Study on the Location of China's Air Logistics Hub Airport Based on TOPSIS Model[1]

Xiangyue Wu[1,a], ***Lihua Jiang***[1,b] **and Ran Wei**[2,c,*]

[1]*Department of Maritime Transport, Naval Logistics Academy, Tianjin, China*
[2]*School of Economics and Management, Civil Aviation University of China , Tinjin,China*
a. caucxywu@qq.com, b. Jlihua2007@126.com, c. weiran2350@sina.com
**corresponding author: Ran Wei*

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Abstract: With the economic globalization and integrated development, the air logistics industry has been upgraded, and the phenomenon of coupling and coordinated development of airports and regional economies have become more and more obvious. The business volume of the air logistics industry, which mainly focuses on air cargo, has surged and the development prospects are good. However, at present, a good freight development channel has not yet been established in China to support the rapid development of air logistics. The development of air logistics needs to implement the cargo priority strategy through the cargo hub airport, realize the priority of air cargo, and gather the air carrier flow to create an air logistics ecosystem. Based on China's air logistics development market, This study builds a location model for China's air cargo hub airport, and uses the TOPSIS model evaluation method to conclude that it is more suitable to establish a national air logistics hub airport in Wuhan City Circle, Hubei Province.

1. Introduction

China's cargo and mail transportation volume reached 7.12 million tons, an increase of 12.5% month on month in 2017. CAAC predicts that in the next 20 years, China will grow by 10.6% to become the largest market of air cargo. Air logistics has a good development prospect, but it still faces many problems. First of all, in the form of Cargo organization, the concept of "heavy passenger and light cargo" leads to the cargo following the passenger. The main network of passenger transport is point-to-point, which has great limitations on the scale of transport capacity and logistics efficiency. Secondly, in terms of air cargo hardware facilities, the total number of cargo aircraft in China is about 131, only one-fifth of the number of FedEx. Limited air cargo facilities cannot meet the demand of people for air cargo under the background of the Internet. Finally, the distribution of air cargo in China is unbalanced. The polarized distribution of goods supply leads to the mismatch between demand and supply, resulting in the waste of resources, high cost and low efficiency of air logistics. Based on the experience of foreign air logistics development, the establishment of air cargo hub airport and hub and spoke route network can effectively improve the handling capacity, resource utilization and economic benefits of air logistics.

2. Literature Review

The research on airport location at home and abroad is focused on the passenger airport.

Among the research results of hub location, barahohna & daskin (1998) used integer programming to study facility location[1]; Jiang Dayuan (2005) used Baumol wolf model to calculate logistics distribution center[2]; Zhu huanping (2008) used fuzzy multiple criteria decision-making based on triangular fuzzy number to study logistics distribution center location[3]. Lu houqing (2012) and others used PCA to make a comprehensive evaluation of the airport[4]; Cao Xueming (2010) established a two-level planning model for the multi-airport system and found that the adjustment and balance of the interests of customers and the airport will help the resource allocation and capacity coordinated utilization of the airport in addition to meeting the constraints of the airspace[6].This study can use the theoretical methods of passenger transportation hub location selection to consider the characteristics of the development of air logistics to construct an air cargo location model and use quantitative and qualitative analysis methods to select the location of China's air logistics hub airport.

3. Establishment of Index System

3.1. Characteristics of Air Cargo Hub Airport

Air cargo is different from air passenger transportation. Air cargo can endure multiple transits, and the source of cargo can rely on the comprehensive transportation system to reach the cargo hub, and then the transit cargo hub is scattered to various destinations, effectively improving the integrated logistics transfer rate. As the hub of air logistics, first of all, the location of Cargo hub airport can be moderately far away from the source of goods. Even if the hub economy is underdeveloped and the demand for air cargo is insufficient, it may still be selected. However, its geographical location must be in the geographical center of the service scope, which can cover a wide area in a shorter time and facilitate the improvement of airport connectivity. For example, foreign air cargo hubs such as Memphis, Louisville and Huntsville airports, international cargo hubs such as Dubai International Airport, Ted Stevens Anchorage International Airport and Changi International Airport are all located in the geographical center of the service area. Secondly, transportation infrastructure is a necessary condition for the development of comprehensive transportation hubs, such as the comprehensive transportation with Memphis Airport as the center The transportation system includes five first-class Railways (six railway terminals), Mississippi River (the fourth largest inland terminal in the United States) and seven expressways. The three-dimensional transportation improves the organizational form of logistics, which is conducive to the implementation of multimodal transport. Thirdly, the demand for the hinterland of air logistics is directly related to the economic structure, port distribution, foreign trade and high-tech industry cluster of the hinterland. For example, Shanghai Pudong Airport, Hong Kong airport, Yangtze River Delta and Pearl River Delta provide sufficient supply for the two airports respectively; finally, the air hub cluster area is a high-tech industry cluster area, and the realization of industrial development depends on innovation-driven, and the core of innovation-driven is talent-driven. Therefore, talent is one of the core elements to realize air logistics and related industries.

3.2. Determination of the Index System

According to the characteristics of air logistics hub, This study constructs the airport location model of an air logistics hub from four aspects: air cargo geographical centrality, transportation infrastructure, hinterland economic environment, and scientific and technological talents. Specific indicators are shown in Table 1.

1) Air cargo has a high demand for the timeliness, so in the process of location selection of air logistics hub, geographical location and air cargo source are one of the key factors of hub location selection. Geographical location should cover more hinterland in the minimum flight time. In addition, the source of air cargo is close to the hub airport. With the above two points, This study will use the gravity method to introduce the geographical centrality of air cargo as the index of the hub location.

2) The integrated infrastructure is the concentrated embodiment of the connectivity of the local integrated transportation system, and the hardware guarantee for the development of air-to-air, air-rail, air-land, air-sea,and other multimodal transport. Multimodal transport can effectively expand the flow, improve the level of organization and transportation, and realize reasonable transportation, which can save transportation costs and improve transportation quality. In this paper, the mileage of roads, railways, waterways (inland rivers) and Cargo transport turnover of each province is used as the comprehensive infrastructure indicators to determine the location of hub airports.

3) The hinterland economic environment can directly reflect the regional economic structure and the development potential of air logistics. Because of the characteristics of air transportation, This study will analyze the economic environment of hinterland by economic structure, trade dependence, number of high-tech enterprises and number of first-class ports.

4) Science and education talents reflect the development level of education. The establishment of Cargo hub airport attracts the aggregation of relevant high-tech industries, which is a talent intensive industry. High- quality education is a strong guarantee for the supply of science and education talents. The main research object of this study is universities in all provinces and cities, which are measured from the training function and contribution of scientific research.

Table 1: Cargo airport location index analysis.

Target layer	First level index	Second level index
air logistics hub airport	Geographical centrality of air cargo	Geographical centrality of air cargo
	Science and education talents	Training ability of science and education talents
		Contribution of scientific research
	Transportation infrastructure	Highway mileage
		Railway mileage
		Waterway mileage
	Hinterland economic environment	Number of national first-class ports
		economic structure
		Dependence on foreign trade
		Number of high-tech industrial companies

Note: the economic structure in the index adopts the sum of the proportion of the second and third industries in the region; the scientific and educational talents adopt the research results of Zhang jinzong[5].

4. Model Building

TOPSIS is a common multi-objective decision evaluation method. It mainly uses multiple decision-making objectives to choose the best. In this paper, TOPSIS is used to establish the location model of a Cargo hub airport.

4.1. Dimensionless Data Processing

Assumed to exist C Alternative Airports $\{c_1,c_2......c_c\}$ There are m evaluation indexes, which should

be recorded $\{m_1,m_2......m_m\}$ City c_iIndex J of$x_{ij}(i = 1,2......c;\ j = 1,2......m)$Matrix $X = (x_{ij})_{c\times m}$

Represents an alternative airport set C_i Pairs of index sets M_i Decision matrix for:

$$X = (x_{ij})_{c\times m} = \begin{bmatrix} x_{11} & \cdots & x_{1m} \\ \vdots & & \vdots \\ x_{c1} & \cdots & x_{mm} \end{bmatrix};$$

$$(i = 1,2......c;\ j = 1,2......m) \quad (1)$$

Because of the different dimensions in the evaluation indexes, the numerical value is treated dimensionless in the analysis. Standardization of decision matrix

1) For cost indicators M_iTime:

$$a_{ij} = \frac{x_j^{max} - x_{ij}}{x_j^{max} - x_j^{min}};$$

$$(i = 1,2 \ldots\ldots c;\ \ j = 1,2 \ldots\ldots m) \qquad (2)$$

2) For benefit indicators M_i Time:

3)

$$a_{ij} = \frac{x_{ij} - x_j^{mix}}{x_j^{max} - x_j^{min}}; \qquad (3)$$

$$(i = 1,2 \ldots\ldots c;\ \ j = 1,2 \ldots\ldots m);$$

In formula, $x_j^{max} = \max\left\{\frac{x_{ij}}{1} < i < c\right\}$; $x_j^{mix} = \min\left\{\frac{x_{ij}}{1} < i < c\right\}$;

The decision matrix of the standard index after dimensionless treatment is expressed as

$$A = \left(a_{ij}\right)_{m \times n} = \begin{bmatrix} a_{11} & \cdots & a_{1m} \\ \vdots & & \vdots \\ a_{c1} & \cdots & a_{mm} \end{bmatrix};$$

$$(i = 1,2 \ldots\ldots c;\ \ j = 1,2 \ldots\ldots m) \qquad (4)$$

4.2. Weight Selection

In this paper, quantitative and qualitative comprehensive research will be carried out, and AHP will be used to determine the weight of indicators. The AHP model is divided into levels. The target layer is A, the standard layer is C and the indicator layer is P. the indicator layer structure of the airport location is shown in the figure. AHP analysis method needs to score the importance of elements in each layer. In this paper, we take 5 expert scoring method to assign a value, according to the matrix composed of upper and lower relations. This study uses this method to form a judgment matrix for the first level indexes.

$$\begin{bmatrix} \omega_{11} & \omega_{12} & \cdots & \omega_{C} \\ \omega_{21} & \omega_{22} & \cdots & \omega_{2C} \\ \vdots & \vdots & & \vdots \\ \omega_{n1} & \omega_{n2} & \cdots & \omega_{nc} \end{bmatrix} \qquad (5)$$

Building the second level index judgment matrix

$$\begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1C} \\ p_{21} & p_{22} & \cdots & p_{2C} \\ \vdots & \vdots & & \vdots \\ p_{n1} & p_{n2} & \cdots & p_{nc} \end{bmatrix} \quad (6)$$

Nine level scaling method and square root method to calculate the maximum value of the eigenvector level of matrix index τ_{max}. check the consistency of matrix CI and random consistency indicator RI Value. Use the ratio of the two $CR < 0.1$, it is considered to have test consistency. Otherwise, the inspection fails.

$$\mathrm{CI} = \frac{\tau_{\max} - \mathrm{n}}{(\mathrm{n}-1)} \quad (7)$$

$$\mathrm{CR} = \frac{\tau_{\max} - \mathrm{n}}{(\mathrm{n}-1) \times \mathrm{RI}} \quad (8)$$

After processing, the weighted standard matrix and its index weight are setβ_j

$$Z = \begin{bmatrix} \beta_1 a_{11} & \cdots & \beta_j a_{1m} \\ \vdots & & \vdots \\ \beta_1 a_{c1} & \cdots & \beta_j a_{cm} \end{bmatrix} \quad (9)$$

4.3. Location Model of a Cargo Hub Airport

TOPSIS is a multi-objective decision-making model, also known as the pros and cons distance method. It sorts the evaluation objects by detecting the distance between the evaluation object and the optimal solution and the worst solution. If the evaluation object is closest to the optimal solution and the worst solution at the same time, it is the best; otherwise, it is not the best. TOPSIS model is used to solve the Cargo hub airport

$$s^+ = (maxz_{i1}, maxz_{i2}, \cdots, max_{ij}) = \{S_1^+, S_2^+ \cdots S_n^+\}$$

$$s^- = (minz_{i1}, minz_{i2}, \cdots, min_{ij}) = \{S_1^+, S_2^+ \cdots S_n^+\} \quad (10)$$

Evaluation objectsD_i^+和 D_i^-

$$D_i^+ = \sqrt{\sum_{i=1}^{n} (z_{ij} - s_j^+)^2} \quad (11)$$

$$D_i^- = \sqrt{\sum_{i=1}^{n} \left(z_{ij} - s_j^-\right)^2} \quad (12)$$

In styleD_i^+Represents the distance from city I to the optimal solution, D_i^-Represents the distance from city I to the worst solution.

The approach degree of each evaluation index object to the optimal schemeP_i

$$P_i = \frac{D_i^-}{D_i^- + D_i^+} \quad (13)$$

$0 \leq P_i \leq 1$, $P_i \rightarrow 1$,It shows that the evaluation object is the best.Finally pressP_iThe evaluation results are given.

5. Application of the Model

5.1. Model Simplification

1. In order to facilitate the research, This study takes the Cargo throughput as the main reference basis and initially proposes to take the top 20 airports in the country as hub alternative airports and carry out the evaluation of the geographical centrality of air cargo.

2. The geographical location of the system is the same in the area, city and field involved.

3. After the evaluation of the geographical centrality of air cargo in the alternative airports, the top five airports are regarded as the alternative airports of the final hub airports.

5.2. Data Processing

5.2.1. Geographical Centrality of Air Cargo

a. Primary alternative Airport

Based on the 2016 National Airport statistics bulletin. The top 20 airports in terms of cargo and mail throughput were selected. Respectively: Beijing, Shanghai (Pudong and Hongqiao), Guangzhou (Guangdong), Chengdu (Sichuan), Shenzhen (Guangdong), Kunming (Yunnan), Xi-an (Shaanxi), Chongqing, Hangzhou (Zhejiang), Xiamen (Fujian), Nanjing (Jiangsu), Wuhan (Hubei), Changsha (Hunan), Urumqi (Xinjiang), Qingdao (Shandong), Zhengzhou (Henan), Haikou（Hainan, Haikou (Hainan), Tianjin.

b. Quantifying the geographical location of the primary Airport

Quantify the top 20 airports and coordinate their locations.

Table 2: Geographic center degree coordinate of each cargo airport location.

Airport name	coordinate	Airport name	coordinate
Beijing / capital	(4.8, 21.2)	Shanghai / Hongqiao	(10.0, 24.5)
Chongqing / Jiangbei	(11.5, 16.0)	Xiamen / Gaoqi	(14.5, 23.0)
Zhengzhou / Xinzheng	(7, 20)	Sanya / Phoenix	(18.6, 17.5)
Changsha / Huanghua	(12.5, 20.0)	Qingdao / Liuting	(7, 23.5)
Xi-an / Xianyang	(8.3, 17.5)	Nanjing / Lukou	(10.6, 23.0)
Wuhan / Tianhe	(10.9, 20.6)	Kunming / Changshui	(14.0, 13.6)
Urumqi / Diwopu	(2, 6)	Hangzhou / Xiaoshan	(11.0, 24.0)
Tianjin / Binhai	(5.1, 22)	Haikou / Meilan	(17.5,18.0)
Shenzhen / Bao-an	(16.0, 20.8)	Guangzhou / Baiyun	(15.5, 20.0)
Shanghai / Pudong	(10.0, 24.5)	Chengdu / Shuangliu	(10.8, 14.8)

Data source: 2017 National Airport annual report, collected by the author.

geographical centrality of air cargo in the alternative Airport

As shown in Table 2, the center of gravity coordinates are calculated through the geographical advantages of flow and location by the center of gravity location method.

$$x_0 = \sum_1^n \frac{c_i \omega_i x_i}{c_i \omega_i},\ y_0 = \sum_1^n \frac{c_i \omega_i y_i}{c_i \omega_i}; \tag{14}$$

In formula (14) x_0,y_0, Represents the proposed airport location coordinates; n is the capacity of the alternative airport; x_i、 y_i The abscissa and ordinate of the location of the alternative airport are respectively represented, $c_i$is the weight of the alternative airport; $\omega_i$for airport Cargo flow.

In order to select the administrative region where the best candidate airport is located, f is used to express the geographical centrality of air cargo, that is, the square of the distance between each airport and the target airport. The smaller the value, the closer to the target airport. The location map of a Cargo hub airport is shown in Figure 1.

$$\mathrm{F} = (x_i - x_0)^2 + (y_i - y_0)^2 \tag{15}$$

As shown in Figure 1, we can get the coordinates of alternative cities

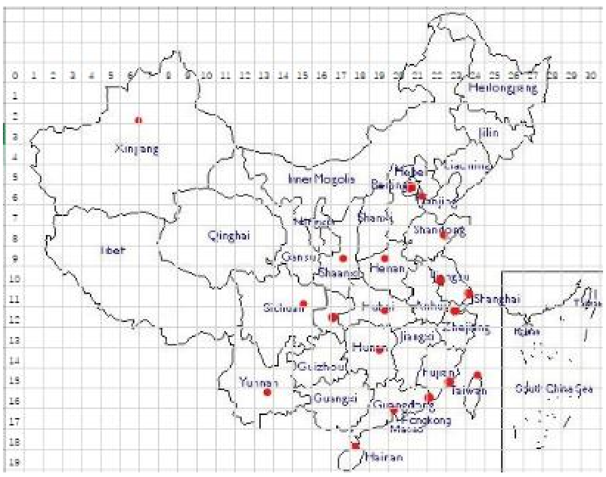

Figure 1: Location map of cargo airport.

Table 3: Ranking of geography center of air cargo at cargo airports.

Airport	Geographic centrality	ranking	Airport	Geographic centrality	ranking
Wuhan / Tianhe	0.6053	1	Xiamen / Gaoqi	24.8798	11
Changsha/Huanghua	3.5877	2	Chengdu / Shuangliu	25.8234	12
Nanjing / Lukou	9.7463	3	Qingdao / Liuting	26.1488	13
Xi-an / Xianyang	10.9906	4	Shenzhen / Bao-an	29.9040	14
Zhengzhou / Xinzheng	13.0456	5	Tianjin / Binhai	34.8604	15
Chongqing / Jiangbei	15.8322	6	Beijing / capital	35.5013	16
Hangzhou / Xiaoshan	17.1422	7	Kunming / Changshui	50.9081	17
Shanghai / Pudong	21.7337	8	Haikou / Meilan	51.0020	18
Shanghai / Hongqiao	21.7337	9	Sanya / Phoenix	69.4986	19
Guangzhou / Baiyun	23.9288	10	Urumqi / Diwopu	26.7308	20

Data source: 2017 National Airport annual report, collected by the author

(4) Determination of alternative hub airport

Table 3 is the ranking table of airport air cargo geographical centrality, so it can be concluded that the alternative airports will be obtained in Wuhan, Changsha, Nanjing, Xi-an and Zhengzhou.

5.2.2. Determination of Weight

After dimensionless data processing:

$$\begin{array}{c} \\ c_1 \\ c_2 \\ c_3 \\ c_4 \\ c_5 \end{array} \begin{array}{c} \begin{matrix} m_1 & m_2 & m_3 & m_4 \end{matrix} \\ \begin{bmatrix} 0.98 & 0.61 & 0.10 & 0.87 \\ 0.01 & 0.22 & 0.01 & 0.70 \\ 0.50 & 0.96 & 0.23 & 1.00 \\ 0.40 & 0.47 & 0.21 & 0.03 \\ 0.01 & 0.01 & 0.05 & 0.55 \end{bmatrix} \end{array} \tag{16}$$

In equation (19) ω_1, ω_2, ω_3, ω_4 They respectively represent the geographical centrality of air cargo, science and education talents, transportation infrastructure and hinterland economy. Weight matrix of each index:

$$[\omega_1, \omega_2, \omega_3, \omega_4][0.4560, 0.0442,0.3029,0.1969] \tag{17}$$

ω_1, ω_2, ω_3, ω_4 can be divided into three parts: geographical centrality of air cargo, science and education talents, transportation infrastructure and economic environment in the hinterland.

5.3.Data Analysis

After weighted weight in the above matrix analysis, each index matrix:

$$\begin{array}{c} \\ c_1 \\ c_2 \\ c_3 \\ c_4 \\ c_5 \end{array} \begin{array}{c} \begin{array}{cccc} m_1 & m_2 & m_3 & m_4 \end{array} \\ \begin{bmatrix} 0.4470 & 0.0257 & 0.0303 & 0.1713 \\ 0.0046 & 0.0093 & 0.0030 & 0.1378 \\ 0.2281 & 0.0405 & 0.0697 & 0.1969 \\ 0.1824 & 0.0198 & 0.0636 & 0.0059 \\ 0.0046 & 0.0004 & 0.0151 & 0.0098 \end{bmatrix} \end{array} \tag{18}$$

m_1、m_2、$m_3$and m_4They respectively represent the geographical centrality of air cargo, science and education talents, transportation infrastructure and hinterland economic environment. c_1、c_2、c_3、c_4、c_5 They represent the cities of Wuhan, Changsha, Nanjing, Xi-an and Zhengzhou respectively.

$$s^+ = (maxz_{i1}, maxz_{i2}, \cdots, max_{ij}) = \{0.4470, 0.0405, 0.0697, 0.1969\} \tag{19}$$

$$s^- = (mixz_{i1}, mixz_{i2}, \cdots, mix_{ij}) = \{0.0046, 0.004, 0.0300, 0.0059\}$$

After calculation, the proximity of each airport is shown in Table 4. The ranking of proximity is: Wuhan > Nanjing > Xi-an > Changsha > Zhengzhou

Table 4: Cargo airport comprehensive evaluation table.

City of Airport	D_i^+	D_i^-	P_i
Wuhan	0.0493	0.4738	0.9058
Nanjing	0.2190	0.3041	0.5814
Xi-an	0.3270	0.1889	0.3661
Changsha	0.4524	0.1322	0.2262
Zhengzhou	0.4851	0.0128	0.0256

6. Conclusions and Discuss

Based on the TOPSIS model, Wuhan (Hubei) is more suitable to build a national cargo hub airport with its geographical advantages, perfect, good hinterland economic environment and high-quality education and scientific research environment. However, considering the limited airspace of Wuhan Tianhe Airport and the separation of passenger and freight, the location of the freight hub airport should avoid the air passenger transport and stagger the densely populated areas. The location should be selected within the Wuhan metropolitan area (the area with a radius of 100 km with Wuhan as the center). The establishment of a freight hub airport will help to improve the air cargo transfer rate and the operation efficiency of China's air logistics.

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