seminars, exchange meetings, etc. Encourage teachers, students, and technical personnel from enterprises to actively participate and promote the sharing of technology, information, and resources.

7.3 Dynamically Adjusting Education and Industrial Structure, Creating Low Altitude Logistics Application Scenarios

Pay close attention to the development trend of the industry: Universities and research institutions closely monitor the development trend and market demand of the low-altitude logistics industry. Timely adjust the direction of education and research priorities to ensure effective alignment between educational content and market demand. Jointly creating low-altitude application scenarios: Both schools and enterprises jointly plan and implement the creation of low-altitude application scenarios. Design innovative and practical application scenarios based on actual needs and market demands. Utilize the research advantages of universities and the market experience of enterprises to jointly promote the research and application of low-altitude application scenarios. Strengthening vocational skills training: In response to the characteristics and needs of the low-altitude logistics industry, strengthen vocational skills training. Offering relevant vocational training courses and certificate exams to improve the skill level and comprehensive quality of industrial workers. Promote industrial transformation and upgrading: Promote the transformation and upgrading of low-altitude logistics industry through the integration of industry and education. Encourage enterprises to adopt new technologies, processes, and materials to enhance the competitiveness and sustainable development capabilities of the industry.

7.4 Promoting the Transformation of Scientific Research Achievements with Driving Innovation in Low-altitude Logistics Technology

Establish a sound mechanism for the transformation of scientific and technological achievements, set up specialized departments or teams for the transformation of scientific and technological achievements, and be responsible for the evaluation, transformation, and promotion of scientific and technological achievements. Establish processes and standards for the transformation of scientific and technological achievements to ensure their efficiency and standardization. Establish a

science and technology achievement transformation fund to provide financial support for the transformation of scientific and technological achievements. Encourage enterprises, social capital, and other entities to participate in the establishment and operation of funds. Protect intellectual property rights, strengthen the promotion and training of intellectual property rights, and enhance the awareness of intellectual property rights among teachers and students. Improve the mechanism for safeguarding intellectual property rights and ensure effective protection of the legitimate rights and interests of scientific and technological achievements.

7.5 Optimizing the Low-altitude Logistics Talent Training Mode and Improve the Quality of Training

Dynamically adjust the professional settings and course content, and adjust the professional settings and course content of universities according to the development trend and market demand of the low-altitude logistics industry. Add professional directions related to low-altitude logistics, such as UAV technology, aviation management, etc. Strengthen the practical teaching process and increase the proportion of practical teaching in the curriculum system, such as experiments, practical training, internships, etc. Building practical training bases through school enterprise cooperation, providing students with practical opportunities in real-life scenarios. Accelerate the cultivation of interdisciplinary talents and encourage cross disciplinary training, such as the integration of computer science, mechanical engineering, aviation management and other majors. Offering interdisciplinary courses to cultivate students' comprehensive qualities and innovative abilities.

8. Conclusion

Under the background of new quality productive forces, it is a long-term and arduous task to promote the deep integration of industry and education, and to promote the development of UAV low-altitude logistics. Low-altitude economy is an important focus to accelerate the formation and improvement of new quality productive forces, and low-altitude logistics is one of the core areas of low-altitude. The low-altitude logistics based on UAV application has significant advantages. Building a three-level logistics distribution network of "hub-grid-terminal" and improving the design of UAV transportation schemes can increase logistics transportation frequency, improve logistics efficiency, achieve full process monitoring, and have significant demonstrative significance. Through exploring applications in multiple fields and scenarios, low-altitude logistics can provide sustainable development momentum for the low-altitude, profoundly change traditional logistics models, and explore more innovative application scenarios. On this basis, deep integration of industry and education will be carried out from multiple dimensions around the field of low-altitude logistics, improve the effectiveness of industry education integration through base construction, long-term mechanisms, structural adjustments, training mode, and results transformation, and provide strong support for the healthy and sustainable development of low-altitude logistics industry.

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