Research on Overall Evaluation Model for Traffic Transportation Efficiency of Equipment based on Rough Set Theory

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Abstract. On the basis of overall consideration on influence factors of traffic transportation efficiency of equipment, based on Completeness, Maneuverability, Rationality and Comparability, this paper proposes a safe, cost-effective, universal and timely evaluation index system for traffic transportation efficiency of equipment, puts forward a quantitative calculating approach for the weight of evaluation index system for traffic transportation efficiency of equipment and creates an overall evaluation model for traffic transportation efficiency of equipment based on rough set theory. The evaluation index system and evaluation model for traffic transportation efficiency of equipment proposed in this paper are quantitative calculation approaches to improve and evaluate traffic transportation efficiency of equipment, which paves the way for further research on traffic transportation efficiency of equipment.

1. Introduction

The R&D and usage of equipment is a complex system engineering, which are highly exploratory and integrated, with a large number of evaluation and decision-making issues involved [1]. Equipment efficiency analysis is an important theory and method for judging, selecting and optimizing the equipment's combat readiness, transportation, reliability and other related issues [2]. Traffic transportation efficiency of equipment directly affects maneuverability of equipment. No matter how sophisticated the equipment is, if it cannot be assembled quickly and effectively, its combat effectiveness cannot be fully exerted [3]. Therefore, it is particularly important to scientifically evaluate the traffic transportation efficiency of equipment.

In recent years, Chinese scholars have realized that it's important to evaluate the traffic transportation efficiency of equipment, and experts and scholars have also carried out extensive exploration and thorough research in this field. Zhang Lei et al. [4] have created an evaluation model of wartime military airlift efficiency based on the entropy approach, which solves the problem of incomplete transport efficiency evaluation data to a certain extent. Sheng Youwen et al. [5] have made a quantitative analysis on the factors affecting the traffic transportation efficiency of military container in respect of the features of military container transportation, and have created a model for selecting
optimal traffic transportation efficiency for transporting military containers in combination with the fuzzy neural network approach. Zhang Jianing [2] has made a comparative analysis on traditional efficiency evaluation approaches and created an overall evaluation model for traffic transportation efficiency of warehoused goods with analytical hierarchy process and ABC approaches. Based on the existing research results, this paper takes into account the influence factors of traffic transportation efficiency of equipment, creates the evaluation index system for traffic transportation efficiency of equipment, applies the rough set theory to the weight calculation of the evaluation index system for traffic transportation efficiency of equipment, and also uses an integrated evaluation method to create the overall evaluation model for traffic transportation efficiency of equipment based on the rough set theory.

2. Construction of an Evaluation Index System for Traffic Transportation Efficiency of Equipment

The evaluation index system for traffic transportation efficiency of equipment is the outcome of evaluation objectives, and should cover safety, cost-effectiveness, universality, timeliness and other indexes to evaluate the traffic transportation efficiency of equipment. It improves the strategic maneuverability of equipment, reduces transport maintenance costs and shortens the transportation time.

2.1 Principles for creating the evaluation index system

Identifying and constructing a systematic and reasonable evaluation index system based on certain construction principles is the premise of creating an evaluation model for traffic transportation efficiency of equipment. The principles [6, 7] adhered to construct an overall evaluation index system for traffic transportation efficiency of equipment are as follows:

2.1.1 Completeness. The traffic transportation efficiency of equipment should be fully reflected in the evaluation index system.

2.1.2 Maneuverability. The evaluation index must be quantitative if possible, to perform an intuitive comparison based on values.

2.1.3 Rationality. The evaluation index must have a clear boundary and reasonable contents, to clearly express the contents to be compared.

2.1.4 Comparability. The same evaluation index must be comparable among different traffic transportation efficiency.

2.2 Evaluation index system for traffic transportation efficiency of equipment

In this paper, the frames [7, 8 and 9] of the evaluation index system for traffic transportation efficiency of equipment are constructed based on the construction principles from aspects of safety, cost-effectiveness, universality and timeliness, as detailed in the following figure 1.
1. Evaluation Index System for Traffic Transportation Efficiency of Equipment

2.2.1 Safety index. Safety index refers to the probability that the transportation task of the equipment is completed under conditions specified in a scheme of traffic transportation efficiency, which is expressed by the reliability of traffic transportation efficiency. Given the same conditions, the higher the reliability value, the better the traffic transportation efficiency.

2.2.2 Cost-effectiveness index. The cost-effectiveness includes costs of packaging, loading/unloading, storage and transportation, specifically referring to the sum of staff, procurement, maintenance, energy consumption and leasing costs incurred in transportation. Given the same conditions, the less the sum of costs, the better the traffic transportation efficiency.

2.2.3 Universality index. The universality index is related to the number, type and volume of the special transportation resources involved in the traffic transportation efficiency, and is expressed by the ratio of the number, type and volume of the general transport resources to that of the total transportation resources. Given the same conditions, the larger the universality value is, the better the traffic transportation efficiency.

2.2.4 Timeliness index. Timeliness of traffic transportation efficiency is expressed by transportation time, on-time delivery rate, intact delivery rate, staff and equipment availability. On-time delivery rate is expressed by the ratio of on-time delivery times to total delivery times of military equipment; intact delivery rate is expressed by the ratio of intact delivery times to total delivery times of military equipment to the destination; staff and equipment availability is expressed by the ratio of the actual number of staff and equipment to the total number of staff and equipment. Given the same conditions, the higher the timeliness value, the better the traffic transportation efficiency.
3. Creation of an Evaluation Model for Traffic Transportation Efficiency of Equipment based on Rough Set Theory

3.1 Weight calculation method [8, 9, 10 and 11]

In this paper, the rough set theory combining qualitative and quantitative methods is used to analyze the evaluation decision table of traffic transportation efficiency of equipment, in which the evaluation indexes of traffic transportation efficiency are discretized through formulating the discrete data processing rules. Then the weights of evaluation indexes of traffic transportation efficiency are calculated according to rough set theory.

3.1.1 Information system. In rough set theory, the collection of study objects is called a domain of discourse that is usually expressed by U. In the domain of discourse, a two-dimensional information table consisting of the attribute values of the objects is called an information system on U.

Definition 1 $S = (U, C, V, f)$ is an information system; wherein, $U = \{x_1, x_2, \ldots, x_n\}$, $C$, $V$ and $f: U \times C \rightarrow V$ refer to domain of discourse, conditional attribute set, collection of attribute values and function that assigns an information value for each attribute of each study object respectively.

3.1.2 Indiscernibility relation. For a set of objects in the domain of discourse $U = \{x_1, x_2, \ldots, x_n\}$, if they are assigned with the same values on an attribute (set), they cannot be discerned according to the attribute (set), which is called indiscernibility relation in the rough set.

Definition 2 In the information system $S = (U, C, V, f)$, in terms of $P \subseteq C$, if each of a set of objects has the same attribute $p \in P$, such objects are viewed to be in an equivalence relation based on attribute subset $P$. In rough sets, this equivalence relation is defined as an indiscernibility relation, which is expressed as follows:

\[
\text{IND}(P) = \{(x_i, x_j) \in U \times U | \forall a \subseteq P, f(x_i, x_j) = f(x_p, x_j)\}
\]

Relation $\text{IND}(P)$ constitutes a division of $U$ and is expressed by $\frac{U}{\text{IND}(P)} = \{p_1, p_2, \ldots, p_n\}$, abbreviated as $U/P$.

3.1.3 Attribute importance. In the information system, the importance of attributes is characterized by the change of information content in the information table before and after the attributes are removed.

Definition 3 In $S = (U, C, V, f)$, $\forall c \in C$. Supposing $U/c = \{C_1, C_2, \ldots, C_n\}$, the importance of attribute $c$ is defined as follows:

\[
\text{sig}(\{c\}) = \sum_{j=1}^{n} \frac{|C_j| |U - C_j|}{|U|(|U| - 1)}
\]

3.1.4 Attribute weight. In the HU-based discernibility matrix, $|C_i| |U - C_i|$ refers to the total discernibility elements generated by attribute $c_i$ in the discernibility matrix, which is usually regarded as the heuristic information, that is, if the total discernibility attribute produced by an attribute $c_i$ is larger, the attribute $c_i$ is more important.

Definition 4 In the information system $S = (U, C, V, f)$, $\forall c_i \in C$, and the weight of attribute $c_i$ in the information system can be defined as per the following formula:

\[
W(\{c_i\}) = \frac{\text{sig}(\{c_i\})}{\sum_{i=1}^{n} \text{sig}(\{c_i\})}
\]

3.2 Evaluation model

In this paper, the comprehensive evaluation method is used to sort design schemes for traffic transportation efficiency of equipment. Based on the determination of attribute weight above, it is assumed that the weight vector of evaluation indexes of traffic transportation efficiency of equipment is denoted as $W = (w_1, w_2, \ldots, w_m)^T$, $w_s \geq 0$ and $\sum_{s=1}^{m} w_s = 1$ after normalization. Vector $R_{m \times n}$
refers to a normalized index of decision vector, and the comprehensive evaluation model for traffic transportation efficiency in design schemes for traffic transportation efficiency of equipment can be expressed as follows:

\[ Z_i = \sum_{j=1}^{m} w_j r_{ij} \]

(4)

4. Examples

4.1 Case scenario

In order to meet the strategic requirements of a certain army, a new research equipment needs to be developed, and eight design schemes for traffic transportation efficiency of equipment are given, as shown in Table 1. It is expected to evaluate the transportation efficiency of the eight design schemes for traffic transportation efficiency of equipment from safety, cost-effectiveness, universality and timeliness, so as to find out the optimal scheme.

| Scheme | Safety (%) | Cost-effectiveness (RMB 10,000) | Universality (%) | Timeliness (%) |
|--------|------------|---------------------------------|------------------|----------------|
| A1     | 97         | 10                              | 70               | 80             |
| A2     | 95         | 15                              | 80               | 80             |
| A3     | 96         | 11                              | 60               | 90             |
| A4     | 95         | 12                              | 70               | 80             |
| A5     | 94         | 13                              | 80               | 70             |
| A6     | 97         | 12                              | 80               | 80             |
| A7     | 98         | 13                              | 70               | 80             |
| A8     | 97         | 9                               | 70               | 80             |

4.2 Evaluation for traffic transportation efficiency

4.2.1 Calculation of importance. Based on the above-mentioned evaluation index system of traffic transportation efficiency and the information of the design scheme for traffic transportation efficiency of equipment, 10 experts are arranged to score the evaluation indexes of traffic transportation efficiency of each alternative scheme, with a maximum of 5 scores and a minimum of 0 score. The scores of the 10 experts are averaged to get the scores of the indexes of each alternative scheme, as shown in Table 2:

| Scheme | C1  | C2  | C3  | C4  | C5  | C6  | C7  | C8  | C9  | C10 | C11 | C12 |
|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| A1     | 4.56| 4.53| 4.45| 3.45| 3.56| 4.25| 3.24| 4.03| 4.23| 3.98| 3.96| 4.04|
| A2     | 4.85| 4.23| 4.38| 2.87| 3.12| 4.32| 3.87| 4.14| 4.86| 3.56| 3.87| 4.04|
| A3     | 4.12| 3.93| 4.65| 4.28| 4.29| 4.52| 4.56| 4.56| 4.13| 4.56| 4.78| 4.08|
| A4     | 3.53| 4.65| 4.12| 3.56| 4.45| 3.87| 4.21| 3.87| 3.87| 4.02| 3.98| 4.04|
| A5     | 4.82| 4.12| 3.86| 2.96| 3.26| 4.51| 4.02| 4.06| 4.81| 4.03| 4.23| 3.96|
| A6     | 2.78| 4.86| 4.66| 4.65| 4.89| 3.03| 3.35| 3.02| 3.02| 3.04| 3.67| 3.87|
| A7     | 3.28| 3.69| 4.68| 3.63| 4.86| 2.98| 4.03| 3.86| 3.86| 3.89| 3.67| 4.02|
| A8     | 3.67| 4.46| 4.07| 3.97| 4.52| 4.56| 3.98| 4.02| 4.02| 4.76| 4.23| 4.56|

The weight of each efficiency evaluation index is determined on the basis of rough set theory. First, it is necessary to discretize each efficiency evaluation index shown in Table 2. In this paper, by rounding up to an integer, the indexes with scores of (4.5, 5], (4.0, 4.5], (3.5, 4.0], (3.0, 3.5] and below 3.0 are respectively judged to be excellent and recorded as 5, good and recorded as 4, medium and recorded as 3, poor and recorded as 2 and very poor and recorded as 1. Thus, the set of all conditional attribute values after discretization can be obtained, as shown in Table 3:
Table 3 Decision after Discretization

| Scheme | C₁ | C₂ | C₃ | C₄ | C₅ | C₆ | C₇ | C₈ | C₉ | C₁₀ | C₁₁ | C₁₂ |
|--------|----|----|----|----|----|----|----|----|----|-----|-----|-----|
| A₁     | 5  | 5  | 4  | 3  | 3  | 4  | 2  | 4  | 4  | 3   | 3   | 4   |
| A₂     | 5  | 4  | 4  | 1  | 2  | 4  | 3  | 4  | 5   | 3   | 3   | 4   |
| A₃     | 4  | 3  | 5  | 4  | 4  | 5  | 5  | 5  | 4   | 5   | 4   | 5   |
| A₄     | 3  | 4  | 4  | 3  | 4  | 3  | 4  | 3  | 4   | 3   | 4   | 3   |
| A₅     | 5  | 4  | 3  | 1  | 2  | 5  | 4  | 4  | 5   | 4   | 4   | 3   |
| A₆     | 1  | 5  | 5  | 5  | 5  | 2  | 2  | 2  | 2   | 3   | 3   | 3   |
| A₇     | 2  | 3  | 5  | 3  | 5  | 1  | 4  | 3  | 3   | 3   | 4   |
| A₈     | 3  | 4  | 4  | 3  | 5  | 5  | 3  | 4  | 5   | 4   | 5   | 5   |

According to rough set theory, the equivalence relation of 12 condition attributes namely C₁, C₂, C₃, C₄, C₅, C₆, C₇, C₈, C₉, C₁₀, C₁₁ and C₁₂ in Table 3 can be obtained:

\[
\text{U}/(C₁) = \{\{A₁, A₂, A₅\}, \{A₃\}, \{A₄, A₈\}, \{A₇\}, \{A₆\}\}; \text{U}/(C₂) = \{\{A₁, A₂, A₅\}, \{A₂, A₄, A₅, A₈\}, \{A₃, A₇\}\}; \text{U}/(C₃) = \{\{A₁, A₂, A₄, A₈\}, \{A₃, A₆, A₇\}, \{A₉\}\}; \text{U}/(C₄) = \{\{A₁, A₂, A₅\}, \{A₃\}, \{A₄, A₉\}, \{A₅\}\}; \text{U}/(C₅) = \{\{A₁, A₂, A₇, A₈\}, \{A₂, A₅\}\}; \text{U}/(C₆) = \{\{A₃, A₅, A₈\}, \{A₁, A₂, A₅, A₈\}, \{A₄, A₇\}\}; \text{U}/(C₇) = \{\{A₃, A₅, A₇, A₈\}, \{A₂, A₉\}, \{A₁, A₆\}\}; \text{U}/(C₈) = \{\{A₃, A₅, A₇, A₈\}, \{A₁, A₃, A₇, A₈\}, \{A₄, A₇\}\}; \text{U}/(C₉) = \{\{A₂, A₅\}, \{A₁, A₃, A₆\}, \{A₄, A₇\}, \{A₆\}\}; \text{U}/(C₁₀) = \{\{A₂, A₅\}, \{A₃, A₅, A₇, A₈\}, \{A₂, A₉\}, \{A₁, A₆\}\}; \text{U}/(C₁₁) = \{\{A₃, A₅, A₇, A₈\}, \{A₁, A₂, A₄, A₆, A₇\}\}; \text{U}/(C₁₂) = \{\{A₅\}, \{A₁, A₂, A₃, A₄, A₇\}, \{A₅, A₆\}\}
\]

According to the formula (2) for calculating importance based on rough set theory, the importance of the above condition attributes can be calculated. Taking attributes C₁ and C₂ as examples, the specific algorithm of importance of its attributes is as follows:

\[
s_{\text{sig}}(C₁) = \frac{|\{A₁, A₆\}| U - \{A₁, A₆\}|}{|U|(|U| - 1)} + \frac{|\{A₃\}| U - \{A₃\}|}{|U|(|U| - 1)} + \frac{|\{A₄, A₈\}| U - \{A₄, A₈\}|}{|U|(|U| - 1)} \\
+ \frac{|\{A₇\}| U - \{A₇\}|}{|U|(|U| - 1)} + \frac{|\{A₆\}| U - \{A₆\}|}{|U|(|U| - 1)} \\
= \frac{3 \times 5}{8 \times 7} + \frac{1 \times 7}{8 \times 7} + \frac{2 \times 6}{8 \times 7} + \frac{1 \times 7}{8 \times 7} + \frac{1 \times 7}{8 \times 7} = \frac{48}{56}.
\]

\[
s_{\text{sig}}(C₂) = \frac{|\{A₁, A₂, A₅\}| U - \{A₁, A₂, A₅\}|}{|U|(|U| - 1)} + \frac{|\{A₃, A₇\}| U - \{A₃, A₇\}|}{|U|(|U| - 1)} \\
+ \frac{|\{A₂, A₄, A₅, A₈\}| U - \{A₂, A₄, A₅, A₈\}|}{|U|(|U| - 1)} \\
= \frac{2 \times 6}{8 \times 7} + \frac{4 \times 4}{8 \times 7} + \frac{2 \times 6}{8 \times 7} + \frac{4 \times 4}{8 \times 7} = \frac{40}{56}.
\]

In a similar way, the calculation results of importance of other attributes are:

\[
s_{\text{sig}}(C₃) = \frac{38}{56}, s_{\text{sig}}(C₄) = \frac{42}{56}, s_{\text{sig}}(C₅) = \frac{46}{56}, s_{\text{sig}}(C₆) = \frac{46}{56}, s_{\text{sig}}(C₇) = \frac{46}{56}, s_{\text{sig}}(C₈) = \frac{42}{56}, s_{\text{sig}}(C₉) = \frac{46}{56}, s_{\text{sig}}(C₁₀) = \frac{46}{56}, s_{\text{sig}}(C₁₁) = \frac{34}{56}, s_{\text{sig}}(C₁₂) = \frac{34}{56}.
\]
4.2.2 Weight calculation. According to rough set theory, we can get:

$$\sum_{i=1}^{m} \sigma_{i}(\{c_i\}) = \frac{508}{56}$$

Then according to the weight calculation formula (3) of rough set theory, the weight values of 12 condition attributes namely $C_1$, $C_2$, $C_3$, $C_4$, $C_5$, $C_6$, $C_7$, $C_8$, $C_9$, $C_{10}$, $C_{11}$ and $C_{12}$ can be obtained, as shown in Table 4:

**Table 4** Weight Value of Traffic Transportation Efficiency Evaluation Index for Traffic
Transportation Efficiency of Equipment in Alternative Design Schemes

| Attribute | Weight | Attribute | Weight | Attribute | Weight | Attribute | Weight |
|-----------|--------|-----------|--------|-----------|--------|-----------|--------|
| $C_1$     | 0.0945 | $C_4$     | 0.0827 | $C_7$     | 0.0906 | $C_{10}$  | 0.0906 |
| $C_2$     | 0.0787 | $C_5$     | 0.0906 | $C_8$     | 0.0827 | $C_{11}$  | 0.0669 |
| $C_3$     | 0.0748 | $C_6$     | 0.0906 | $C_9$     | 0.0906 | $C_{12}$  | 0.0669 |

4.2.3 Analysis of evaluation results. Based on the weight results above and Table 3, the comprehensive evaluation results of traffic transportation efficiency in alternative design schemes for traffic transportation efficiency of equipment can be obtained by the comprehensive evaluation model calculation formula (4), as shown in Table 5:

**Table 5** Comprehensive Evaluation Results of Alternative Design Schemes for Traffic
Transportation Efficiency of Equipment

| Alternative schemes                                | Comprehensive evaluation values of traffic transportation efficiency | Ranking of evaluation results |
|---------------------------------------------------|---------------------------------------------------------------------|-------------------------------|
| Alternative design scheme $A_1$ for traffic       | 3.6620                                                               | 4                             |
| transportation efficiency                         |                                                                     |                               |
| Alternative design scheme $A_2$ for traffic       | 3.5085                                                               | 5                             |
| transportation efficiency                         |                                                                     |                               |
| Alternative design scheme $A_3$ for traffic       | 4.4183                                                               | 1                             |
| transportation efficiency                         |                                                                     |                               |
| Alternative design scheme $A_4$ for traffic       | 3.4928                                                               | 6                             |
| transportation efficiency                         |                                                                     |                               |
| Alternative design scheme $A_5$ for traffic       | 3.7055                                                               | 3                             |
| transportation efficiency                         |                                                                     |                               |
| Alternative design scheme $A_6$ for traffic       | 3.0201                                                               | 8                             |
| transportation efficiency                         |                                                                     |                               |
| Alternative design scheme $A_7$ for traffic       | 3.2132                                                               | 7                             |
| transportation efficiency                         |                                                                     |                               |
| Alternative design scheme $A_8$ for traffic       | 4.0717                                                               | 2                             |
| transportation efficiency                         |                                                                     |                               |

According to the comprehensive evaluation results of the design scheme for traffic transportation efficiency of equipment obtained from the above table, the advantages and disadvantages of the alternative design scheme for traffic transportation efficiency of equipment can be ranked as: $A_3$, $A_8$, $A_6$, $A_4$, $A_5$, $A_1$, $A_2$, $A_7$, $A_6$, in which $A_3$ is the optimal design scheme, $A_8$ is second only to $A_3$, and $A_6$ is the worst. Therefore, it can be concluded that the alternative $A_3$ shall be selected as the design scheme for traffic transportation efficiency of the equipment.

5. Conclusion
The evaluation of traffic transportation efficiency of equipment is a difficult point in the research of equipment transportation. In recent years, China has recognized the importance of research on
equipment transportation, carried out a series of related researches on equipment transportation and obtained some research results, but it is still in the stage of development research, with certain gap compared with foreign countries. From the aspects of security, timeliness, cost-effectiveness and universality, this paper synthetically analyzes the influence factors of traffic transportation efficiency of equipment, introduces rough set theory, gives the quantitative calculation method of evaluation index of traffic transportation efficiency of equipment and creates a comprehensive evaluation model of traffic transportation efficiency of equipment based on rough set theory, which solves the problem of efficiency evaluation for traffic transportation efficiency of equipment to a certain extent, provides a reference method for selecting the optimal design scheme of traffic transportation efficiency of equipment, and has a certain reference significance.

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