# Research on Group Decision Model of Civil Aviation Emergency Transport Based on Foreground Regret Theory

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Keywords: Civil Aviation Emergency Transport, Group Decision Making, Cumulative Prospect Theory, Regret Theory and Comprehensive Utility Value.

Abstract: For the decision problem of civil aviation emergency transport task, a solution of civil aviation emergency transport group decision model based on prospect-regret theory is proposed. First of all, on the basis of considering civil aviation transport mission uniqueness superposition decision makers using airport emergency support ability, flight time, assembly time, flight cost as attribute value to evaluate the aviation emergency transport scheme, by calculating the cumulative prospect value and regret theory of different scheme regret joy value, combined with the expert weight to regret joy value weighted calculate comprehensive utility value, and the comprehensive utility value is the best solution. Using this approach can provide a more comprehensive reference for air transport in states of emergency.

## 1 INTRODUCTION

In the field of emergency transport, effective decision-making models are important for improving transport efficiency, reducing risk and achieving sustainable development. Traditional decision-making model often only consider decision makers in absolute rational decision, ignoring the decision maker preferences for risk and benefit and may produce regret after making a choice, and these close to the actual situation of limited rational factors in the actual decision-making may have a significant impact on the results.

The cumulative prospect theory is a theory of decision behavior describing people in the context of uncertainty, proposed by Kahneman and 1979 by Tversky (Kahneman and Tversky, 2014) Tang Qionghua (Tang et al., 2022) Based on the cumulative prospect theory, the traditional impedance function is modified to study the railway passenger flow distribution method. Meng (Meng and Wang, 2022). They applied it to the distribution path optimization of electric vehicles, and built a decision model based on quantitative attributes. The regret theory was proposed by economists Bell and Loomes Sugden in 1982, comparing decision options with their expected reference point, and making decisions based on the attribute utility value and regret pleasure value of the options. Scholar Hao Minxi (Hao, 2022) Apply regret theory to the study of subway emergency evacuation by considering physiological and psychological factors such as pedestrian homogeneity and heterogeneity. Prospect-regret theory is a mixed theory of risk decision making that takes into account multiple emotional and cognitive factors. It can help decision makers to more comprehensively consider the risks and benefits of decision making, and reduce decision errors. Zhang Peng (Zhang et al., 2021) In view of the existing risk assessment method of oil and gas pipeline, they proposed a risk mode analysis method of oil and gas pipeline without considering the psychological behavior characteristics of limited rationality and regret avoidance. In the aspect of civil aviation emergency transportation, some scholars have completed the construction of optimal path model and analysis method of such factors as driving time, path distance, path complexity and so on (Shi and Chen, 2019; Song and Li, 2022.

At present, there is no decision model research in the field of civil aviation emergency transport decision-making. To this end, this study aims to more fully consider the psychological factors and emotional responses of decision makers, and explore the prospect-regret theory based on the prospect-regret decision.

In the field of civil aviation, there are often some urgent air transport tasks. Different from the ordinary



Song, Y. and Meng, Q.
Research on Group Decision Model of Civil Aviation Emergency Transport Based on Foreground Regret Theory.
DOI: 10.5220/0012880600004536

In *Proceedings of the 1st International Conference on Data Mining, E-Learning, and Information Systems (DMEIS 2024)*, pages 75-81
ISBN: 978-989-758-715-3

decision-making scenario, the civil aviation emergency transport group requires the most reasonable and lowest risk decision quickly.

When these emergencies occur, the decision-making of air transport needs to be timely and scientific. The timely performance of decision ensures the timeliness of the task. Scientific decision-making can ensure the accuracy of the decision as much as possible.

This model takes the transportation scheme given by the airline as the evaluation object, takes the attribute value of each scheme as the initial data, and specifically calculates the comprehensive utility value of each scheme based on the attribute tendency rate of each scheme. Finally, the scheme with the highest comprehensive utility value is the best scheme.

# 2 THEORETICAL PRINCIPLE

## 2.1 Cumulative Foreground Theory

The cumulative prospect theory considers people's risk attitude and value judgment when facing uncertainty in the decision analysis. The decision maker not only evaluates the possible outcomes of various options but also determines the value of each outcome based on the underlying outcome and probability weighting function. Policymakers tend to assess risk using a biased treatment of probability, describing decision-makers' perception of the value of different outcomes and their subjective weighting of probabilities.

$$V(f) = \sum_{i=0}^{n} \pi^{+} v(x_i) + \sum_{i=-m}^{0} \pi^{-} v(x_i) \tag{1}$$

By introducing affective effects and asymmetry effects (Camerer and Weber, 1992), The theory explains some of the behavioral characteristics people exhibit in decisions, such as risk aversion, loss aversion and preference reversal. It provides a framework to more accurately describe and predict human decision-making behavior.

## 2.2 Regret Theory

Regret theory in decision analysis the regret that people may feel after making a choice. Policymakers not only evaluate the outcomes of the various options, but also consider the degree of regret that may be felt after choosing each option, compared to other unselected options. Policymakers will choose the option to reduce potential regret whenever possible. The theory deeply explores the psychological mechanisms behind decision-making behavior by quantifying the regret feelings that individuals experience in decision-making (Bell, 1982)

$$Z(x) = \sum_{j}^{m} (G_{ij}(x) + R_{ij}(x)) \tag{2}$$

Regret theory provides an important framework for explaining emotional and regret influences in decision behavior. By considering regret pleasure values and attribute utility values, regret theory is able to more accurately explain the choices and behaviors of decision makers.

## 2.3 Prospect-Regret Theory

Prospect-regret theory considers that a decision maker not only estimates the expected utility in terms of the value and probability of the potential outcome, but also considers the degree of regret he may feel after making a certain choice compared with other unselected options. By considering the cumulative prospect value and regret joy value, the prospect-regret theory provides a more comprehensive and scientific decision framework, as shown in Figure 1.

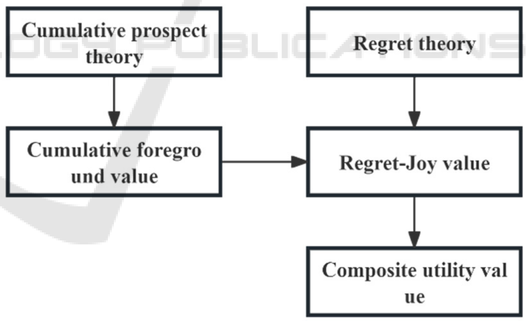


Figure 1: Prospect-Regret Theory Technical framework.

# 3 CIVIL AVIATION EMERGENCY TRANSPORT GROUP DECISION MODEL

## 3.1 Model Characteristic Indicators Were Determined

Combined with the particularity of the civil aviation industry, many reference factors are involved in the face of emergency transport tasks. For example, security, resource availability and communication and coordination skills, as well as time efficiency, economic cost control and other cost factors. After study, the following 4 parameters were determined as characteristic parameters of the evaluation scheme:

Guarantee ability: income-type index. The support capability mainly includes the task response speed between the upper and lower levels, the complete degree of professional equipment in the airport, the number of dispatching aircraft, etc. Five indicators were identified as the typical characteristic indicators of civil aviation support capability assessment through reference (Song and Li, 2022).

Assembly time: cost-type index. Medical teams in different cities need time to gather and go to the airport, flight support time at airports in different cities, time to board and load cargo.

Flight time: a cost-type index. Pure flight time from different cities to the destination airport.

Flight cost: a cost-type index. Taking off from different starting cities to destination cities requires various cost support, including fuel costs, airport costs, crew costs and other costs. Other expenses mainly include aircraft maintenance, air navigation service fee, etc.

## 3.2 Decision-Making Model

Obtain task data: Make data statistics combined with the given transportation scenario. Raw data were determined for subsequent calculations.

Determine the attribute value: compare the relative size of the support capability; estimate the assembly time; obtain the flight time; and estimate the flight cost.

Identify each indicator reference point: determine the reference point for the decision maker to evaluate the results, usually the current state or expected reference point. The main methods of finding reference points are normal distribution method, expected value method, zero point method and so on (Jiang, 2015). The method of giving reference point makes the subjective factors of decision makers have a great influence on the decision result; normal distribution method is applicable for large data volume, leading to inaccurate estimation of density function. The data volume of this study is relatively small and the data used are determined, so it is appropriate to use the average of the data as the reference point.

Calculate the value function: Use the value function to quantify the value of the result. The value function calculates the value function of the four attribute values respectively. The value function is usually nonlinear, with different sensitivities to losses and gains. The common value function is the type S curve, with increasing marginal utility for obtained values and diminishing marginal utility for loss values.

$$v(x_i) = \begin{cases} (x_i)^\alpha & , x_i \geq 0 \\ -\mu(-x_i)^\beta , & x_i < 0 \end{cases} \tag{3}$$

$x_i$Is the benefit value calculated by the decision maker according to the reference value; $\alpha$, $\beta$ indicates yes and against coefficient, where 0 <$\alpha$ and $\beta$ <1. If $\alpha = \beta$, it means that the risk assessment of the decision maker for the benefit value is biased, the size of $\alpha$ and $\beta$ determines the sensitivity of the decision maker; $\mu$ means the avoidance of benefit loss, used to measure the aversion of the decision maker to the scheme when the benefit loss, and means that the decision maker is more sensitive to the equivalent loss. Take $\alpha$ =1.21, $\beta$ =1.02, and $\mu$ =2.25.

Normalization of value function: the value function value of different groups is calculated according to the value function formula and then the dimensional standardization integration.

*Cost-based indicators:*

$$a_i = \frac{|v|_{max} - v_i}{|v|_{max} - |v|_{min}} \tag{4}$$

*Income indicators:*

$$a_i = \frac{v_i - |v|_{min}}{|v|_{max} - |v|_{min}} \tag{5}$$

$$v_{合} = \sum_{i=1}^{n} a_i v_i \tag{6}$$

$$a_1 + a + \cdots + a_n = 1 \tag{7}$$

$a_i$ is the proportion of the different value function values to the value function values with the largest absolute value.

The value function values calculated from the four attribute values in this model are normalized, and the final value function values are added according to different attribute value values.

Calculate the decision weight function: Use the decision weight function to determine the weights of the different results. The decision weight function measures the relative importance of the decision maker for different outcomes. It is usually non-linear, and the data mainly represents the bias of the decision makers for different attribute values in different schemes.

$$\pi_{(t)}^{+} = \omega^{+}\left(\sum_{\tau=1}^{n} p_{\tau}\right) - \omega^{+}\left(\sum_{\tau=t+1}^{n} p_{\tau}\right) \quad (8)$$

$$\pi_{(t)}^{-} = \omega^{-}\left(\sum_{\tau=1}^{t} p_{\tau}\right) - \omega^{-}\left(\sum_{\tau=t+1}^{t-1} p_{\tau}\right) \quad (9)$$

$$\max Q = \sum_{i=1}^{n}\sum_{j=1}^{m} v_{ij}^{+}\pi^{+}(\omega_j) - \sum_{i=1}^{n}\sum_{j=1}^{m} v_{ij}^{-}\pi^{-}(\omega_j) \quad (10)$$

$$s.t.\begin{cases}\sum_{j=1}^{m}(\omega_j) = 1 \\ else\ \omega_j \geq 0\end{cases} \quad (11)$$

*among:*

$$\omega^{+}(p) = \frac{p^{x}}{[p^{x} + (1-p)^{x}]^{\frac{1}{x}}} \quad (12)$$

$$\omega^{-}(p) = \frac{p^{\delta}}{[p^{\delta} + (1-p)^{\delta}]^{\frac{1}{\delta}}} \quad (13)$$

$\pi_{(t)}^{+}$ and $\pi_{(t)}^{-}$ represent the decision weight function of gain and loss respectively, $p$ represents the probability of each scenario value given by the expert, $\omega^{+}(*)$ and $\omega^{-}(*)$ represent the weight function of gain and loss respectively, showing a monotonically increasing S curve, x and $\delta$ represent different coefficients of the decision maker with different attitudes to gain and loss. Take x=0.61 and $\delta$ =0.69.

Calculate the cumulative foreground value: combine the value function and the weight function to calculate the cumulative foreground value for each result. The cumulative foreground value is the product of the value function and the weight function, representing the comprehensive evaluation of each outcome. The cumulative foreground values of all the results were summed to obtain the cumulative foreground values for the scheme.

$$V(f) = \sum_{i=0}^{n} \pi^{+} v(x_i) + \sum_{i=-m}^{0} \pi^{-} v(x_i) \quad (14)$$

Calculate the regret-pleasure value: substitute the calculated cumulative foreground value into the regret-joy value formula. For each decision option, the corresponding regret pleasure value was calculated. The regret pleasure value indicates the regret or satisfaction that a decision maker may feel after making a choice. The common formula is to use the difference between the maximum attribute utility value and the other attributes.

$$Z(x) = \sum_{j}^{m}(G_{ij}(x) + R_{ij}(x)) \quad (15)$$

$$R_{ij}(x) = 1 - exp[\varepsilon|\frac{V_{ij}(x) - V_{ij}^{+}(x)}{V_{ij}^{+}(x) - V_{ij}^{-}(x)}|] \quad (16)$$

$$G_{ij}(x) = 1 - exp[-\varepsilon|\frac{V_{ij}(x) - V_{ij}^{+}(x)}{V_{ij}^{+}(x) - V_{ij}^{-}(x)}|] \quad (17)$$

$R_{ij}(x)$ is the regret function, $G_{ij}(x)$ is the joy function, ε is the regret avoidance coefficient, and the general value is 0.3.

Therefore, the theory of cumulative prospect and the theory of regret are integrated, making the multiple emotions of decision makers considered in the decision calculation.

Finally, the final comprehensive utility value is calculated according to the different weights of different experts. The larger the comprehensive utility value is, the better the scheme is.

### 3.3 A. Key Parameter Adaptation Value

The favor-opposition coefficient in the value function is usually 0.88. This data is obtained by the author of the cumulative prospect theory in the United States. This index is usually less than 1, which means that the decision maker has a weakening sensitivity to the benefit. Through industry research and data collection, combined with the unique decision environment of civil aviation transportation, the parameters are adjusted as follows:

It is understood that for the civil aviation industry, the greater the benefit deviation of the results, the greater the hidden danger of the actual situation, that is, the sensitivity of the decision makers to the benefits should gradually increase. Therefore, according to the research object of this paper, it is appropriate to choose the yes and opposition coefficient greater than 1. Avavailable from reference (Zheng, 2007) the approval coefficient is 1.21 and the opposition coefficient 1.02.

In the civil aviation emergency transport industry, it attaches more importance to the airport support capacity, followed by the value of time. In contrast, it has less attention to the value of cost. Then, the weight ratio of the four key factors of the guarantee evaluation system is determined through data collection as 0.5:0.2:0.2:0.1.

# 4 ANALYSIS OF THE CASES

## 4.1 Case Description

Taking an air transport task of the epidemic in Hubei in 2020 as an example for calculation and analysis, according to the specific situation of the task: the COVID-19 in 2020,123 medical personnel and medical supplies are needed to the Three Gorges Airport in Yichang, Hubei. Combined with the objective conditions at that time, there were four staging areas for Hangzhou, Haikou, Dalian and Kunming to choose from. The five characteristic values of the guarantee capability data will be comprehensively scored, with a score range of 1 to 5 points. The following Table 1 and Table 2 are the example scoring criteria for two of the aspects.

1. Support ability of emergency plan (weight: 25%)
2. Emergency response speed (weight: 20%)
3. Support capacity of emergency equipment (weight: 25%)
4. Emergency communication support capability (weight: 20%)
5. Support ability of emergency drill (weight: 10%)

Table 1: Scoring table of emergency equipment support capacity.

| grade | appraise | code of points |
|---|---|---|
| 1 | To be improved | There are certain emergency equipment but the quantity is insufficient and uneven distribution. |
| 2 | same as | Emergency equipment and resources can cover basic emergency situations. |
| 3 | preferably | More complete emergency equipment and resources are provided with appropriate maintenance. |
| 4 | good | Emergency equipment and resources are complete, including high-performance special equipment, to adapt to all kinds of emergency situations. |
| 5 | outstanding | Emergency equipment and resources are very advanced and sufficient to respond to the most extreme situations in time. |

Combined with the above situation, an airline company gives four schemes as shown in Table 3:

Table 2: Scortable of emergency communication support capability.

| grade | appraise | code of points |
|---|---|---|
| 1 | To be improved | The plan is outdated and rarely updated; emergency communication equipment often fails. |
| 2 | same as | Plan meet basic needs and are updated regularly, but problems may arise in complex situations. |
| 3 | preferably | Emergency communication plan is detailed, and can basically meet all kinds of emergency situations. |
| 4 | good | Emergency communication plan is complete, regular drill, constantly updated and optimized. |
| 5 | outstanding | The emergency communication plan includes all kinds of extreme situation plans, which are updated regularly and familiar to all staff. |

Table 3: Airline plan sheet.

| Plan name | s1 | s2 | s3 | s4 |
|---|---|---|---|---|
| place of departure | Hangzhou | seaport | Dalian | Kunming |
| air-range /km | 940 | 1333 | 1405 | 1193 |
| Scheme aircraft | A330-300 | 737-800 | 737-900 | A320ceo |
| Guarantee ability | 4.65 | 4.45 | 4.05 | 4.25 |
| car detention time under accumulation/h | 3.5 | 2.5 | 3.75 | 4.08 |
| flight time /h | 2.25 | 2.5 | 3.25 | 2 |
| Flight cost /ten thousand yuan | 15.9 | 10.4 | 12.8 | 11.5 |

In this case, there are 4 decision makers, composed of two director decision makers and two deputy director decision makers. The weight ratio of the 4 decision makers is 0.1:0.4:0.1:0.4. The different schemes have different preferences, and the probability given by the four decision makers is as follows:

$$Q1=\begin{pmatrix}0.24 & 0.22 & 0.15 & 0.08\\ 0.23 & 0.42 & 0.10 & 0.25\\ 0.33 & 0.30 & 0.18 & 0.16\\ 0.36 & 0.14 & 0.20 & 0.09\end{pmatrix}$$

$$Q2=\begin{pmatrix}0.36 & 0.22 & 0.23 & 0.15\\ 0.38 & 0.21 & 0.20 & 0.20\\ 0.29 & 0.21 & 0.23 & 0.09\\ 0.27 & 0.25 & 0.15 & 0.08\end{pmatrix}$$

$$Q3=\begin{pmatrix}0.29 & 0.23 & 0.21 & 0.09\\ 0.32 & 0.22 & 0.18 & 0.22\\ 0.33 & 0.24 & 0.20 & 0.11\\ 0.10 & 0.15 & 0.23 & 0.14\end{pmatrix}$$

$$Q4=\begin{pmatrix}0.20 & 0.18 & 0.25 & 0.12\\ 0.22 & 0.21 & 0.37 & 0.14\\ 0.15 & 0.16 & 0.19 & 0.15\\ 0.19 & 0.24 & 0.21 & 0.17\end{pmatrix}$$

## 4.2 Case Analysis

Reference point: According to the characteristics of the data in this case, the average value is used as the reference point. According to support capability, assembly time, S flight time and flight cost array:

{4.65，4.45，4.05，4.25}；
{3.5，2.5，3.75，4.08}；
{2.25，2.5，3.25，2}；
{15.9，10.4，12.8，11.5}。

Each takes its average: 4.35, 3.4575, 2.5, 12.65.

In this case, the decision maker can directly obtain the weight ratio of the four indicators of 0.5:0.2:0.2:0.1.

The array of profit and loss values for calculated guarantee capability, assembly time, flight time and flight cost are:

{0.3，0.1，-0.3，-0.1}；
{0.425，-0.9575，0.625，0.933}；
{-0.25，0，0.75，-0.5}；
{3.25，-2.25，0.15，-1.15}。

Value function: The value function of support capability, assembly time, flight time and flight cost are:

{0.23298，0.06166，-0.65894，-0.21487}；
{0.0219，-2.1525，0.22595，0.56352}；
{-0.54712，0，0.70603，-1.10951}；
{4.16273，-5.14528，0.10071，-2.59474}。

dimensional integration: it can be calculated from the dimensional standardization formula, the final array of value functions is:

{0.69247，0.84679，-0.15022，0.53503}

Decision weight function: The decision weight function of the four decision makers is respectively:

$$\pi_1=\begin{pmatrix}0.14869 & 0.13058 & 0.11531 & 0.28497\\ 0.29352 & 0.06656 & 0.22357 & 0.2791\\ 0.22519 & 0.12848 & 0.15669 & 0.33422\\ 0.15968 & 0.16123 & 0.07093 & 0.34971\end{pmatrix}$$

$$\pi_2=\begin{pmatrix}0.21673 & 0.16237 & 0.11312 & 0.34971\\ 0.25703 & 0.13463 & 0.10841 & 0.3599\\ 0.15968 & 0.18104 & 0.10766 & 0.31298\\ 0.14869 & 0.13058 & 0.12894 & 0.30201\end{pmatrix}$$

$$\pi_3=\begin{pmatrix}0.15968 & 0.16789 & 0.11798 & 0.31298\\ 0.27199 & 0.11967 & 0.11243 & 0.32898\\ 0.18016 & 0.15402 & 0.12318 & 0.33422\\ 0.20803 & 0.16476 & 0.10444 & 0.1863\end{pmatrix}$$

$$\pi_4=\begin{pmatrix}0.18978 & 0.18301 & 0.09914 & 0.26076\\ 0.20803 & 0.25223 & 0.11203 & 0.27312\\ 0.21673 & 0.13694 & 0.09679 & 0.22691\\ 0.23342 & 0.14567 & 0.13078 & 0.25437\end{pmatrix}$$

Cumulative foreground value: The four calculated cumulative foreground values are:

{0.3811，0.53819，0.49269，0.40646}
{0.34021，0.36866，0.28425，0.2943}
{0.40693，0.48397，0.44156，0.31663}
{0.3635，0.38226，0.35455，0.40896}

Count the regret joy value according to the formula of regret joy value:

{0.05978，0.1491，0.12366，0.07449}
{0.08846，0.1047，0.05609，0.06194}
{0.09154，0.13514，0.11126，0.03913}
{0.08959，0.1003，0.08444，0.11546}

Combined with the decision weight of the four decision makers (0.1:0.4:0.1:0.4), the comprehensive utility value of the group decision is calculated as:

{0.086352，0.110424，0.079704，0.082322}

According to the calculation results, $Z_2 > Z_1 > Z_4 > Z_3$, so scheme 2 is better than others.

After the calculation results are verified by means of expert visit and inquiry, the calculation results of this paper are consistent with the actual situation.

The initial data of this model are added to the method of literature (Wan et al., 2022) and literature (Zhang and Liu, 2022), with literature(Wan et al., 2022) calculated using only cumulative prospect theory and literature(Zhang and Liu, 2022) using only regret theory. After the calculation, the comprehensive utility value is obtained as follows:

{0.42182，0.46495，0.40512，0.4094}

{0.36784，0.86385，0.51108，0.45095}

Comprehensive utility values for each scheme are calculated as described in Table 4.

Table 4: Comprehensive utility value of each scheme.

| scheme | Comprehensive utility value | Literature (Wan et al., 2022) | Literature (Zhang and Liu, 2022) |
|---|---|---|---|
| 1 | 0.086352 | 0.42182 | 0.36784 |
| 2 | 0.110424 | 0.46495 | 0.86385 |
| 3 | 0.079704 | 0.40512 | 0.51108 |
| 4 | 0.082322 | 0.4094 | 0.45095 |
| sort | Z2>Z1>Z4>Z3 | Z2>Z1>Z4>Z3 | Z2>Z3>Z4>Z1 |

Can be seen from the table literature(Wan et al., 2022) method to calculate the sort of cumulative prospect value and prospect-regret theory sort, compared with only using the cumulative prospect theory, prospect-regret theory considering the different choice results for decision makers psychological regret or happy feeling, more comprehensive consider the civil aviation decision makers for the influence of decision results. As the regret avoidance coefficient changes, so does the ranking of decision results. After literature [13] uses the regret theory, the scheme ranking is different from the other two methods, because the theory used in this paper considers the prospect and risk preference, more comprehensively considers the psychological activities, and more in line with the realistic decision scenario. Therefore, the prospect-regret theory of this paper is more superior and effective in comparison.

## 5 CONCLUSIONS

This paper combines cumulative prospect theory and regret theory to construct a risk decision model suitable for civil aviation emergency transport group decision. The model not only focuses on the expected utility in the decision-making process, but also takes into account the possible regret and joy of decision makers in the face of different outputs, so as to more comprehensively and carefully evaluate the transportation scheme. This study verifies the practicability and superiority of the model through real cases. The model calculation results show that the group decision model is not only more insightful when comparing different transport schemes, but also more accurate in predicting the decision maker behavior than using a single cumulative prospect theory or regret theory.

In future applications, the model can provide more scientific and all-round decision support for airlines' transportation tasks in emergencies, ensuring the best solution, while reducing the psychological burden of decision makers in the selection process. With the expansion of practical application scenarios, the generality and stability of the model need to be further verified and improved, so as to provide more empirical research basis for aviation emergency transportation.

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