Research on suitability evaluation standard of green road of "Four-New Technology" Based on AHP

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Abstract: The Ministry of transport and provincial transportation departments recommend outstanding transportation scientific and technological achievements every year, and carried out a large number of highway construction demonstration projects. However, the selection of “four new technologies” has become a difficult problem for managers and builders. This paper analyzes the current situation of suitability evaluation and “Four-New Technology” in Zhejiang Province. After a large number of research on green road policy, demonstration project, standard and technological promotion results, the suitability evaluation standard of "four new technologies" of green road is established.

1. Introduction

The 19th National Congress of the Communist Party of China proposed that ‘building ecological civilization’ is the policy of sustainable development of the Chinese nation. We should protect the environment and achieve the harmonious coexistence with nature. The concept of green development, saving and intensive, low-carbon and environmental protection is also clearly put forward in the outline of construction of transportation power. According to the International Energy Agency (IEA), transportation systems consume about a third of the world's energy and there is a gradual upward trend. By 2017, transportation has surpassed industrial production and residents' life, becoming the largest energy consumption factor in the world [1].

Cui Shengnan [2] established a comprehensive post evaluation system of ecological environmental impact of highway construction projects based on analytic hierarchy process (AHP). Yu Hang [3] focused on the construction and maintenance of green highway pavement in Jiangxi Province, and used the validity ratio and Martian system theory were used to detect and optimize the primary indicators. So as to established the evaluation index system of green highway of Jiangxi Province. Wang Jin [4] constructed a low-carbon evaluation index system in the basis of highway design, construction, operation and maintenance.

There is a lack of Research on suitability evaluation standard of green road of "Four-New Technology". In order to popularize energy saving and emission reduction technology in highway industry and gradually form a consensus on energy conservation and emission reduction. The establishment of evaluation criteria is very timely and necessary.
2. Applying AHP model to determine weight

Generally speaking, the application steps of AHP are as follows:

2.1. Construct pairwise comparison judgment matrix of each level

Compared the indicators of the same level, the results are expressed by 1 ∼ 9, the meaning of the number showed in table 1.

| Importance scale | meaning |
|------------------|---------|
| 1                | the two elements, equally important |
| 3                | the two elements, the former is slightly more important than the latter |
| 5                | the two elements, The former is obviously more important than the latter |
| 7                | the two elements, The former is more important than the latter |
| 9                | the two elements, The former is extremely important than the latter |
| 2, 4, 6, 8       | Intermediate value of adjacent judgment |

There are n evaluation objects: $x = \{X_1, X_2, ..., X_n\}$. According to the results of experts’ evaluation, we can define the comparison judgment matrix $A$ as:

$$A = \begin{bmatrix} 1 & a_{12} & a_{13} & \cdots & a_{1n} \\ a_{21} & 1 & a_{23} & \cdots & a_{2n} \\ a_{31} & a_{32} & 1 & \cdots & a_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & a_{n3} & \cdots & 1 \end{bmatrix}$$

2.2. Calculate the weight of evaluation index with root method

(1) calculate the product of elements in each row of judgment matrix $A$, $M_i = \prod_{j=1}^{n} a_{ij}$; $i = 1, 2, \cdots, n$.

(2) Calculate the n-th root of each row $Mi$, $\bar{w}_i = n \sqrt[n]{M_i}$, $i = 1, 2, \cdots, n$, $n$ is the order of the matrix.

(3) Normalization of the vector $[\bar{w}_1, \bar{w}_2, \cdots, \bar{w}_n]^T$, $w_i = \bar{w}_i / \sum_{i=1}^{n} \bar{w}_i$

2.3. Calculate the maximum eigenvalue of judgment matrix $A$: $\lambda_{max} = \sum_{i=1}^{n} (Aw)_i / mw_i$

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Figure 1: AHP model diagram
2.4. First level consistency test
Calculate the single layer consistency index: 
\[ c_l = \frac{\lambda_{\text{max}} - n}{n-1} \]. The consistency ratio of judgment matrix is 
\[ C_r = C_l/R_l \]. When \( C_r < 0.1 \), the judgment matrix has satisfactory consistency.

2.5. Hierarchical total ranking and consistency test
Multi-level combination calculation is needed.
\[
w^k = R^k w^{k-1} = \begin{bmatrix}
w_{11}^k & w_{12}^k & \cdots & w_{1m}^k \\
w_{21}^k & w_{22}^k & \cdots & w_{2m}^k \\
\vdots & \vdots & \ddots & \vdots \\
w_{n1}^k & w_{n2}^k & \cdots & w_{nm}^k \\
\end{bmatrix}
\]

Comprehensive inspection index of layer K: 
\[ C_l^k = C_l^k \]
When \( C_l^k < 0.1 \), the judgment matrix has satisfactory consistency.

3. Case study
Six experienced experts are invited to set the index weight of each level. Firstly, the experts are divided into three groups to determine different index weights. Secondly, each group assign values according to the principle of pairwise index comparison based on the 1-9 scale method. Finally, the weight will be determined through collective discussion.

3.1. Judgment matrix
We can obtained the first level index judgment matrix as follows:

| C1- | C1- | C1- | C1- | C2- | C2- | C2- | C3- | C3- | C4- | C4- | C5- |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| C2  | C3  | C4  | C5  | C6  | C3  | C4  | C5  | C6  | C3  | C4  | C5  |

| 3   | 2   | 1/2 | 4   | 5   | 2   | 1/3 | 3   | 4   | 1/3 | 3   | 4   | 6   | 2   |

3.2. First level weight calculation index
The weights are as follows

| index       | technological innovation C1 | economic cost C2 | quality and intelligence C3 | green energy-saving C4 | Humane Environment C5 | Service and management C6 |
|-------------|-----------------------------|------------------|-----------------------------|------------------------|-----------------------|-------------------------|
| weight      | 0.258                       | 0.153            | 0.124                       | 0.358                  | 0.064                 | 0.043                   |

3.3. Consistency test of primary indicators
Calculated, it can be obtained that \( \lambda_{\text{max}} = 6.23 \), CI=0.046, CR=0.036<0.1
Meet the consistency test.

3.4. Secondary index weight and consistency test
We can obtained the second level index judgment matrix as follows:
### Table 4 Weight calculation results

| C11/C12 | C11/C13 | C11/C14 | C11/C15 | C12/C13 | C12/C14 | C12/C15 | C13/C14 | C13/C15 | C14/C15 | C21/C22 | C21/C23 | C21/C24 | C21/C25 | C22/C23 | C22/C24 | C22/C25 | C23/C24 | C23/C25 | C24/C25 | C31/C32 | C31/C33 | C31/C34 | C31/C35 | C31/C36 | C32/C33 | C32/C34 | C32/C35 | C32/C36 | C33/C34 | C33/C35 | C33/C36 | C34/C35 | C34/C36 | C35/C36 | C41/C42 | C41/C43 | C41/C44 | C41/C45 | C42/C43 | C42/C44 | C42/C45 | C43/C44 | C43/C45 | C44/C45 | C51/C52 | C51/C53 | C51/C54 | C52/C53 | C52/C54 | C53/C54 | C61/C62 | C61/C63 | C61/C64 | C62/C63 | C62/C64 | C63/C64 |
|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| 1/2     | 3       | 1/3     | 1/3     | 5       | 1/2     | 1       | 1/4     | 1/33    | 1/2     | 3       | 2       | 3       | 2       | 1/2     | 2       | 3       | 2       | 1/2     | 3       | 2       | 1/2     | 2       | 3       | 2       | 1/2     | 2       | 3       | 2       | 1/2     | 2       | 3       | 2       | 1/2     | 2       | 3       | 2       | 1/2     | 2       | 3       | 2       | 1/2     | 2       | 3       | 2       | 1/2     | 2       | 3       | 2       | 1/2     | 2       | 3       |

### 3.5. Calculate the second level index weight and consistency test

- **Technological innovation**: $[0.106, 0.231, 0.059, 0.305, 0.299]^T$, consistency test: $\lambda_{max} = 5.355$, CI=0.089, CR=0.079<0.1, Meet the consistency test.
- **Economic cost**: $[0.366, 0.179, 0.236, 0.125, 0.095]^T$, consistency test: $\lambda_{max} = 5.28$, CI=0.070, CR=0.062<0.1, Meet the consistency test.
- **Quality and intelligence**: $[0.334, 0.109, 0.239, 0.169, 0.056, 0.093]^T$, consistency test: $\lambda_{max} = 6.271$, CI=0.054, CR=0.043<0.1, Meet the consistency test.
- **Green energy-saving**: $[0.182, 0.100, 0.270, 0.163, 0.286]^T$, consistency test: $\lambda_{max} = 5.416$, CI=0.104, CR=0.093<0.1, Meet the consistency test.
- **Humane Environment**: $[0.328, 0.121, 0.379, 0.171]^T$, consistency test: $\lambda_{max} = 4.214$, CI=0.072, CR=0.080<0.1, Meet the consistency test.
- **Service and management**: $[0.339, 0.403, 0.149, 0.108]^T$, consistency test: $\lambda_{max} = 4.241$, CI=0.080, CR=0.090<0.1, Meet the consistency test.

### 3.6. Hierarchical total ranking and consistency test

According to the calculation results of the first level index and the second level index, we can obtain that: CR=0.043<0.1. Meet the consistency test.

### 3.7. Summary of weight calculation results

According to the guidance on the implementation of green highway construction and the notice on developing typical demonstration projects of green highway issued by the Ministry of Transport in 2016, the ‘Guiding Opinions on accelerating green transportation development in Zhejiang Province’, the ‘Technical guide for green highway construction in Hubei Province’, the ‘Technical guide for green highway construction in Guangdong Province’, the authors establish the green highway evaluation index system. In the meantime, I also learn the concept of ecological protection, resource saving, energy saving and low-carbon, safety and wisdom, from Zhang Zhengyi and Wang Xinqi.

The evaluation is carried out from six aspects: technological innovation, economic cost, quality and intelligence, green energy-saving, humane environment, service and management. The system includes 6 first level indicators and 29 second level indicators.

### Table 5 Index system and Weight summary

| one-level indicators | Weight | two-level indicators | Weight | Scoring criteria |
|----------------------|--------|----------------------|--------|------------------|
| technological innovation | 0.258 | degree of innovation | 0.027 | International major scientific and technological innovation (80,100] points, Major scientific and technological innovation in China (50,80] points, General science and technology innovation [0,50] points |
|                       |        | level of producti on | 0.060 | International leading (90,100] points, International advanced (80,90] points, Domestic leading (70,80] points, Domestic advanced (60,70] points, Domestic average [0,60] points |
|                       |        | research team        | 0.015 | National grade R & D center or laboratory (80,100] points, provincial and ministerial level R & D center or |
| Economic Cost | 0.153 |
|---|---|
| Technical Support | 0.079 |
| Economic and Social Benefits | 0.077 |
| Life Cycle Cost | 0.056 |
| Construction Cost | 0.027 |
| Maintenance Cost | 0.036 |
| Environmental Protection Cost | 0.019 |
| Timing Cost | 0.015 |
| Quality Engineering | 0.041 |
| Information Management | 0.014 |
| Degree of Industrialization | 0.030 |
| Degree of Standardization | 0.021 |
| Stability of Effect | 0.007 |
| Safety and Durability | 0.012 |
| Ecological Environment Protection | 0.065 |
| Resource Saving | 0.036 |
| Green Energy-Saving | 0.358 |
| Recycling | 0.096 |
| Material Localization | 0.023 |
| Energy Saving and Low Carbon | 0.138 |
| Operability | 0.021 |
| Strategic Planning | 0.008 |
| Humane Environment | 0.064 |
| Regional Humanities | 0.024 |
| Openness of Technology | 0.011 |

- **Economic Cost**:
  - Technical support: 0.079
  - Economic and social benefits: 0.077
  - Life cycle cost: 0.056
  - Construction cost: 0.027
  - Maintenance cost: 0.036
  - Environmental protection cost: 0.019
  - Timing cost: 0.015
  - Quality engineering: 0.041
  - Information management: 0.014

- **Quality and Intelligence**:
  - Degree of industrialization: 0.030
  - Degree of standardization: 0.021
  - Stability of effect: 0.007
  - Safety and durability: 0.012
  - Ecological environment protection: 0.065
  - Resource saving: 0.036

- **Green Energy-Saving**:
  - Recycling: 0.096
  - Material localization: 0.023
  - Energy saving and low carbon: 0.138
  - Operability: 0.021
  - Strategic planning: 0.008

- **Humane Environment**:
  - Regional Humanities: 0.024
  - Openness of Technology: 0.011

- **Other Components**:
  - Laboratory (60,80 points, Municipal R & D center or laboratory (40,60 points, Others [0,40 points)
  - Implemented in national major science and technology projects (80,100 points, Implemented in provincial projects (50,80 points, Implemented in regional projects [0,50 points)
  - Significant economic and social benefits (60,100 points, Average economic and social benefits (0,60 points)
  - Low (80,100 points, Middle (50,80 points, High [0,50 points)
  - Low (80,100 points, Middle (50,80 points, High [0,50 points)
  - Information management during the entire process (70,100 points, Information management in part of the process [0,70 points)
  - Over 80% (70,100 points, Below 80% [0,70 points)
  - Standardization activities are carried out effectively (70,100 points, The standardization activities are generally carried out [0,70 points)
  - The location and personnel are different, The implementation effect is stable (70,100 points, The implementation effect is unstable [0,70 points)
  - High (70,100 points, Low [0,70 points)
  - No obvious ecological damage (70,100 points, Causing obvious ecological damage [0,70 points)
  - The material recovery rate reaches 80% or above (80,100 points, Below 80% (50,80 points, no recycling [0,50 points)
  - Materials do not need to be imported or mixed in other places (70,100 points, Materials need to be imported or mixed in other places [0,70 points)
  - The energy saving effect is obvious (70,100 points, The energy saving effect is general [0,70 points, Without energy saving effect (0)
  - Strong operability (70,100 points, Weak operability (0,70 points)
  - Conform to national and regional planning (80,100 points, Conform to provincial planning (50,80 points, Conform to municipal planning (0,50 points, Do not conform to planning (0)
  - Very much in line with regional humanities (80,100 points, Generally consistent with regional humanities (50,80 points, Do not conform to regional humanities (0,50 points)
  - Without infringing technology and patented technology (2.0-4.0 points), With infringing technology and patented technology (0-2.0 points)
4. Conclusion

Combined with the characteristics of highway engineering, construction conditions and resources of Zhejiang Province based on the AHP, the authors construct green highway evaluation system, which including 6 first level indicators and 29 second level indicators, with a full score of 100, and give detailed scoring standards.

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