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Comprehensive Evaluation of Intelligent Expressway Road-Related Project

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Abstract. As a new type of traffic mode, the road test facilities and cloud control platform of the intelligent expressway not only serve the intelligent expressway but also have an impact on the existing traffic operation. Therefore, with a series of ' new ' influences, a new type of road-related project emerges as the times require, and affects the existing expressway in a way that combines ' information data and entity structure. In order to study the road-related engineering of this new intelligent highway, this paper establishes an intelligent highway road-related evaluation system by analyzing the research situation and technical means of the existing intelligent highway. And by studying the weight and comprehensive safety level of different indexes in the system, the analytic hierarchy process, entropy weight and Fuzzy calculation method are used as the core to enrich the shortcomings of the existing road-related engineering in the intelligent highway.

Keywords. Intelligent highway, road-related engineering, analytic hierarchy process, entropy weight method, extension matter-element method, comprehensive evaluation model, safety evaluation system

1. Introduction

The construction of intelligent transportation mainly includes six key links, namely, traffic management system, traffic information system, bus information system, parking system, business management system and vehicle control system [1]. Among these six systems, the most critical technologies are information technology communication technology and control technology. In order to effectively form a scientific traffic control system, these core technologies should be better integrated into the actual traffic field [2].

The traffic control system is mainly to achieve the following four functions: (1) Congestion management: intelligent analysis of traffic congestion. (2) Guarantee safety: danger identification, accident prediction. (3) System operation: traffic online deduction and prediction. (4) Traffic control: traffic incident screening, daily police patrol.

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The core of intelligent transportation lies in the word "wisdom." Through the application of high technology, the visual "brain" is installed for transportation, so that the whole transportation system can be predicted. The intelligentization and digitization of the expressway is an inevitable requirement for the development of intelligent traffic digital traffic.

At the same time, with the rapid development of sensor technology and unmanned driving technology, it has also made great technical support for the development of modern intelligent transportation.

The operation of sensor sensing technology uses laser, imaging equipment, millimeter wave, radar and other on-board sensors to obtain information data, and uses the Internet of vehicles to integrate and analyze multiple and complex vehicle driving data, so as to capture effective data and provide comprehensive and reliable decision-making basis for vehicle drivers [3]. The driving environment of automobiles is changeable and complex, which requires sensor sensing technology to have extremely high road condition detection and recognition accuracy, so as to provide sufficient and real information basis for safe driving and intelligent driving of automobiles.

Autonomous driving requires the use of sensors and a variety of algorithms, relying on the automatic driving system to complete the automatic operation of the car. The intelligent vehicle automatic driving system is the key to realize the automatic driving of the car, and it is also the premise to ensure the safe operation of the vehicle [4]. The realization of automatic driving mainly depends on the automatic driving system. The whole automatic driving system is equivalent to the ' brain ' of human beings. Therefore, the research and development of automatic driving system is the key to realize automatic driving. At present, the analysis of automobile automatic driving system includes driving assistance system, partial automation system, high automation system and complete automation system.

2. Road-related Engineering of Intelligent Expressway

2.1. The Grading of Road-related Projects of Intelligent Expressways Appears

Intelligent expressway is based on the operation characteristics of expressway, comprehensively utilizes modern information technology, integrates and constructs intelligent perception, intelligent communication, intelligent management and intelligent service supporting system, and continuously evolves with the development of technology to provide sustainable service support for future traffic travel experience and all-weather safe passage [5].

The realization of intelligent expressway mainly realizes intelligent service through cutting-edge information technology equipment. Therefore, it is of great significance to build cutting-edge information technology equipment through road-related projects and classify related intelligent expressway road-related projects. The level of intelligent high-speed road-related projects is divided into service capabilities and system conditions. It is divided into grades I to IV from low to high. High-level intelligent content covers low-level intelligent content [6]-[7].

Level I, the construction of the traditional charge, communication, monitoring three systems, as well as the operation control center, to meet the basic needs of highway users, to provide video surveillance, operation scheduling, information query and other basic services;

Level II, the infrastructure is gradually digitized and informationized, which provides the basic conditions for the next step of intelligent development, and realizes the comprehensive digital monitoring and management of major infrastructure, safety guidance services under severe meteorological conditions and other services;

Level III, the vehicle infrastructure coordination system and operation control center are built to realize the intelligent management and control environment of network coordination. It has the ability to support new technologies such as high-level automatic driving and truck formation driving, and provides high-precision information services such as vehicle infrastructure coordination safety management and control, lane level and accompanying.

Level IV, providing services such as automatic / manual driving mixed traffic flow control, quasi-all-weather traffic, infrastructure self-diagnosis and repair capabilities, and new energy supply. The smart expressway has sustainable, low-emission, resource-saving, and supports the ability to withstand severe weather and natural disasters.

2.2. Index Selection of Road-related Engineering of Intelligent Expressway

The selection process of intelligent highway engineering indexes is carried out according to the steps of collecting and sorting out the impact indexes to be screened, determining the consulting experts, screening the indexes, and consulting the indexes to be determined. The specific process is shown in figure 1.

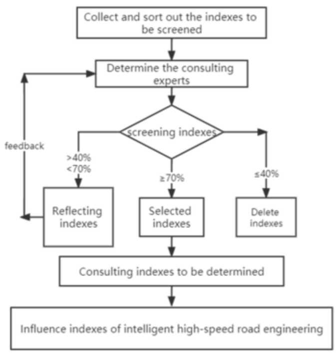

Figure 1. Index selection flow chart.

By sorting out the local standards of smart highways in different provinces, highway traffic technical specifications and some cross-industry specifications, the indexes of the impact of smart highways on existing traffic operations are sorted out.

3. Analytic Hierarchy Process- Fuzzy Calculation Comprehensive Evaluation Model

3.1. Calculating Index Weight by Analytic Hierarchy Process

- Construction matrix.

Through the nine-level scaling method, a matrix representing the relative influence degree between different influence indexes at the same level is constructed, which is called the construction matrix [8-14]. The construction matrix is shown in equation 1. Each element of the construction matrix is the relative ratio between the importance of each factor (influence indexes). It is not difficult to see that the elements of the main diagonal of the construction matrix are the ratio of the importance of each influence indexes to itself, so the values of each element of the main diagonal are 1. And the elements symmetrical along the main diagonal are compared with each other because of the importance of the two influence indexes, so the numerical product of the elements symmetrical along the main diagonal is 1.

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1j} \\ a_{21} & 1 & \cdots & a_{2j} \\ \cdots & \cdots & 1 & \cdots \\ a_{i1} & a_{i2} & \cdots & 1 \end{bmatrix} \tag{1}$$

Determine the weight coefficient by the method [15]. (1) Normalize the construction matrix A; (2) Add each $\bar{a_{ij}}$ in row separately to obtain ϖ_i. (3) Get the weight coefficient ω_i by normalization of ϖ_i.

$$\overline{a_{ij}} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \quad i, j = 1,2,\ldots,n \tag{2}$$

$$\varpi_i = \sum_{j=1}^{n} \bar{a_{ij}} \quad i, j = 1,2,\ldots,n \tag{3}$$

$$\omega_i = \frac{\varpi_i}{\sum_{i=1}^{n} \varpi_i} \quad i, j = 1,2,\ldots,n \tag{4}$$

$\bar{a_{ij}}$ is the proportion of an element to all elements in the column.ϖ_i is the algebraic sum of the weights of each element in a row to all elements in the same column.ω_i is the algebraic sum of the proportion of each element in a row to all elements in the same column and the algebraic sum of the proportion of each element in all rows to all elements in the same column.

The Matlab calculation tool is used to compile the analytic hierarchy code to determine the weight coefficient, and the results are verified to be correct.

Due to the lack of rationality test of the influence indexes weight calculated by the judgment matrix, the judgment matrix is tested according to the consistency method and related parameters in the analytic hierarchy process [16]. The corresponding relation table between the average Random consistency Index and the Construction Matrix is shown in table 1.

- Consistency index CI.

$$CI = \frac{\lambda_{max}}{n-1} \tag{5}$$

- Consistency coefficient CR.

$$CR = \frac{CI}{RI} \tag{6}$$

Formula factor: n--order of constructing matrix

RI--average random consistency index

$\lambda_{\max}$--Construct the maximum eigenvalue of matrix

Table 1. The corresponding relation Table between the average Random consistency Index and the Construction Matrix.

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

The consistency index CI is the key parameter to test the rationality of the construction matrix. When its value is less than 1 / 10, the construction matrix is reasonable. Otherwise, the existing construction matrix is unreasonable, and the matrix needs to be reconstructed until the test conditions are met. When the construction matrix is less than the third order, there is no need for consistency test.

3.2. The Calculation and Evaluation Results of the Fuzzy Calculation Method

Fuzzy Computing Concept.

The fuzzy mathematical theory created by Professor L.A. Zadeh has been widely used to describe and study fuzzy phenomena. As an important part of fuzzy mathematics theory, fuzzy computation aims to solve the problem of partial uncertainty, that is, fuzziness. In short, thousands of things are different, but some things have their approximations, how to distinguish the differences in these approximations, in the actual operation process is difficult to accurately achieve. Therefore, in order to better deal with the approximate fuzzy problems in road-related projects, we can use fuzzy calculation method to calculate.

Fuzzy Calculation Method Content.

(1) Build factor set. We integrate the indexes of the road-related project evaluation system into a group.

(2) Constructed evaluation set. For each indicator of the indicator group, the range of evaluation results is determined and formed into a group.

(3) Determine the membership degree of each indicator and determine the specific evaluation matrix. The membership degree of each indicator can be understood as the completion degree of each indicator for its corresponding evaluation interval. The membership function can be constructed by subjective experience method. The element of the evaluation set reflects the situation of each indicator factor, and the membership degree is the value of the representation of the situation. The establishment of evaluation matrix depends on the membership degree of all factors.

(4) Determination of index weights. Each indicator in the factor set has different contribution to the whole evaluation result, so it is necessary to calculate the weight of each indicator to distinguish its influence. Finally, a weight matrix is constructed according to the determined combined weights of each index to prepare for the final fuzzy evaluation results.

(5) Calculation of fuzzy evaluation results. According to the evaluation matrix determined by the opinions of the expert group and the weight matrix composed of the combined weights of each index, the membership degree of the whole road-involved project to each grade can be obtained, and then the fuzzy evaluation score can be calculated linearly with the corresponding scores of each grade.

$$Q = W \times R \times T = W \times \begin{Bmatrix} R_{y1} \\ R_{y2} \\ \vdots \\ R_{yn} \end{Bmatrix} \times T \tag{7}$$

4. Actual Case Analysis

4.1. General Situation of Project

The Tianjin section of the Jinshi Expressway is divided into three sections, of which the eastern section is from the coastal expressway to the Changshen expressway, which is about 31.3 km long. The middle section is from Changshen Expressway to Beijing-Shanghai Expressway, which is about 36 km long. The western section of the Beijing-Shanghai Expressway to Hebei Province, the total length of about 12.5 km.

This project is the Tianjin West Section of the Tianjin-Shijiazhuang Expressway Project (hereinafter referred to as "this project "). The whole line is located in Jinghai District of Tianjin and is east-west. It starts from Huxinzhuang Interchange in the east and connects with the middle section of Jinshi Expressway. After crossing the Yunxi Paigan Canal in the west, it passes through the north side of Zhangcun Village. After continuing to cross the planned Fuhuang Road, Heilonggang River and the planned western highway in the west, it connects the UHV and Langwa Village. After crossing the Wangkou Paigan Canal, Jinlai Highway, Ziyaer River and Ziya River in the west, it stops at the boundary between Tianjin and Hebei Province, and connects with the Hebei section of Jinshi Expressway between Xiaohe Village and Yanzhuang Village, with a total length of about 12.5 km.

The main line of this project adopts the standard of fully enclosed, fully interchanged and all controlled access expressway. The design speed is 120 km / h, two-way six lanes, and the subgrade width is 34.5 meters. There are 2 interchanges, 1 hub interchange and 1 single horn interchange.

4.2. Establish an Intelligent Highway Road-related Engineering Evaluation System Based on this Actual Case

According to the discussion of the expert group and summarizing the results of the discussion, the index scale of intelligent high-speed road-related engineering is developed, as shown in table 2. The scoring method of the fixed scale is the subtraction system, that is, the total score of each index is 100, and the deduction value is determined according to the situation of each index, and then the actual score of the index is obtained.

Table 2. Intelligent highway road-related engineering index scale.

Intelligent highway road-related engineering	(A)Surveillance system intrusion	(A1)Monitoring stations invade existing ones Land for highways	If monitoring stations such as vehicle information monitoring stations and geological disaster displacement real-time monitoring stations intrude into the limits of existing highway buildings, 60 points will be deducted; If it affects the visual distance of existing highway traffic, 70 points will be deducted. The remaining controllable scores are determined by the expert group.

		(A2)Detect early warning robot intrusions There are existing highways	Because the monitoring and warning robot mostly uses the guardrail as the track for monitoring. Therefore, the monitoring and warning robot is easy to invade the existing highway area through the on-ramp. If the above phenomenon occurs, 60 points will be deducted. The remaining controllable scores are determined by the expert group.
	(B)Communication system intrusion	(B1)Wireless communication device intrusion	Wireless communication devices that use LTE-V2X/5G-V2X communication technology to sense and receive vehicle location, speed, status and other information in real time, and send real-time road status and traffic information to vehicles will be deducted 70 points if the roadside equipment intrude into the control area of the existing highway building. The remaining controllable scores are determined by the expert group.
		(B2)Vehicle wireless terminal	If you design a wireless information application platform for running vehicles, 50 points will be deducted. If the wireless information application platform has a single function or unstable operation, 20 points will be deducted. If the chauffeured bus is equipped with WiFi access equipment to build an integrated wireless information application platform, 30 points will be added. The rest of the score is determined by the expert.
	(C)Sensory system intrusion	Traffic flu awareness equipment Trespass on existing highway	If the traffic flu detection equipment such as microwave traffic flow detector and DSRC collection equipment intrudes into the control area of the existing expressway building, 70 points will be deducted. The remaining controllable scores are determined by the expert group.
		Weather sensing equipment Trespass on existing highway	Visibility detector, road condition detector, temperature and humidity integrated detector, wind speed and direction integrated detector, rainfall detector and other meteorological sensing equipment intruding into the control area of the existing highway building, deduct 70 points. The remaining controllable scores are determined by the expert group.
	(D)Toll collection system Poor connection	(D1)Fewer manual toll lanes	The intelligent highway toll system is mainly based on unsensed toll lanes. If the manual toll lanes cannot meet the requirements of ordinary highway vehicles, 50 points will be deducted. 70 points will be deducted for manual toll lanes designed for emergency and backup purposes only. The remaining controllable scores are determined by the expert group.
	(E)Poor connectivity of driverless lanes	(E1)The driverless vehicle strayed Ordinary highway Emergency measures	Those who fail to consider the formulation of emergency measures for unmanned vehicles straying into ordinary expressways will be deducted 60 points; If the emergency measures fail to make the driverless vehicle leave the lane of the existing highway within half an hour, 40 points will be deducted. The remaining controllable scores are determined by the expert group.
		(E2)No driver on ramp Lane design	If the new smart highway connects to the existing smart highway, the on-ramp does not consider the driverless lane design, 70 points will be deducted; If there is a large gap between the width of the driverless lane and the width of the operating lane on the ramp, 40 points will be deducted. The remaining controllable scores are determined by the expert group.

	(F)Old and new highways Cohesion problem	(F1)Cloud center update phase traffic Impaired regulation	During the construction of the smart highway, those who adjust and improve the cloud center traffic information processing system resulting in a decline in traffic regulation capacity will be deducted 40 points; Those who fail to provide traffic information effectively and cause serious traffic safety hazards will be deducted 70 points. The remaining controllable scores are determined by the expert group.
		(F2)Smart highway traffic Control affects both high speed Highway traffic operation	If the lane control and vehicle-road collaborative design of the new smart highway lead to difficult access of on-ramp vehicles and traffic congestion on the existing highway, 60 points will be deducted. The remaining controllable scores are determined by the expert group.
		(F3)Driver loses intelligent traffic After information service Short-term discomfort	The on-ramp area and the local area that access the existing ordinary highway lack intelligent traffic information prompt design resulting in short-term discomfort and driving difficulties for the driver will be deducted 70 points. The remaining controllable scores are determined by the expert group.

4.3. Evaluation of Specific Cases of Intelligent Expressway Road-related Project

The evaluation results were calculated by using fuzzy synthesis method, as shown in table 3. Firstly, the evaluation matrix is prepared according to the index rank membership degree determined by the expert group.

Table 3. Evaluation vector matrix calculation table.

Evaluation matrix R_{yi}
$R_{y1} = \begin{Bmatrix} 0.3 & 0.4 & 0.2 & 0.05 & 0.05 \\ 0.35 & 0.35 & 0.15 & 0.1 & 0.05 \end{Bmatrix}$
$R_{y2} = \{0.35 \quad 0.25 \quad 0.2 \quad 0.15 \quad 0.05\}$
$R_{y3} = \begin{Bmatrix} 0.3 & 0.45 & 0.2 & 0.05 & 0 \\ 0.25 & 0.4 & 0.2 & 0.1 & 0.05 \end{Bmatrix}$
$R_{y4} = \{0.2 \quad 0.35 \quad 0.2 \quad 0.15 \quad 0.1\}$
$R_{Y5} = \begin{Bmatrix} 0.35 & 0.35 & 0.15 & 0.1 & 0.05 \\ 0.3 & 0.25 & 0.2 & 0.15 & 0.1 \end{Bmatrix}$
$R_{y6} = \begin{Bmatrix} 0.15 & 0.25 & 0.4 & 0.15 & 0.05 \\ 0.3 & 0.35 & 0.15 & 0.1 & 0.1 \\ 0.2 & 0.25 & 0.35 & 0.05 & 0.15 \end{Bmatrix}$

Combining three secondary indexes with high weights (fewer manual toll lanes, intrusion of monitoring stations into existing highway land and intrusion of wireless communication equipment), it is found that the expert level membership of three secondary indexes (fewer manual toll lanes, intrusion of monitoring stations into existing highway land and intrusion of wireless communication equipment) is low.

By multiplying the vector W composed of index weights and the matrix R composed of evaluation vector Ri with the corresponding score representative value vector T of each index, the evaluation score Q is obtained, and the evaluation score Q is 81.32.

$$Q = W \times R \times T = W \times \begin{Bmatrix} R_{y1} \\ R_{y2} \\ R_{y3} \\ R_{y4} \\ R_{y5} \\ R_{y6} \end{Bmatrix} \times T$$

$$= \{0.143 \quad 0.048 \quad 0.168 \quad \cdots \quad 0.029\} \times \begin{Bmatrix} 0.3 & 0.4 & 0.2 & 0.05 & 0.05 \\ 0.35 & 0.35 & 0.15 & 0.1 & 0.05 \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ 0.2 & 0.25 & 0.35 & 0.05 & 0.15 \end{Bmatrix} \times \begin{Bmatrix} 95 \\ 85 \\ 75 \\ 65 \\ 55 \end{Bmatrix} = 81.32 \quad (8)$$

5. Summary

Based on the current high-speed development of wisdom and the actual needs of intelligent high-speed road-related projects, this paper studies the structure and classification of intelligent high-speed road-related projects, the key factors affecting the quality of service, and forms the evaluation system of intelligent high-speed road-related projects by consulting and learning relevant scientific research results, so as to supplement the evaluation of intelligent high-speed road-related projects. After studying the analytic hierarchy process and the extension matter-element method, the AHP- Fuzzy calculation comprehensive evaluation method is formed. This method comprehensively uses the analytic hierarchy process to determine the index weight; using the extension matter-element theory, the comprehensive intelligent high-speed evaluation results are calculated. The establishment of AHP- Fuzzy calculation comprehensive evaluation method evaluates the comprehensive service ability of intelligent high-speed road-related projects, and provides reference for the follow-up research of intelligent high-speed road-related projects.

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