Research on Airport Leading Goods Selection based on Maximum Entropy Principle

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Abstract. Based on the principle of maximum entropy, this paper conducts the goal planning modeling of the whole evaluation system, studies the selection of the airport's dominant goods, and verifies the applicability of the model by the case of Guangzhou Baiyun International Airport. On the basis of the current development of domestic and international air cargo, the importance of the structure of the airport's dominant cargo is explained. Then the model of airport dominant cargo selection is constructed on the basis of the principle of maximum entropy. According to the selection model, the empirical analysis of the main cargo types of Guangzhou Baiyun International Airport is conducted. Finally, according to the final evaluation value of each indicator, the dominant goods of the airport are selected to achieve reasonable allocation of limited resources so as to make corresponding proposals, to improve the overall economic efficiency of the airport, and to optimize airport development.

Keywords: Principle of maximum entropy; airport; Leading cargo category; Guangzhou Baiyun International Airport.

1. Foreword

At present, the planning of airport cargo is mainly carried out through the forecast of cargo throughput. During the early planning of traffic nodes, the planning of leading goods is an important task, which is the basis of its functional layout design, plan design and project design. Different cities have different needs for different goods. The same goods may have different economic benefits for different airports. Different airports also have different types of infrastructure, and the resources occupied by various goods are different. Therefore, when the airport develops to a certain degree, goods with good efficiency and high industrial relevance will be regarded as the main types of goods of an airport. Nevertheless, goods with average benefits but occupying a large quantity of resources and affecting the overall efficiency of the airport need to be chosen reasonably at the time of planning.

China's total air cargo is second only to that of the United States, but there is still a big gap with the United States. According to data from China’s National Bureau of Statistics, the domestic air cargo turnover is less than one-half of that of the United States, while China has a larger landmass and Chinese population is four times that of the United States. This shows that China’s air cargo still has a lot of room for development. Moreover, from the perspective of cargo capacity, China's air cargo capacity is generally low. At present, China's air cargo is still mainly transported in the belly of passenger planes, supplemented by all cargo plane transportation. Currently the number of domestic freighters is rather scarce. Take SF Airlines, the largest cargo airline in China, for example. At present, there are altogether 48 full cargo planes, and the proportion of all domestic cargo planes in other airlines is even lower. The Fed's fleet in America boasts more than 700 planes; hence a big gap in capacity.

In these days, domestic research on leading goods mainly focuses on ports. For example, Yu Ling [1], taking ecologically-oriented port-led cargo selection as the research object and using the principle of maximum entropy to construct a multi-objective planning model for ecological benefits, has conducted a quantitative analysis of the types of leading goods in Xiamen Port. Some studies are intended for optimizing the business of specific companies and regions, such as Shang Zhiyu [2],
which has proposed an optimization plan for the port cargo structure, and concluded that the research on the optimization of the company's cargo structure is of great significance, regarding the serious disconnect between the increase in cargo throughput and economic benefits due to the company's unreasonable structure of goods. Relevant research was carried out abroad as early as in the last century. For example, KENYON [3] has studied a number of factors affecting port competition, such as the demand for goods in the hinterland of the port, technological progress and traffic accessibility, and optimized the intelligent status and cargo structure of major US ports. There are also related studies on the importance of air cargo, such as Franziska [4] which believes that air cargo plays a key role in the air transport chain and the global economy and that as for other modes of transportation, the demand for air cargo is a derivative one.

The above-mentioned literature provides a good foundation for the cargo type planning and research of a port, but the research focus is still the port cargo type. There is insufficient consideration for selection of the dominant cargo type of the airport. That is, the research on the dominant cargo type is not carried out in the airport. Owing to insufficiency of systematic research on the current domestic research on airport leading goods, this paper further divides the research area, takes the selection of leading goods of the airport as the research object, and establishes the corresponding optimization model for solution.

2. Constructing the Model of Airport Leading Goods Selection based on the Principle of Maximum Entropy

2.1 Maximum Entropy Principle

In information theory, maximum entropy refers to the greatest uncertainty, which is mainly used to solve a problem of decision-making or inference under the condition that the prior knowledge is insufficient. The choice of airport leading goods is also susceptible to uncertainty. And it is necessary to retain all possibilities. Therefore, the maximum entropy model is applicable to the study of airport leading cargo selection. In information theory, the larger the entropy, the more information that can be transmitted. In a model of airport leading goods selection, the larger the entropy, the more adequate the more reflection of the information of the evaluation index.

2.2 Building an Evaluation Matrix and “Equivalent” Processing

To build a selection model based on the principle of maximum entropy, it is necessary to construct a matrix of the equivalent value of each indicator.

First, build an evaluation matrix of the goods' type set against the indicator set. Assume that the dominant species is selected among n types of goods, marked as \( Q = \{Q_1, Q_2, \ldots, Q_n\} \); the evaluation index of each type of goods is set at m, marked as \( P = \{P_1, P_2, \ldots, P_m\} \). The evaluation value of the \( j \) index \( P_j \) of the type \( Q \) is represented by \( x_{ij} \) (\( i = 1, 2, \ldots, n; j = 1, 2, \ldots, m \)), and then \( n \times m \) index values of \( n \) types of goods constitute a matrix \( A = (x_{ij})_{nm} \), becoming the evaluation matrix of the goods' type set against the indicator set:

\[
A = \begin{pmatrix}
x_{11} & \cdots & x_{1m} \\
\vdots & \ddots & \vdots \\
x_{n1} & \cdots & x_{nm}
\end{pmatrix}
\]  

Then let the standard object be \( P_{n+1} \), take the average of the k column of each evaluation index \( k = (1, 2, \cdots, m) \), and get the evaluation value of the \( k \) indicator of the standard object \( X_{ok} = \frac{1}{n} \sum_{i=1}^{n} x_{ik} \).
Add the evaluation value \((x_{01}, x_{02}, \ldots, x_{0m})\) of the standard object to the matrix \(A\), as the \(n + 1\) row of the matrix \(A\), an extended evaluation matrix \(A'_{(n+1) \times m}\) is obtained:

\[
A'_{(n+1) \times m} = \begin{pmatrix}
x_{11} & \cdots & x_{1m} \\
\vdots & \ddots & \vdots \\
x_{n1} & \cdots & x_{nm} \\
x_{01} & \cdots & x_{0m}
\end{pmatrix}
\]

Finally, in order to prevent evaluation indicators from affecting each other due to the order of magnitude, the expansion matrix needs to be made “equivalent”. The \((n+1)\) row \((x_{01}, x_{02}, \ldots, x_{0m})\) is selected as the “standard equivalent”, and then the index of each row is divided by the standard equivalent to obtain a matrix \(R'\) of the equivalent value of each index:

\[
R' = \begin{pmatrix}
r_{11} & \cdots & r_{1m} \\
\vdots & \ddots & \vdots \\
r_{n1} & \cdots & r_{nm} \\
1 & \cdots & 1
\end{pmatrix}
\]

### 2.3 Establishment and Solution of Multi-objective Programming Model

The next step is to obtain the weight of each evaluation index, which is the key to evaluating whether a type of cargo is the dominant species. Let the weight vector of the \(m\) evaluation indicators be \(W = (w_1, w_2, \ldots, w_m)\), and the final evaluation value of the \(i\) scheme is \(U_i = U_j = \sum_{j=1}^{m} (w_j r_{ij})\).

According to the principle of maximum entropy and the definition of "standard object", construct the target planning equation:

\[
\begin{align*}
\max & \quad (-\sum_{i=1}^{n} w_j \ln w_j) \\
\min & \quad \left(-\sum_{i=1}^{n} f_i(w)\right) = \min \left(\sum_{i=1}^{n} \sum_{j=1}^{m} (w_j (1 - r_{ij})^2)\right)
\end{align*}
\]

In the process of weighting indicators, it is necessary to construct constraints so that the \(j\) index can reflect the superiority of the scheme more than the \(k\) index:

\[
\sum_{j=1}^{m} w_j = 1, w_j \geq 0, j = 1, 2, \ldots, m
\]

\[
w_j > w_k, j \geq 1, m \geq k, \forall j \neq m
\]

According to the meanings expressed by equations (4) to (5), the following multi-objective programming models can be constructed:
In order to solve equation (6), construct a Lagrange function:

\[
F(w, \lambda) = \delta \sum_{i=1}^{n} \sum_{j=1}^{m} (w_j (1-r_{ij})^2) + (1-\delta) \sum_{j=1}^{m} (w_j \ln w_j) - \lambda(\sum_{j=1}^{m} w_j - 1)
\]

(7)

According to necessary conditions of the existence of extreme values, the following is obtained:

\[
\frac{\partial F}{\partial w_j} = \delta \sum_{i=1}^{n} (1-r_{ij})^2 + (1-\delta)(1+\ln w_j) - \lambda = 0, j = 1,2,\ldots,m
\]

(8)

\[
\frac{\partial F}{\partial \lambda} = \sum_{j=1}^{m} w_j - 1 = 0
\]

(9)

\[
\frac{\exp\left[-1-\delta \sum_{i=1}^{n} (1-r_{ij})^2 / (1-\delta)\right]}{\sum_{j=1}^{m} \exp\left[-1-\delta \sum_{i=1}^{n} (1-r_{ij})^2 / (1-\delta)\right]}, j = 1,2,\ldots,m
\]

(10)

3. Empirical Analysis

3.1 Overview of Guangzhou Baiyun International Airport

Guangzhou Baiyun International Airport (hereinafter referred to as Baiyun Airport) covers an area of 18 square kilometers. It is located at the junction of Renhe Town in Baiyun District and Xinhua Town in Huadu District in the north of Guangzhou. The airport is about 28 kilometers away from the center of Guangzhou. It is one of the three air hubs in China. In 2017, the passenger throughput reached 65,836,900 person-times, an increase of more than 6 million person-times, viz., 10.2%, over 2016. At present, Baiyun Airport ranks as the 13th airport in the world; among the top 13 airports, Baiyun Airport ranks first in terms of the addition of passengers and the rate of the increment. By December 2017, the known route network of Baiyun Airport had extended to all parts of the world. There were more than 210 navigation points, including nearly 90 international and regional destinations. More than 75 airlines had been operating here. With the T2 terminal being put into use in April 2018, the enlarged Baiyun Airport can meet operational needs of takeoffs and landings of 620,000 flights, comings and goings of 80 million passengers and handling of 2.5 million tons of cargo and mail.
As the largest import and export port in South China, Guangzhou has a superior geographical position. As an important transportation hub, Baiyun Airport can radiate to all major and medium-sized cities in the hinterland of China, extend to Southeast Asia, and connect to Europe, America and Australia with its unique transportation system of land, sea and air. Therefore, the optimal selection of the structure of the goods is essential to improve the overall economic efficiency of the airport.

### 3.2 Construction of Cargo Type Selection Index System for Guangzhou Baiyun International Airport

The land resources required for airport construction are generally large, so is Baiyun Airport as a large air hub. Therefore, selection of goods requires choice of goods with a high degree of resource utilization. To this end, this paper takes output value per unit area as an evaluation index used to reflect resource saving of the goods. The formula for calculating this indicator is:

$$c_i = \frac{Y_i}{S_i}$$

In the formula: $Y_i$ is the annual output value of the $i$ type of goods; $S_i$ is the area of the airport land occupied by the $i$ type.

Waste discharge at the airport is mainly gas emissions, especially carbon emissions. Therefore, the unit carbon emission output value is used as an indicator to evaluate environmental benefits of the goods. The following is the formula for calculating the indicator:

$$e_i = \frac{Y_i}{P_i}$$

In the formula: $P_i$ is the annual CO$_2$ emissions of the $i$ goods.

Leading goods of the airport should act as both a guide to industrial development and a driver of related industries. Therefore, this paper uses the industrial influence factor to evaluate the industrial relevance of the goods; the greater the factor, the greater the impact of the goods on other industries. The following is the formula for calculating this indicator:

$$F_i = \frac{\sum_{j=1}^{n} R_{ij}}{n \sum_{j=1}^{n} \sum_{i=1}^{n} R_{ij}}$$

In the formula: $R_{ij}$ is the inverse coefficient of Leontief.

Selection of high-efficiency airport leading goods is conducive to the improvement of the overall economic efficiency of the airport, and the economic benefits of the goods can be measured by the input-output ratio of the goods. That is, the economic benefits are measured by the rate of labor capital output. The following is the formula for calculating this indicator:

$$G_i = \frac{Y_i^2}{K_i L_i}$$

In the formula: $K_i$ is the capital investment of $i$ goods.
Finally, the airport leading goods should also stimulate local employment, so it is also advisable to consider employment indicators. This paper expresses the airport employment index by the number of employed people per unit area of land. The formula for calculating this indicator is:

\[ E_i = \frac{L_i}{S_i} \]

In the formula: \( L_i \) is the labor input of \( i \) goods.

### 3.3 Choice of Leading Goods’ Types

According to the constructed matrix model and various indicators, the initial matrix \( A \) is constructed, and the matrix \( A \) can be extended to obtain the expansion matrix \( A' \):

\[
A' = \begin{pmatrix}
c_1 & e_1 & F_1 & G_1 & E_1 \\
\vdots & \vdots & \vdots & \vdots & \vdots \\
c_n & e_n & F_n & G_n & E_n \\
c_0 & e_0 & F_0 & G_0 & E_0
\end{pmatrix}
\]

After \( A' \) is processed as equivalent, \( R' \) is obtained as follows:

\[
R' = \begin{pmatrix}
c_1 & e_1 & F_1 & G_1 & E_1 \\
c_0 & e_0 & F_0 & G_0 & E_0 \\
c_2 & e_2 & F_2 & G_2 & E_2 \\
\vdots & \vdots & \vdots & \vdots & \vdots \\
1 & 1 & 1 & 1 & 1
\end{pmatrix}
\]

There are things in this step needing to be further explained. Firstly, since the weight is measured according to the principle of maximum entropy, it is necessary to sort each indicator before the measurement. As an infrastructure project for transportation, the airport is the most important for guidance of relevant industries. Secondly, some goods stranded at the airport occupy land resources for a long time, resulting in waste of resources. Thirdly, since air transportation is the costliest mode of transportation, economic benefits of the goods directly affect the overall efficiency of the airport. Therefore, the evaluation indicators established in this paper are sorted according to rankings of the weight. The results are: industrial relevance, resources, economic benefits, environmental benefits, and employment.

After substitution of the data in the matrix \( R' \) in the equation (12), it is only necessary to change the size of \( \delta' \) in order to obtain the weight \( w_j \) of each index. Therefore, by changing \( \delta' \), a set of weights that best match equation (7) can be selected to obtain the weighted result \( w_j, j = 1,2,\cdots,m \). Combined with the index evaluation value of each kind of goods, the final evaluation value \( U_i \) of each kind of goods can be calculated. According to the final evaluation value of the \( i \) plan, the final evaluation value of each index can be obtained, and finally, comparison of the size of the \( U_i \) values leads to the sorting of goods types.

### 4. Conclusion

In the overall planning of the airport, the planning of the leading goods is a basic and important part. The structure of the goods is an important factor affecting the overall economic benefits of the
airport. With the gradual improvement of the airport infrastructure in these years and the increase in airport cargo throughput, the airport's requirements for economic benefits of goods are also increasing. Therefore, for the types of goods which occupy a large amount of resources but with low benefits, they need to be compressed at the time of airport planning.

On the basis of summarizing selection methods in other transportation hubs, this paper uses the principle of maximum entropy to model the multi-objective planning of the evaluation system and select the dominant types of airport goods by quantitative methods. Combined with actual situations of the airport, the relevant indicator system is established to solve the problem of choice of leading goods which has long plagued airlines, thereby not only providing practical theoretical methods for selection of airport leading goods, but also furnishing theoretical basis for relevant work of airlines.

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**References**


