Research on Comprehensive Evaluation Index System of Traffic Infrastructure Construction

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Abstract. In order to accelerate the modern engineering management, promote the transformation and upgrading of highway and waterway engineering construction and development, improve the quality, safety and operation service level of highway and waterway engineering, the article sets up an evaluation index system on seven promotion such as engineering design level, management level, technological innovation ability, quality level, safety level, green environment level and soft power of quality engineering. This article combines Delphy Method and analytic hierarchy process (AHP) to analyze the weight of the index, select the project to carry on the empirical evaluation. Finally, this article examines the scientificity and rationality of the evaluation index system.

1. Introduction
Since the 80s of the last century, the construction of transportation infrastructure in China has developed rapidly for more than 30 years. China has built up a number of engineering Cross Sea Bridges, long tunnels and large coastal port projects which has important influence in the world. Meanwhile, transportation infrastructure industry accumulated a lot of experience of quality and safety management of engineering construction, it promotes the quality and safety management of the construction of highway water transportation project in China1.

This article is based on the major special activities organized by the Ministry of transportation and transportation which was named “Building the quality project of highway water transportation”, for improving the management level, improving the quality and safety management level of traffic base design, strengthening innovation to drive development ability, which study on the evaluation index system of "quality engineering". By characterizing the characteristics of "quality engineering" in all aspects and its interrelated indicators, this article constitutes an organic whole with internal structure to set up a series of index systems to evaluate the quality engineering, to breakthrough and innovation of the highway water transportation in the fields of technology, management, standards and so on2.

2. Evaluation Target
In December 26th, 2016, the Ministry of transportation issued "guidance on building the quality of highway water quality project", it further interprets the connotation of quality engineering3:

Construction idea: It embodies the concept of people-oriented, essential safety, life cycle management and value engineering.

Management measures: It embodies the guidance of lean construction, emphasizes the implementation of responsibility and integrity, and deepens humanism, specialization, standardization, information and refinement.
Technical Progress: It embodies technological innovation and breakthroughs, advanced technology theories and methods can be widely applied, it also includes the exploration and improvement of advanced and applicable new technologies, new processes, new materials, new equipment new standards and so on.

Quality Assurance: It is based on the durability of the project, reflecting the coordination of construction, operation and maintenance, harmony between engineering and natural humanities, the balanced development of engineering entity quality, function quality, appearance quality and service quality.

Security Management: It aims at the pursuit of the essential safety of engineering and risk control, and promotes the coordinated development of engineering structure safety, construction safety and use safety.

Engineering Construction: Insisting on Sustainable Development, it has achieved remarkable achievements in ecological environmental protection, resource conservation, energy conservation, emission reduction and so on.

Figure 1. Evaluation Target of Quality Engineering

3. Construction of evaluation index system

1) Building the hierarchical structure model

Building a hierarchical analysis structure model, AHP can be used to solve the related problems in the field of economic management. This level is divided into three layers: the target layer, the standard layer and the index layer.

- The target layer (I): It includes the target and the result of the target. There is only one element in this layer.
- The standard layer (II): It is an intermediate link to achieve the goal. It can be divided into several levels. For example, the standard layer I, the standard layer II and so on.
- The index layer (III): The options and targets for achieving goals and guidelines

Figure 2. Hierarchical structure diagram
The number of layers in hierarchical is related to the complexity and exhaustion of the analytical problems. If you want to analyze the problem in detail, you need to build a good hierarchy.

2) Constructing the judgment matrix of comparison

For the \( n \) elements, the judgment matrix of the comparison is \( C = (C_{ij})_{n \times n} \). The judgment matrix of the structure is as follows:

\[
\begin{array}{cccc}
B_1 & C_1 & C_2 & \ldots & C_n \\
C_1 & C_{11} & C_{12} & \ldots & C_{1n} \\
C_2 & C_{21} & C_{22} & \ldots & C_{2n} \\
\vdots & \vdots & \vdots & \ddots & \vdots \\
C_n & C_{n1} & C_{n2} & \ldots & C_{nn}
\end{array}
\] (1)

3) Checking the consistency of judgment matrix

The consistency test is to test the coordination between the elements' importance and avoid the conflicting phenomena between the elements. In the AHP method, lead into the negative mean value of the other characteristic roots outside the maximum eigenvalue of the matrix, use this as an indicator of the deviation of the judgment matrix from the consistency.

\[
CI = \frac{\lambda_{\text{max}} - n}{n - 1}
\] (2)

To test the consistency of decision makers’ judgement thinking, the smaller the CI value, it shows that the better the consistency of the judgment matrix is better. The greater the CI value, the greater the degree of deviation from the complete consistency of the judgment matrix.

4) Hierarchical single order

The relative importance of a factor at a certain level relative to a certain factor in the previous level, it can be reduced to the maximum characteristic root and the eigenvector problem of the calculation judgment matrix.

\( \text{Calculation of the product of each element in a judgement matrix } M_i \):

\[
M_i = \prod_{j=1}^{n} a_{ij}
\] (3)

\( \text{Calculation of the } n \text{ square root } \overline{W_i} \text{ of } M_i \):

\[
\overline{W_i} = \sqrt[n]{M_i}
\] (4)

\( \text{Normalization of vector } W_i \):

\[
W_i = \frac{\overline{W_i}}{\sum_{j=1}^{n} \overline{W_j}}
\] (5)

Then \( W = [W_1, W_2, \ldots, W_n]^T \) is the eigenvector.

\( \text{The maximum eigenvalue of the calculation judgment matrix: } \lambda_{\text{max}} \)
\[ \lambda_{\text{max}} = \sum_{i=1}^{n} \left( \frac{AW_i}{nW_i} \right) \] 

5) Total ranking of layers
According to the hierarchical structure, a layer by layer calculation should be carried out from the upper layer of the upper layer. Thus, the ranking values of the lowest level relative to the relative importance of the highest level can be calculated.

6) Make the corresponding decision based on the results of the previous steps
Finally through consistency test, it is concluded that the weight of quality engineering evaluation index.

4. Evaluation index system
This paper, through extensive social investigation, consulted experts and consulted relevant documents, decomposed 7 target level indicators into 27 two level indicators, and then decomposed 27 two level indexes into 80 specific indexes. As follows:

| The Target Layer (I) | The standard layer (II) | The index layer (III) |
|----------------------|-------------------------|----------------------|
| **Design Level A₁**  | **System Design B₁₁**   | Life Cycle Cost Concept C₁₁₁ (0.2469) |
|                      | (0.4428)                | Integration Concept of Building and Raising C₁₁₂ (0.2922) |
|                      |                         | Durability Guarantee C₁₁₃ (0.1401) |
|                      | The concept of Ecological Environment Protection B₁₂ | Standardization and Generalization Design C₁₁₄ (0.1768) |
|                      | (0.1341)                | Security Risk Protection C₁₁₅ (0.1440) |
|                      | Engineering Aesthetics B₁₃ | The Use of Ecological Protection Technology C₁₂₁ (0.5000) |
|                      | (0.1028)                | Location Rationality of Ecological Line Selection C₁₂₂ (0.5000) |
|                      | Humanization Design B₁₄ | The Beauty of Vegetation in the Road Area C₁₃₁ (0.3333) |
|                      | (0.1999)                | |
|                      | Service Level B₁₅       | |
|                      | (0.1204)                | |
| **Management Level A₂** | Specialization of Management B₂₁ | The Degree of Fusion with the Natural Environment C₁₃₂ (0.3333) |
|                      | (0.3976)                | Cultural Fusion Degree of Regional Humanistic Characteristics C₁₃₃ (0.3333) |
|                      | Standardization of Construction B₂₂ | Perfection Degree of the Service Area C₁₄₁ (0.5693) |
|                      | (0.3005)                | Supporting Facilities of the Road C₁₄₂ (0.2557) |
|                      | Refinement of Management B₂₃ | Residents' Satisfaction along the Road C₁₄₃ (0.1750) |
|                      | (0.2622)                | |
|                      | Informatization of Management B₂₄ | Speciality and Quantity of the Service Person C₁₵₁ (0.4242) |
|                      | (0.0304)                | Satisfaction Survey C₁₵₂ (0.1515) |
|                      | Normalization of Group Management B₂₅ | Dynamic Design and Optimal Design C₁₅₃ (0.4242) |
|                      | (0.0093)                | |
| **Technological Innovation A₃** | Application of New Technology B₃₁ | Professional Management Ability C₂₁₁ (0.6667) |
|                      | (0.6667)                | The Degree of Integrity of Management System C₂₁₂ (0.3333) |
|                      |                         | Degree of Process Standardization C₂₂₁ (0.5000) |
|                      |                         | Factory Production and Assembly Construction C₂₂₂ (0.5000) |
|                      |                         | Refinement of Management of Construction C₂₃₁ (0.5000) |
|                      |                         | Standardization of Management System C₂₃₂ (0.5000) |
|                      |                         | Informatization of Engineering C₂₄₁ (0.7500) |
|                      |                         | Coverage of BIM C₂₄₂ (0.2500) |
|                      |                         | The Perfect Situation of the Management System of the Construction Team C₂₅₁ (0.5699) |
|                      |                         | The Construction of Group Culture C₂₅₂ (0.1616) |
|                      |                         | The Percentage of Real Name Management for Group Staff C₂₅₃ (0.2332) |
|                      |                         | The Extension of the First System of Group C₂₅₄ (0.0353) |

Application of New Craftwork C₃₁₁ (0.2500)
Application of New Technology C₃₁₂ (0.2500)
Application of New Equipment C₃₁₃ (0.2500)
Application of New Materials C₃₁₄ (0.2500)
Number of Technological Innovation Results C₃₂₁ (0.1581)
| Achievements of Scientific Research and Innovation B₃₂ (0.3333) | The Situation of Management and Institutional Innovation C₃₂ (0.2376) |
|---------------------------------------------------------------|---------------------------------------------------------------|
| The Situation of Major Technical Problems Breakthrough C₃₂ (0.5770) |
| Situation of Group Innovation and Micro Innovation C₃₂ (0.0273) |

| Quality Management System B₄₁ (0.4151) | Implementation Degree of Key Person’s Duty C₄₁ (0.5000) |
|------------------------------------------|----------------------------------------------------------|
| Quality Risk Prevention and Control System B₄₂ (0.1562) | Implementation Degree of Quality Responsibility Tenure System C₄₁₂ (0.5000) |
| Quality Risk Prevention and Evaluation C₄₂₃ (0.3333) | The Implementation Degree of the Construction Scheme Demonstration Review System C₄₂₂ (0.6667) |
| Process Quality Control B₄₃ (0.2967) | The Implementation Degree of the Three Inspection System C₄₃₁ (0.4042) |
| Durability Safeguard Measures B₄₄ (0.0394) | Improvement of Durability Construction Technology C₄₄₁ (0.1693) |
| Construction Quality B₄₅ (0.0926) | The Standard of Durability Control Index C₄₄₂ (0.3545) |
| Safety of Construction Process B₅₁ (0.4374) | Quality Inspection of Key Structure C₄₄₃ (0.3545) |
| Structural Safety B₅₂ (0.4165) | Quality Inspection of Concealed Engineering C₄₄₄ (0.0847) |
| Security Service Level B₅₃ (0.1461) | Quality Inspection of Important Materials C₄₄₅ (0.0370) |

| Security Level A₅ (0.0925) | Process Quality Control B₄₃ (0.2967) |
|----------------------------|-------------------------------------|
| Physical Quality C₅₁ (0.7500) | Appearance Quality C₅₁₂ (0.2500) |
| Safety of Construction Process B₅₁ (0.4374) | Safety Construction Site C₅₁₁ (0.6105) |
| Structural Safety B₅₂ (0.4165) | Safety Standardization Construction C₅₁₂ (0.1695) |
| Environmental Environmental Protection B₆₁ (0.3833) | Dual Prevention System C₅₁₃ (0.2200) |
| Resource Conservation B₆₂ (0.3833) | Key Index of Structural Safety C₅₁₂ (0.5000) |
| Conserve Energy and Reduce Emissions B₆₃ (0.2333) | Intelligent Early Warning C₅₂₂ (0.5000) |
| Environmental Protection Level A₆ (0.0621) | Integrity of Safety Facilities C₅₃₃ (0.3333) |
| Conservation of Water and Soil C₆₁₂ (0.3167) | Eco-Efficient Monitoring of Environmental Monitoring System C₆₁₃ (0.8000) |
| Destruction of Vegetation C₆₁₃ (0.2100) | Land Saving C₆₂₁ (0.3333) |
| Social Impact rate C₆₁₄ (0.0800) | Recycling and Recycling of Waste Materials C₆₂₂ (0.3333) |
| Land Saving C₆₂₁ (0.3333) | Application of Water Saving and Timber Conservation Technology C₆₂₃ (0.3333) |
| Reduction of Energy Consumption in Construction C₆₃₃ (0.4583) | Energy Saving Technology and Clean Energy Utilization C₆₃₁ (0.2708) |

| Soft Power A₇ (0.0420) | Quality Construction of Controller B₇₁ (0.2500) |
|------------------------|-----------------------------------------------|
| Post Assessment and Continuing Education C₇₁₁ (0.6000) | Improving the Quality of the Front-line Workers B₇₂ (0.2500) |
| System of Excitation and Security C₇₁₂ (0.4000) | Quality Engineering Culture B₇₁ (0.2500) |
| System of Assessment and Training C₇₁₂ (0.7500) | Brand Strategy B₇₄ (0.2500) |
| System of Incentive and Guarantee C₇₁₂ (0.2500) | Core Culture C₇₃₄ (0.3333) |
| Propaganda Work C₇₁₃ (0.3333) | Core Competitiveness C₇₃₅ (0.3333) |
| The Cultivation System of Quality Culture C₇₃₂ (0.6667) | |
The weight of the index calculated by the analytic hierarchy process can be used to evaluate the actual situation of the specific project, which can truly reflect the quality of the construction.

5. Conclusions

The system completely covers all the contents of the quality of the highway water engineering. A standard system for building quality engineering has been formed. It sums up a unique, replicable and popularized management model. It puts forward the way to realize the operation which can be realized. The construction of the highway water transportation project according to the index system, could meet the requirements of "quality engineering" for highway transportation which was formulated by the Ministry of Transportation.

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