Grey Incidence Analysis Applied to Civil Aircraft Customization Process

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Abstract: The airlines need to select the optional equipment according to their individual development demands and the manufacture's standard specification manual when purchasing a new airplane. For this customization process, the selection theory is mainly based on qualitative analysis and quantitative analysis. The grey incidence analysis (GIA) is used for modeling, which evaluates the correlations between optional equipment and airlines' individual demands. Meanwhile, the customization demands are quantitatively processed as different weights in evaluation index system with analytical hierarchy process. Then, the value of grey incidence degree is obtained which shows whether the optional equipment is on the purchasing list or not. Finally, two airlines' customization demands are applied in the example of aircraft cabin's seats, so two different purchasing priorities and equipment installation lists can be obtained. The results and comparisons verify the reasonable of modeling, which provides an objective scheme of aircraft equipment selection.

Key words: airlines; grey incidence analysis (GIA); customization process; civil aircraft equipment selection; individual demand

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0 Introduction

During the civil aircraft selection process, the airlines need to determine the aircraft type according to the fleet planning and routes situation firstly. After that, the manufacturer provides the standard specification manual for the airlines. Then, the airlines select the optional equipment according to their individual demands. The above steps are called customization process. The civil aircraft equipment selection in this paper discusses which size and type of equipment assembly can guarantee the safe operation and economic benefits.

In the manufacturing industries which are similar to the aircraft manufacturing industry, some of them have begun the strategy of personalized customization. For example, in the industry of the automotive, He[1], after the profound investigation on market and the manufacture of FAW-Volkswagen Audi brand, uses the key external factors analysis, the key internal factors analysis, and SWOT analysis to get the quantitative strategic planning matrix which helps the company to identify its advantages and disadvantages, opportunities and threats. Then, give the deep interpretation of the FAW-Volkswagen Audi customization selection. Meng et al.[2] come up with an interactive and virtual platform of car's exhibition, which met the future customer's individual demands and promoted user experience in the environment of electronic commerce. At the same time, he proposed a platform architecture of car's virtual exhibition and individual customization system based on the internet.

In terms of the aircraft manufacturing industry, airlines need to make the decisions after considering the comprehensive factors, including its

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future planning and the airworthiness regulation. In the current field of academic research, Mavris and Kirby[3] come up with the evaluation index system in the process of aircraft selection, which used technical and economical index to choose aircrafts. Givoni and Pai et al.[4,5] analyzed the tendency of aircraft selection in condition of the promotion of flight rate and seat kilometer utilization, then gave some main factors affecting the aircraft selection. Gollnick et al.[6] analyzed multi-objective decisions on aircraft selection using the robustness. On the basis of market demand forecasting and the type selection, Zhu et al.[7] gave the evaluation of the aircraft′s type using grey-analytic hierarchy process and data envelopment analysis, and they paid more attention to the flight economic such as cabin′s arrangement and flight rate. Whereas, three issues could not be ignored. First, in the selection objects, most of the studies focused on the aircraft type selection, while equipment selection of certain aircraft type gained less attention[3-4,6,8]. Second, in evaluation factors, most studies only considered the fleet planning or the economic cost[5,9-10], while few studies considerd the factors which combined safety, passenger comfort and maintainability together. In the research method of type selection, analytic hierarchy process (AHP) is the main method[7,11]. This method can judge the merits of different types, but the data are too subjective because the final results directly depend on experts′ sorting. For example, there are six evaluation indexes evaluating the options. In the typical AHP method, several experts sort the options in evaluation index system. Consequently, the results would prefer the highest ranking options. If Ranks 2 and 3 have an obvious preference, while Ranks 3 and 4 almost have the same preference, however, the results cannot show the detail differences. Therefore, it probably make the final results deviate from the actual situation.

The large number of studies reveal that in the practical selection work of airlines, the aircraft type selection have objective basis on quantitative analysis. However, most airlines decide the optional equipment installation list of a certain aircraft type just by qualitative analysis, which is decided by selection office or market center. The final selections are mostly decided according to the past experience. Obviously, such decisions are outdated, which lack objective basis.

Besides the above literature review and practical situations, one factor we cannot ignore is that in China, the aircraft type selection is decided mainly by Civil Aviation Adminstration China (CAAC), while the airlines cannot make decisions sometimes. However, the aircraft equipment selection can be decided by airlines themselves. As a results, besides the economic, it is important to study the equipment selection problem in civil aircraft customization process with objective method and the comprehensive evaluation.

1 GIA Method for Modeling

1.1 GIA model

The grey incidence analysis (GIA) method is a part of the grey system theory, it is used for modeling that information of the process is incomplete[12-13]. The problem of equipment customization process can be regarded as a grey system. GIA evaluates the coincidences between the optional equipment and the evaluation factors using the grey incidences rather than the sorting method of AHP[14-16]. It can reduce the subjectivity and arbitrariness compared with AHP. Furthermore, the conventional GIA modeling is improved by calculating different weights of all evaluation indexes instead of averaging them, which reflect the individual differences of customization demands.

The customization modeling can be divided into four steps. First, the evaluation factors are determined to establish the evaluation index system. Second, the evaluation matrix is set to calculate the correlation degrees of each options through a series of matrix operations. Third, the modeling is improved the calculation of correlation degrees in conventional GIA model, which replaces the uniform value by different weights processed by AHP. Last, the correlation degrees are calculated, and the sequences of degrees reflect the preference of each equipment options.

1.2 Evaluation index system

For some equipment, such as seats, handrails and harness, no matter which individual demands are, each airplane should install these equipment, based on the airworthiness regulations. However, for some optional equipment, such as entertainment equipment or charging equipment, depending on guest demands, the selections are different. The optional equipment is just evaluated.

Referring to some description documents from Bombardier Aerospace Regional Aircraft[17] and some literatures[3,18], this study evaluates the equipment from four aspects: technical (A_1), economic (A_2), marketing (A_3) and safety (A_4). After that, a subset of criteria are established and assigned for each one of those previous four aspects. A two-stage evaluation index system is showed as Fig. 1. The suboridnate factors are used as evaluation matrix's row parameters in the following model.

The meaning and the scales of each factors are illustrated as follows:

Technical A_1 As for airlines, technology is one of the most important factors in the selection of optional equipment. On the one hand, airlines need to consider whether the company has the pilots who hold the airplane driving licenses of this type. Furthermore, they also need to consider whether the stuff has the ability to keep the aircraft's normal operation, called maintainability. Maintainability is used as the secondary evaluation index.

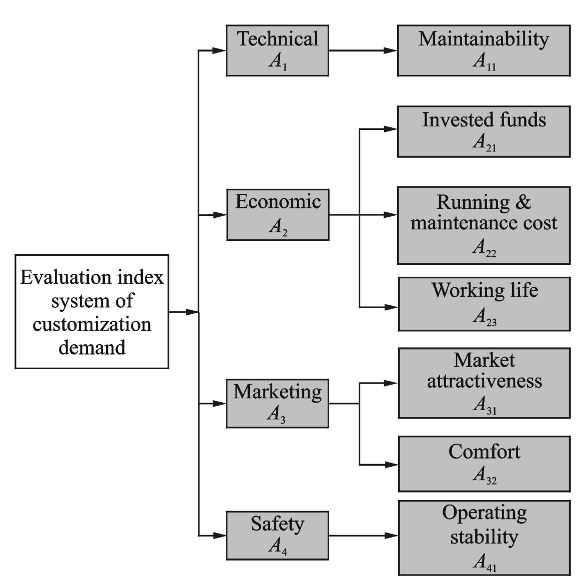

Fig. 1 Secondary evaluation index system

Maintainability A_{11} Refer to the repairing difficulty, including the components, electronic circuit, and its impact on the other equipment etc.

A_{11} is an uncertain factor. It is divided five degrees in fuzzy mathematics to indicate its levels, namely excellent, good, average, poor and inferior, and its corresponding membership grades: 0.9, 0.7, 0.5, 0.3 and 0.1[19].

Economic A_2 Economic cost is the factor which airlines mostly care about. It includes the budget and the benefit that confine the development of the airline, so they usually hope to get abundant reward after the large investment. Under such circumstances, considering the type of aircraft and the optional equipment they can choose, they usually wish to fulfill the abundant system function with the lowest cost and the longest working life. In reality, airline needs to calculate the detail budget before the decisions are made. Both the selection department and the maintenance engineering department should control it strictly. Invested funds (A_{21}), running & maintenance cost (A_{22}) and working life (A_{23}) are used as the secondary evaluation index system.

Invested funds A_{21} Refer to the costs of purchasing the equipment, including the electronic circuit, the reconstruction costs and human resource payment etc.

A_{21} is a certain factor, and it is indicated by a numerical value.

Running & maintenance cost A_{22} Refer to the equipment's annual cost in operation.

A_{22} is a certain factor, and it is indicated by a numerical value.

Working life A_{23} Refer to the life of the seats working on the aircraft which indicates the economic cost and benefits.

A_{23} is an uncertain factor, and its classification and membership grades are the same as A_{11}.

Marketing A_3 In the era of market economy, aircraft, the costly products, the airlines concentrate more on the selection of the optional equipment. In order to improve the competitiveness, airlines usually select the type of the aircraft in light of its competitor, so does the selection of the aircraft equipment.

Generally speaking, choosing the equipment which is better than its competitor can improve the competitiveness. Market attractiveness(A_{31}) and comfort(A_{32}) are used as the secondary evaluation index system.

Marketing attractiveness A_{31} Refer to the attraction of the equipment to passengers and it indicates the potential economic benefits.

A_{31} is an uncertain factor, and its classification and membership grades are the same as A_{11}.

Comfort A_{32} Refer to the degree of comfort that passengers feel and this factor indicates the potential economic benefits.

A_{32} is an uncertain factor, and its classification and membership grades are the same as A_{11}.

Safety A_4 With the increasing number of aircraft accidents, equipment′s safety operation becomes more and more important. Only one accident may lead to devastating disaster. Therefore, it is vital to prohibit the accident happened. Operation stability (A_{41}) is used as the secondary evaluation index system.

Operation stability A_{41} Refer to the security and stability of the equipment in operation, including the possibility of damage.

A_{41} is an uncertain factor, and its classification and membership grades are the same as A_{11}.

2 Modeling for Customization Process

The GIA method is the core part of customization model. It can be divided into four steps. First, the evaluation matrix is established with raw data. Second, the original matrix is transformed into standardization one through a series of operations. Third, determine the reference index set. Last, calculate the correlation degree. The modeling processes are as follows.

2.1 Evaluation matrix with raw data

In this model, m and n are denoted as the number of options, evaluation factors, respectively. The evaluation matrix $\boldsymbol{M}$ is established as follow

$$\boldsymbol{M}=\begin{bmatrix} m_{11} & m_{12} & \cdots & m_{1N} \\ m_{21} & m_{22} & \cdots & m_{2N} \\ \vdots & \vdots & m_{ij} & \vdots \\ m_{M1} & m_{M2} & \cdots & m_{MN} \end{bmatrix} \tag{1}$$

where $i=1,2,\cdots,M$, $j=1,2,\cdots,N$. m_{ij} means the coincidence of optional item i in the evaluation factor j, and for more information to its scale, please refer to Section 1.2.

2.2 Standardization

Because the dimension and scales of the evaluation matrix $\boldsymbol{M}$ are not the same, the modeling usually cannot calculate the correlation degree directly. Therefore, the raw data need standardizing into dimensionless ones, so that the scales are consistent. The conversion Eq. (2)[12-13] is as follows

$$s_{ij}=\frac{m_{ij}-m_j^{\min}}{m_j^{\max}-m_j^{\min}} \tag{2}$$

where $m_j^{\min}$ and $m_j^{\max}$ mean the minimum and maximum value of the coincidences and s_{ij} the standardized coincidence of optional item i in the evaluation factor j.

Using Eq. (2) to operate matrix $\boldsymbol{M}$, the standardization matrix $\boldsymbol{S}$ is obtained as follows

$$\boldsymbol{S}=\begin{bmatrix} s_{11} & s_{12} & \cdots & s_{1N} \\ s_{21} & s_{22} & \cdots & s_{2N} \\ \vdots & \vdots & s_{ij} & \vdots \\ s_{M1} & s_{M2} & \cdots & s_{MN} \end{bmatrix} \tag{3}$$

2.3 Reference index set

The optimum values or ideal values are chosen as the reference indexes from $\boldsymbol{S}$. The most ideal reference index set is composed of the best set of values. It means that the reference index set is the benchmark of the entire indexes. Then the grey correlation degrees are used as measures to evaluate the coincident degrees between the reference index and the entire indexes. The higher the degree is, the more coincidence between the optional equipment and the customization demands, and vice versa.

The reference index set

$$\boldsymbol{R}_0=[r_{01},r_{02},\cdots r_{0j},\cdots,r_{0N}] \quad j=1,2,\cdots,N \tag{4}$$

For the efficient indexes (the higher the better), the reference index is the maximum $s_j^{\max}$, while for the cost indexes (the less the better), the reference index is the minimum $s_j^{\min}$.

2.4 Correlation degrees

To begin with, the range matrix $\boldsymbol{R}$ is calculated by the operation $r_{ij}=|r_{0j}-s_{ij}|, i=1,2,\cdots,M$, $j=1,2,\cdots,N$.

Then, the calculation of correlation degree ξ_{ij} of each index in the matrix $\boldsymbol{R}$ is showed in Eq. (5)[12-13]

$$\xi_{ij}=\frac{\min_i \min_j r_{ij}+\xi_0\times\max_i \max_j r_{ij}}{r_{ij}+\xi_0\times\max_i \max_j r_{ij}} \tag{5}$$

where ξ_0 is the resolution coefficient, and it is a constant which ranges from 0 to 1. The less this value is, the higher the resolution is. In this paper, $\xi_0=0.5$ with reference to the grey system theory[20].

Finally, the correlation degrees matrix $\boldsymbol{\xi}$

$$\boldsymbol{\xi}=\begin{bmatrix}\xi_{11} & \xi_{12} & \cdots & \xi_{1N}\\ \xi_{21} & \xi_{22} & \cdots & \xi_{2N}\\ \vdots & \vdots & \xi_{ij} & \vdots\\ \xi_{M1} & \xi_{M2} & \cdots & \xi_{MN}\end{bmatrix} \tag{6}$$

where $\xi_i=[r_{i1},r_{i2},\cdots r_{ij},\cdots,r_{iN}]$ means the correlation degrees of the optional equipment i.

3 Optional Index Evaluation Model Based on Grey Incidence Analysis

3.1 AHP method

For the index system mentioned in Section 1.2, different airlines prefer different factors. For example, the small airlines with feeder lines transportation pay more attention to economic benefits, while the large-scale airlines with long-distance flights might pay more attention to passengers′ comfort. In this paper, the different weights of each index reflect the customers′ individual demands. Since the customization demands are qualitative descriptions in most cases, for example, the airline can decide that index ″Maintainability″ is more important than index ″Marketing attractiveness″, but they cannot give the numerical weights of all indexes directly. Therefore, AHP is used to quantitatively process the qualitative description, which improves the traditional GIA model by averaging the different indexes. The modeling processes are showed in next section.

3.2 Weights of evaluation indexes

3.2.1 Judgment matrix

The traverse method of paired comparison is used to construct the judgment matrix $\boldsymbol{B}$, and the airline compares the seven indexes in pair. b_{jk} represents the importance between index j and index k. The Saaty 1—9 scale method[21] is used to represent the comparison results numerically, which scales and meanings are shown in Table 1.

Table 1 Scales and meanings of judgment matrix B

Scale	Meaning
1	j is the same as k
3	k is a little more important than j
5	k is obvious more important than j
7	k is strongly more important than j
9	k is extremely more important than j
2,4,6,8	the medium of 1—3,3—5,5—7,7—9
1/(1—9)	j is more important than k

Then, the judgment matrix $\boldsymbol{B}$ is set according to Table 1 by the airline.

$$\boldsymbol{B}=\begin{bmatrix}b_{11} & b_{12} & \cdots & b_{1N}\\ b_{21} & b_{22} & \cdots & b_{2N}\\ \vdots & \vdots & b_{jk} & \vdots\\ b_{N1} & b_{N2} & \cdots & b_{NN}\end{bmatrix} \tag{7}$$

Obviously, $b_{jk}=\frac{1}{b_{kj}}$, j, $k=1,2,\cdots,N$.

3.2.2 Consistency check

The consistency check of the judgment matrix is to guarantee the consistency of the indexes. In case that the importance sequences are contradicted from each other. For example, ***A*** is more important than ***B***, and ***B*** is more important than ***C***, but ***C*** is more important than ***A***.

The maximum eigenvalue $\lambda_{\max}$ of matrix ***B*** is computed by Matlab programming. The consistency index $\mathrm{CI}=\frac{\lambda_{\max}-n}{n-1}$, and n is the matrix order. Then, the corresponding mean random consistency index RI is found from Table 2[22], so the consistency rate $\mathrm{CR}=\frac{\mathrm{CI}}{\mathrm{RI}}$.

Table 2 Mean random consistency indexes RI with matrix order from 1—7

Order	1	2	3	4	5	6	7
RI	0	0	0.52	0.89	1.12	1.26	1.36

When $\mathrm{CR}<0.1$, the judgment matrix is consistency. When $\mathrm{CR}\geqslant 0.1$, the judgment matrix is inconsistency, which needs adjustment.

3.2.3 Calculating weights

The row vector of judgment matrix ***B*** is normalization processed into $\overline{\boldsymbol{B}}$, $\bar{b}_{jk}=\frac{b_{jk}}{\sum_{k=1}^{N}b_{jk}}(j,k=1,2,\cdots,N)$, then sum the indexes of each column $\overline{w}_j=\sum_{j=1}^{N}\bar{b}_{jk}(j,k=1,2,\cdots,N)$.

After that, $\overline{w}_j$ is processed normalization into w_j

$$w_j=\frac{\overline{w}_j}{\sum_{j=1}^{N}\overline{w}_j}\qquad j=1,2,\cdots,N$$

$$\boldsymbol{w}=(w_1,w_2,\cdots,w_N)\tag{8}$$

where $\boldsymbol{w}$ is the corresponding weights vector, and $w_1+w_2+\cdots+w_N=1$.

3.3 Grey correlation degrees

The coincidences between the optional equipment and customization demands are measured by grey correlation degree C_i, and $C_i\in[0,1]$. It is calculated by

$$C_i=\xi_i\cdot\boldsymbol{w}^{\mathrm{T}}=\sum_{j=1}^{N}\xi_{ij}\cdot\boldsymbol{w}_j\tag{9}$$

The selection priorities of all options can be computed by sequencing the degrees in certain customization demands. The higher degree indicates that the equipment is more coincident with the customer's individual demands, and vice versa. If the study sets up a threshold for the correlation degree excluding the equipment below such threshold, the equipment selection list can be decided which excludes the equipment that below the threshold.

4 Application

In the example of Bombardier-Q400 cabin's seats, Airlines X and Y need to select the optional equipment. Four options are shown as follows:

Video equipment Installed in front of seats, it is convenient for passengers to watch some movies, news, etc.

Lighting lamp Installed on one side of seats, provided the passengers for reading.

Intelligent tray table Upgraded from traditional seat tray, the notebook computer, iPad or other electronic products can be placed on it.

Charging equipment Provide charging service for electronic products.

4.1 GIA modeling

4.1.1 Evaluation matrix

Table 3 reflect the coincidence degrees between the optional equipment and evaluation indexes. The equipment costs refer to the standard specification manual of Bombardier-Q400[17]. The two kinds of economic costs (A_{21} and A_{22}) refer to the aircraft selection documents from two airlines. And the evaluation levels "excellent, good, average, poor and inferior" for A_{11}, A_{23}, A_{31}, A_{32} and A_{41} refer to the investigation report which obtained by interviewing the two airlines' related stuff.

Table 3 Evaluation of options

Equipment	Index						
	Maintainability A_{11}	Invested funds A_{21}	Running & maintenance cost A_{22}	Working life A_{23}	Market attractiveness A_{31}	Comfort A_{32}	Operation stability A_{41}
Video equipment	good	50	30	excellent	good	excellent	good
Lighting lamp	average	15	25	good	inferior	average	average
Intelligent tray table	good	20	5	poor	average	good	good
Charging equipment	average	30	40	excellent	excellent	excellent	average

After that, the evaluation matrix $\boldsymbol{M}$ with raw data is set as follows

$$\boldsymbol{M}=\begin{bmatrix}0.7 & 50 & 30 & 0.9 & 0.7 & 0.9 & 0.7\\0.5 & 15 & 25 & 0.7 & 0.3 & 0.5 & 0.5\\0.7 & 20 & 5 & 0.3 & 0.5 & 0.7 & 0.7\\0.5 & 30 & 40 & 0.9 & 0.9 & 0.9 & 0.5\end{bmatrix} \tag{10}$$

Plug $\boldsymbol{M}$ into the normalization matrix $\boldsymbol{S}$

$$\boldsymbol{S}=\begin{bmatrix}1 & 1 & 0.7 & 1 & 0.7 & 1 & 1\\0 & 0 & 0.6 & 0.7 & 0 & 0 & 0\\1 & 0.1 & 0 & 0 & 0.3 & 0.5 & 1\\0 & 0.4 & 1 & 1 & 1 & 1 & 0\end{bmatrix} \tag{11}$$

4.1.2 Correlation degrees

According to Section 2.3, A_{11}, A_{23}, A_{31}, A_{32} and A_{41} are efficient indexes (the higher the better), so the reference index is 1. While A_{21} and A_{22} are cost indexes (the less the better), so the reference index is 0. Set the reference indexes $\boldsymbol{R}_0=[1\ 0\ 0\ 1\ 1\ 1\ 1]$, and $r_{ij}=|r_{0j}-s_{ij}|$.

$$\boldsymbol{R}=\begin{bmatrix}0 & 1 & 0.7 & 1 & 0.3 & 0 & 0\\1 & 0 & 0.6 & 0.7 & 1 & 1 & 1\\0 & 0.1 & 0 & 0 & 0.7 & 0.5 & 0\\1 & 0.4 & 1 & 1 & 0 & 0 & 1\end{bmatrix} \tag{12}$$

In matrix $\boldsymbol{R}$ and $\min_i\min_j r_{ij}=0$ and $\max_i\max_j r_{ij}=1$. Set $\xi_0=0.5$, so the correlation degree $\xi_{ij}=\dfrac{0.5}{r_{ij}+0.5}$.

$$\boldsymbol{\xi}=\begin{bmatrix}1 & 0.3 & 0.4 & 0.3 & 0.6 & 1 & 1\\0.3 & 1 & 0.5 & 0.4 & 0.3 & 0.3 & 0.3\\1 & 0.8 & 1 & 1 & 0.4 & 0.5 & 1\\0.3 & 0.5 & 0.3 & 0.3 & 1 & 1 & 0.3\end{bmatrix} \tag{13}$$

Each row of matrix $\boldsymbol{\xi}$ indicates the grey correlations of a piece of equipment.

4.2 Calculating weights of index system

Two Airlines X and Y are applied to reflect the individual demands. The two selection results can be compared after modeling.

(1) For Airline X, according to the interview report, the importance degrees between indexes are given as follows:

First, check the consistency. The judgment matrix $\boldsymbol{B}$ is established according to Table 4, and the maximum eigenvalue $\lambda_{\max}=7.6674$. Therefore, the consistency index $\mathrm{CI}=\dfrac{\lambda_{\max}-n}{n-1}=0.11$, and based on the last column of Table 2, the mean random consistency index $\mathrm{RI}=1.36$. The rate of consistency $\mathrm{CR}=\dfrac{\mathrm{CI}}{\mathrm{RI}}=0.082<0.1$, so the judgment matrix $\boldsymbol{B}$ represents consistency.

Table 4 Customization demands of Airline *X*

Index	A_{11}	A_{21}	A_{22}	A_{23}	A_{31}	A_{32}	A_{41}
A_{11}	1	2	2	3	2	1/3	2
A_{21}	1/2	1	2	2	1/3	1/5	1/2
A_{22}	1/2	1/2	1	1/2	1/3	1/5	1/2
A_{23}	1/3	1/2	2	1	1/3	1/2	1/2
A_{31}	1/2	3	3	3	1	1/5	1/3
A_{32}	3	5	5	2	5	1	3
A_{41}	1/2	2	2	2	3	1/3	1

Then, each row of the matrix $\boldsymbol{B}$ is normalized.

$$\bar{\boldsymbol{B}}=\begin{bmatrix}0.08 & 0.16 & 0.16 & 0.24 & 0.16 & 0.03 & 0.16\\0.08 & 0.15 & 0.31 & 0.31 & 0.05 & 0.03 & 0.08\\0.14 & 0.14 & 0.28 & 0.14 & 0.09 & 0.06 & 0.14\\0.07 & 0.10 & 0.39 & 0.19 & 0.07 & 0.10 & 0.10\\0.05 & 0.27 & 0.27 & 0.27 & 0.09 & 0.01 & 0.03\\0.13 & 0.21 & 0.21 & 0.08 & 0.21 & 0.04 & 0.13\\0.05 & 0.19 & 0.19 & 0.19 & 0.28 & 0.03 & 0.09\end{bmatrix} \tag{14}$$

Third, sum the indexes of each column.

$$\bar{\boldsymbol{W}}=[0.58\quad 1.22\quad 1.80\quad 1.42\quad 0.95\quad 0.30\quad 0.73] \tag{15}$$

Finally, $\overline{\boldsymbol{W}}$ is normalizated.

$$\boldsymbol{W}_X = [0.08 \quad 0.17 \quad 0.26 \quad 0.20 \quad 0.14 \quad 0.04 \quad 0.11] \tag{16}$$

where $\boldsymbol{W}_X$ is the weight vector of seven evaluation indexes in Airline X's customization demands. It is seen that Airline X prefer to economic indexes, two indexes of cost (investment, running and maintenance) account for most of the weights. As for the running and maintenance cost, it has taken up the percentage of 25.76. After that, it is followed by the working life, which weights up to 20.35%.

(2) For Airline Y, according to the interview report, the importance degrees between indexes are given as follows.

Similarily, the judgment matrix $\boldsymbol{B}$ is established according to Table 5 and the maximum eigenvalue $\lambda_{\max} = 7.4453$. Therefore, the consistency index $\mathrm{CI} = \frac{\lambda_{\max} - n}{n-1} = 0.0742$, and based on the last column of Table 2, the mean random consistency index RI=1.36. The rate of consistency $\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} = 0.0546 < 0.1$, so the judgment matrix $\boldsymbol{B}$ is consistency. The matrix $\boldsymbol{B}$ is operated with the same steps.

$$\boldsymbol{W}_Y = [0.07 \quad 0.22 \quad 0.21 \quad 0.13 \quad 0.24 \quad 0.05 \quad 0.08] \tag{17}$$

$\boldsymbol{W}_Y$ is the weight vector of seven evaluation indexes in Airline Y's customization demands. From this weight vector, we find that Airline Y pays more attention to marketing attractiveness, which weights up to 23.77%, and after that followed by the two indexes of costs.

Table 5 Customization demands of Airline *Y*

Index	A_{11}	A_{21}	A_{22}	A_{23}	A_{31}	A_{32}	A_{41}
A_{11}	1	3	2	2	5	1/2	2
A_{21}	1/3	1	1/2	1/2	2	1/4	1/3
A_{22}	1/2	2	1	1/2	1/2	1/4	1/2
A_{23}	1/2	2	2	1	2	1/3	1/3
A_{31}	1/5	0.5	2	1/2	1	1/3	1/3
A_{32}	2	4	4	3	3	1	2
A_{41}	1/2	3	2	3	3	1/2	1

4.3 Results of grey correlation degrees

According to Eq. (9), Eq. (13) is multiplied by Eqs. (16) and (17), and the results of correlation degrees are computed as follows.

According to Table 6, Airline X's choosing priorities are:

Intelligent tray table > Video equipment > Lighting lamp > Charging equipment;

And for Airline Y, the choosing priorities are:

Intelligent tray table > Charging equipment > Video equipment > Lighting lamp.

Table 6 Grey correlation degrees in two airlines' customization demands

Grey correlation degree	Video equipment C_1	Lighting lamp C_2	Intelligent tray table C_3	Charging equipment C_4
Airline X	0.543	0.503	0.862	0.488
Airline Y	0.545	0.523	0.791	0.569

4.4 Comparisons and discussions

Comparing the two results, it is found that the two airlines prefer different equipment. For Airline X, they can prior buy intelligent tray table and video equipment, while they will not install option like charging equipment. For Airline Y, they can prior buy intelligent tray table, charging equipment and video equipment, while they will not install option like lighting lamp.

According to Section 4.2, it is found that Airline X prefers the running and maintenance costs, and the working life is subordinate. Consequently, in the selection results of Airline X, the intelligent tray table and video equipment can be contained. These two options are cheaper in operation than the equipment like charging equipment. In the same way, Airline Y prefers marketing attractiveness most, so the charging equipment which appeals the passengers will be contained in the final selection list. Likewise, the lighting lamp which does not attract the most passengers has the lowest priority.

The results indicate that the GIA model can solve the selection problem of aircraft equipment, and the comparisons also indicate that the AHP model can reflect differrent customization demands.

In this paper, we can set the threshold of C to determine the selection list more scientific. For example, we set the threshold $C=0.54$, then the selection list of Airline X are intelligent tray tables and video equipment. While Airline Y's selection list are intelligent tray table, charging facilities and video equipment. Obviously, different threshold decide differrent final selections. However, the choosing of threshold cannot only consider just one equipment system like seats. It should be set according to the whole aircraft system. In this paper, we do not give the equipment's classification of the whole aircraft system, so it is meaningless to set a threshold. In further study, the problem can be solved if we consider the reasonable classification of the whole aircraft equipment. We should also point that the established index system is aim to evaluate the cabin optional equipment. If we want to determine the whole aircraft equipment system, we should consider more detailed factors (Fuel cost, fare revenue, widths of seats, etc.) to establish a more complete index system. After that, the unified threshold will decide the whole selection list in certain customization demands.

5 Conclusions

The GIA model is used for determining the aircraft equipment selection in customization process. Seven evaluation factors including maintainability, invested funds, running and maintenance cost, etc. are chosed to evaluate the optional equipment. AHP is used for processing quantitative the qualitative description of individual demands, which is indicated by different weights in evaluation index system. The traditional GIA model which calculated the correlation degrees by averaging all correlation degrees is improved. Finally, the model indicates the relationship between customization demands and optional aircraft equipment by numerical correlation degrees. In the practical application, the customer will prefer the equipment with higher correlated degrees.

The GIA and AHP model mainly improve the present situation of civil aircraft selection. The GIA model mentioned in this paper have two benefits in practice. On one hand, it makes the airlines' selection meet their individual demands better. On the other hand, the aircraft manufacturers can integrate the customization demands into their design and production process, so the unnecessary costs can be reduced, and the efficiency of the aircraft system configuration mode can be enhanced. Therefore, both of the airlines and manufacturers can benefit from such model, which makes a win-win situation.

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