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An Airfield Minimum Operating Strip Selection Method Based on the TOPSIS Method

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Abstract
With Multiple Attribute Decision Making (MADM) method, the selection of airfield Minimum Operating Strip (MOS) schemes is researched. The influencing factors of the selection decision making are analyzed. The weight values of these factors are determined. Then the decision making optimization method based on TOPSIS is presented. At last, the feasibility of the method is validated with a calculation example.

Key words: Minimum Operating Strip (MOS); Multiple Attribute Decision Making (MADM); Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

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INTRODUCTION

As an essential platform for airplane smoothly takeoff and landing, the airfield's using state directly relates to the give full scope to the air force combat effectiveness. In this paper, the using state of airfield is mainly pointed to the airfield runway pavement. Since the World War Ⅱ (WWⅡ), aircraft became larger and required stronger runway to carry them. Once the air force's combat effectiveness cannot be brought into play properly, that is bound to affect the fight for control of the air war zone, and thus affect the course of the war. Therefore, the airfield has an extremely important military value today. At the same time, the airfield's area is huge, and the characteristic of airfield's installations is so obviously. Accordingly, the airfield can easily be found by the enemy reconnaissance in wartime, and it is difficult to take some general means for camouflage. With precise information warfare, long-range attack weapons and precision-guided weapons are used widely. In a word, the airfield has become a prime target for attacks in wartime.

After the attack on the airfield, damaged runway rapidly repairing work must be completed as soon as possible, in order to quickly restore normal function of the airport. Rapid repairing work for airfield runway must be completed as soon as possible. Firstly, the damage assessments for airfield runway need to be completed as soon as possible. After the damage assessment is analyzed with support mission requirements, an optimal airfield emergency operating strip (EOS) scheme should to be presented quickly. This is to be achieved within the minimum time as much as possible to restore the airfield use function. Therefore, the selection of EOS schemes is directly related to the implementation of the follow-up airfield repairing work. And the rationality of the optimal EOS scheme is important.

Aimed on the selection of emergency operating strip, a mathematical model based on system analysis method is established. With a confirmation analysis for an example, a feasible analysis method is presented to solve the selection of EOS.

1. THE MAIN FACTOR FOR THE SELECTION OF EOS

The selection of MOS is started in the field of U.S. military firstly. USAF early started to research on the airfield runway rapid repairing work in the 1970s. In these researches, they called the emergency operating strip (EOS) as Minimum Operating Strip (MOS). MOS is defined that the minimum requirements runway strips to meet the specific and/or configuration of the aircraft to the airport or combat weight maximum takeoff/landing runway in a particular airfield. The determining methods and criteria for MOS are ested and corrected with some combats. The latest achievement is mainly reflected in the 'U.S. Air Force airfield rapid repair manual' (2008 edition). In this manual, these relevant precautions and procedures are briefly described. When making a decision of MOS selection, the GeoExPT software system specially developed is used. However, the appropriate specialized software system is still not to be researched and developed in our country, and the selection of MOS is also lack of a standard method.

The decision of MOS selection, involving multiple influential factors, is a typical Multiple Attribute Decision Making (MADM) problem (Li, 2002; Hwang & Yoon,1981). Among these factors, the main influence factors of MOS selection are researched by some experts in our country. And some technique criterions are laid down too. In these technique criterions, some principles of MOS selection are presented. Based on these technique criterions and research, there are some relevant factors to be presented in this paper.

1.1 The Engineering Quantity of Runway Rapidly Repairing Work

The engineering quantity for MOS is directly related to the time of the rapid repairing work needed. The smaller quantities, and the rapid repairing time is shorter. It should be noted that, the engineering quantity is not only including runways, also other components such as taxiways and apron.

1.2 Normally Dispatched Capacity of Aircraft

The MOS selected should be able to ensure that the aircraft can be dispatched normally and freely. In other words, the multiple taxiways should be connected each other, otherwise it will seriously affect the efficiency of the airfield.

1.3 Original Navigation Facility Utilization

The MOS selected is best to keep the availability of existing navigation equipment. In other words, this requires that the center line of MOS should be coincident with the centerline of the original runway. Even if the MOS cannot use the original runway centerline, then must ensure that the relationship between the two centerlines is parallel. Otherwise, it will seriously affect the use of the MOS repaired. At the same time, because the original navigation equipment is not available, other emergency navigation devices need to be set up rapidly or fixed navigation equipment to be rebuilt. These works will greatly increase the time to repair the airfield.

1.4 Runway Pavement Quality of MOS

The runway pavement quality is related to the safety and smoothness of flight. So the quality of MOS should be possible to achieve the quality standards of the original runway pavement. The quality standards should include strength, smoothness and roughness, etc. for the actor, many detailed requirements are laid down in many countries.

1.5 Expansion Capability of MOS

The MOS selected should be able to have some degree of expansion capability based on the needs of the service task. This is also an essential basis for making decision of MOS selection. The expansion capability of MOS is better, the ability of service and support better.

1.6 Unexploded Ordnances Situation

During the MOS selection, the explosive ordnance disposal (EOD) is considered necessary. Before the runway rapid repairing, the unexploded ordnances (UXO) must be disposed. The number of unexploded ordnances in the MOS selected is more, the more time to runway rapid repairing. This is because the task of exclusion of unexploded ordnance being very difficult and extremely dangerous, not only time consuming, but also it may cause casualties. And the bomb destroy crater formed after the unexploded ordnances detonation still needs to be processed.

In summary, the corresponding six factors mentioned above, the effect factors set $S=\{S_1 \cdots S_6\}$ for the MOS selection can be presented.

2. THE WEIGHT DETERMINATION

Various options MOS schemes sorted are a typical problem on multi-attribute decision making. In this paper, the method of technique for order preference by similarity to ideal solution (TOPSIS)(Fu, 2007) is used to analyze of the MOS selection. The TOPSIS method is a commonly multi-attribute decision method to analyze limited decision-making schemes in the field of system engineering. The TOPSIS method is a dual basis method (ideal solution and anti-ideal solution) essentially. The advantage of TOPSIS method is able to compare the various decision-making schemes and sorted. The original data matrix normalized is established, and the optimal solution and the worst solution from these limited decision-making schemes can be found by the matrix. Then the distances between a certain scheme of the scheme set and the optimal (and the worst) solution are calculated respectively. The distance is defined by the square root of the sum of squares of the difference. Then the degree of near-optimal solutions can be derived. At last, the distance calculated is as a result of a comparison of the merits of the program is based. Ultimately, this distance is the basis for evaluation of these schemes.

The above analysis for the six factors influencing the MOS selection, the rate range of 1 to 10 is provided. The weights of each factor can be drawn by the expert scoring method.

ω_1=10, ω_2=8, ω_3=6, ω_4=3, ω_5=1, ω_6=7.

After normalization, the set of weights is obtained as follows:

ω=(0.2857 0.2286 0.1714 0.0857 0.0286 0.2).

3. ANALYSIS OF EXAMPLES

For example, we can suppose that a certain airfield is attacked in wartime. And the set of MOS selection is defined as $A=(A_1, A_2, A_3, A_4)$. The specific circumstances of each scheme are shown in Table 1.

Table 1
The Specific Circumstances of Four Schemes Aimed Influencing Factors

Schemes	Engineering quantity of runway rapid repairing (m^3)	Normally dispatched capacity of aircraft	Original navigation facility utilization	Pavement quality of MOS	Expansion capability of MOS	Number of Unexploded ordnances
A_1	560	8	5	8	8	1
A_2	380	5	6	5	5	2
A_3	340	4	4	6	4	3
A_4	460	6	8	7	6	2

Among these six influencing factors, the engineering quantity of runway rapid repairing and the number of unexploded ordnances factors are the cost type evaluation. And the remaining four factors are efficiency type evaluation. In these six factors, in addition to engineering quantity and the number of unexploded ordnance being actual value, the rest are graded by the rate range of 1 to 10.

According to the following equation (1):

$$x'_{ij}=\frac{x_{ij}}{\sqrt{\sum_{i=1}^{n}x_{ij}^2}} \tag{1}$$

In the equation, i=1, 2, …, 4; j=1, 2, …, 6.

With the four schemes scores normalized, the decision matrix is calculated and listed as follows:

$$D=\begin{bmatrix} 0.6320 & 0.6737 & 0.4211 & 0.6065 & 0.6737 & 0.2357 \\ 0.4288 & 0.4211 & 0.5053 & 0.3790 & 0.4211 & 0.4714 \\ 0.3837 & 0.3369 & 0.3369 & 0.4549 & 0.3369 & 0.7071 \\ 0.5191 & 0.5053 & 0.6737 & 0.5307 & 0.5053 & 0.4714 \end{bmatrix}$$

By the above weight set, the weight matrix can be calculated as follows:

$$V=\begin{bmatrix} 0.1806 & 0.1540 & 0.0722 & 0.0520 & 0.0193 & 0.0471 \\ 0.1225 & 0.0963 & 0.0866 & 0.0325 & 0.0120 & 0.0943 \\ 0.1096 & 0.0770 & 0.0577 & 0.0390 & 0.0096 & 0.1414 \\ 0.1483 & 0.1155 & 0.1155 & 0.0455 & 0.0145 & 0.0943 \end{bmatrix}$$

By the matrix V, the ideal solution and negative ideal solution can be determined out as follows:

V^+=(0.1096 0.1540 0.1155 0.0520 0.0193 0.0471)

V^-=(0.1806 0.0770 0.0577 0.0325 0.0096 0.1414)

According to the following equation (2) and equation (3):

$$d_i^+=\sqrt{\sum_{j=1}^{n}(v_j-v_j^+)^2} \tag{2}$$

$$d_i^-=\sqrt{\sum_{j=1}^{n}(v_j-v_j^-)^2} \tag{3}$$

In the equation, i=1, 2, …, 4; j=1, 2, …, 6.

Thus, the distance between ideal solution and certain scheme and the distance between negative solution and the scheme can be calculated separately (Nie & Liu, 2007 and Zhang, Li & Lin, 2009).

d^+_1=0.0832, d^-_1=0.1245; d^+_2=0.0836, d^-_2=0.0825; d^+_3=0.1357, d^-_3=0.0713; d^+_4=0.0726, d^-_4=0.0910.

According to the following equation (4):

$$U(A_i)=d^-_i/(d^+_i+d^-_i) \tag{4}$$

The relative efficiency values of each scheme can be calculated, such as:

$U(A_1)$=0.5994,
$U(A_2)$=0.4967,
$U(A_3)$=0.3444,
$U(A_3)$=0.5561.

According to these values, the order of decision can be arranged out: $A_1>A_4>A_2>A_3$.

Among the above four MOS schemes, although the maximum amount of rapid repairing engineering quantity belongs to the scheme A_1, but because of other indicators of A_1 with a high degree of close to the ideal solution, so that scheme A_1 becomes the best solution with comprehensive evaluation. On the contrary, despite the minimum amount of rapid repairing engineering quantity belongs to the scheme A_3, but because of the low score of other indicators, so it becomes the worst solution. On the facts, this result also reflects the thinking of multi-attribute decision making.

CONCLUSION

Based on the above analysis, because the selection of MOS scheme is a typical multi-attribute decision making problems, so using the TOPSIS method to solve the selection problem is entirely feasible in theory. In this paper, the feasibility of the TOPSIS method is proven by a case. TOPSIS method can effectively be considering all kinds of factors, and the one-sidedness of purely qualitative decision-making can be avoided. Thus the rationality of decision-making is improved. This method is simple and convenient application.

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