Research on Collaborative Innovation Network Mechanism of General Aviation Enterprises Based on Complex Network

Liang Zhang*
Guangzhou Civil Aviation College, Guangzhou, Guangdong, 510403

*Corresponding author: liangzhang@caac.edu.cn

Abstract. In order to better promote the collaborative innovation ability among general aviation enterprises and promote the high-quality development of general aviation industry, this paper is based on the social network relationship theory and embeddedness principles, using the general aviation enterprises as structural embedding to determine the key nodes of the innovation network. The value chain, supply and demand chain, and information sharing behavior are used as relational embeddings to build a general aviation enterprise chain innovation network. On this basis, from the aspects of network topology graph, node degree, clustering coefficient, etc., quantitative analysis of the structure and characteristics of the general aviation enterprise innovation network is carried out, so as to lay a foundation for the functional orientation of the main body of collaborative innovation in the aviation industry. The research shows that: At present, the collaborative innovation of general aviation enterprises has not formed a scale. The innovation of enterprises mainly relies on large-scale general aviation enterprises with state prefix. Most general aviation enterprises have weak innovation capabilities, and the small and medium-sized general aviation enterprises are in the initial development stage. Therefore, it is necessary to strengthen the support of various types of general aviation enterprises, provide support in terms of funds and policies and so on, so as to promote the improvement of collaborative innovation capabilities among various types of general aviation enterprises.

1. Introduction
The "Guiding Opinions on Promoting the Development of the General Aviation Industry" issued in May 2016 positions the general aviation industry as a "strategic emerging industry system" in China. This positioning reflects the country's basic judgment and expectations of the "two wings flying together" of the air transport industry and the general aviation industry. The "Report of the Nineteenth National Congress of the Communist Party of China" pointed out that "socialism with Chinese characteristics has entered a new era, which is a new historical orientation for China's development." As an important force in the national strategic emerging industry, the general aviation industry is bound to achieve a new stage of development from high-quality development to high-quality development. The new era of socialism with Chinese characteristics will surely lead the development of China's general aviation industry into a new era.

The general aviation enterprise is the economic main body that constitutes the general aviation market, and it is the basic force that guarantees the stable development of the general aviation industry. Ho
However, the overall strength and operation level of general aviation enterprises are low at the present stage, and the number of navigable enterprises and navigable flights is small, and the basic facilities and equipment required to ensure safe flight are lacking; Limited resources are difficult to integrate effectively; Homogeneous competition between industrial chains and project duplication; Insufficient infrastructure and lagging service guarantees; The government's coordination is not smooth, the policy has the double problem of overlapping and vacuum, and regulatory methods and means cannot meet the needs of general aviation development.

Based on the social network relationship theory and embeddedness principle, the paper takes the general aviation enterprise as the structural embedding to determine the key nodes of the innovation network. The value chain, supply and demand chain, and information sharing behavior are used as relational embeddings to build a general aviation enterprise chain innovation network. On this basis, from the aspects of network topology graph, node degree, clustering coefficient, etc., quantitative analysis of the structure and characteristics of the general aviation enterprise innovation network is carried out, so as to lay a foundation for the functional orientation of the main body of collaborative innovation in the aviation industry.

2. Collaborative innovation network model construction of general aviation enterprise based on complex network

According to the complex network theory, the collaborative innovation network model of general aviation enterprises $G = (V, E)$ can be established, where $V$ represents various types of general aviation enterprises and $E$ represents the relationship between various types of general aviation enterprises. In the collaborative innovation network diagram of general aviation enterprises, the nodes represent various types of general aviation enterprise innovation subjects, while the edges represent the relationships between the various innovation entities, and there are multiple collaborative innovation communication relationships between the aggregation nodes on the edges, such as information exchange, technology delivery, business contacts, etc. Based on the edges of the network, an adjacency matrix is constructed:

$$
C_G(V,E) = \begin{bmatrix}
    e_{11} & \cdots & e_{1n} \\
    \vdots & \ddots & \vdots \\
    e_{n1} & \cdots & e_{nn}
\end{bmatrix}
$$

Where, $e_{ij} = 1$ indicates that there is a connection between general aviation enterprise $i$ and general aviation enterprise $j$, that is, there are relationships between nodes $I$ and $j$ in the exchange of information, transfer of technology, business transactions, etc.; $e_{ij} = 0$ indicating that there is no connection between general aviation enterprise $i$ and general aviation enterprise $j$, that is, there is no relationship between the nodes $I$ and $j$ in the exchange of information, transfer of technology, business transactions, etc.

Based on the above analysis, the UNCIECET software was used to form a complex network model, and finally the general aviation enterprise collaborative innovation network model was constructed with 81 nodes and 213 edges.

3. Analysis of collaborative innovation network evaluation model for general aviation enterprises

3.1. Evaluation index of general aviation enterprise collaborative innovation network evaluation model

Complex systems as an independent discipline emerged in the 1990s, and complex networks as an effective tool and method for studying complex systems began in the late 1990s. As we all know, complex system is composed of many subsystems interacting with each other. If the subsystems are abstracted into nodes, and the interaction between the subsystems is abstracted into the edges connecting the nodes, the complex system can be abstracted into a complex network. Today, the research on complex networks has covered most of the actual network fields, and some of them are closely related to the industri
al economy, and initially formed a relatively mature research framework, reflects the complex network of research paradigm and methods, to reveal the characteristics and evolution law of industrial organization provides a new tool.

3.1.1. Node degree. Taking various types of general aviation enterprises as network nodes, the node degree is the number of edges connected between this node and other nodes, and the calculation formula is:

\[ k_i = \sum_j a_{ij} \]  

(2)

Where, \( a_{ij} \) is the number of connected edges between node \( v_i \) and node \( v_j \). In the general aviation enterprise collaborative innovation network evaluation model, the greater the degree of the node, the greater the role of the node in the network and the greater its role in the collaborative innovation of general aviation enterprises.

3.1.2. Clustering coefficient. The clustering coefficient reflects the clustering degree of nodes in the network. It is defined as the variable \( E_i \) that actually exists between \( k_i \) nodes divided by the total number of possible edges \( k_i(k_i - 1)/2 \), the calculation formula is:

\[ C_i = \frac{2E_i}{k_i(k_i - 1)} \]  

(3)

The clustering coefficient \( C \) of the whole network is the average of all nodes' clustering coefficients, and the calculation formula is:

\[ C = \frac{1}{N} \sum_i C_i \]  

(4)

3.1.3. Average path length. In the network, the average path length between two nodes refers to the number of edges on the shortest path connecting the two nodes. The average distance \( d_{ij} \) between all nodes is the average path length of the entire network, which is represented by \( L \) and reflects the difficulty of communication between the nodes of the network, the calculation formula:

\[ L = \frac{2}{N(N+1)} \sum_{i \neq j} d_{ij} \]  

(5)

3.2. Analysis of collaborative innovation network model of general aviation enterprises

The collaborative innovation of general aviation enterprises was analyzed by using UNCIECET software, and the degree values of 81 nodes were calculated. Through calculation, it is found that China Southern Airlines General Aviation Co., Ltd., CITIC Haizhi and other state prefix enterprises have higher degree values, which are much higher than other non-state prefix enterprises, which is also in line with the current development status of China's general aviation industry. The large difference in the degree value of each node in the network also shows that there is a significant difference in the innovation capabilities of China's general aviation companies. Most general aviation companies' innovation capabilities are obviously underdeveloped.

Using the UNCIECET software to calculate the general aviation enterprise collaborative innovation network density is 0.0418, the network connectivity is not strong; the average path length between nodes is 3.381, which means that the communication of collaborative innovation between any two general aviation enterprises in the network needs to pass through the connection of four nodes on average, which means that there are many structural holes in the network.
4. Conclusion

Through the analysis of the collaborative innovation network model of general aviation enterprises, we get the following conclusion: At present, the scale of collaborative innovation of general aviation enterprises has not yet formed, and the innovation of enterprises mainly depends on large-scale general aviation enterprises with state prefixes, most general aviation enterprises have weak innovation capabilities, small and medium-sized general aviation companies are already in the initial development stage. Therefore, it is necessary to strengthen the support of various types of general aviation enterprises, provide support in terms of funds and policies and so on, so as to promote the improvement of collaborative innovation capabilities among various types of general aviation enterprises.

References

[1] Liu Luming. Research on the relationship between enterprise collaborative innovation network characteristics and collaborative innovation performance [D]. 2019.

[2] Fan Ruguo. Research on collaborative innovation of SME clusters based on complex network theory [J]. Business Economics and Management, 2014 (03): 63-71.

[3] Xie Leilei, Zuo Weibing. Research on the action mechanism of the elements of collaborative innovation system in colleges and universities under complex network vision [J]. Journal of Economic Research, 2019 (28).

[4] Wang Xiaofan, Li Xiang, Chen Guanrong. Complex network theory and its application [M]. Tsinghua University Press, 2006.

[5] Li Xiaojia, Zhang Peng, Di Zengru, et al. Community structure in complex networks [C] // The 4th National Network Science Academic Forum and Proceedings of the Summer School for Postgraduates. 2008.