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Construction technology and quality control measures for expressway traffic safety facilities

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Abstract

Expressway traffic safety facilities are facilities and equipment ensuring expressway safety. In order to improve the construction technology and quality control performance of expressway traffic safety facilities, a construction quality control method for expressway traffic safety facilities based on parametric fusion tracking control and piecewise linear regression analysis of construction schedule is proposed. In this paper, the ANSYS software was adopted for model analysis to construct a constrained parameter model for construction quality control of an expressway traffic safety facility and a nonlinear constitutive relation model for safety facility construction. The construction technical parameters about the expressway traffic safety facility were designed optimally based on the construction strength, anti-collision ability and mechanics characteristics. The adaptive parameter fusion tracking method was adopted to establish an information management structure model for construction progress management of the expressway traffic safety facility and the model covered geometric information, physical information and capital investment. The big data analysis and piecewise linear regression analysis methods were used to optimally control the construction schedule of the expressway traffic safety facility. The simulation results show that in optimization and control of construction technology of the expressway traffic safety facility, the proposed method can improve construction quality and provide relatively good optimization ability of each parameter about construction quality description and relatively high process control quality. Therefore, this method can play a good guiding role in construction quality optimization of expressway traffic safety facilities.

Keywords – expressway, traffic safety facility, construction technology, quality control

1. Introduction

With the rapid development of China's economy, the progress and speed of expressway construction have been continuously promoted and the mileage of expressways has been increased significantly year by year. Expressway construction has entered a period of rapid development. As an important infrastructure for the development of national economy, expressway plays an important role in developing transportation and improving the quality of life of people. With the rapid development of expressways, the construction of expressway safety facilities has received great attention. The construction quality of expressway traffic safety facilities is related to the operational capacity of the entire highway and the safety of people's lives and property [12]. In the construction of expressway traffic safety facilities, new technologies, new processes and new materials should be adopted and excellent construction processes and technologies should also be

adopted to ensure transportation safety. It is of great significance to study construction technologies and quality control methods of expressway traffic safety facilities.

Expressway traffic safety facilities mainly include protective fences, indicator lights, instruction plates, speed bumps, buffer belts, central isolation belts, green vegetation, etc. Construction technologies of expressway traffic safety facilities are fundamental and decisive for the construction of expressways themselves, so it is necessary to optimize and upgrade construction technologies of expressway traffic safety facilities to improve the safety and quality of them based on construction quality control optimization model design. Conventional construction quality control methods for expressway traffic safety facilities mainly include the fuzzy control method, neural network control method, game control method and joint control method [1, 16]. In those methods, a constrained parameter model for construction technology quality control of expressway traffic safety facilities is constructed and the fuzzy cost constraint and construction quality equilibrium game methods are adopted to achieve optimal control of construction technology quality of expressway traffic safety facilities. In addition, a more institutionalized and standardized construction technology system and construction quality management system are established through engineering technology optimization and engineering accuracy adjustment to promote the optimization and upgrading of construction technology and quality control of expressway traffic safety facilities. Certain results have been achieved in this aspect. In reference [6], a construction schedule optimization control method for expressway traffic safety facilities based on building information modeling (BIM) integrated control is proposed. In this method, a digital information processing method is adopted for data analysis of expressway traffic safety facility construction management to achieve optimal control of construction quality to expressway traffic safety facilities based on construction quality-related information fusion and big data mining method. A good quality control effect has been achieved with this method. However, this method performs not well in parametric simulation of expressway traffic safety facility components, and cannot accurately control construction quality. In reference [7], a construction technology optimization method for expressway traffic safety facilities based on stiffness softening transfer model and stress characteristic analysis is proposed. In this method, the construction technologies for protective fences of expressway traffic safety facilities are designed optimally, which improves the anti-collision capability and tensile capacity of expressway traffic safety facilities. However, this method performs not well in the control of the overall construction quality of expressway traffic safety facilities. In reference [15], a construction quality control model based on correlation equilibrium game is proposed. In this model, the overall construction quality of expressway traffic safety facilities is controlled optimally through the correlation analysis and significance test methods to improve the global reliability of the construction process. However, this method causes high computational complexity and performs not well in real-time control under constraints during construction.

In order to solve the above problems, a construction quality control method for expressway traffic safety facilities based on parametric fusion tracking control and piecewise linear regression analysis of construction process is proposed in this paper. Firstly, the constrained parameter model and ontology structure model for construction technology optimization and quality control of an expressway traffic safety facility were analyzed. Then the construction quality control process was designed optimally and the fusion tracking identification and segmentation fitting control methods of control parameters were adopted for optimal construction quality control of the expressway traffic safety facility. Finally, simulation test analysis was carried out, which shows the superiority of the method proposed in this paper in improving construction technologies and quality control performance of the expressway traffic safety facility.

2. Constrained parameter model and constitutive relation of construction quality control

2.1. Constrained parameter model for construction quality control of expressway traffic safety facilities

The ANSYS software was adopted for model analysis to construct a constrained parameter model for construction quality control of an expressway traffic safety facility. Under the improvement of the construction quality management system, the construction quality of the expressway traffic safety facility is related to the construction environment of expressways, investment, human factors, operating level and other parameters about expressways [18]. A nonlinear creep relation model for construction quality control of the expressway traffic safety facility was constructed through the correlation detection and sample regression statistical analysis methods, and the first-order differential equation was adopted to describe the normal distribution model for construction quality control of the expressway traffic safety facility as follows:

$$DoG(x, y) = \frac{1}{2\pi} \left[\frac{1}{\sigma_1^2} e^{-\frac{(x^2+y^2)}{2\sigma_1^2}} - \frac{1}{\sigma_2^2} e^{-\frac{(x^2+y^2)}{2\sigma_2^2}} \right] \quad (1)$$

$$= G(x, y, \sigma_1) - G(x, y, \sigma_2)$$

where σ_1 and σ_2 represent the route parameter and strength limit involved in the expressway safety facility, respectively an $G(x, y, \sigma_1)$ and $G(x, y, \sigma_2)$ represent the material property and technical parameter of construction of the safety facility, respectively. In order to quantitatively analyze the construction quality control process of the expressway traffic safety facility, during the whole cycle of monitoring, the constrained parameter set X of the expressway traffic safety facility construction project was described as a concept set containing P -dimensional vectors. There were c categories in X , which represented the support vector set attribute of construction quality control of the expressway traffic safety facility [4]. The conduction equation for quality control under construction technology innovation is obtained as follows through the high-order linear control method:

$$\mu \frac{\partial h}{\partial t} = K_x \left(\frac{\partial h}{\partial x} \right)^2 - \frac{\partial h}{\partial z} (K_z + p) + p \quad (2)$$

where μ represents the elastic modulus coefficient of construction quality control; K_x, K_z represent the protective stress component parameters of the expressway safety facility and p represents the fixed component of creep strain in the $n+1$ th and n -th time steps. The orthogonal basis vector of completeness of construction information about the expressway traffic safety facility was constructed and represented by $y^{(k)}$, and $s_j^{(k)}$ and $y_j^{(k)}$ were adopted to represent linear input and reversible invariant output of the information model system of the expressway traffic safety facility, respectively. The expression of penetration model for construction quality control of the expressway traffic safety facility is obtained through the constitutive constrained control method as follows [20]:

$$K_n \frac{\partial h}{\partial n} \Big|_{\Gamma_1} = q(x, y, z, t) \quad (3)$$

where $q(x, y, z, t)$ represents a set of orthonormal bases for quality control parameters x, y, z, t , and Γ_1 represents a uniform normal distribution function. On this basis, the constrained parameter model for construction quality control of the expressway traffic safety facility was constructed, and

the adaptive parameter fusion and identification tracking methods were adopted for each control constraint parameter to optimize the solution and design of construction quality control process [3, 9, 14].

2.2. Constitutive relation model of construction nonlinear creep

A nonlinear creep constitutive relation model for construction of the safety facility was constructed, and the construction technical parameters about the expressway traffic safety facility were designed optimally based on the construction strength, anti-collision ability and mechanics characteristics. Under the equivalent elastic stress distribution, the relation between yield strength of the expressway traffic safety facility and mechanical parameters of anti-collision ductility of them is described as:

$$\sigma_y^2 = E[y_j^T(n)y_j^*(n)] \tag{4}$$

$$R_{xx}(k) = E[X(n)X^H(n-k)] \tag{5}$$

where $X(n)$ represents the Toeplitz matrix of $x(n)$. The base stress control method was adopted to optimize the design of construction technology and improve the tensile capacity of the expressway traffic safety facility [17]. The estimated mechanical tensile strength of the expressway traffic safety facility is obtained as follows:

$$\hat{h}_j = \frac{1}{\sigma_y^2} R_{xx}(K-1)f_j(n) \tag{6}$$

where σ_y^2 is the variance of the tensile strength bearing component of the expressway traffic safety facility with respect to $y_j(n)$. The equivalent stress distributed estimation method was used to calculate $R_{xx}(k)$ and the deformation parameter of the expressway traffic safety facility after being impacted by an automobile was obtained. The strain increment of the expressway traffic safety facility is estimated according to the deformation parameters as follows:

$$\tilde{x}(n) = x(n) - \tilde{h}_j(n) * \hat{s}(n) \tag{7}$$

where $\tilde{h}_j(n) * \hat{s}(n)$ represents the constitutive creep distribution function of $y_j(n)$. Under the action of conduction mechanics, the horizontal and vertical mechanical loading methods were adopted to carry out positive tamping for safety implementation to improve the mechanical distribution ability of the expressway traffic safety facility after impact. When the mean value of orthogonal quantities $\tilde{x}(n)$ and $y_j(n)$ was 0, the traffic safety facility was in normal distribution with the mechanical transfer equation of δ after being impacted, namely:

$$E[\tilde{X}(n)y_j^*(n-k)] = 0 \tag{8}$$

where $k = K - 1$. $\tilde{X}(n)$ is the Toeplitz matrix of $\tilde{x}(n)$. It can be seen that the forward conduction mechanics tracking control method can improve the impact withstand capability of traffic safety facilities. According to this technical guidance, the elastic deformation incremental correction method was adopted to optimize the construction technology of the expressway traffic safety facility [8,19,11]. The ductile mechanical parameter distribution model for construction control is obtained and described as follows:

$$K_n \frac{\partial h}{\partial n} - \frac{h-h_s}{\sigma} \Big|_{\Gamma_2} = 0 \tag{9}$$

where the constitutive relation model of construction nonlinear creep satisfied:

$$\begin{cases} u_{tt} - \Delta u + F = 0, \\ (u, \partial_t u)|_{t=0} = (u_0, u_1) \in \dot{H}_x^\mu \times \dot{H}_x^{\mu-1} \end{cases} \quad (10)$$

At this time, the elastic strain increment of the safety facility is $b = 2AC$, a satisfies $Ca^4 \leq \frac{1}{2}$ and the output load is $s, \bar{s} \geq 0$. The ductility expansion and uniaxial stress state assessment methods were adopted for pre-tightening of the bolts of the safety facility within the prediction range of n steps to make the test piece of the road traffic safety facility reach the yield load [10].

3. Optimization of the construction quality control model

3.1 Optimization calculation of construction technical parameters

In order to optimize the design of construction technology of the expressway traffic safety facility and optimize the construction quality control based on construction of the constrained parameter model for construction quality control of the expressway traffic safety facility and the nonlinear creep model for safety facility construction, a construction quality control method for expressway traffic safety facilities based on parametric fusion tracking control and piecewise linear regression analysis of construction process is proposed in this paper [2]. The construction technical parameters of the expressway traffic safety facility were designed optimally based on the construction strength, anti-collision ability and stress characteristics, and the inertial parameters of construction quality control were obtained to be $K_b^{bw}(S)$, $K_d^{cp}(S)$, $D_{a,p}$, $M\alpha_{a,b}$ and $M\beta_{a,d,p}$. The completeness orthogonal constraint control method was adopted to obtain the construction quality control vector constraint model. It is:

$$\min_{z_b^{bw}, z_d^{cp}, z_{a,p}^{dm}, z_{a,b}^\alpha, z_{a,d,p}^\beta} \sum_{b \in B} z_b^{bw} K_p^{bw}(S) + \sum_{d \in D} z_d^{cp} K_d^{cp}(S) + \sum_{a \in A} \sum_{p \in P} z_{a,p}^{dm} D_{a,p} + \sum_{a \in A} \sum_{b \in B} z_{a,b}^\alpha M \alpha_{a,b} + \sum_{a \in A} \sum_{d \in D} \sum_{p \in P} z_{a,d,p}^\beta M \beta_{a,d,p} \quad (11)$$

$$S.t. \quad z_b^{bw} R_p^{bw} + z_d^{cp} R_p^{cp} + z_{a,p}^{dm} + z_{a,b}^\alpha + z_{a,d,p}^\beta \geq V_p, \quad a \in A, b \in B, d \in D, p \in P, \quad (12)$$

$$z_b^{bw}, z_d^{cp}, z_{a,p}^{dm}, z_{a,b}^\alpha, z_{a,d,p}^\beta \geq 0, \quad a \in A, b \in B, d \in D, p \in P. \quad (13)$$

The benefit cost function of the expressway traffic safety facility construction was described as a nonlinear incremental function, and the linear game method was used for game control of the construction process of the traffic safety facility [5]. The process game control function of construction cost and construction quality is obtained as follows:

$$Q_i(P) = \frac{(e_i - P_i)[\rho(N-2)+1] - \rho \sum_{i \neq j} (e_j - P_j)}{(1-\rho)[\rho(N-1)+1]} \quad (14)$$

The formula Q_i ($i = 1, 2, \dots, N$) was solved in a combination way. In order to optimize the construction quality gain component, the parameter fusion matching and attribute clustering method were adopted for adaptive optimization [13], and the first-order partial derivative of P_i was solved through $U(Q)$ and then the derivative was set to 0.

$$\frac{\partial U(Q)}{\partial Q_i} = e_i - Q_i - \rho \sum_{i \neq j} Q_j - P_i = 0 \tag{15}$$

where z_b^{bw} , z_d^{cp} , $z_{a,p}^{dm}$, $z_{a,b}^a$ and $z_{a,d,p}^\beta$ are related material item, related human item and related cost item and other items in construction quality control of the expressway traffic safety facility. The adaptive Kalman filtering method was used to control the parameter fusion. The parameter fusion output is obtained as follows:

$$\begin{aligned} \mu_s(v(\cdot)) = & \sum_{b \in B} z_b^{bw*} K_p^{bw}(S) + \sum_{d \in D} z_d^{cp*} K_d^{cp}(S) + \sum_{a \in A} \sum_{p \in P} z_{a,p}^{dm*} D_{a,p} \\ & + \sum_{a \in A} \sum_{b \in B} z_{a,b}^{\alpha*} M \alpha_{a,b} + \sum_{a \in A} \sum_{d \in D} \sum_{p \in P} z_{a,d,p}^{\beta*} M \beta_{a,d,p} \end{aligned} \tag{16}$$

where the optimal game function of construction quality control can be obtained by derivation of P_i through $R_i(P)$. The fuzzy decision function of construction quality control of the expressway traffic safety facility was constructed based on the benefit function and cost function to optimally solve the control parameters and optimize the design of quality control.

3.2. Construction control optimization solution of the expressway traffic safety facility and implementation steps

The adaptive parameter fusion tracking method was adopted to establish the construction progress management model of the expressway traffic safety facility, and the standardization function was constructed to analyze the relation between quality control and benefit control of the expressway traffic safety facility construction. The decision variable is obtained as follows:

$$V_i = \frac{X_{\max}^i - X^i}{X_{\max}^i - X_{\min}^i} \tag{17}$$

Under the constraint of construction quality control in the whole process, the optimal fuzzy decision function for quality control of expressway traffic safety facility construction was obtained. The adaptive weighted learning was conducted to the constrained parameters of expressway traffic safety facility construction. The feature quantities of quality optimization control are obtained as follows:

$$\begin{cases} C_1(s) = \frac{Q_1(s)}{Q_2(s)} \\ C_2(s) = \frac{Q_2(s)}{1 - M(s)Q_2(s)} \end{cases} \tag{18}$$

The big data analysis and piecewise linear regression analysis methods were adopted to obtain the optimal game function for construction quality control of the expressway traffic safety facility. It is:

$$R_i(P) = (1 - \alpha) P_i \left[(e_i - P_i) F_1 - \sum_{i \neq j} (e_j - P_j) F_2 \right] \tag{19}$$

According to the results of adaptive parameter fusion, the optimal solution output of construction quality control is obtained as follows:

$$F_1 = \frac{\rho(N-2)+1}{(1-\rho)[\rho(N-1)+1]} \quad (20)$$

$$F_2 = \frac{\rho}{(1-\rho)[\rho(N-1)+1]} \quad (21)$$

The segmentation control and fuzzy decision-making methods were adopted for optimal control of construction quality. The deviation of P_i was solved through $R_i(P)$ and the derivative was set to 0.

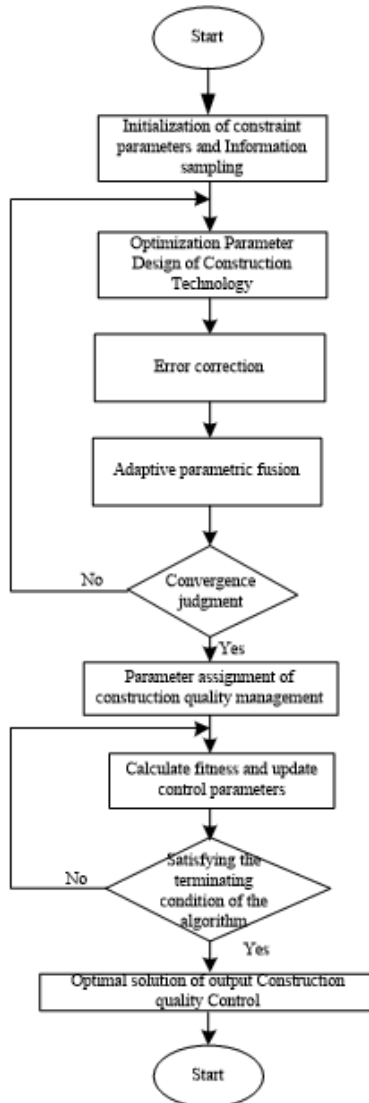


Fig. 1 - Implementation flow chart

Then it is obtained that

$$\frac{\partial R_i(P)}{\partial P_i} = (1-\alpha)e_i F_1 - \sum_{i \neq j} (1-\alpha)(e_j - P_j)F_2 - 2(1-\alpha)P_i F_1 = 0 \quad (22)$$

Under the optimal quality control constraints, the optimal solution for the control law is obtained as follows:

$$P_i^* = \frac{e_i F_1 - \sum_{i \neq j} (e_j - P_j)F_2}{2F_1} \quad (23)$$

P_j^*, \dots, P_M^* can be calculated through analogy, and the design of the construction quality control model of the expressway traffic safety facility can be optimized in this way. Finally, the flow chart for construction quality control of the expressway traffic safety facility designed in this paper is obtained as shown in Figure 1.

4. Simulation experiment and result analysis

In order to test the application performance of the method proposed in this paper in construction quality control of expressway traffic safety facilities, a simulation experiment was carried out. The experimental hardware platform was a platform with Pentium Dual-Core, 2.6 GHz and memory of 2 G. Matlab 7 simulation tool was adopted for numerical simulation FENIX of expressway traffic safety technology optimization and quality control. Autodesk Revit MEP and Autodesk Revit Architecture were adopted to construct the Simulation platform for construction safety control of expressway traffic safety facilities. The longitudinal elastic modulus parameter was set to 70 cm/s²; the stress parameter of the traffic safety protection facility was set to 225 KPa/m; the normalized parameter of the connection stress of the safety facility was set to 0.38; the sampling sample size for original data set of construction quality control was set to 2000; the training set was set to 1024 and the iteration step of quality control simulation was set to 100. Based on the above simulation environment and parameter settings, quality control of expressway traffic safety facility construction was simulated and the finite element simulation diagram of the construction platform is obtained as shown in Figure 2

In the construction model shown in Figure 2, construction technology optimization and quality control of the expressway traffic safety facility were carried out. The parameter optimization results are obtained as shown in Table 1.

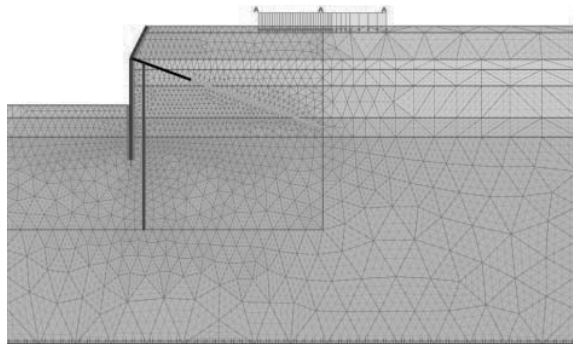


Fig. 2 - Finite element simulation of expressway safety facility construction platform

Tab. 1 - Optimization of construction technical parameters

Construction group	Quality level (100%)	Construction efficiency level (100%)	Normalized value of control cost
X_{11}	0.543**	0.676	0.434
X_{12}	0.465	0.943	0.532
X_{13}	0.253	1.245**	0.943**
X_{21}	0.654	0.544	0.422
X_{22}	0.245	1.765	0.323
X_{23}	0.686	0.544	0.321
X_{31}	0.787*	0.954	0.343**
X_{32}	0.766	0.323	0.347
X_{33}	0.767	1.455	0.543
X_{34}	0.434	1.334	0.676
X_{35}	0.465*	1.256**	0.212
X_{41}	0.434	0.687	0.783*
X_{42}	0.565*	1.433	0.433
X_{43}	0.543	0.465	0.434*
X_{51}	0.654**	1.216	0.434
X_{52}	0.215	0.234**	0.543
X_{53}	0.543	1.654	0.132*
X_{54}	0.212	0.223**	0.324

where ** and * mean significant situations at the 1% and 5% levels, respectively.

According to the above parameter optimization results, construction technology optimization and quality control were carried out. The method proposed in this paper and conventional methods were compared in construction quality control performance, and the comparison results of calculation overhead and construction process quality benefit were obtained as shown in Figure 3 and Figure 4. Analysis of Figure 3 shows that with the increase of the number of iteration steps in the construction quality control of expressway safety facilities, the time overhead of those algorithms is gradually increased, and the calculation cost of the method proposed in this paper is the smallest, 12.5% and 23.6% shorter than that of the two conventional methods, so the method proposed in this paper improves the real-time quality control capability.

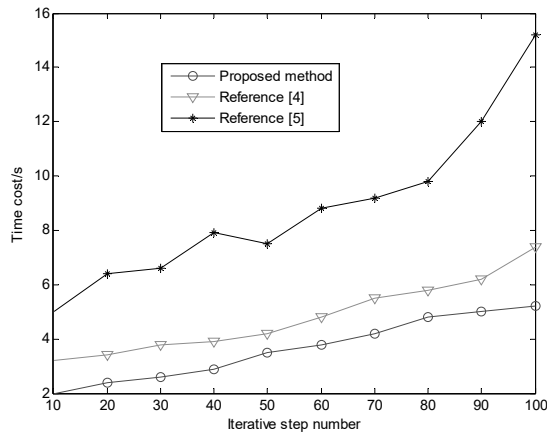


Fig. 3 - Comparison of computation overhead

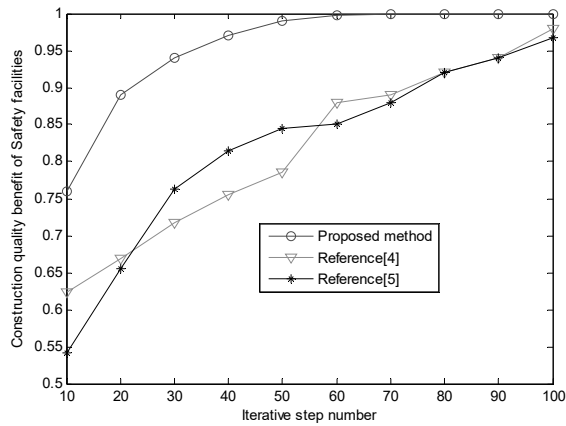


Fig. 4 - Comparison of construction quality and efficiency

The simulation results in Figure 4 show that with the increase of the number of iteration steps, the quality and efficiency of the three methods for expressway safety facility construction are continuously improved and the method proposed in this paper provides better smoothness of quality control and a quality benefit, 34.7% and 28.5% more than that provided by the two conventional methods, which indicates that the method proposed in this paper greatly improves the construction technical performance and quality of expressway traffic safety facilities.

5. Discussion and analysis

According to the construction characteristics of expressway traffic safety facilities, the expressway construction technology and quality control measures were studied, and the reliability of the method proposed in this paper was verified through an experiment. During the experiment, the optimal values were selected from many experiment groups, and the construction technical parameters were optimized, which improved the accuracy of the simulation experiment. Two indexes, construction cost and construction quality benefit, were selected for the contrast experiment, which increased the reliability of simulation results. The quality control method for expressway traffic safety facilities based on parametric fusion tracking control and piecewise linear regression analysis of construction process proposed in this paper provides a basis for expressway safety guarantee measures and for rapid evaluation of many aspects of transportation systems, such as location safety and the effects of safety improvement measures.

Due to the complexity of the study issue and the limitations of time and work experience, there are still some problems and deficiencies that need to be further explored, which are mainly the following aspects:

- 1) The improvement of the organization and management process of safety and security measures for the construction process of transportation facilities. The construction of expressways is affected by many factors, so it is necessary to formulate perfect technical standards for safety protection measures for expressway construction projects, so as to better guide the implementation of various construction projects.
- 2) Safety evaluation standards for traffic facility construction. In terms of safety evaluation, there is no unified standard evaluation index system yet, so it is necessary to further study the unified standard evaluation index system, especially for expressway traffic.

6. Conclusion

- 1) In the construction of expressway traffic safety facilities, new technologies, new processes and new materials should be adopted and excellent construction processes and technologies should also be adopted to ensure transportation safety.
- 2) In order to improve the quality control ability and construction quality of expressway traffic safety facilities, a construction quality control method for expressway traffic safety facilities based on parametric fusion tracking control and piecewise linear regression analysis of construction schedule is proposed in this paper.
- 3) A constraint parameter model for construction quality control of an expressway traffic safety facility was constructed and a nonlinear creep relation model for construction quality process control of it was constructed through correlation detection and sample regression statistical analysis methods to optimize the construction technology and improve the anti-collision performance and mechanical performance of the safety facilities. The adaptive parameter fusion tracking method was adopted to establish a construction quality control model of expressway traffic safety facilities to optimize the construction process control of expressway traffic safety facilities.
- 4) The study shows that in optimization and control of construction technology of expressway traffic safety facilities, the proposed method can improve construction quality and provide relatively good optimization ability of each parameter about construction quality description and relatively high process control quality. Therefore, this method has good application value in construction control of expressway traffic safety facilities.

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Dynamic traffic safety grade evaluation model for road sections based on gray fixed weight clustering

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Abstract

The conventional gray prediction model GM (1, 1) cannot accurately analyze the dynamic traffic index information of complex and scattered road sections because it may cause relatively large error and performs not well in stability. In order to solve this problem, a dynamic traffic safety grade evaluation model for road sections based on gray fixed weight clustering is designed. In this method, the gray clustering evaluation method is adopted for gray clustering to complex and scattered traffic safety grade evaluation indexes, and the gray fixed weight clustering method is adopted to weight each clustering index in advance; the clustering weight of each index is set by a fuzzy consistent matrix, on which the fixed weight coefficient of the index is calculated and the clustering vector is constructed; the cluster coefficients and cluster vectors are combined to obtain the clustering indexes of traffic safety evaluation; then a BP neural network dynamic traffic safety grade evaluation model for road sections is constructed according to the indexes, so as to accurately evaluate the dynamic traffic safety grade of road sections. The experiment results show that the designed model method can effectively evaluate the dynamic traffic safety grade of 31 road sections in areas with a high probability of traffic congestion with small evaluation error and high stability, so it meets the design requirements.

Keywords – gray fixed weighted clustering, complex and scattered, clustering weight, BP neural network, road section, traffic safety grade

1. Introduction

With the rapid development of social economy, the speed of domestic motorization and automobileization has been improved and the demand for urban road traffic has risen steadily, so the dynamic traffic safety of road sections has gradually become a key issue of current concern, and traffic accidents have cost a great deal of national and people's lives and property. In order to reduce the probability of traffic safety accidents, it is necessary to evaluate the dynamic traffic safety grade of road sections. In reference [9], an indefinite length method for dynamic clustering road sections based on the concentration level of accident area is proposed; an accident prediction model is designed based on the negative binomial distribution and a safety evaluation method for

road sections based on negative binomial distribution is proposed. This method is only suitable for expressways with good road straight conditions, and has certain limitations. In reference [5], an evaluation method through a road traffic safety grade cloud model is proposed based on the ambiguity and randomness characteristics of road traffic safety grade evaluation, which involves too complicated evaluation data and causes relatively low evaluation efficiency. In reference [12], an evaluation model for tunnel structure health state based on gray fixed weight clustering is constructed based on the gray clustering theory, analytic hierarchy method and information entropy theory. This evaluation method causes relatively large error and performs not well in stability. In reference [19], it is proposed to take the conflict rate and speed deviation change coefficient as safety evaluation indexes to construct a VISSIM simulation model. In this model, the gray clustering method is used to evaluate the safety of the conflict rate and CVSD index of each section in construction areas. This evaluation model may cause relatively large error and performs not well in stability. In reference [20], a road operation evaluation method based on two-stage K-means clustering (TSKC) is studied. In order to solve the problem of arbitrariness of K-means clustering number selection and the randomness of clustering center selection, a K-means clustering method based on ergodicity is proposed. The clustering number and initial center are determined by clustering attractiveness, and then they are taken as initial conditions for the second stage K-means clustering to obtain the traffic pattern. Model attractiveness, road section evaluation index and distribution equilibrium degree are proposed to evaluate the traffic condition of road sections. However, this method performs not well in stability and may causes a relatively large gap between the obtained results and actual situation.

In consideration of fact that the interference factors of traffic safety in cities are not simple and the interference of each factor is featured with grayness, a dynamic traffic safety grade evaluation model based on gray fixed weight clustering is proposed in this paper to accurately and stably evaluate the dynamic traffic safety grade of road sections. This method has a high application value.

2. Dynamic traffic safety grade evaluation model for road sections based on gray fixed weight clustering

The index information obtained in dynamic traffic safety grade evaluation to road sections is relatively complicated and scattered, so the gray fixed weight clustering method is adopted for gray clustering to traffic safety evaluation index information to lay a good foundation for further macroscopic evaluation of road traffic safety, so as to improve the evaluation efficiency. In consideration of the different importance of gray clustering indexes, a fuzzy consistent matrix is adopted to determine the weight of clustering indexes and a gray fixed weight clustering analysis method is proposed. Using this method, the traffic safety evaluation clustering index values are selected.

2.1. Gray clustering method

Gray clustering is performed to the gray numbers among whitening numbers in different clustering indexes in clustering targets to distinguish the gray category of the clustering target.

(1) Construct an evaluation matrix

Set n pre-evaluation samples in dynamic traffic safety evaluation of road sections as clustering targets $\{R_i\}(i = 1, 2, \dots, n)$, and m evaluation indexes as clustering indexes $\{P_j\}(j = 1, 2, \dots, m)$. sevaluation criteria include four grades: grade I, grade II, grade III, and grade IV,

which are set as clustering gray categories $\{G_k\}(k = 1, 2, \dots, s)$. Then based on the sample value a_{ij} of the j -th clustering index of the i -th clustering target, the clustering sample evaluation matrix is determined to be A :

$$A = \begin{pmatrix} a_{11} & a_{12} & A & a_{1m} \\ a_{21} & a_{22} & A & a_{2m} \\ M & M & M & M \\ a_{n1} & a_{n2} & A & a_{nm} \end{pmatrix} = (a_{ij})_{n \times m} \quad (1)$$

(2) Determine the whitening weight function λ_j^k of gray category in evaluation matrix.

A probability and statistical method is adopted to determine the evaluation standard, and the real data of the evaluation indexes are subjected to dimensionless analysis to determine the cumulative percentage frequency of the data. Then a cumulative percentage frequency curve is drawn, and different corresponding cumulative percentage frequency on the curve is determined. The whitening value of each gray category is set. The traffic safety is divided into four grades: excellent, good, medium and poor. The four grade are described by A_j^1, A_j^2, A_j^3 and A_j^4 . The corresponding whitening values of the four grades on the cumulative whitening percent frequency curve are 15%, 40%, 60% and 85%. $K = 1, 2, 3, 4$ represents the four gray categories.

(3) Decide clustering weight

Step one: Clustering weight analysis [6,11].

The gray-whitening weight function clustering method is adopted to check whether the retrieval target belongs to the type with different original settings. If there is a difference in the meaning and dimension between clustering index, and the quantity difference is large, the use of the gray variable weight clustering will produce an index, which has no effect in clustering [2,3]. At this time, the initial value processing operator and the mean value processing operator are adopted to convert each index sample into dimensionless data and then clustering is performed to hem [13,17]. This method has the same effect on all clustering indexes, so it will not reflect the difference in clustering effects between different indexes. The gray fixed weight clustering method is adopted to weight each clustering index in advance [4,14,16]. Clustering weight of each index is set through the fuzzy consistent matrix. The different between the importance and effect of indexes is analyzed to low the subjectivity based on experience in decision making.

Step one: Calibrate clustering weight.

Construct the fuzzy priority relation matrix C .

$$C = (b_{jl})_{m \times m} \quad (2)$$

where the priority relation coefficient of clustering index P_j to P_l is set to b_{jl} . If P_j is not inferior to P_l , $b_{jl} = 1$; if P_j is equal or superior to P_l , $b_{jl} = 0.5$; if P_j is not superior to P_l , $b_{jl} = 0$. m is the order of the matrix C .

The priority relation matrix C is converted into fuzzy consistent matrix β .

$$\beta = (r_{jl})_{m \times m} \quad (3)$$

where $r_{jl} = \frac{r_j - r_l}{2m} + 0.5$ and $r_j = \sum_{l=1}^m b_{jl}$. The priority relation coefficient of clustering target P_j to P_l is set to r_{jl} , and j and l are clustering indexes. The weight Ω_j of clustering index P_j is calculated using the square root method:

$$\Omega_j = \frac{\bar{\Omega}_j}{\sum_{j=1}^m \bar{\Omega}_j}$$

$$\bar{\Omega}_j = \left(\prod_{l=1}^m r_{jl} \right)^{\frac{1}{m}} \quad (4)$$

(4) Calculate the index fixed weight clustering coefficient σ_i^k .

Clustering coefficient is a criterion for assessing the gray category of a clustering object. Based on the clustering index weight in formula (4), the index fixed weight clustering coefficient is set as:

$$\sigma_i^k = \sum_{j=1}^m f_j^k (R_{ij}) \Omega_j \quad (5)$$

where the clustering object is set to be i , and the index fixed weight clustering coefficient of i that belongs to gray category k is described by σ_i^k . The weight of the clustering index j is set to Ω_j .

(5) Construct the clustering vector σ_i .

$$\sigma_i = (\sigma_{i1}, \sigma_{i2}, \dots, \sigma_{ik}) \quad (6)$$

where the clustering vector of the clustering object i is σ_i .

(6) Based on the index fixed weight clustering coefficient in formula (5), the clustering vectors in formula (6) are combined, and the clustering index for dynamic traffic safety grade evaluation of road sections is obtained as follows:

$$\sigma_i^{k*} = \max \{ \sigma_i^1, \sigma_i^2, \dots, \sigma_i^s \} \quad (k = 1, 2, \dots, s) \quad (7)$$

where the clustering object i belongs to gray category k^* .

Because the unit of each evaluation index is different [1], the indexes cannot be compared and analyzed directly. Therefore, it is necessary to implement dimensionless processing on index values [10] and set each index within 0~100. The following formula is adopted:

$$p_{ij} = \frac{P_{ij} - P_{ij}^{\min}}{(P_{ij}^{\max} - P_{ij}^{\min})} \times 100 \quad (8)$$

where the index value is set to p_{ij} ; the processed index value is described by P_{ij} . The year is set to i , $i = 1, 2, \dots, n$ and the index is set to j , $j = 1, 2, \dots, m$.

2.2. BP neural network evaluation model

Based on the traffic safety grade evaluation clustering index values obtained in the above section, a BP neural network evaluation model is constructed to evaluate the dynamic traffic safety grade of road sections [15]. The neural network topology covers the hidden layers and the number of nodes they contain, and the way they are connected. The principle of neural network topology is to combine ICMP, ARP and SNMP to check the active devices of the specified network, obtain all active devices, then obtain the basic information of the devices through SNMP, determine the device type based on the basic information and obtain the details of corresponding device according to the device type.

The artificial neural network is a model for analyzing the complex social phenomena through knowledge representation, reasoning analysis and associative memory, which has an application prospect that cannot be underestimated in the overall evaluation [18]. Network generalization ability refers to the adapt ability of machine learning algorithms to new samples. The purpose of learning is to learn the laws behind the data pairs. For data other than the learning set with the same law, the trained network can also give appropriate output. The generalization ability reflects the ability of recognizing sample sets other than the training set of neural network, which plays a decisive role in the application of neural networks in actual production.

The gray fixed weight clustering algorithm is used to improve the topology and learning methods of BP neural network, so as to enhance the generalization ability of BP neural networks.

According to the characteristics of dynamic traffic safety evaluation of road sections, a BP neural network structure with two hidden layers and one output layer is set to realize comprehensive evaluation of traffic safety grade.

The neuron transfer function of the hidden layers belongs to type S , and the output neurons are linear, so it can be similar to any function.

Type s_1 : type Tansig(x).

$$f(x) = \text{tansig}(x) = (e^x - e^{-x}) / (e^x + e^{-x}) \quad (9)$$

Type s_2 : type Logsig(x).

$$f(x) = \text{logsig}(x) = 1 / (1 + e^{-x}) \quad (10)$$

$$\text{Type Purelin: } f(x) = \text{purelin}(x) = x \quad (11)$$

where e is the error function and x is the input vector.

When the neural network method is adopted to evaluate the dynamic traffic safety grade of road sections, the determination of the input and output values of the sample mode is an important step [7]. The evaluation index values are set as the input values of the network, and the evaluation results of the gray fixed weight clustering are set as input value. When the sample input value is set, each evaluation index is set according to the setting principle of the dynamic safety evaluation indexes for road sections [8]. The input vector is set to {population mortality, vehicle accident rate, operation accident rate}, the output target vector to $\{\sigma_i^A, \sigma_i^B, \sigma_i^C, \sigma_i^D\}$, where $i = 1, 2, \dots, m$; i is the evaluation object and the affiliated gray categories are described by A, B, C, D. The transfer function of each layer, training function and learning rate l_r of the network and the iterative goal E of the network are set, and then learning training for this neural network is performed to finally evaluate the dynamic traffic safety grade of road sections through the neural network.

3. Experiment analysis

The following experiment was conducted to verify the effectiveness and performance advantages of the model. In this experiment, a total of 31 road sections with a high probability of traffic congestion in July were selected and evaluated in dynamic traffic safety grade through the model proposed in this paper. The specific evaluation example process is as follows:

3.1. Gray clustering evaluation

(1) Determine the whitening value $f_j^k(x_{ij})$.

According to each complex and scattered evaluation index value in the 31 road sections with a high probability of traffic congestion in Table 1, the cumulative percentage frequency curve of three indexes is plotted to determine the whitening values of the four gray categories: Gray category: $t = \{\text{Excellent (A) Good (B) medium (C) Poor (D)}\}$. The evaluation indexes are:

$$f_j^k(x_{ij}) = \begin{bmatrix} 0.238 & 0.470 & 0.545 & 0.708 \\ 0.125 & 0.252 & 0.335 & 0.835 \\ 0.078 & 0.168 & 0.185 & 0.570 \end{bmatrix}$$

Tab. 1(a) - Traffic safety evaluation index values of 31 road sections

Road section number	1	2	3	4	5	6	7	8
Index 1	0.5288	0.6979	0.5343	0.5284	0.4349	0.6179	0.3989	0.1983
Index 2	0.2599	0.6789	0.5789	0.4420	0.5349	0.3289	0.3298	0.6288
Index 3	0.3999	0.7987	0.0988	0.2011	0.1399	0.4109	0.3338	0.3791

Tab. 1(b) - Traffic safety evaluation index values of 31 road sections

Road section number	9	10	11	12	13	14	15	16
Index 1	0.5236	0.5879	0.7353	0.2239	0.7539	0.4269	0.6114	0.2415
Index 2	0.4888	0.0459	0.1329	0.2269	0.2392	0.3966	0.0218	0.1493
Index 3	0.9999	0.0928	0.2446	0.3536	0.2188	0.3667	0.0472	0.1541

Tab. 1(c) - Traffic safety evaluation index values of 31 road sections

Road section number	17	18	19	20	21	22	23	24
Index 1	0.1	0.1419	0.8417	0.389	0.0986	0.1	0.2987	0.0822
Index 2	0.2	0.3682	0.1	0.1977	0.7789	0.9999	0.2084	0.7929
Index 3	0.1	0.2	0.006	0.1541	0.1925	0.7075	0.1974	0.7289

Tab. 1(d) - Traffic safety evaluation index values of 31 road sections

Road section number	25	26	27	28	29	30	31
Index 1	0.2997	0.9386	0.2598	0.4394	0.7792	0.9999	0.9001
Index 2	0.3067	0.9999	0.3958	0.8729	0.9771	0.9372	0.7625
Index 3	0.1	0.8199	0.2411	0.7672	0.9551	0.9729	0.3509