A Study on the Classification and Development Stages of Regional Aviation Hubs in China Based on Network Value and Place Value

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ABSTRACT

To scientifically identify disparities in the development levels of regional aviation hubs and to ensure a rational alignment between hub resources and market demand, this study evaluates 29 regional hub airports in China. First, an evaluation index system is constructed incorporating both network value and place value dimensions. The entropy weight method is then applied to determine the weights of the indicators and to calculate the respective value scores for each airport. Subsequently, the elbow method is employed to determine the optimal number of clusters, and hierarchical clustering is utilized to classify the 29 airports into three distinct categories: highly developed, moderately developed, and lowly developed regional hubs. Finally, tailored strategic recommendations are proposed: highly developed hubs should strengthen international connectivity and establish high-frequency express routes; moderately developed hubs should expand hinterland integration through trunk-feeder networks; and low-developed hubs should focus on aviation-tourism synergy by promoting premium tourist routes.This study classifies hub airports from the dual perspectives of network value and place value, revealing a pyramid-shaped hierarchical structure of development among regional hub airports in China, thereby providing a theoretical foundation for the differentiated development of hub airports.

Keywords: Regional aviation hubs, Airport classification, Network value, Place value

1. Introduction

As the backbone of China's airport system, regional aviation hubs play a pivotal role in the air transport network [1].The 'Action Plan for Building a Civil Aviation Powerhouse in the New Era', issued by the Civil Aviation Administration of China, explicitly states that in the future, China is committed to establishing a comprehensive national airport system. This system will be underpinned by world-class airport clusters and international aviation hubs as core pillars, with regional aviation hubs serving as key backbone forces, and non-hub airports and general aviation airports acting as important supplements. This clearly establishes the 'backbone' status of regional aviation hubs within China's airport system.Data from the CAAC's annual airport production statistics bulletin reveal that between 2010 and 2021, the 29 regional hub airports served as key nodes in China's airport operations system. Although they represent only a small fraction of the country's total airports, these hubs handle approximately 35% of the nation’s passenger throughput, 25% of cargo throughput, and 30% of flight movements. This clearly demonstrates their crucial role as backbone nodes within China's air transport network[2,3].

However, with the rapid advancement of regional hub development, how to scientifically assess their varying levels of development has become a topic requiring further in-depth research [4].Airport evaluation, as an important area of research in transport engineering, has attracted the attention of numerous scholars. Several studies have explored the assessment of airport efficiency, proposing efficiency rankings for airports at different hierarchical levels and the number of high-efficiency airports at various stages [5,6].With regard to airport evaluation indicators, existing research has examined multiple dimensions, including a comprehensive system of indicators such as airport operational scale and functional positioning, government agencies' development of airport capacity and allocation of funds, airport connectivity, and facilities [7,8,9,10].To date, existing research has achieved certain results in the evaluation and classification of single-place dimensions or single-network dimensions, such as airport benefits, airport route network connectivity and airport infrastructure; however, research systematically integrating the topological value of airports as network nodes with their local attribute value as economic places remains relatively weak. This gap limits a holistic understanding of how airports simultaneously function as transport nodes and territorial assets. To address this, the present study focuses on 29 regional hub airports in China and aims to develop a comprehensive classification that captures both their network roles and place-based resources. Based on this, this paper proposes a comprehensive evaluation framework based on network value and place value, aiming to conduct a scientific classification and differentiated analysis of the development levels of regional aviation hubs in China.

The subsequent structure of this paper is as follows: Section 2 reviews the relevant literature on airport classification and value assessment; Section 3 details the evaluation indicator system and methodology based on network value and place value, as well as the construction of a route value assessment model for typical airports; Section 4 presents the results of the cluster analysis and the classification of regional hubs; Section 5 summarises the main research findings and discusses their managerial implications and future research directions.

2. Literature Review

The scientific classification and value assessment of airports are prerequisites for achieving differentiated development among airports at different stages of development, optimising resource allocation, and formulating targeted policies[11,12]. With the increasing complexity of air transport networks and the diversification of airport roles, single-dimensional classification is no longer sufficient to fully demonstrate the value of airports within the air transport system. In recent years, scholars have explored airport classification and assessment from various dimensions, laying a theoretical foundation for understanding the multifaceted attributes of airports[13,14].This paper aims to review and critique existing research from the dual perspectives of 'network value' and 'place value', with a view to providing more systematic theoretical support for studies on the classification and developmental stages of regional aviation hubs in China.

Early and mainstream studies on airport classification have largely focused on operational scale and explicit functional roles[15]. Such research typically employs quantitative analytical methods, categorizing airports based on core indicators such as passenger and cargo throughput and flight movements. For example, Wang Qingzhao employed factor analysis and cluster analysis to classify China's top 20 airports by cargo volume, analyzing the hierarchical differences in aviation logistics development levels across different airports[16]. Jiang Zhongnan and Yang Xubiao focused more specifically on cargo functions, categorizing airports into five types, including core hub-type and cargo-advantage-type, thereby refining airport positioning based on the cargo value chain[17].In the passenger sector, Zhang Xiaoyan et al. focused on the growth potential of regional airports, selecting average annual growth rates and increments in passenger throughput as core indicators to construct a classification system based on dynamic development characteristics, thereby providing a reference for long-term airport planning[18].

Another category of research approaches airports from the perspective of service providers and complex systems, focusing on their intrinsic qualities and operational efficiency. Bae W et al. started from passenger-perceived Airport Service Quality (ASQ) to establish an evaluation system covering dimensions such as cleanliness, infrastructure and staff service[19]; this assessment is directly related to the soft power of airports as 'places' in attracting passengers and airlines.In contrast, Qi Lin et al. introduced a resilience assessment framework, focusing on the airport system's capacity to absorb, adapt to and rapidly recover from emergencies[20].Although this emphasis on dynamic adaptability differs from conventional functional classification perspectives, it reflects the strategic role airports play as critical infrastructure in maintaining regional connectivity and economic stability; this effectively complements the functional positioning of an airport's 'network value' under abnormal conditions.

Such research deepens our understanding of the connotations of an airport's 'place value', which encompasses not only physical facilities but also service experiences and system reliability. However, these studies similarly fall short in exploring the 'network value' of airports—specifically, how they generate spillover effects and facilitate the flow of factors through their route networks under normal conditions.

Research into the differentiation between hub and non-hub airports constitutes an important branch of airport classification[21,22,23,24]. Jiao Huijun and Yang Xinbeng employed a comprehensive methodology combining three-stage super-efficiency DEA, backpropagation neural networks and cluster analysis, aiming to classify China's hub airports into tiers from a perspective of coordinated development, thereby avoiding homogeneous competition[25].This touches upon the issue of functional division of labour among airports within regional airport systems. Zheng Wenjuan focuses on non-hub airports, combining classification with regional development drivers to identify categories such as tourism-driven and economy-driven airports[26].The innovative aspect of this research perspective lies in its attempt to link the development drivers of airports with the place functions of their respective regions (such as tourism resources and economic industries), thereby preliminarily demonstrating the driving role of 'place value' in airport development. In addition, Ma Yifei pointed out that the current hub layout suffers from issues such as having sufficient capacity but lacking efficiency, being large but not strong, and having connections but lacking smooth flow, and that there is an urgent need to establish a function-oriented, tiered aviation hub system[27].

However, while existing research takes into account the role of hubs as nodes within a network when defining and classifying them, it often still relies on throughput volume as the core proxy variable. There is scope for further analysis of the 'network value' of hub airports, such as network connectivity, transfer capacity, and the breadth and depth of route coverage.Regarding the classification of non-hub airports, some studies have incorporated regional economic factors, but have not yet conducted a systematic correlation analysis linking these to the airports' own route network characteristics[28,29,30].

In summary, existing literature has yielded fruitful results in airport classification and evaluation, providing important theoretical references for this study. However, most studies are conducted from a single or limited number of dimensions, such as operational scale, service functions, and cargo functions. Therefore, this study adopts a dual perspective of 'network value' and 'place value' to construct a more comprehensive analytical framework for classifying regional aviation hubs in China.

3. Model Construction

3.1 Basic Characteristics of the Research Subjects

Regional aviation hubs originate from the systematic classification of China's modern airport system. The 13th Five-Year Plan for Civil Aviation in China identifies regional hubs as including Hangzhou, Wuhan, Nanjing, Tianjin, Haikou, Xiamen, Changsha, Zhengzhou, Qingdao, Guizhou, Dalian, Wenzhou, Fuzhou, Sanya, Shijiazhuang, Lhasa, Xining, Yinchuan, Changchun, Guilin,Hefei, Shenyang, Lanzhou, Hohhot, Taiyuan, Nanchang, Ningbo, Jinan and Nanning; that is, regional aviation hubs refer to the airports in these 29 cities. This study defines a regional aviation hub as: a key node within the national comprehensive airport system that performs the core functions of regional air transport distribution and transfer . In accordance with relevant planning documents, this specifically covers the airports in 29 cities, including Hangzhou, Wuhan, Nanjing, Zhengzhou and Qingdao.

3.2 Construction of a Classification Model for Regional Hub Value Assessment

3.2.1 Network value indicator system

Different airports vary in terms of connectivity, accessibility and node importance within the transport network, and consequently differ in their ability to enhance the overall efficiency of the route network. Therefore, this paper analyses the network value of the 29 regional hub airports by examining their connectivity, accessibility and node importance from a transport network perspective.

Table 1. Regional aviation hub network value evaluation indicator system

Dimension	Indicator Name	Indicator Explanation	Indicator Attribute
Network Value	Connectivity	Reflects the degree of connection and efficiency between the airport and the route network;	Positive
	External Accessibility	Reflects the ease of travel from one airport to another;	Negative
	Internal accessibility	Reflects the ease of access to the airport from within the city;	Positive
	LNDH Index	Reflects the importance of an airport node within the network;	Positive

Source: By authors.

(1) Regional aviation hub connectivity

Airport connectivity refers to the overall level of connection with the rest of the world via direct flights or indirect connections through other airports. It is a core indicator for measuring the value and strategic position of an airport within the route network, and directly influences the overall efficiency of the route network. Considering the degree centrality in complex networks, this reflects an airport's reach and importance within a local scope of the network;Betweenness centrality reflects an airport's ability to achieve rapid connectivity with other airports within the route network with the fewest possible transfers; Proximity centrality reflects the frequency with which an airport acts as a 'bridge' within the route network. Therefore, a model reflecting the connectivity of regional hub airports is constructed based on the three indicators of degree centrality, betweenness centrality and proximity centrality, with the calculation formula shown in (1):

$$NCCI_i = w_1 C_D(i) + w_2 C_C(i) + w_3 C_B(i) \quad \text{[Formular 1]}$$

*W:*denotes the weight.

$C_D(i)$:represents the degree centrality of airport i.

$C_C(i)$:represents the proximity centrality of airport i.

$C_B(i)$:represents the betweenness centrality of airport i.

Based on the fundamental principles of complex network theory, a regional hub-and-spoke route network model has been constructed G=(V, E). Within this model framework, each airport is abstracted as a network node, while the actual operational routes between airports are represented as edges connecting the nodes.Here, V represents the set consisting of m nodes{1,2,...,m}, while E denotes the set of edges connecting the nodes. The route connection between airport x and airport y is denoted by a_{xy}, and an adjacency matrix B of dimension m×m is constructed. To mathematically express the network topology, the matrix element a_{xy} is set to 1 when a route exists between airport x and airport y, and to 0 when no route exists between the two airports.

Three metrics for evaluating node centrality; the specific calculation formulas and definitions are shown in Table 2.

Table 2. Node centrality indicators

Basic indicators	Formulas and Symbols	Definition
Degree Centrality	$C_{D(i)} = \frac{k_i}{n-1}$ [Formular 2]	Measures the number of edges directly connected to node i, intuitively reflecting the node's influence and importance within a local region of the network.
Proximity Centrality	$C_{c(i)} = \frac{n}{\sum_{j=1}^{n} d_{ij}}$ [Formular 3]	The reciprocal of the average shortest path length from node i to all other nodes in the network. This precisely quantifies the efficiency of information transmission; a higher value indicates that node i can achieve rapid connectivity with other nodes in the network with the fewest number of hops.
Intermediary Centrality	$C_{B(i)} = \sum_{s \neq i \neq t} \frac{N_{st}^{i}}{G_{st}}$ [Formular 4]	The frequency with which node i acts as a 'transport hub' within the network. By calculating the probability of this node appearing in the shortest paths between other nodes, it provides a detailed picture of the extent to which it controls the flow of network resources. A higher value for this metric indicates that node i acts as a 'bridge' more frequently in the transmission of information and resources across the network.

Source: By authors.

(2) External Accessibility of Regional Aviation Hubs

External accessibility in this paper refers solely to accessibility between airports, excluding accessibility from other transport hubs within the city to the airport.According to the theoretical perspective of David-S Vale [31], the concept of accessibility primarily describes the ease with which individuals or groups can reach other regions from a given geographical location via the transport system. Domestic scholars such as Jiang Bo [32], Shao Bo [33] and Yao Yongling [34] have all used external accessibility indicators to measure the network efficiency of regional transport hubs.

Given that flight frequency indicators in air transport can more scientifically reflect the strength of connections between two locations, this study has developed an 'improved gravity model based on flight frequency', thereby enabling a more accurate measurement of the external accessibility of regional aviation hubs. The calculation formula is as follows:

$$M_x = \frac{\sum_{y=1}^{n}(T_{xy} \times P_y)}{\sum_{y=1}^{n} P_y} \quad \text{[Formular 5]}$$

$$P_y = \sqrt{GDP_y POP_y} \quad \text{[Formular 6]}$$

$$N_x = \frac{\frac{M_x}{n_x} \times \sum_{x=1}^{n}(T_{xy} \times P_y)}{\sum_{y=1}^{n} P_y} \quad \text{[Formular 7]}$$

M_x: represents the weighted average travel time (min) for airport x.

T_{xy}: represents the shortest flight time (min) from airport x to airport y.

P_y: represents the quality of city y where airport x is located.

GDP_y: represents the gross regional product.

POP_y: represent the population of city y.

N_x: represents the weighted average travel time for airport x based on flight frequency.

n_x: represents the daily flight frequency of airport x, defined as the sum of the frequencies of flights departing from, transiting through, and arriving at airport x each day.

N_x is inversely proportional to the external air accessibility of airport x. N_x the smaller the value, the better the external air accessibility of airport x, and vice versa.

(3) Internal connectivity of regional aviation hubs

As airports cannot provide a 'door-to-door' service, travellers typically need to use other modes of transport to cover the journey from their point of departure to the airport and from the airport to their final destination.Martijn Brons [35] conducted a satisfaction survey among Dutch rail passengers and found that internal accessibility has a significant impact on overall journey satisfaction 錯誤! 找不到參照來源。 . As the degree of integration between an airport and the city's internal transport system directly affects travellers' journey efficiency, the extent of integration between the airport and the urban transport network must be considered when assessing airport accessibility. This paper introduces the concept of “internal accessibility” to denote the level of convenience between the airport and the city's internal transport system.

Drawing on the indicators used by David S. Vale to evaluate the Lisbon metro network in Portugal, the assessment is based on the number of public transport routes and metro lines operating between the airport and the city center. If an airport is connected to the metro, its standardized internal accessibility score is set to 1; furthermore, the weighting coefficients for the standardised scores of bus routes are shown in Table 3.

Table 3. Assignment coefficients for standardized assessment values of the number of bus routes

Bus routes/route	m≥15	10≤m<15	5≤m<10	1<m<5	m≤1
Internal reachability index Normalised evaluation value	1	0.8	0.6	0.4	0.2

Source: By authors.

(4) Importance of Regional Aviation Hub Nodes

Within a route network, neighbouring nodes exert a significant influence on a node's importance; therefore, the Local Nearest Neighbours H-index (LNDH index) is introduced to assess the importance of nodes in the network. The importance of nodes in the network is calculated using a ranking algorithm: with the formula as follows:

$$d(x)=\sum_{y\in\Gamma(x)} a_{xy} \quad \text{[Formular 8]}$$

$$D(x)=\sum_{y\in\Gamma(x)} d(x) \quad \text{[Formular 9]}$$

$$Ld(x)=\frac{d(x)}{\max\limits_{y\in v} d(y)} \quad \text{[Formular 10]}$$

$$LD(x)=\frac{D(x)}{\max\limits_{y\in v} D(y)} \quad \text{[Formular 11]}$$

$$\mu_{(x)}=\frac{h_{index}(x)}{\max\limits_{y\in\Gamma(x)} h^2_{index}(y)} \quad \text{[Formular 12]}$$

$$LNH_{index}(x)=h_{index}(x)+\sum_{y\in\Gamma(x)} \mu_{(y)} * h_{index}(y) \quad \text{[Formular 13]}$$

$$LNDH_{index(x)}=Ld(x)+LD(x)+LNH_{index}(x) \quad \text{[Formular 14]}$$

The set V comprehensively covers all network nodes.

a_{xy}: represents the connection relationship between nodes V_x and V_y, where $a_{xy}=1$ indicates that the two nodes are connected, while $a_{xy}=1$ indicates no connection.

d(x): represents the connection strength of node V_x.

D(x): represents the total connection strength of neighboring nodes.

$H_{index}(x)$: represents the influence of node V_x.

Ld(x): represents the standardized value of the node degree.

LD(x): represents the standardized sum of the degree values of neighboring nodes.

μ(x): represents the weighting coefficient for the secondary influence of neighboring areas.

$LNH_{index}(x)$: represents the synergy between a node's own influence and that of its neighboring nodes.

$LNDH_{index}(x)$: represents the importance score of node V_x.

3.2.2 Venue value indicator system

This section evaluates the airport's intrinsic value from the perspective of the airport itself, assessing its economic value based on the three key aviation performance indicators: passenger throughput, cargo and mail throughput, and flight movements; evaluating its infrastructure value based on the number of runways, the number of aircraft stands, and terminal floor area; and comprehensively assessing the airport's site value based on its economic value and infrastructure value.

Table 4. Regional aviation hub value evaluation indicator system

Dimension	Indicator Name	Indicator Explanation	Indicator Attribute
Site Value	Annual Passenger Throughput	The number of passengers arriving at and departing from the airport within a year;	Positive
	Annual Cargo and Mail Volume	The total weight of cargo and mail handled by the airport over the course of a year;	Positive
	Annual Flight Movements	The total number of aircraft take-offs and landings on the airport runway within a year;	Positive
	Terminal Area	The total floor area of the airport terminal, which is a key indicator of the airport's scale and passenger handling capacity;	Positive
	Number of Runways	The number of runways within an airport available for aircraft take-off and landing directly affects the airport's operational capacity and flight handling efficiency;	Positive
	Number of Stands	The number of fixed positions within an airport available for aircraft to park, embark and disembark passengers, load and unload cargo, and receive ground services; this is a key indicator of an airport's service capacity and operational scale;	Positive

Source: By authors.

3.2.3 Entropy method

The 'entropy method' is a comprehensive evaluation method that determines weights by utilising the information content provided by entropy. As the units of measurement for the various indicators within the airport value assessment framework differ, and the orders of magnitude vary significantly, this paper employs the 'entropy method' to calculate the weights of each value indicator and the value scores for airports within the regional hub network. First, the network value indicators and site value indicators for regional hub airports are assigned codes, as shown in Table 5.

Table 5. Numbering of airport value indicators

Dimension	Second-level Indicators	Number
Network Value	External Accessibility	X1
	Internal Accessibility	X2
	LNDH Index	X3
	Connectivity	X4
Venue Value	Annual Passenger Throughput	X5
	Annual Cargo Throughput	X6
	Annual Number of Movements	X7
	Terminal Area	X8
	Number of Runways	X9
	Number of Aircraft Stands	X10

Source: By authors.

The specific steps of the entropy method are as follows:

(1) Data standardization

The formula for data standardisation is as follows:

For positive indicators:

$$Y_{ij} = \frac{X_{ij} - min(X_j)}{max(X_j) - min(X_j)} \quad \text{[Formular 15]}$$

For reverse indicators:

$$Y_{ij} = \frac{max(X_j) - X_{ij}}{max(X_j) - min(X_j)} \quad \text{[Formular 16]}$$

X_{ij}: represents the raw data for the indicators.

$max(Xj)$: represents the maximum value of the jth data point.

$min(Xj)$: represents the minimum value of the jth metric.

Yij: represents a standardized data value.

(2) Calculating the entropy value of an indicator

The formula for calculating the entropy value of each indicator is as follows:

$$E_j = -\frac{1}{ln(n)} \sum_{i=1}^{n} p_{ij}\, lnp_{ij} \quad \text{[Formular 17]}$$

$$p_{ij} = \frac{Y_{ij}}{\sum_{i=1}^{n} Y_{ij}} \quad \text{[Formular 18]}$$

If $p_{ij}=0$, then we define:

$$\lim_{p_{y \to 0}} p_y ln p_y = 0 \quad \text{[Formular 19]}$$

n: represents the number of evaluation objects.

E_j: represents the entropy value of the indicator.

(3) Calculating the coefficient of variation for each indicator.

Calculate the coefficient of variation for each indicator based on the calculated entropy values:

$$g_j = 1 - E_j \quad \text{[Formular 20]}$$

g_j: represents the coefficient of variation.

(4) Calculating the weights of the indicators

The formula is as follows:

$$W_j = \frac{g_j}{\sum_{j=1}^{m} g_j} \quad \text{[Formular 21]}$$

m: represents the number of indicators.

W_j: represents the weight of the jth indicator.

(5) Calculating the composite score

$$S_i = \sum_{j=1}^{m} W_j \times Y_{ij} \quad \text{[Formular 22]}$$

S_i: represents the score of the i-th evaluation object.

4. Analysis of Results

4.1 Analysis of Regional Aviation Hub Connectivity

The values for degree centrality, proximity centrality and betweenness centrality of regional hub airports within the route network were calculated using the formulae in Table 6; the specific values are shown in Table 6.

Table 6. Centrality characteristics of regional air hub nodes in 2021

Airport	Degree Centrality	Proximity centrality	Betweenness Centrality
Hangzhou/Xiaoshan	119	517	535.047
Changsha/Huanghua	108	506	447.513
Nanjing/Lukou	106	505	409.775
Tianjin/Binhai	106	503	490.970
Haikou/Meilan	103	502	491.460
Wuhan/Tianhe	102	498	322.221
Zhengzhou/Xinzheng	99	496	503.676
Qingdao/Jiaodong	96	494	310.798
Xiamen/Gaoqi	96	492	186.010
Guiyang/Longdongbao	95	491	174.559
Dalian/Zhoushuizi	95	488	256.478
Wenzhou/Longwan	92	488	226.176
Shenyang/Taoxian	91	486	268.474
Lanzhou/Zhongchuan	90	482	172.238
Nanning/Wuxu	89	480	135.193
Fuzhou/Changle	87	479	138.183
Jinan/Yaoqiang	84	478	183.120
Sanya/Fenghuang	81	477	106.415

Yinchuan/Hedong	81	474	91.169
Taiyuan/Wusu	78	474	61.156
Ningbo/Lishe	77	473	107.462
Nanchang/Changbei	75	473	70.723
Hohhot/Baita	72	470	281.015
Changchun/Longjia	71	467	65.998
Guilin/Liangjiang	67	466	85.885
Xining/Caojiabao	66	463	72.593
Shijiazhuang/Zhengding	65	463	170.504
Hefei/Xinqiao	63	461	43.991
Lhasa/Gonggar	52	450	152.694
Average	86	482	226.258

Source: By authors.

This paper employs the entropy method to calculate the weightings of indicators affecting the connectivity of regional hub airports, and uses SPSS software to compute the weighted values; the specific results are shown in Table 7.

Table 7. Table of weights for connectivity indicators

Item	Weight Coefficient
Centrality	10.39%
Proximity centrality	30.23%
Betweenness centrality	59.38%

Source: By authors.

As shown in Table 7, betweenness centrality has the highest weighting at 59.38%; proximity centrality has a weighting of 30.23%; and degree centrality has the lowest weighting at 10.39%.

By substituting the values and weight coefficients for degree centrality, proximity centrality and betweenness centrality of regional aviation hubs into Formula 1 to calculate their connectivity, the specific results are shown in Table 8.

Table 8. Regional aviation hub connectivity values in 2021

Rank	Airport	NCCI	Rank	Airport	NCCI
1	Hangzhou/Xiaoshan	535.047	16	Lanzhou/Zhongchuan	172.238
2	Zhengzhou/Xinzheng	503.676	17	Shijiazhuang/Zhengding	170.504
3	Haikou/Meilan	491.460	18	Lhasa/Gonggar	152.694
4	Tianjin/Binhai	490.970	19	Fuzhou/Changle	138.183
5	Changsha/Huanghua	447.513	20	Nanning/Wuxu	135.193
6	Nanjing/Lukou	409.775	21	Ningbo/Lishe	107.462
7	Wuhan/Tianhe	322.221	22	Sanya/Fenghuang	106.415
8	Qingdao/Jiaodong	310.798	23	Yinchuan/Hedong	91.169

9	Hohhot/Baita	281.015	24	Guilin/Liangjiang	85.885
10	Shenyang/Taoxian	268.474	25	Xining/Caojiabao	72.593
11	Dalian/Zhoushuizi	256.478	26	Nanchang/Changbei	70.723
12	Wenzhou/Longwan	226.176	27	Changchun/Longjia	65.998
13	Xiamen/Gaoqi	186.010	28	Taiyuan/Wusu	61.156
14	Jinan/Yaoqiang	183.120	29	Hefei/Xinqiao	43.991
15	Guiyang/Longdongbao	174.559		Average	226.258

Source: By authors.

As shown in Table 8, there are significant differences in connectivity among the 29 regional hub airports. Hangzhou Xiaoshan International Airport has the highest connectivity among regional aviation hubs, with a value of 535.047; Hefei Xinqiao International Airport has the lowest connectivity among regional aviation hubs, with a value of 43.991.Eleven airports, including Zhengzhou Xinzheng International Airport, Haikou Meilan International Airport and Tianjin Binhai International Airport, have connectivity values higher than the average for all regional hub airports, while the remaining 18 airports have connectivity below the average. In particular, Changchun Longjia International Airport, Taiyuan Wusu International Airport and Hefei Xinqiao International Airport have relatively low connectivity and require special attention.

4.2 Analysis of External Accessibility Results for Regional Aviation Hubs

The weighted average travel times for the 29 regional hub airports in 2021 were calculated using Equation 5-7, with the specific results shown in Table 9. There are significant differences in the external accessibility of regional hub airports. The weighted average travel time based on flight frequency is inversely proportional to external accessibility; Hangzhou Xiaoshan International Airport has the shortest weighted average travel time and the best external accessibility;Lhasa Gonggar International Airport has the longest weighted average travel time and the lowest external accessibility. The mean weighted average travel time for regional hub airports is 59.436. Among these, 12 airports, including Hangzhou Xiaoshan International Airport and Zhengzhou Xinzheng International Airport, have weighted average travel times below the mean, indicating that their regional hub route networks operate with high efficiency.Among them, 17 airports, including Haikou Meilan International Airport and Guilin Liangjiang International Airport, had weighted average travel times above the mean, indicating that the operational efficiency of their regional hub route networks is relatively low.

Table 9. Calculated weighted average travel times for regional aviation hubs in 2021

No.	Airport	N_x	No.	Airport	N_x
1	Hangzhou/Xiaoshan	26.348	16	Shenyang/Taoxian	52.083
2	Zhengzhou/Xinzheng	39.828	17	Sanya/Fenghuang	52.696
3	Wuhan/Tianhe	42.279	18	Fuzhou/Changle	52.696
4	Qingdao/Jiaodong	42.892	19	Nanchang/Changbei	52.696
5	Xiamen/Gaoqi	43.505	20	Hohhot/Baita	52.696

6	Changsha/Huanghua	44.118	21	Hefei/Xinqiao	53.309
7	Dalian/Zhoushuizi	45.343	22	Nanning/Wuxu	53.309
8	Nanjing/Lukou	45.343	23	Ningbo/Lishe	53.922
9	Jinan/Yaoqiang	45.343	24	Lanzhou/Zhongchuan	53.922
10	Wenzhou/Longwan	45.343	25	Shijiazhuang/Zhengding	53.922
11	Tianjin/Binhai	45.956	26	Changchun/Longjia	54.534
12	Taiyuan/Wusu	45.956	27	Yinchuan/Hedong	54.534
13	Haikou/Meilan	50.858	28	Xining/Caojiabao	54.534
14	Guilin/Liangjiang	52.083	29	Lhasa/Gonggar	59.436
15	Guiyang/Longdongbao	52.083		Average	49.016

Source: By authors.

4.3 Analysis of Internal Accessibility Results for Regional Aviation Hubs

Data on the number of bus routes and metro lines serving 29 regional hub airports was collected from the airports' official websites to determine the internal accessibility of these 29 regional aviation hubs. The specific results are shown in Table 10.

Table 10. Internal accessibility of regional aviation hubs in 2021

No.	Airport	Numberofbusroutes	Numberofmetrolines	Internalaccessibility
1	Tianjin/Binhai	28	1	1
2	Shijiazhuang/Zhengding	3	1	1
3	Hohhot/Baita	7	1	1
4	Dalian/Zhoushuizi	10	1	1
5	Hangzhou/Xiaoshan	7	2	1
6	Xiamen/Gaoqi	26	1	1
7	Nanjing/Lukou	3	1	1
8	Qingdao/Jiaodong	8	1	1
9	Fuzhou/Changle	15	0	1
10	Wenzhou/Longwan	2	1	1
11	Ningbo/Lishe	8	1	1
12	Zhengzhou/Xinzheng	3	1	1
13	Wuhan/Tianhe	9	1	1
14	Guiyang/Longdongbao	9	1	1
15	Shenyang/Taoxian	12	0	0.8
16	Haikou/Meilan	14	0	0.8
17	Changsha/Huanghua	12	0	0.8
18	Taiyuan/Wuxu	6	0	0.6
19	Nanchang/Changbei	5	0	0.6
20	Nanning/Wuxu	5	0	0.6
21	Guilin/Liangjiang	10	0	0.6

22	Yinchuan/Hedong	5	0	0.6
23	Changchun/Longjia	4	0	0.4
24	Jinan/Yaochang	4	0	0.4
25	Hefei/Xinqiao	4	0	0.4
26	Sanya/Fenghuang	4	0	0.4
27	Lanzhou/Zhongchuan	4	0	0.4
28	Xining/Caojiabao	4	0	0.4
29	Lhasa/Gonggar	1	0	0.2
	Average	8	0.4	0.8

Source: By authors.

As shown in Table 10, 14 of the 29 regional hub airports have an internal connectivity value of 1, indicating that their overall internal connectivity is relatively good. The mean internal connectivity value for the 29 regional hub airports is 0.8, with 14 airports—including Tianjin Binhai International Airport, Shijiazhuang Zhengding International Airport and Hangzhou Xiaoshan International Airport—having internal connectivity values higher than the average for regional hub airports.Twelve airports, including Taiyuan Wusu International Airport, Nanchang Changbei International Airport and Nanning Wuxu International Airport, have internal connectivity values below the average for all regional hub airports; among these, Lhasa Gonggar International Airport has the lowest internal connectivity and requires particular attention.

4.4 Analysis of the Importance of Regional Aviation Hub Nodes

The importance of the 29 regional hub airports in 2021 was calculated using Formula 8-14. As shown in Table 11, there are significant differences in the importance of these 29 regional hub airports. Among them, Changsha Huanghua International Airport has the highest node importance, at 69.989, making it the most influential of the 29 regional hub airports;Lhasa Gonggar International Airport has the lowest node importance, at 59.761, and exerts the least influence among the 29 regional hub airports. Twelve airports, including Changsha Huanghua International Airport and Hangzhou Xiaoshan International Airport, have node importance values higher than the average for regional hub airports, while the remaining 17 airports have values below the average, indicating that the overall node importance of regional aviation hubs is generally above average.

Table 11. Node importance of regional aviation hubs in 2021

Airport	$d(x)$	$D(x)$	$LD(x)$	$\mu_{(x)}$	$LNDH_{index}(x)$
Changsha/Huanghua	111	5486	0.905	0.024	69.989
Hangzhou/Xiaoshan	111	5288	0.897	0.023	69.619
Wuhan/Tianhe	106	5,290	0.818	0.023	68.388
Nanjing/Lukou	106	5115	0.815	0.020	68.116
Tianjin/Binhai	105	5074	0.808	0.020	67.767
Zhengzhou/Xinzheng	103	5031	0.803	0.019	67.159

Lanzhou/Zhongchuan	94	5112	0.792	0.020	66.701
Haikou/Meilan	99	4999	0.791	0.019	66.531
Guiyang/Longdongbao	98	4999	0.791	0.019	66.261
Nanning/Wuxu	87	4980	0.788	0.019	65.849
Qingdao/Jiaodong	91	4,673	0.786	0.019	65.739
Wenzhou/Longwan	87	4,855	0.783	0.015	65.149
Shenyang/Taoxian	86	4,732	0.773	0.014	64.649
Xiamen/Gaoqi	84	4827	0.783	0.013	64.253
Dalian/Zhoushuizi	85	4241	0.763	0.013	64.244
Sanya/Fenghuang	78	4842	0.794	0.012	63.721
Yinchuan/Hedong	76	4663	0.684	0.012	63.317
Jinan/Yaoqiang	81	4,387	0.779	0.012	63.221
Nanchang/Changbei	73	4706	0.687	0.012	63.067
Tianyan/Wusu	75	4623	0.682	0.011	63.017
Fuzhou/Changle	76	4512	0.674	0.011	63.011
Ningbo/Lishe	70	4331	0.677	0.011	62.745
Hohhot/Baita	69	4291	0.632	0.010	62.633
Hefei/Xinqiao	63	4172	0.575	0.009	62.572
Guilin/Liangjiang	64	4051	0.597	0.009	62.554
Shijiazhuang/Zhengding	64	3920	0.545	0.009	62.532
Xining/Caojiaobu	62	3957	0.571	0.009	62.524
Changchun/Longjia	58	3,774	0.555	0.008	62.426
Lhasa/Gonggar	36	2163	0.358	0.006	59.761
Mean	82	4589	0.721	0.014	64.742

Source: By authors.

4.5 Analysis of the Classification Results for Regional Aviation Hubs

The network value and place value scores for regional hub airports are shown in Tables 12 and 13 below:

Table 12. Regional air hub network value scores

No.	Airport	Score	No.	No.	Score
1	Hangzhou/Xiaoshan	2819.495	16	Changchun/Longjia	994.636
2	Wuhan/Tianhe	1933.719	17	Tianjin/Binhai	958.106
3	Haikou/Meilan	1851.007	18	Wenzhou/Longwan	923.121
4	Zhengzhou/Xinzheng	1823.211	19	Ningbo/Lishan	892.808
5	Nanjing/Lukou	1678.233	20	Fuzhou/Changle	868.863
6	Guiyang/Longdongbao	1584.119	21	Nanning/Wuxu	848.546
7	Xiamen/Gaoqi	1522.392	22	Shenyang/Taoxian	833.278
8	Qingdao/Jiaodong	1,491.522	23	Lhasa/Gonggar	803.577

9	Nanchang/Changbei	1487.490	24	Hefei/Xinqiao	802.895
10	Sanya/Fenghuang	1421.537	25	Taiyuan/Wusu	626.517
11	Changsha/Huanghua	1395.084	26	Xining/Caojiabao	574.905
12	Jinan/Yaoqiang	1281.680	27	Shijiazhuang/Zhengding	524.667
13	Dalian/Zhoushuizi	1252.751	28	Guilin/Liangjiang	434.525
14	Lanzhou/Zhongchuan	1088.892	29	Yinchuan/Hedong	401.617
15	Hohhot/Baita	1020.274		Average	1177.223

Source: By authors.

As shown in Table 12, Hangzhou Xiaoshan International Airport ranks first in terms of network value. Thirteen airports, including Hangzhou Xiaoshan International Airport and Nanjing Lukou International Airport, have network values above the average, indicating that the network value of these 13 airports is being effectively utilized. Seventeen airports, including Lanzhou Zhongchuan International Airport and Hohhot Baita International Airport, have network values below the average, suggesting that their network value is only partially realised and that there is still room for optimisation.The network value of two airports, including Guilin Liangjiang International Airport and Yinchuan Hedong International Airport, is below 500, indicating that these two airports have significant potential for optimising their network value.

Table 13. Regional aviation hub place value scores

No.	Airport	Score	No.	No.	Score
1	Hangzhou/Xiaoshan	12,378.730	16	Tianjin/Binhai	2772.509
2	Nanchang/Changbei	7,150.677	17	ShijiazhuangZhengding	2767.716
3	Changsha/Huanghua	6877.265	18	Hohhot/Baita	2483.768
4	Sanya/Fenghuang	5552.339	19	Hefei/Xinqiao	2478.743
5	Jinan/Yaochang	4952.379	20	Shenyang/Taoxian	2338.678
6	Nanjing/Lukou	4415.675	21	Xining/Caojiaobu	2229.798
7	Wuhan/Tianhe	4408.064	22	Nanning/Wuxu	1936.352
8	Qingdao/Jiaodong	4128.855	23	Wenzhou/Longwan	1931.881
9	Zhengzhou/Xinzheng	4,127.744	24	Yinchuan/Hedong	1931.683
10	Haikou/Meilan	3,880.762	25	Lanzhou/Zhongchuan	1928.305
11	Xiamen/Gaoqi	3870.422	26	Ningbo/Lishan	1927.880
12	Dalian/Zhoushuizi	3853.211	27	Taiyuan/Wusu	1792.159
13	Fuzhou/Changle	3594.339	28	Lhasa/Gonggar	1387.714
14	Guiyang/Longdongbao	3583.271	29	Guilin/Liangjiang	1246.350
15	Changchun/Longjia	3028.810		Average	3619.1751

Source: By authors.

As can be seen from the data in Table 13, few airports have fully realised their place value. Hangzhou Xiaoshan International Airport ranks first in terms of the development of its own intrinsic value, with the degree to which this value has been fully realised far exceeding that of other airports.

Twelve airports, including Hangzhou Xiaoshan International Airport and Nanchang Changbei International Airport, have a place value above the average, indicating that their intrinsic value has been well developed.Seventeen airports, including Fuzhou Changle International Airport and Guiyang Longdongbao International Airport, have a site value below the mean, indicating that their intrinsic value has not been adequately developed. Among these, Lhasa Gonggar International Airport and Guilin Liangjiang International Airport have site values below 1,500, ranking last among the 29 regional aviation hubs, suggesting significant potential for optimisation of their place value.

Based on the network value and place value scores of regional aviation hubs, this paper employs the 'Elbow Method' to calculate the sum of squared errors for different k-values, plots these values, and then identifies the 'elbows' or 'inflection points' in the graph to determine the optimal number of clusters.Once the optimal number of clusters has been determined, the “hierarchical clustering analysis method” is employed to divide the regional aviation hubs into multiple groups, maximising similarity within the same group and minimising similarity between different groups. As can be seen in Figure 1, when k=3, the rate of decrease in the intra-cluster sum of squared errors is the fastest, whereas at higher k-values, the rate of decrease slows significantly; therefore, k=3 can be selected as the optimal number of clusters.

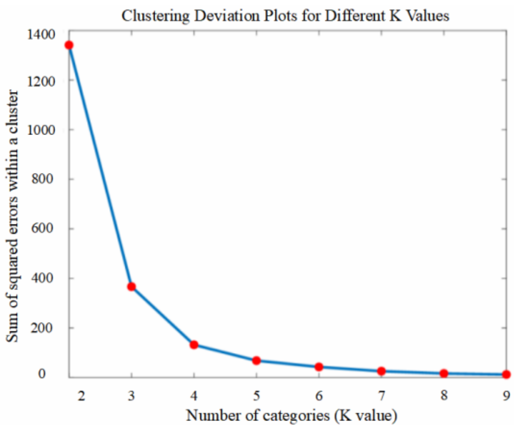

Figure 1. Elbow method for determining the optimal number of clusters

Source: By authors.

After determining the optimal number of clusters to be 3, systematic cluster analysis was performed using SPSS software, yielding a systematic clustering dendrogram for the 29 regional hub airports, as shown in Figure 2.

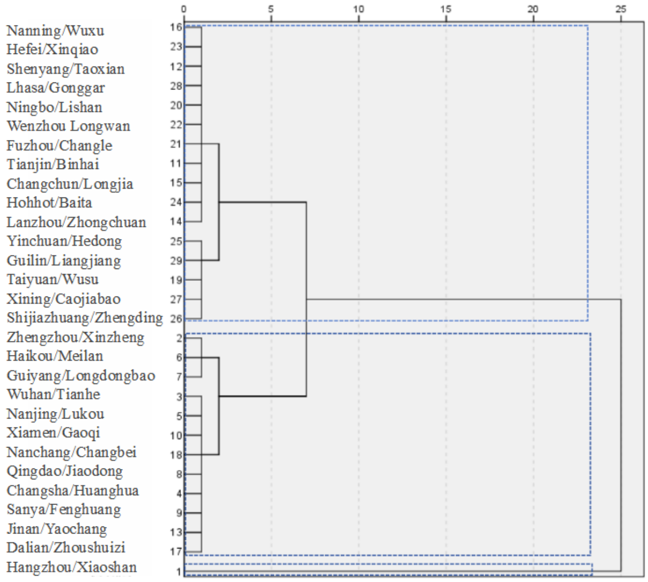

Figure 2. System clustering dendrogram

Source: By authors.

Based on the system clustering dendrogram in Figure 2, it can be seen that the 29 regional hub airports are classified into three categories. Table 15 presents the results of the classification of regional aviation hub types: there is 1 highly developed airport, 12 moderately developed airports, and 16 lowly developed airports.

Table 14. Results of the regional aviation hub typology

Regional aviation Hub Type	Airport
Highly developed regional aviation hub	Hangzhou Xiaoshan International Airport
Moderately developed regional aviation hubs	Nanjing Lukou International Airport, Haikou Meilan International Airport, Xiamen Gaoqi International Airport, Changsha Huanghua International Airport, Zhengzhou Xinzheng International Airport, Qingdao Jiaodong International Airport, Guiyang Longdongbao International Airport, Dalian Zhoushuizi International Airport, Sanya Phoenix International Airport, Jinan Yaoqiang International Airport, Nanchang Changbei International Airport, Wuhan Tianhe International Airport
Lowly developed regional aviation hubs	Lhasa Gonggar International Airport, Xining Caojiabao International Airport, Yinchuan Hedong International Airport, Changchun Longjia International Airport, Guilin Liangjiang International Airport,Hefei Xinqiao International Airport, Shenyang Taoxian International Airport, Lanzhou Zhongchuan

	International Airport, Hohhot Baita International Airport, Taiyuan Wusu International Airport, Ningbo Lishe International Airport, Nanning Wuxu International Airport, Tianjin Binhai International Airport, Wenzhou Longwan International Airport, Fuzhou Changle International Airport, Shijiazhuang Zhengding International Airport

Source: By authors.

As shown in Table 14, when airports are classified based on value assessment, regional hub airports exhibit a 'pyramid-shaped' distribution pattern, reflecting significant gradations in the development of regional aviation hubs in China. A higher proportion of airports fall into the 'lowly developed' category of regional aviation hubs, while there is only one airport in the 'highly developed' category.Among these, Hangzhou Xiaoshan International Airport, located within a highly developed regional aviation hub, exhibits network value and intrinsic place value that are significantly higher than those of other types of airports, as particularly evident in indicators such as connectivity, passenger throughput and terminal area.Among the moderately developed regional aviation hubs, 12 airports—including Nanjing Lukou International Airport, Haikou Meilan International Airport and Xiamen Gaoqi International Airport—exhibit higher network value and intrinsic value than those in the low-development category.Among the lowly developed regional aviation hubs, 16 airports—including Shenyang Taoxian International Airport, Xining Caojiaobu International Airport and Yinchuan Hedong International Airport—rank at the lower end of the regional aviation hubs in terms of network value and intrinsic place value.

5. Conclusions and Recommendations

Given that regional aviation hubs play a pivotal role in China's route network, and that different types of airports occupy distinct positions and fulfil different functions within this network, an assessment of the value of China's regional aviation hubs was conducted. Cluster analysis was employed to classify 29 regional hubs, yielding the following findings:

(1) The value of regional hub airports exhibits a 'pyramid-shaped' distribution, with distinct gradations.Based on an analysis of the value of airports within the transport network and their intrinsic place value, a regional hub airport value evaluation framework comprising 10 indicators across two dimensions—network value and place value—was established. Cluster analysis was employed to classify regional aviation hubs into three categories: “highly developed”, “moderately developed” and “lowly developed” regional aviation hubs.

(2) The “highly developed” regional aviation hubs comprise only Hangzhou Xiaoshan International Airport, which possesses the highest airport value and a distinct value advantage amongst regional aviation hubs;“Moderately developed” regional aviation hubs include 12 airports such as Nanjing Lukou International Airport, Haikou Meilan International Airport and Xiamen Gaoqi International Airport, with their airport value ranking in the middle tier of regional aviation hubs; “Lowly developed” regional aviation hubs include 16 airports such as Shenyang Taoxian International Airport, Xining Caojiaobu International Airport and Yinchuan Hedong International Airport, with

their airport value ranking at the lower end of regional aviation hubs.

Based on the above research findings, the following recommendations are proposed for the development of these three categories of regional hub airports:

(1) For “highly developed” regional aviation hubs, the primary focus should be on strengthening connections with international aviation hubs, establishing high-frequency air express routes, and implementing “public transport-style” route operations to meet passengers' needs for “immediate departure upon arrival”.

(2) “Moderately developed” regional aviation hubs should rely on the “air-rail intermodal transport” model to create a seamless, integrated passenger service system, extend the air transport network deep into the inland hinterland, and establish a comprehensive transport network structure characterised by “trunk lines connecting and feeder lines interlinking”.

(3) “Lowly developed” regional aviation hubs should focus on the integrated development of aviation and tourism, launching premium tourist routes to ensure effective coordination between civil aviation planning and tourism planning.

This study focuses on the two dimensions of network value and place value to classify China’s regional aviation hubs, revealing a pyramid-shaped hierarchical structure of development. The findings provide differentiated strategic directions for airports at various levels. Future research could extend this framework to other categories of airports, incorporate dynamic time-series data to track the evolution of value, and empirically examine the causal mechanisms between network value and place value.

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Conflicts of Interest

The authors confirm that there are no conflicts of interest.

References

[1] Li, G. and Guan, T.Y. Evaluation of the Competitiveness of Regional Aviation Hubs. Integrated Transport, 2024, 46(01), 18-22. DOI: 10.20164/j.cnki.cn11-1197/u.2024.01.003.

[2] Li, G., Yuan, H., Zhang, X. and Wang, X. Research on the input-output efficiency of civil aviation industry to regional economy in China based on DEA modeling. Journal of Management Science and Operations, 2024, 2(1), 1-22.

[3] Li, G., Dai, L., Xue, Y., Zheng, X., Yang, S., Chen, Y., Li, Z. and Shao, M. Recognition of value of international aviation hub air shuttle on hub route network. Journal of Management Science and Operations, 2025, 3(1), 1-20.

[4] Zhang, P.W. and Du, F.M. Analysis of Spatio-Temporal Distribution Differences in Slot Resources at Regional Hub Airports: A Case Study of Chengdu and Chongqing. Science, Technology and Engineering, 2022, 22(08), 3294-3299.

[5] Pamucar, D., Özçalıcı, M. and Gurler, H.E. Evaluation of the efficiency of world airports using WENSLO-ARTASI and Monte-Carlo simulation. Journal of Air Transport Management, 2025, 124, 102749. DOI: 10.1016/j.jairtraman.2025.102749.

[6] Ngo, H.T., Huynh, N.T. and Yang, C.C. A sequential approach to airport efficiency evaluation: Integrating two-stage DEA and truncated regression. Journal of Air Transport Management, 2026, 131, 102922. DOI: 10.1016/j.jairtraman.2025.102922.

[7] Adikariwattage, V., de Barros, A.G., Wirasinghe, S.C. et al. Airport classification criteria based on passenger characteristics and terminal size. Journal of Air Transport Management, 2012, 24, 36-41.

[8] Yang, X.B. and Liu, J. Classification of domestic airports based on functional positioning. Journal of Civil Aviation University of China, 2018, 36(02), 20-22.

[9] Rodríguez-Déniz, H., Suau-Sanchez, P. and Voltes-Dorta, A. Classifying airports according to their hub dimensions: an application to the US domestic network. Journal of Transport Geography, 2013, 33, 188-195.

[10] Zhang, Q., Wang, B., Xue, D.S. et al. Spatiotemporal Evolution of the Competitiveness of Chinese and European Aviation Hub Cities: An Analysis Based on an Improved Connectivity Utility Model [J]. Geographical Science, 2025, 45(7): 1465–1474. DOI: 10.13249/j.cnki.sgs.20240717.

[11] Li, G., Tian, Y.X. and Mukthar, J.K.P. DEA efficiency-based coupling and coordination analysis of China civil aviation industry and regional economy. Journal of Intelligence Technology and Innovation, 2024, 2(2), 17-34.

[12] Li, G., Chen, Y., Xue, Y., Dai, L., Zheng, X., Yang, S., Shao, M. and Li, Z. Study on the influence mechanism of the development of China's civil aviation transport industry on the upgrading of industrial structure. Journal of Intelligence Technology and Innovation, 2025, 3(1), 24-44.

[13] Zhou, W., Yuan, L.G. and Mao, H.L. A Study on the Classification of Domestic Airports Handling Over 10 Million Passengers Annually from the Perspective of Flight Boarding Bridge Utilization Rates. Journal of Civil Aviation, 2025, 9(03), 33-37+49.

[14] Khanjanasthiti, I., Bajracharya, B. and O'Hare, D. Towards More Sustainable Planning Decisions Around Airports: Investigating Global Airport Classifications and Proposing a Four-Tiered System for Australia. Sustainability, 2025, 17(12), 5259-5259. DOI: 10.3390/SU17125259.

[15] Qin, C.G. Practices and Reflections on the Sustainable Operation of Regional Airports. Air Transport Business, 2023, 461(10).

[16] Wang, Q.Z. Comparative Classification and Empirical Analysis of Cargo Airports in China. Shanghai Airport—2019 Annual Collection of Papers, 2019, 108-112.

[17] Jiang, Z.N. and Yang, X.B. Definition and Classification of Cargo Airports Based on Factor Analysis and Cluster Analysis. Logistics Technology, 2023, 42(10), 58-60.

[18] Zhang, X.Y., Xiao, W.J. and Zhang, H.J. Classification of Regional Airports' Growth Potential Based on Traffic Volume Characteristics. Integrated Transport, 2021, 43(12), 39-44. DOI: 10.20164/j.cnki.cn11-1197/u.2021.12.007.

[19] Bae, W. and Chi, J. Content Analysis of Passengers' Perceptions of Airport Service Quality: The Case of Honolulu International Airport. Journal of Risk and Financial Management, 2021, 15(1), 5.

[20] Qi, L., Huai, Y.C., Chen, X.L., Dai, K.J. and Huang, X. An Evaluation Method for Airport Resilience Based on Dynamic Bayesian Networks. Science, Technology and Engineering, 2024, 24(35), 15276-15284.

[21] Tan, K.L. From Hub to Landmark: Functional Upgrades and Urban Integration in Airport Construction. Sichuan Architecture, 2026, 46(01), 14-16.

[22] Li, W.B. and Li, Z.S. Enhancing the Functions of International Aviation Hub Airports to Support the Development of International Consumer Hub Cities. China Economic and Trade Guide, 2023, 1049(11).

[23] Luo, T. Leveraging the Value of Airport Platforms to Build a New Model for Aviation Hubs. Civil Aviation Management, 2026, (02), 25-29.

[24] Li, C.H., Zhao, L.Y. and Zhang, W.N. A Study on Development Strategies for Large Hub Airports from a Regional Coordination Perspective: A Case Study of the Pearl River Delta Hub (New Guangzhou) Airport. Transportation, Ports, and Shipping, 2025, 12(06), 8-15. DOI: 10.16487/j.cnki.issn2095-7491.2025.06.003.

[25] Jiao, H.J. and Yang, X.B. A Study on the Comprehensive Classification of Hub Airports in China. Journal of East China Jiaotong University, 2020, 37(06), 88-95. DOI: 10.16749/j.cnki.jecjtu.2020.06.012.

[26] Zheng, W.J. A Study on Development Strategies for Non-Hub Airports Based on Airport Classification and Passenger Growth Logic. Integrated Transport, 2024, 46(09), 125-130.

[27] Ma, Y.F. Building a Function-Oriented Aviation Hub [J]. Macroeconomic Management, 2025, (10): 59–65+72. DOI: 10.19709/j.cnki.11-3199/f.2025.10.004.

[28] Vale, D.S., Viana, C.M. and Pereira, M. The extended node-place model at the local scale: Evaluating the integration of land use and transport for Lisbon's metro network. Journal of Transport Geography, 2018, 69, 282-293.

[29] Yang, X.B. A Further Discussion on Cluster Analysis and Targeted Policies for China's World-Class Airport Clusters. Civil Aviation Management, 2025, (05), 6-11.

[30] Ke, Y.S. and Wei, W. A Study on the Optimization of Route Networks for Hub Airports. Intelligent Computers and Applications, 2025, 15(05), 149-155. DOI: 10.20169/j.issn.2095-2163.250521.

[31] Han, S.H., Chen, S.W. and Li, N. Robustness Analysis and Optimization of Aviation Networks from a Multi-Layer Network Perspective. Journal of Xiamen University (Natural Science Edition), 2026, 1-13.

[32] Jiang, B., Chu, N.C., Li, Y., Chen, Y. and Shen, B.R. High-speed rail accessibility and land value: A literature review and outlook. Economic Geography, 2019, 39(07), 9-13.

[33] Shao, B., Li, R.R., Ye, C. and Cao, F. The Spatial Pattern Evolution of Accessibility and Regional Economic Linkages under the High-Speed Rail Network: An Empirical Analysis Based on Fujian Province. East China Journal of Economics and Management, 2020, 34(08), 33-43.

[34] Yao, Y.L. and Zhao, Y.Q. Spatial Spillovers, Labour Inflows and Urban Economic Growth of High-Speed Rail. East China Journal of Economics and Management, 2022, 36(04), 1-9.

[35] Brons, M., Givoni, M. and Rietveld, P. Access to railway stations and its potential in increasing rail use. Transportation Research Part A, 2009, 43, 136-149.