Research on the Construction and Evolution Path of the Low-Altitude Economy Industrial Ecosystem Driven by Data Elements

Gongsheng Gang*
Baise University, Baise, Guangxi, China
**Corresponding Author*

Abstract: Against the backdrop of the accelerating development of the digital economy, data, as a new type of production factor, is reshaping industrial structures. As a strategic emerging industry, the low-altitude economy focuses on the operation of aircraft within intelligent networks and relies on massive, multidimensional, and real-time data to build its industrial ecosystem. From a data-driven perspective, this paper proposes a trinity system composed of data infrastructure, platform hubs, and application scenarios, emphasizing the critical role of the "data flywheel" effect in the self-reinforcement and expansion of the ecosystem. A three-stage evolutionary path model—emerging exploration, growth integration, and mature symbiosis—is constructed. The study concludes that data serves as the core driving force and evolutionary engine of the low-altitude economy ecosystem, contributing to a deeper understanding of the interactive mechanisms between data elements and industrial ecosystems, and providing references for enterprises in formulating data strategies and ecological niche strategies.

Keywords: Data Elements; Low-Altitude Economy; Industrial Ecosystem; Data Flywheel; Digital Economy

1. Introduction

With the accelerating development of the digital economy, data has emerged as the fifth major production factor following land, labor, capital, and technology. Its factorization and assetization processes are reshaping industrial development paradigms [1]. As a strategic emerging industry, the low-altitude economy centers on the intelligent network operation of aircraft such as drones and eVTOLs, leveraging massive, multidimensional, and real-time data to empower scenarios like smart logistics, aerial transportation, and urban governance, thereby demonstrating enormous market potential and growth prospects. The low-altitude economy is not a mere extension of the traditional aviation industry but a complex industrial system that is deeply data-driven and inherently born in the digital era [2].

However, current systematic research on the industrial ecosystem of the low-altitude economy remains relatively scarce. It is urgent to address how data elements reconstruct the industrial ecosystem of the low-altitude economy, how its core components and internal coordination mechanisms operate, and how the ecosystem's evolutionary path transitions from emergence to maturity. An in-depth exploration of these issues will help clarify the development logic and path selection of the low-altitude economy.

The theoretical significance of this study lies in integrating the theories of "data elements" and "industrial ecosystems" and applying them to the emerging field of the low-altitude economy. This research constructs a data-driven analytical framework to unveil the unique industrial structure and evolutionary mechanisms of the low-altitude economy, thereby enriching the theoretical research on data-enabled industrial ecosystems. Practically, this paper aims to provide strategic guidance for industry participants such as aircraft manufacturers, technology suppliers, operation service providers, and data platform enterprises, assisting them in accurately positioning their roles within the ecosystem and formulating effective data strategies and ecological niche strategies.

2. Literature Review

Academic discussions on data elements have evolved from the early perception of data as mere information or resources to the recognition of its economic status as an independent production factor [3]. Theoretical research generally agrees that data elements possess economic

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characteristics significantly different from traditional factors, such as non-rivalry, low-cost replicability, and increasing returns to scale resulting from massive aggregation and deep analysis [4]. These characteristics determine that the value creation mechanism of data in economic activities is unique. Regarding the value realization pathways of data elements, scholars commonly outline a value chain encompassing data collection, storage, processing, circulation, and application [5]. In recent years, with the advancement of data factor marketization reforms, academic attention has focused on data assetization, pricing, property rights definition, and transaction mechanisms, striving to solve the theoretical and practical challenges of transforming data from a resource into capital.

As an emerging research field, current literature on the low-altitude economy primarily concentrates on defining the industry concept, depicting application scenarios, and analyzing development challenges. Studies generally define the low-altitude economy as a comprehensive economic form driven by low-altitude flight activities of various manned and unmanned aerial vehicles, promoting the integrated development of related sectors [6]. It relies on key technologies such as drones, electric vertical take-off and landing aircraft (eVTOL), and Advanced Air Mobility (AAM), as well as supporting infrastructures like communication (5G-A), navigation (Beidou), and perception systems. On the application side, existing studies extensively explore the vast potential of the low-altitude economy in areas such as smart logistics, emergency rescue, agricultural and forestry protection, power line inspection, geographic surveying, and aerial tourism. At the same time, researchers are also acutely aware that the development of the low-altitude economy still faces multiple challenges, including complex airspace management, underdeveloped safety standards and regulatory frameworks, low public acceptance, and weak ground infrastructure [7].

The industrial ecosystem theory draws on perspectives from natural ecosystems, abandoning the linear thinking of traditional industry chains, and emphasizes the dynamic symbiotic relationships among enterprises and institutions within an “industrial community” [8]. The theory focuses on the dominant role of “keystone species” (such as platform enterprises and core technology firms) in ecosystem stability and evolution, highlighting complex interactions like “symbiosis, competition, and predation” among actors, and regards ecosystem evolution as a dynamic process jointly driven by technology, market, and policy, which has been widely applied in the study of high-tech industries [9]. The evolution of industrial ecosystems is considered a dynamic process progressing from formation, growth to maturity (or decline), significantly influenced by technological innovation, market demand, and policy environments.

Existing literature, from the dimensions of data element value, low-altitude economy application scenarios, and industrial ecosystem structures, provides a theoretical foundation for this study. However, research on the low-altitude economy largely remains at the levels of industry chains and technologies, lacking systematic analysis from an ecosystem perspective. While studies on data elements highlight their importance, they insufficiently explore the micro-level pathways through which data reshapes industrial ecosystems. Therefore, this study places data elements at the core, integrating the holistic and evolutionary perspectives of industrial ecosystems, and attempts to systematically explore the construction logic and evolutionary characteristics of the low-altitude economy, offering new analytical perspectives and approaches for related theoretical research and practical applications.

3. Theoretical Analysis

3.1 Ecosystem Construction Mechanism Driven by Data

The construction of the low-altitude economy industrial ecosystem is essentially an organizational collaboration process centered around the realization of data value. Unlike the linear nesting structure of traditional industry chains, this ecosystem is composed of three core units: data infrastructure, data platform hubs, and data-driven applications, achieving efficient linkage through data flow and feedback mechanisms.

Data infrastructure serves as the physical foundation for data collection and transmission, including 5G-A communication, Beidou navigation, and various perception networks. It ensures the real-time, high-precision acquisition and seamless transmission of multi-source data, laying the groundwork for subsequent intelligent processing. Data platform hubs act as the intelligent nerve center of the ecosystem, responsible for data aggregation, processing, and analysis tasks, such as low-altitude flight service management platforms and digital twin systems. Through advanced algorithms and computing power, these platforms transform raw data into actionable intelligence, enabling informed decision-making across the ecosystem.

Data-driven applications represent the value output end of the ecosystem, encompassing scenarios like smart logistics, aerial transportation, and emergency rescue. These applications are not only producers of data but also beneficiaries of intelligent services, constantly feeding back new operational data to refine system performance.

The three components form a positive feedback loop through the “data flywheel” mechanism. Applications generate data that is input into platforms; platforms optimize services through intelligent analysis, thereby enhancing application efficiency and user experience, attracting more application participants, further enriching data volume and dimensions, and continuously strengthening platform capabilities. As the ecosystem scales, the richness and diversity of data further amplify its self-reinforcing effects. The continuous flow and value transformation of data become the key driving force for the self-reinforcement and expansion of the ecosystem, fostering a dynamic, evolving industrial environment.

3.2 Evolutionary Path of the Ecosystem—A Three-Stage Model

The formation and development of the low-altitude economy industrial ecosystem is a dynamic evolutionary process that progresses from simplicity to complexity and from partial to holistic. This process can be summarized into three stages: Emerging Exploration Stage, Growth Integration Stage, and Mature Symbiosis Stage, each reflecting distinct shifts in data utilization, ecosystem structure, and collaborative dynamics.

3.2.1 Emerging exploration stage

This stage is primarily driven by technological advancements, with the industry still in its infancy. Core enterprises conduct pilot applications around specific scenarios such as aerial photography and power line inspection, resulting in short and fragmented industry chains. Data circulates within enterprises in closed loops, forming “data silos,” and collaborative mechanisms have yet to be established. Most market participants focus on developing technical capabilities, while lacking a systematic ecological perspective. The absence of unified technical standards and data interoperability further hinders cross-enterprise collaboration, making it difficult to achieve scale effects. Moreover, the industry’s overall understanding of data value remains superficial, limiting the willingness of enterprises to engage in open data sharing. In addition, regulatory and policy frameworks are still in the exploratory phase, providing limited guidance for ecosystem-wide coordination. At this stage, data is regarded as a resource auxiliary to production, with its value reflected in enhancing single-point operational efficiency, while network effects and ecosystem value have not yet been realized.

3.2.2 Growth integration stage

As technologies mature and applications expand, platform-oriented enterprises begin to emerge, taking on the crucial role of connecting various stakeholders and driving the industry’s transition from “pointwise distribution” to “platform aggregation.” Focusing on fields like logistics and urban management, platform enterprises integrate upstream and downstream resources, promoting the initial formation of industry standards. Cross-organizational data exchange becomes feasible, and the ecosystem starts to exhibit initial scale effects. Enterprises begin to recognize the strategic importance of data collaboration, actively seeking partnerships to enhance data richness and service diversity. At this stage, platform enterprises not only aggregate data but also begin to build analytical capabilities, providing scenario-specific intelligent services to ecosystem participants. Data sharing and circulation are realized under the leadership of platforms, and network effects gradually become apparent. During this stage, data evolves from an auxiliary resource into a core asset in platform competition, with the collaborative value of data beginning to be released within vertical sectors.

3.2.3 Mature symbiosis stage

In the mature stage, the ecosystem achieves

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interconnection and interoperability across platforms and sectors, enabling efficient data flow and integration across different scenarios and regions. Multi-dimensional data fusion empowers ecosystem participants to make real-time, intelligent decisions, enhancing the overall agility and resilience of the ecosystem. Ecosystem participants no longer operate in isolated domains but form a highly coordinated collaborative network, where data flows seamlessly between logistics, urban management, meteorology, and emergency services. Data collaboration among platforms optimizes overall scheduling and resource allocation, facilitating system-wide efficiency improvements and enabling innovative cross-domain solutions. With the stable division of labor and collaborative relationships forming an efficient symbiotic network within the ecosystem, mechanisms for data property rights, security, and transactions are progressively refined, ensuring trust and value realization in data interactions. This leads to the emergence of new data service formats, such as airspace capacity forecasting and flight risk assessment services, driving continuous business model innovation and further reinforcing the ecosystem's competitiveness.

4. Conclusion and Prospects

This paper analyzes the construction mechanisms and evolutionary paths of the low-altitude economy industrial ecosystem from the perspective of data elements. The main conclusions are as follows:

First, the ecosystem is not a linear extension of traditional industry chains but a dynamic system comprising data infrastructure, data platform hubs, and data-driven applications. The continuous production, aggregation, and feedback of data—the “data flywheel” effect—drives the ecosystem's self-reinforcement and expansion. Data becomes both the medium and catalyst for value creation, enabling enterprises to build competitive advantages through real-time coordination and intelligent decision-making. As data circulates through the ecosystem, its value is progressively amplified, fostering an environment of continuous innovation and systemic optimization.

Second, its development progresses through three stages: Emerging Exploration, Growth Integration, and Mature Symbiosis. Data evolves from a production input to a competitive resource and ultimately becomes a tradable core asset, fostering new business formats. Each stage reflects a shift in the role of data and a corresponding transformation of the ecosystem’s structure and interaction patterns. The ability of enterprises to adapt to these shifts will directly impact their survival and competitive positioning within the ecosystem.

This study highlights data as both the operational foundation and the key driver of ecosystem evolution. Enterprises should adopt a data-centric strategy, clearly define their role—be it data producer, integrator, or infrastructure provider—and explore data-driven business models like risk assessment and environmental analytics to gain competitive advantages. Moreover, coordinated efforts across enterprises, platform operators, and regulators are essential to build a collaborative and open data ecosystem that balances innovation with governance. Strengthening data interoperability and establishing shared governance mechanisms will further enhance the overall resilience and adaptability of the ecosystem.

However, this research is primarily theoretical and lacks empirical validation. Future studies should focus on case-based empirical research, develop quantitative models to assess data's economic value, and address key issues such as data security, privacy, and property rights to support the sustainable development of the low-altitude economy. In addition, exploring cross-industry data integration mechanisms and dynamic governance models will be critical to ensuring the ecosystem’s adaptability and long-term resilience in a rapidly evolving technological landscape.

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