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Dynamic Set Pair of AHP Method for Aviation Logistics Planning and Research

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Abstract: Aiming at the dynamic characteristics of aviation logistics planning, the set pair analysis theory is introduced based on the Analytic Hierarchy Process and added time series, proposing aviation logistics planning comprehensive evaluation method based on dynamic set pair of AHP method. The example shows that the method solves the dynamic comprehensive evaluation problem of aviation logistics planning.

Key words: Logistics planning, the Analytic Hierarchy Process (AHP), set pair analysis

INTRODUCTION

In recent years, the scale of aviation logistics is extended with the economy developing. The problem of aviation logistics network planning need be solved. Aviation logistics network planning is a system engineering, the evaluation of logistics planning program is an important research content in it. The quality of aviation logistics planning is affected by some factors which are transportation, warehousing, information technology, finance and customer service. People take such factors as the indicators of the evaluation to compare with each other in logistics planning the program and find the best project which is a multi-objective, multi-stage nonlinear integer programming problem containing a lot of uncertainty. In recent years, the main research methods are used, such as fuzzy analysis (An and Ma, 2010; Deng, 2012; Shi, 2012; Su and Li, 2012), analytic hierarchy process (Saaty, 1986, 2006; Wei and Ma, 2012), data envelopment analysis methods (Wan, 2012; Luo and Yang, 2012; Zhao, 2012). However, the process is more complex by the fuzzy analysis and the analytic hierarchy process establishing the comparison matrix or the judgment matrix. The integrated decision-making process greatly depends on subjective judgments of decision makers which could easily lead to uncertainty in the integrated decision-making and the data envelopment analysis putting forward in-out indicators is not the real meaning of the input and output indicators and not meet the strict linear relationship. Not only that, through reading large number of documents, The dynamic evaluation was rarely taken into account in the literature and the environment is dynamic and variable. Research of the dynamic evaluation is of great significance. Therefore, this study takes the aviation logistics network planning program evaluation as researching objects based on the dynamic set pair of the AHP method.

SET PAIR ANALYSIS THEORY

Set pair analysis is a system analysis method proposed by Zhao Keqin at the national system theory meeting in Baotou in 1989. It studies the certainty and uncertainty of two things from the same, different and opposite three aspects, depicting contact of the two different things comprehensively which is the quantitative description of certainty and uncertainty. The essence of the set pair analysis is a kind of uncertainty theory and its core ideology is to regard ensuring uncertain problems as ensuring the uncertain system. The certainty and uncertainty have a mutual connection, influence and restrain and mutual transformation under certain conditions. Set pair analysis methods use the set pair analysis connection degree to describe various uncertainties caused by the fuzzy, the random, the intermediate and incomplete information and thus it changes the dialectical understanding of uncertainty into a concrete understanding of mathematical tools (Yue *et al*., 2012).

Expression of the set pair analysis connection degree is $|\mu = a+bi+cj$, In the equation: A expresses the same degree of two sets which is called the identify degree, b is uncertainty degree of differences of two sets which is called the difference degree, c shows the opposite degree of two sets which is called the opposition degree, i is difference mark symbol or corresponding coefficient which value range is [-1, 1]; j is opposition mark symbol or corresponding coefficient which ruled value is -1. In accordance with the definition, a, b and c are satisfied with the normalized condition: a+b+c = 1.

To define the identify degree a_{kr}, the opposition degree c_{kr} and the difference degree b_{kr} of the set of $\{d_{kr}, u_r\}$ and $\{d_{kr}, v_r\}$ in the comparative interval [Vr, Ur] and the domain $Xr = \{d_{kr}\ u_r\ v_r\}$ (k = 1, 2,..., m).

For benefit index, the identify degree of the set $\{d_{kr}, u_r\}$ is:

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$$a_{kr} = \frac{d_{kr}}{u_r + v_r}$$

the opposition degree is:

$$c_{kr} = \frac{u_r v_r}{(u_r + v_r) d_{kr}}$$

but for cost index, the identify degree of the set $\{d_{kr}, v_r\}$ is:

$$a_{kr} = \frac{u_r v_r}{(u_r + v_r) d_{kr}}$$

the opposition degree is:

$$c_{kr} = \frac{d_{kr}}{u_r + v_r}$$

Because a_k and c_k are relatively certain, they, respectively express positive and negative degrees of S_k closing to the optimal solution U. So, the relative closeness degree of S_k and U is defined:

$$r_k = \frac{a_k}{a_k + c_k}$$

The greater its value is, the closer S_k to U is and the better the project will be. So various programs can be sorted by the size of r_k, selecting the desired program.

DYNAMIC SET PAIR AHP METHOD

Dynamic set pair AHP method is a kind of method which is based on evaluation object and evaluation index for the set pair theory, without consideration of the time factor, only for limitation of two-dimensional static comprehensive evaluation. It adopts the time-series to make it dynamic and analyze respectively the relative closeness degree on evaluation object in different periods of status and determine index weight with the combination of AHP, finally make an order according to the comprehensive scoring of the evaluation object. Its steps are (Sgouridis *et al*., 2011; Gong and Xu, 2011; Guo and Li, 2011; Lin and Huang, 2008).

Construction of decision matrix: Suppose the evaluation time is divided into $t_1, t_2, \ldots, t_k$ period, (k = 1, 2,..., m), the value of x_j index of the program Ai in the various period is expressed with $d_{ij}(t_k)$:

$$D(t_k) = \begin{bmatrix} d_{11}(t_k) & d_{12}(t_k) & \ldots & d_{1n}(t_k) \\ d_{21}(t_k) & d_{22}(t_k) & \ldots & d_{2n}(t_k) \\ \ldots & \ldots & \ldots & \ldots \\ d_{m1}(t_k) & d_{m2}(t_k) & \ldots & d_{mn}(t_k) \end{bmatrix} \quad (k = 1, 2, \cdots, m)$$

From above the matrix, The best program can be get: $A_u(t_k) = (a_{u1}(t_k), a_{u2}(t_k)\ldots, a_{un}(t_k))$ (k = 1, 2,..., m ; j = 1, 2,..., n). In the formula: $a_{uj}(t_k)$ is the j-th index value of the best program in the period of t_k. Getting value principle of $a_{uj}(t_k)$ is selecting optimal value from each kind index of m evaluation objects, that is, to take the maximum value of similar index for benefit index (refers to attribute value as large as possible index) and take the minimum value of similar index for cost index (refers to attribute value as small as possible index):

$$a_{uj}(t_k) = \max_i \{d_{ij}(t_k)\} \quad (x_j \in I_1)$$

$$a_{uj}(t_k) = \min_i \{d_{ij}(t_k)\} \quad (x_j \in I_2)$$

In the equation: (k = 1, 2,..., k; i = 1, 2,..., m; j = 1, 2,..., n)' I_1 is the benefit index set, I_2 is the cost index set.

Similarly, can get the worst project:

$$A_v(t_k) = (a_{v1}(t_k), a_{v2}(t_k)\ldots, a_{vn}(t_k))$$

$$a_{vj}(t_k) = \min_i \{d_{ij}(t_k)\} \quad (x_j \in I_1)$$

$$a_{vj}(t_k) = \max_i \{d_{ij}(t_k)\} \quad (x_j \in I_2)$$

To form the relative closeness degree matrix: To calculate various index value of the evaluation object and the relative closeness degree for the corresponding index value in the ideal program which are respectively expressed with $d_{ij}(t_k)$ and $r_{ij}(tk)$:

$$r_{ij}(t_k) = \frac{a_{ij}(t_k)}{a_{ij}(t_k) + c_{ij}(t_k)}$$

Among $a_{ij}(t_k)$ and $c_{ij}(t_k)$ are obtained by the analysis of the first step to form the index relative closeness degree matrix of the evaluation object and the ideal program which is $r(t_k) = \{r_{ij} r(t_k)\}$.

Using the AHP method to calculate each index weight (Hu and Huang, 2011; Li and Wang, 2012; Xu *et al*., 2010): According to the AHP model, to compare the importance of indexes with the scale method of1 to 9 and the bottom of it according to certain criteria in each layer, construct the judgment matrix, determine the weight of each index using the square root method and pass the consistency test. Finally, to get the weight vector $W(t_k)$ of the bottom index with the use of the correlation matrix method.

Comprehensive evaluation comparison: According to the index weight, the relative closeness degree of the evaluation object of various period and the ideal program is calculated which is named $E(t_k) = r(t_k) \bullet W(t_k)$. The element $e_i(t_k)$ of $E(t_k)$ is the comprehensive evaluation value of the i-th evaluation object in the time of t_k.

The determination of the time weight coefficient $F(t_k)$ is critical in the dynamic evaluation. The different coefficient means different position of the time factor, of course leading to different results. Determination of the time weight coefficient has a variety of methods, such as expert evaluation method (Delphi method) which determines the time weight by experts and value principle of "stress the present rather than the past", that is, the more recent, the more value is, the greater weight coefficient is, on the contrary, the smaller it is. Finally, according to the relative closeness degree $E(t_k)$ of the period and the time weight coefficient vector $F(t_k)$ of the evaluation object, to find the dynamic relative closeness degree H of various the evaluation object:

$$H = E(t_k) \cdot F(t_k) \quad h_i = \sum_{k=1}^{k} e_i(t_k) \cdot f(t_k)$$

Finally, to determine the order of m evaluation objects according to the size of hi in H.

ANALYSIS OF CASES

An aviation freight Co., LTD in Chongqing, as an agent of the national level of aviation freight which bears some logistics businesses of the aviation transportation in Guiyang. Daily business is very broad, mainly related to clothing transportation, air express, fresh cargo and so on. With the gradual expansion of the scale, the company's operations in logistics planning are proposed three options. Option I should make clothing transport and air expresses as the main project, increasing investment costs of warehousing, creating some normal warehouses. Option II adopts fresh cargo and air express as the business-oriented, trying to increase the transportation costs and ensuring quality of transport and service level. Option III offers general cargo transportation and air express as the main project, trying to reduce the cost of investment mainly due to the supply relationship. Four kinds of transport elements are selected, such as transportation, warehousing, information technology and customer service, as the elements of evaluation about aviation logistics enterprise (Fig. 1). The performance of enterprise operational project in these four aspects will be able to reflect the efficiency and effectiveness of its activities more truly and directly (Ma *et al*., 2011; Tang and Zhang, 2006). The project attributing decision table is shown in Table 1.

For example of the t_1 time, decision procedures are below:

- The qualitative index in the decision table is changed into the quantitative index from the Table 2, then to construct decision matrix, select the best project and the worst project from three programs:

$$D(t_1) = \begin{bmatrix} 19.7 & 3 & 3 & 14.1 & 5 & 3 & 8 & 4 & 4 & 4 & 3 \\ 45.2 & 5 & 5 & 11 & 4 & 4 & 7 & 3 & 4 & 5 & 5 \\ 31.5 & 4 & 4 & 9.8 & 3 & 4 & 13 & 5 & 5 & 4 & 4 \end{bmatrix}$$

- The best project: $A_u(t_1)$ = (19.7 5 5 9.8 5 4 7 5 5 5 5
- The worst project: Av(t1) = (45.2 3 3 14.1 3 3 13 3 4 4 3

According to the equation:

$$r_{ij}(t_k) = \frac{a_{ij}(t_k)}{a_{ij}(t_k) + c_{ij}(t_k)}$$

to seek r_{ij} and build the matrix of the relative closeness degree:

$$r(t_1) = \begin{bmatrix} 0.6965 & 0.3750 & 0.3750 & 0.4100 & 0.6250 & 0.4286 & 0.5871 & 0.5161 & 0.4444 & 0.4444 & 0.3750 \\ 0.3035 & 0.6250 & 0.6250 & 0.5331 & 0.5161 & 0.5714 & 0.6500 & 0.3750 & 0.4444 & 0.5556 & 0.6250 \\ 0.4730 & 0.5161 & 0.5161 & 0.5900 & 0.3750 & 0.5714 & 0.3500 & 0.6250 & 0.5556 & 0.4444 & 0.5161 \end{bmatrix}$$

- To find the relative weight of each index by the AHP method

Table 1: Project attributing decision table

		t1			t2			t3		
Project attributing		Project 1	Project 2	Project 3	Project 1	Project 2	Project 3	Project 1	Project 2	Project 3
Transportation	Transportation cost /wan	19.7	45.2	31.5	50.6	37.3	27.6	16.3	29.1	16.3
	Transportation efficiency	Good	Best	Better	Best	Better	Good	Better	Best	Better
	Transportation quality	Good	Best	Better	Best	Better	Good	Better	Best	Better
Warehousing	Warehousing cost /wan	14.1	11	9.8	13	15.2	18.1	7	10.5	7
	Warehousing quality	Best	Better	Good	Good	Better	Best	Better	Best	Better
	Occupying area	Most	More	More	More	More	Most	Less	Most	Less
Information technology	Information cost/wan	8	7	13	6.7	14.1	8.9	4.8	2.7	5.2
	Information level	Better	Good	Best	Good	Best	Better	Better	Good	Best
	System stability	Better	Better	Best	Better	Best	Better	Better	Good	Best
Customer service	Service level	Better	Best	Better	Best	Better	Good	Better	Best	Better
	Customer satisfaction	Good	Best	Better	Best	Better	Good	Better	Best	Better

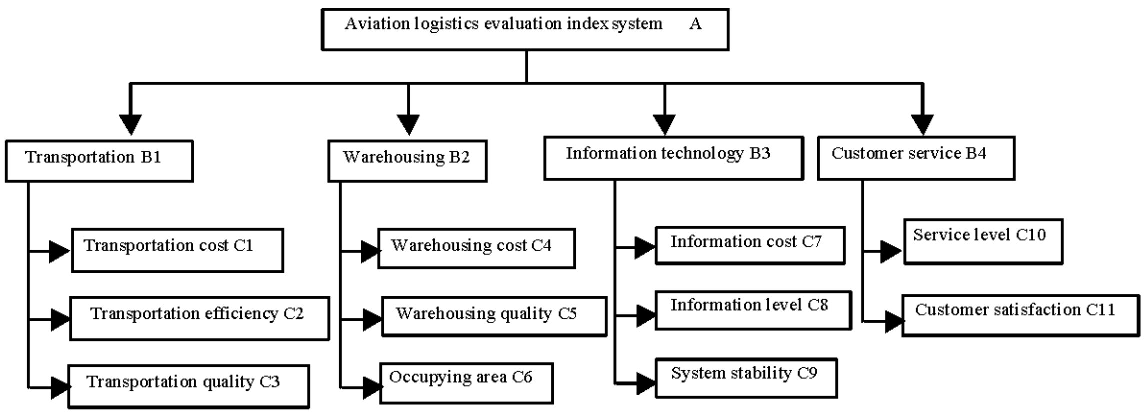

Fig. 1: Aviation logistics evaluation index system

Table 2: Quantificational score table of qualitative index

Index	Good (Less)	Better (More)	Best (Most)
Efficiency index	3	4	5
Cost index	5	4	3

Table 3: Judgment matrix A-B

A	B1	B2	B3	B4	W_i
B1	1	4	3	3	0.504
B2	1/4	1	1/3	1/3	0.084
B3	1/3	3	1	1	0.206
B4	1/3	3	1	1	0.206

Table 4: Correlation matrix table

Variable	B1 (0.504)	B2 (0.084)	B3 (0.206)	B4 (0.206)	$W(t_k)$
C1	0.163				0.082
C2	0.540				0.272
C3	0.297				0.150
C4		0.163			0.014
C5		0.540			0.045
C6		0.297			0.025
C7			0.143		0.029
C8			0.286		0.059
C9			0.571		0.118
C10				0.25	0.051
C11				0.75	0.155

To establish their corresponding judgment matrix of the first and the second layer, such as Table 3.

Having consistency test:

$$AW = \begin{bmatrix} 1 & 4 & 3 & 3 \\ 1/4 & 1 & 1/3 & 1/3 \\ 1/3 & 3 & 1 & 1 \\ 1/3 & 3 & 1 & 1 \end{bmatrix} \cdot \begin{bmatrix} 0.504 \\ 0.084 \\ 0.206 \\ 0.206 \end{bmatrix} = \begin{bmatrix} 2.076 \\ 0.347 \\ 0.832 \\ 0.832 \end{bmatrix}$$

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n}\frac{(AW)_i}{W_i} = \frac{1}{4}\left(\frac{2.076}{0.504}+\frac{0.347}{0.084}+\frac{0.832}{0.206}+\frac{0.832}{0.206}\right) = 4.082$$

$$C.I. = \frac{\lambda_{max}-n}{n-1} = \frac{4.082-4}{4-1} = 0.027$$

By searching table, R.I. = 0.90:

$$C.R. = \frac{C.I.}{R.I.} = \frac{0.027}{0.90} = 0.03 < 0.1$$

The consistency test is qualified and the other judgment matrixes are built and analysed similarly. Finally the weight of the bottom index is calculated by using the correlation matrix Table 4.

- According to the equation $E(t_k) = r(t_k) \bullet W(t_k)$, obtained the comprehensive evaluation value of each program in each period:

$$E(t_1) = (0.4406 \quad 0.5522 \quad 0.5112)$$

$$E(t_2) = (0.5549 \quad 0.5215 \quad 0.4319)$$

$$E(t_3) = (0.4780 \quad 0.5038 \quad 0.4962)$$

The time weight $F(t_l)$ of each period is determined by the Delphi method combined with principle of "stress the present rather than the past" in the document.

Time weight $F(t_l) = (0.451\ 0.317\ 0.232)^T$

It can obtain the degree of integrated dynamic relative approaching of $H = (0.486 \quad 0.531 \quad 0.482)^T$ by $H = E(t_l) \bullet F(t_l)$.

Above can be seen that H2>H1>H3. The company is primarily involved in clothing transport, air express, fresh goods transportation and so on. Owing to growing competition between the aviation logistics industry now, the company should choose Option II to take fresh goods and air express as the main operation, increasing traffic quantity, improving transport quality, guaranteeing service level and understanding customer needs to enhance the long-term performance of the overall aviation logistics.

CONCLUSION

The aviation logistics planning evaluation index system is a multi-level, multi-objective, multi-stage compound system. The aviation logistics planning program is evaluated dynamically by the dynamic set pair of the AHP method. The train of thought is clearer, the method is simple and practical. This method has the following features:

- Using the AHP method to establish a clear aviation logistics planning evaluation index system, combining with both qualitative and quantitative analysis, handling the uniform dimension of various indexes with the set pair analysis theory
- Introducing time series to make the AHP dynamic, rankings of alternatives of aviation logistics planning program to achieve a dynamic comprehensive evaluation of logistics planning according to the comprehensive closeness degree

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