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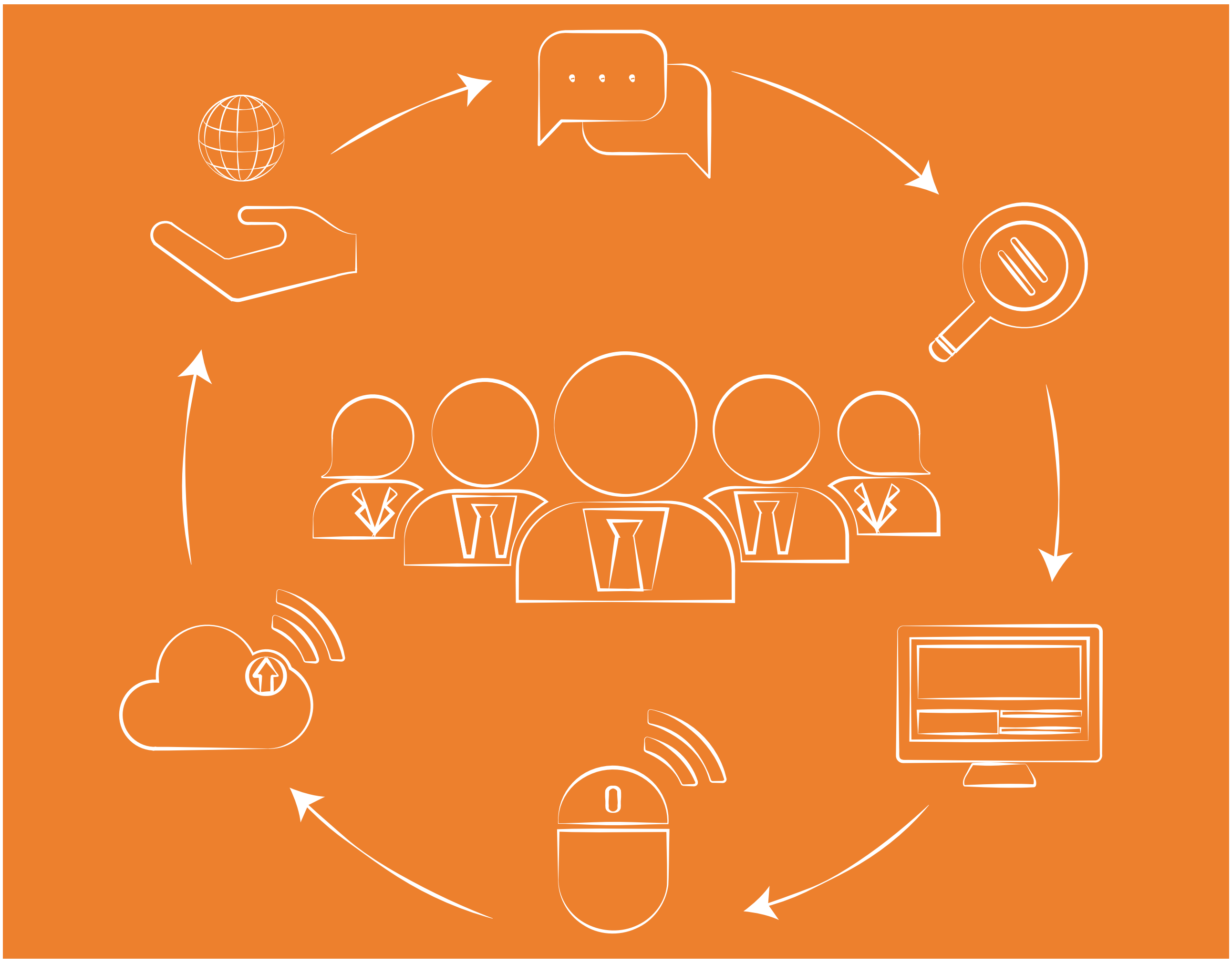

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STUDY OF STRESS PATHS IN ARCHING EFFECT USING FRICTIONAL STRAIN HARDENING AND SOFTENING IN FINE SAND

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ABSTRACT

Arching is one of the most common phenomena that occur in most geotechnical structures. To determine the properties and quality of this phenomenon, a physical model has been designed and constructed. The apparatus comprises rectangular trapdoors with different widths that can yield downward while stresses and deformations are recorded simultaneously. As the trapdoor starts to fail, the whole soil mass deforms elastically. However, after an immediately specified displacement, depending on the width of the trapdoor, the soil mass behaves plastically. This behavior of sand occurs due to the flow phenomenon and continues until the stress on the trapdoor is minimized. Then the failure process develops in the sand, and the measured stress on the trapdoor shows an ascending trend. This indicates a gradual separation of the yielding mass from the whole soil body. Finally, the flow process leads to the establishment of a stable vault of sand called the arching mechanism or progressive collapse of the soil body. To simulate this phenomenon with continuum mechanics, the experimental procedure is modeled in ABAQUS software using stress-dependent hardening in an elastic state and plastic strain-dependent frictional hardening-softening with Mohr Coulomb failure criterion applying user sub-routine. The results show that the experimental data have an acceptable corresponding to the numerical analysis data. So the selected soil behavior could indicate the main aspects of the arching effect, such as the flow that occurs in specific periods of strains. In the following, the stress path in p, q, and p, v space was extracted from numerical analysis, and the results have been discussed.

KEYWORDS

ABAQUS, Arching Effect, Stress Path, PIV, Frictional Strain Hardening and Softening, Fine Sand.

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1. INTRODUCTION

The arch phenomenon is one of the most important phenomena that we deal with in geotechnical engineering. The impact of this phenomenon can be clearly seen in underground and buried structures, so that the amount of force applied to the structure depends on the redistribution of the stress caused by overburden or overburden. Many scientists and researchers have worked in this field in a laboratory and theoretical manner and have written numerous articles. This phenomenon was first observed in the gunpowder storage silos belonging to the French army, and in 1895 John Sen presented the theory of silos. This phenomenon was shown for the first time in a scientific way by an experiment on sand with an open valve conducted by Terzaghi. It was proposed by him in geotechnical engineering. Usually, this phenomenon occurs in places where there are sudden differences in the type of materials in the soil mass. In other words, in the mass, two types of materials with a different modulus of elasticity come into contact and exchange stress with each other. In general, it can be said that arching occurs wherever there is a change of location in the soil mass enclosed between stable supports, whether horizontal or vertical. Also, this phenomenon can exist in all extents of deformation in the soil, so it starts with the occurrence of elastic shear deformations and continues until the irreversible (plastic) deformations and the breaking of parts of the soil mass.

To investigate the arching phenomenon in underground structures, Terzaghi conducted an experiment in which a horizontal valve was lowered. When it was moved, the amount of stress applied to the center of the valve was simultaneously read. Using the results of these experiments and assuming plastic behavior for soil, Terzaghi presented the theory of shear plates. In fact, by considering the balance of forces in the plastic state of the soil, Tarzaghi was able to make the arch phenomenon mathematically legal. After V. Finn, he modified the hypothesis related to Terzaghi's theory and considered the elastic state of the soil. In the following years, many experimental and numerical studies have been conducted to investigate the failure mechanisms of the soil mass above the tunnel (Atkinson and Potts, 1977; Jiang and Yin, 2012; Guo and Zhou, 2013; Han et al., 2017; Franza et al., 2018; Chen et al., 2018; Jin et al., 2021; Zheng et al., 2021). These studies play an important role in improving the understanding of the interaction between tunnels and soil and create a solid foundation for developing theoretical models. After that, the parameters of silo width and lateral stress ratio in Terzaghi theory were modified by many researchers based on model tests and numerical analyzes (Stein et al., 1989; Hendi, 1985; Chen et al., 2015; Zhang et al., 2016). Although many significant modifications have been made based on Terzaghi's loose earth pressure theory, most of the research has focused on shallow tunnels where the failure zone at the top of the tunnel extends to the ground surface when the soil mass is in a limited state. However, for deep tunnels, local failure occurs at the top of the tunnel according to many laboratory tests (Jacobs, 2016; Song et al., 2018) to evaluate the earth pressure on deep tunnels. Based on the existing theoretical models for the shallow tunnel, a limited height of the silo was further considered. Chen and Peng (2018) assumed that the height is 1.5 times the radius of the tunnel based on the numerical results in the soft ground of Shanghai. The local failure height for the deep tunnel is related to the ground subsidence, the phenomenon of soil expansion (change), and the depth of the tunnel cover in the light of the previous study. Zhang et al. (2016) obtained a formula for calculating the local failure height caused by the construction of the deep jacked pipe, in which the relationship between the local failure height, the volume of loosened soils, and soil bulking factors are simultaneously considered, was taken. Zhang's method assumed that the shear bands start from the spring lines of the tunnel section. However, according to the numerical results of Lin et al. (2019), the shear bands developed diagonally from the bottom of the tunnel in the sandy ground. Therefore, the formula presented by Zhang et al. (2016), used to calculate the local failure height, is limited to sand.

However, the previous models for calculating the earth pressure in deep tunnels assumed that the soil mass above the failure zone was not disturbed by the construction of the tunnel and that the earth pressure applied above the failure zone is the stress caused by the weight of the soil above, in fact, soil arching in occurs above the failure zone, which leads to the transfer of earth pressure to both sides of the failure zone. When the arch-bearing capacity of the soil is greater than or equal to the weight of the soil above the failure zone, a cavity can be created above the failure zone. The failure zone is zero. Such an arching effect of the soil above the failure zone has been neglected by previous analytical approaches, which may consequently overestimate the earth pressure exerted on the silo. A new 3D model considering the arch effect above the fracture zone was developed by Chen et al. in 2019. To predict the confining pressure exerted on the surface of the deep shield tunnel. The calculated results by obtaining the new model agree with the experimental results. However, it is assumed that the earth pressure distribution in the loosened zone is uniform. The distribution of earth pressure on the tunnel can be different due to the difference in the distribution of earth losses caused by the construction of the tunnel. For the circular tunnel, Chen and Teng in 2018 pointed out that the vertical earth pressure distribution shows a concave curve; that is, it is smaller in the center line and increases with the increase of the horizontal distance from the center of the tunnel. However, the current tunnel design for tunnels generally assumes vertical earth pressure of uniform width. To reflect the uneven distribution of the vertical earth pressure in the tunnel, Chen and Teng in 2018 assumed that the vertical earth pressure on the tunnel conforms to the distribution of the Gaussian function, and then presented a formula for calculating the earth pressure. However, there is a relatively large error between the model results and the numerical analysis. Based on particle flow theory, Wu et al. in 2019 obtained a modified formula by assuming that the vertical earth pressure on the tunnel corresponds to a trapezoidal distribution. But, in fact, the vertical pressure distribution of the earth is a smooth concave curve.

In this article, in order to determine the characteristics and how this phenomenon occurs, a physical model has been designed and built that can model the arcing phenomenon in a laboratory. In this physical model, valves with different widths have

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been installed to investigate the effect of valve width on the occurrence of this phenomenon. To determine the pattern of stress changes during the event of the arcing phenomenon, miniature stress gauges with a diameter of 14 mm have been used, and to determine the pattern of strain changes, the PIV method has been used. Also, numerical modeling of this phenomenon has been done in Abaqus software and the finite element method. To model the arch phenomenon, the hardening behavior dependent on the stress level in the elastic range and the hardening and softening depending on the plastic strain in the plastic range were used; for this purpose, a program was written in the form of a subroutine in the Fortran environment and then with the help of a compiler Visual Studio has been introduced to Abaqus software.

2. PHYSICAL MODEL

In this research, to model the arcing phenomenon, a physical model was designed and built to provide the ability to model the arcing phenomenon on a laboratory scale.

2.1. SOIL UNDER TEST

A type of non-sticky silty sand passed through a grade 10 sieve, with a constant humidity of 2% and a specific gravity of 2.62, was used for the experiments. The granulation diagram and characteristics of the soil used are presented in Fig. 1 and Table 1, respectively.

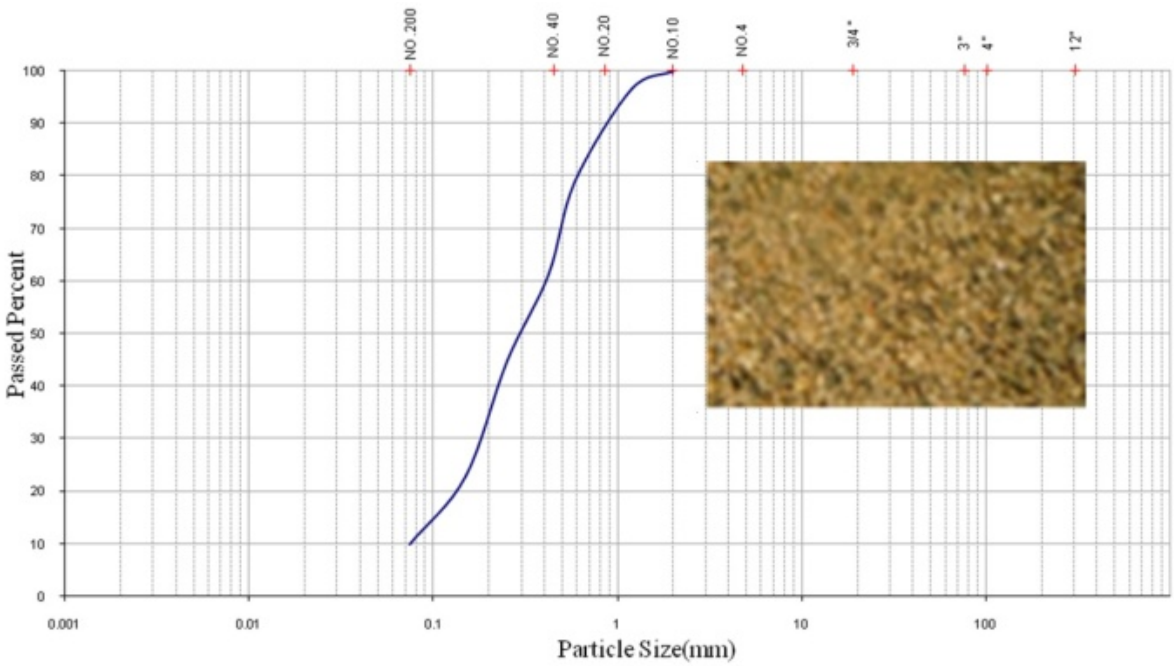

Figure 1. Sand grading curve

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Table 1. Characteristics of the soil used in the research

γ max	17.35 (kN/m³)	F_c	9.5%
γd max	17.01(kN/m³)	G_s	2.62
γmin	12.88 (kN/m³)	M(moisture)	2 %
γd min	12.63 (kN/m³)	Classification	SP-SM
Dmax	2 mm		

2.2. SPECIFICATIONS OF THE BUILT PHYSICAL MODEL

To physically model the arcing phenomenon, a device was designed and built. Fig. 2 shows the fabricated device and test details. The physical model consists of a metal skeleton, in the upper part of which is a rectangular cube tank with a steel frame with internal dimensions of 400 x 1830 and a height of 1250 mm. Its main skeleton is made of steel plates with a thickness of 10 mm and a stud profile. 200 were made. In the outer part of the side plates, five rows of 80-grade corner type hardeners have been used. To increase the strength, the two parts of the skeleton are welded together using 100-grade stud material to eliminate lateral deformation in the skeleton due to the lateral pressure of the soil and the overhead pressure caused by the loading jack. The lower part of the structure consists of three rows of grade 200 stud profiles, along with a 100 mm thick plate welded, and the upper skeleton is made of 100- grade studs with the help of four legs to this 3000 x 600 mm plate is connected. In total, the height of the device is 2200 mm. Two 10 mm thick steel plates are installed on the bottom of the machine's tank, which can be moved to the sides in a sliding manner, and as a result, the distance between the two plates, which is equal to the width of the valve, can be adjusted. Four separate rectangular pieces with widths of 10, 20, 30, and 35 cm were used for movable valves. When using each valve, the two side plates are opened to the sides as wide as the valve, and the desired valve is placed between the two jaws embedded in the side plates, which serve both as a stiffener and as a guide for the valve movement would take. The valve is secured in place using eight provided screws. These valves are made of a 10 mm thick sheet and could move down up to 40 mm. On both sides of the tank, two transparent Plexiglas plates with a thickness of 30 mm were installed to observe the changes in soil locations. To increase the rigidity, a steel grid with stiffeners of 50 mm height and 20 mm thickness was installed, which could be opened, and each of them was connected to the skeleton by 20 screws.

According to Fig. 2, in order to measure the displacements applied to the valves, a strain gauge was installed under the valves. Also, to measure the stresses involved on the valves by the sand, a stress gauge was also established under the device, so that the applied stress from the valves is directly transferred to the stress gauge.

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To apply displacement to the valve, a 10-ton hydraulic jack with a stroke of 70 mm with the ability to adjust the speed was installed under the stress gauge, which enables displacement be applied to the valves. Also, a 20-ton hydraulic jack with a 50 mm stroke with a rigid pressure plate was designed and built to spread the overhead pressure. This overhead pressure system was able to be installed on the device using a roof crane made for this purpose. This capability provided the possibility of filling the tank by installing the sand precipitation system and then re-installing the loading system.

The dimensions of the tank have been chosen according to the maximum width of the valve and the type of soil used, and other physical models have been designed in such a way that while removing the effect of the side borders (walls of the tank) on the results, it is not too large as required so that It is possible to fill and empty the tank. Researchers have chosen physical models with different dimensions to study the arcing phenomenon. In this research, the criteria considered for the study of underground tunnels have been used to select the size of the tank size. In the model made by Branko and his colleagues, the distance from the center of the tunnel with a diameter of 55 cm to the lateral borders of the model is 1.2 times the diameter of the tunnel. in the model made by Kim and his colleagues, for a tunnel with a diameter of 7 cm, this distance is 7 times The diameter of the tunnel selected. On average, in most of the designed modes, the distance from the side walls to the center of the tunnel is in the range of 4 to 6 times the diameter of the tunnel. In this research, taking into account the recommendations of previous researchers and the difficulties caused by building a physical model with large dimensions as well as filling and emptying the tank for multiple tests, the distance from the side walls to the center of the valve with a maximum width (35 cm) is more than 5 times the width of the valve (exactly 5.22 times) was chosen. The width of the built model is equal to 183 cm and equal to the length of the full Plexiglas sheet.

After designing the initial dimensions of the model, the effect of the distance of the side walls selected for the tank was investigated using a numerical model. In this way, in the built numerical model corresponding to the dimensions of the physical model, the distance of the lateral borders of the model was increased to 1.5 and 2 times the initial value, and the results were compared with the values obtained from the selected state. Based on the results obtained from the numerical model, the stresses and strains created as a result of the occurrence of the arch phenomenon did not change with the increase in the distance of the lateral borders. Therefore the distance of 5 times the width of the valve is acceptable for the lateral boundaries of the model.

In the construction of the physical model, the issue of model rigidity and removal of model deformations should be considered. The physical model should have been designed and built so that it would not show any deformation due to the overhead jack force. This issue is significant, especially in the strain measurement results using the image speed measurement method. For this purpose, the box's design was done with great care, and steel sheets with the required hardeners were used to make the

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box. To check the rigidity, the designed physical model was also modeled in the Abaqus software environment. The displacements caused by the lateral pressure caused by the soil and the force applied by the overhead jack were calculated. It was found that the amount of horizontal displacement caused by using a uniform pressure of 2 kg/cm2 on the vertical sides of the steel tank and the Plexiglas plate, which is more than the maximum pressure applied to the walls during the tests, is at most 1 mm. In general, the amount of deformations is minimal and can be ignored, and therefore the built physical model has sufficient rigidity against the applied loads. Modeling of the machine body in Abaqus software is shown in Fig. 3.

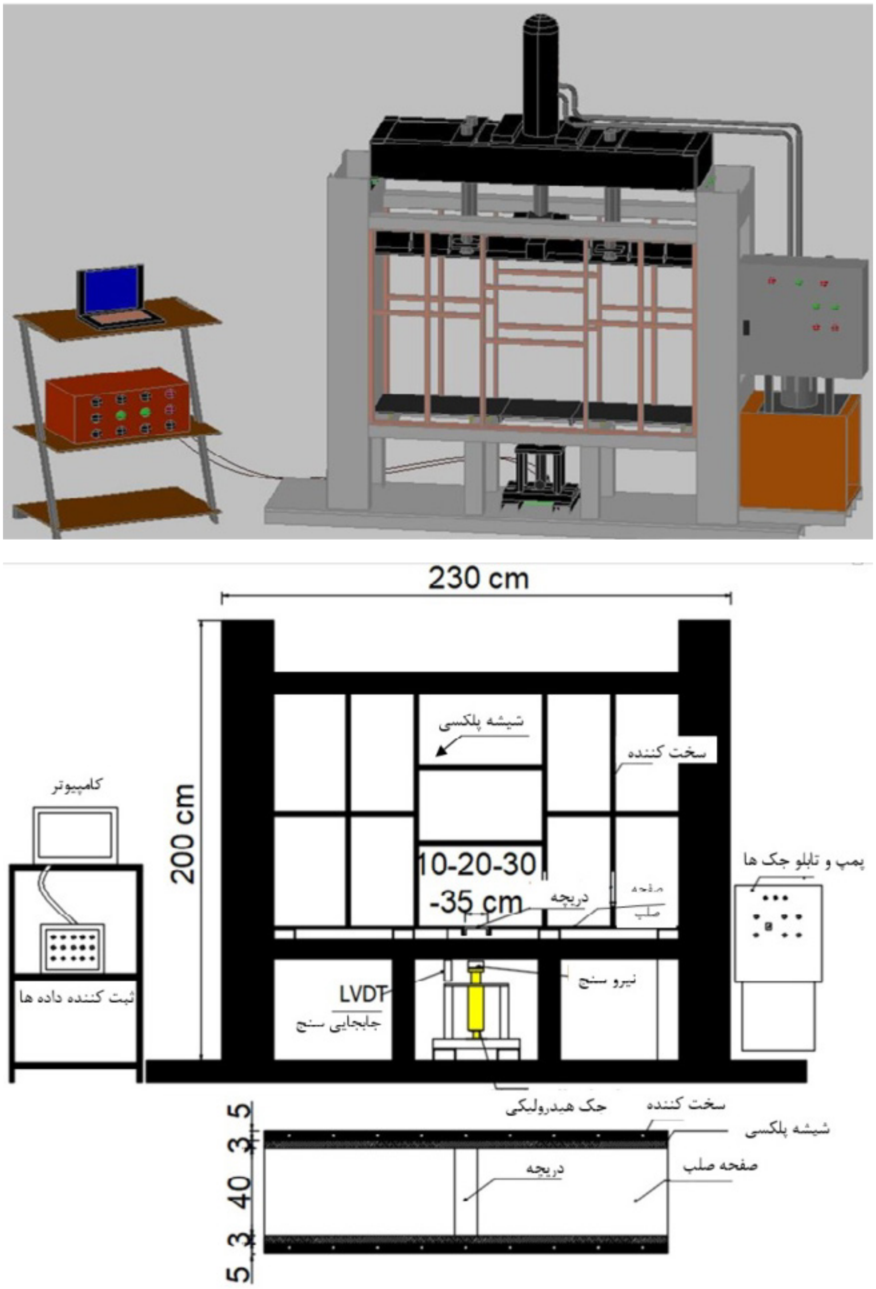

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Figure 2. Built physical model and used strain gauges

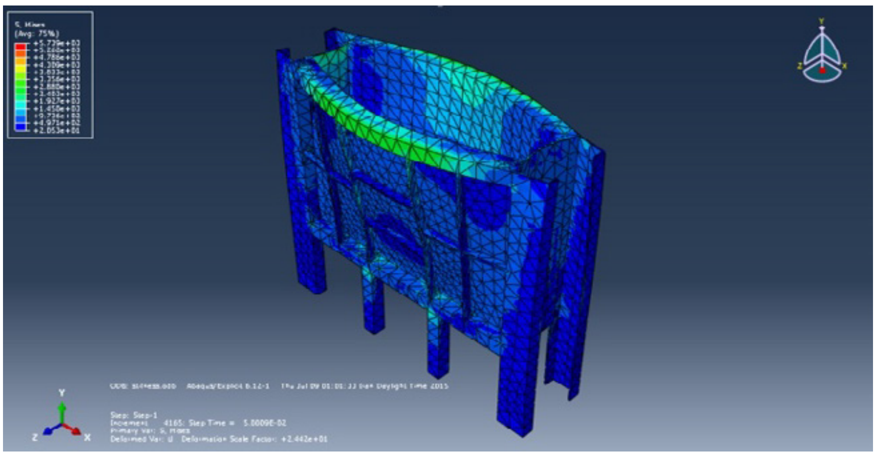

Figure 3. Modeling of the machine body in Abaqus software

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3. NUMERICAL MODEL

Abaqus software has been used for the numerical modeling of the arcing phenomenon. To choose the appropriate element classification, both element type and mesh density have been investigated. To select the proper element type in the base model, the types of introduced elements were checked. The selection of the proper kind of element is made based on the criteria of producing stress conditions. This means that the elements that can establish the stress conditions in place based on the geotechnical characteristics of the site with the highest accuracy and the lowest computational cost have been selected as the appropriate elements to continue the research. Based on the results obtained from these models and comparing the trends of crown changes with each other, the CPE4 element was selected as the most suitable type of element.

In addition to studying the element type, the effect of meshing density on the results has also been investigated. In this way, for different kinds of elements, different meshing densities were also checked and matched with the values of the in-place stresses. To choose the best density of meshing, triangular and quadrilateral elements with different thicknesses were tested, and the changes in the accuracy of the results and their quality were investigated in different modes. Based on these studies, models with coarser meshing do not have smooth behavior in presenting results, and finer meshing gives smoother results. For example, according to the results of this review and preliminary explanations, CPE4 elements with the meshing shown in Figure 4 were selected as the most suitable mode in the model.

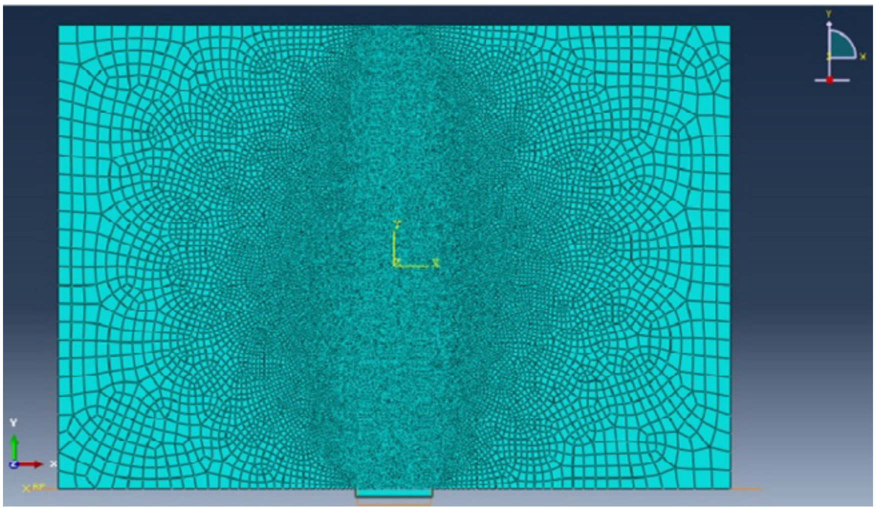

Figure 4. Selected elements in the numerical model

3.1. BEHAVIORAL MODEL GOVERNING THE ARCING PHENOMENON

The behavior before yielding is defined as linear elastic with the secant shear modulus as follows:

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$$Gs = \frac{\tau_y}{\gamma_y} \tag{1}$$

Where and are the strain and shear stress at the yield point, respectively, which can be obtained directly from the test data (the shear stress corresponding to calculating, the thickness of the shear zone must be assumed. Before the formation of the shear band, the shear strain can be seen to have an almost uniform distribution throughout the height of the specimen (D). As a result, it can be defined as follows:

$$\gamma_y = \frac{\delta\chi_y}{D} \tag{2}$$

The same can be considered for the peak shear strain as follows (assuming that the shear band has not yet formed):

$$\gamma_p = \frac{\delta\chi_p}{D} \tag{3}$$

As a result, the plastic shear strain at the peak point will be as follows:

$$\gamma_p^p = \frac{\delta\chi_p - \delta\chi_y}{D} \tag{4}$$

Young's modulus (E) is obtained from the following equation:

$$E = \frac{9KG_s}{3K + G_s} \tag{5}$$

Where K is the bulk modulus. Both the bulk modulus (K) and the secant shear modulus (G_s) are dependent on the stress level, and to consider this dependence, the following equations have been used:

$$K = K_0 \left(\frac{P}{P_{ref}}\right)^b \tag{6}$$

$$G_s = G_0 \left(\frac{P}{P_{ref}}\right)^b \tag{7}$$

Where P_{ref} is the reference pressure for which and Pressure power (b) is a component that expresses the change of elastic module with isotropic pressure. The value of b ranges from 0.435 in small strains to 0.765 in large strains according to the research of Root et al. The appropriate value for the b parameter to show the increase in shear hardness depending on the stress level is 0.5.

Poisson's ratio can be defined using the following equation :

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$$v = \frac{3K - 2G_s}{2\left(3K + G_s\right)} \tag{8}$$

In Figs. 5 and 6, respectively, the diagrams of changes in bulk modulus and modulus of elasticity against the shift in average effective stress are presented.

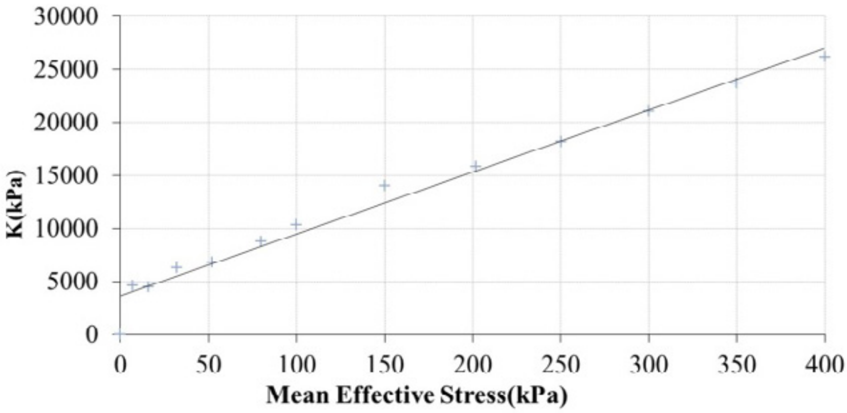

Figure 5. Diagram of bulk modulus against average effective stress

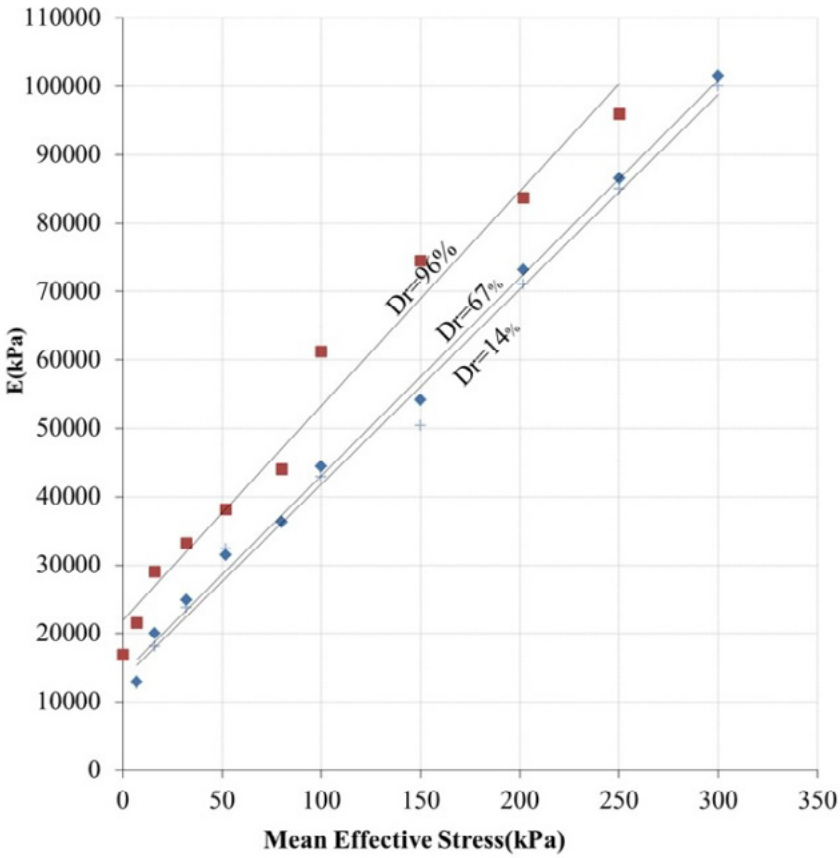

Figure 6. Diagram of modulus of elasticity - average effective stress

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3.2. RUPTURE COVER

In this research, the behavior model used for sand is the elastoplastic behavior model with the Mohr-Coulomb rupture criterion. The hardening and softening behavior dependent on isotropic strain is considered, and to apply this behavior model to the quiet finite element environment ABAQUS 2012 software is coded in FORTRAN language and introduced in ABAQUS software using Visual Studio compiler.

3.3. FRICTION HARDENING

Vermeer and de Borst proposed the equation (9) for the friction-hardening behavior of geotechnical materials, in which the mobilized friction angle (φ_m) depends on the plastic strain (γ_p) and gradually increases until it reaches the peak friction angle:

$$\operatorname{Sin} \varphi_m = 2\left(\frac{\sqrt{\gamma_p \times \gamma_p^p}}{\gamma_p + \gamma_p^p}\right) \operatorname{Sin} \varphi_p \tag{9}$$

Where γ_p^p the plastic shear strain at the peak friction angle is φ_p.

The equation (10) for the variable expansion angle is presented by Rowe, which is called the stress expansion equation and is as follows:

$$\operatorname{Sin} \Psi_m = \frac{\sin \varphi_m - \sin \varphi_{cr}}{1 - \sin \varphi_m \sin \varphi_{cr}} \tag{10}$$

$$\operatorname{Sin} \varphi_{cr} = \frac{\sin \varphi_p - \sin \Psi_p}{1 - \sin \varphi_p \sin \Psi_p} \tag{11}$$

Where Ψ_m and φ_m are the mobilized expansion angle and the mobilized friction angle, respectively, φ_{cr} is the critical friction angle or constant volume friction angle. The mobilized expansion angle is initially hostile and increases with the increase of plastic strain. To avoid this considerable negative value of the expansion angle in minor strains, the following equation was presented by Surid et al.

$$\operatorname{Sin} \Psi'_m = \sin \Psi_m \left(\frac{\sin \varphi_m}{\sin \varphi_{cr}}\right)^p \tag{12}$$

Power P controls the shape of the mobilized expansion angle and is considered 1 in this study. The change in the mobilized expansion angle with plastic strain is shown in Figure 7 for different values of P power.

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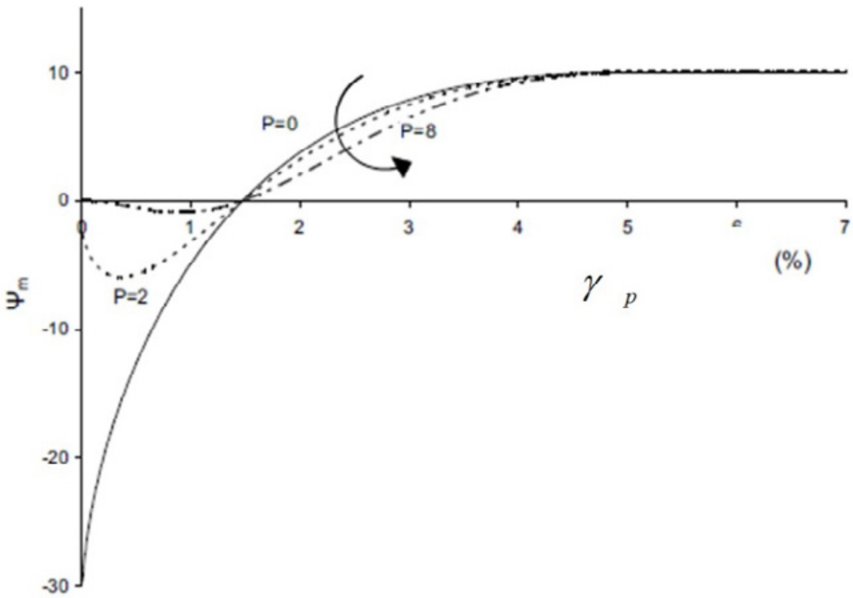

Figure 7. Change of the mobilized expansion angle with P power

3.4. FRICTIONAL SOFTENING

In the two-block shear model of Shibuya et al., it is assumed that after the formation of the shear band (just after the peak point), all plastic shear deformation is formed within the shear band, while the rest of the soil mass remains elastic. Stays assuming that the shear band width (d_B) is $16d_{50}$, where d_{50} is the average sand particle size, the plastic shear strain at which softening is complete (γ_f^p) will be:

$$\gamma_f^p = \gamma_p^p + \frac{\delta\chi_p^p - \delta\chi_y}{16d_{50}} = \frac{\delta\chi_p^p - \delta\chi_y}{D} + \frac{\delta\chi_p^p - \delta\chi_y}{16d_{50}} \tag{13}$$

The strain-dependent softening with the decrease of the mobilized friction angle φ_m and the mobilized expansion angle Ψ_m with the increase of the plastic shear strain is as follows:

$$\varphi_m = \begin{bmatrix} \varphi_p - \frac{\varphi_p - \varphi_{cr}}{\gamma_s^p}\gamma_{oct}^p & \text{for} & \gamma_p^p \leq \gamma_{oct}^p < \gamma_f^p \\ \varphi_{cr} & \text{for} & \gamma_{oct}^p > \gamma_f^p \end{bmatrix} \tag{14}$$

$$\Psi_m = \begin{bmatrix} \Psi_p\left(1 - \frac{\gamma_{oct}^p}{\gamma_s^p}\right) & \text{for} & \gamma_p^p \leq \gamma_{oct}^p < \gamma_f^p \\ \Psi_{cr} & \text{for} & \gamma_{oct}^p > \gamma_f^p \end{bmatrix} \tag{15}$$

$$\gamma_{oct}^p = \frac{2}{3}\left[\left(\varepsilon_1^p - \varepsilon_2^p\right)^2 + \left(\varepsilon_2^p - \varepsilon_3^p\right)^2 + \left(\varepsilon_3^p - \varepsilon_1^p\right)^2\right]^{1/2} \tag{16}$$

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Where φ_p and φ_{cr} are the peak friction angle and critical friction angle, respectively, Ψ_p is the peak expansion angle and the plastic shear strain at the end of softening. Also, plastic strains are the main ones.

3.5. THE DEPENDENCE OF THE FRICTION ANGLE AND EXPANSION ON THE STRESS LEVEL

Since the fact that the friction and expansion angles are dependent on the stress level, and this fact has also been observed in laboratory tests, to determine the shear strength components of sand corresponding to the stress level, direct shear tests under different stress levels were performed. In a particular soil, the value of the internal friction angle φ depends on the amount of stress applied to it. The lower the normal stress, the greater the internal friction angle φ. According to the theory of stress-expansion ratio, the amount of porosity, moisture and expansion are as necessary as the effective normal and shear stresses in analyzing the results and soil behavior. The stress-expansion ratio equation is presented as follows:

$$\frac{\tau}{\sigma} = \tan\left(\varphi_{cr} + \Psi\right) \tag{17}$$

In the above equation, the expansion angle Ψ depends on the initial conditions of the soil. In this research, the results obtained from the experiments have been modified based on the theory of the stress-expansion ratio.

The relationship between the peak friction angle and the critical friction angle can be approximated by the following equation:

$$\tan\varphi_p = \tan\varphi_{cr} + \alpha \tan\psi_p \tag{18}$$

Where α is a constant value, Shibuya and his colleagues have shown that simple shear behavior in the soil is only possible within the range of the shear band. In the box of a simple straight cutting machine (no rotation of the loading plate, smooth walls, adjustable distance between the upper and lower metal plates equal to the thickness of the cutting strip), α can be considered equal to 1. The peak friction angle in-plane strain can be calculated as follows:

$$\text{Sin}\,\varphi_p = \frac{\tan\varphi_p}{\sin\Psi_p + \sin\Psi_p\tan\varphi_p} \tag{19}$$

Figure 8 Changes in stress ratio and volume change (obtained through the vertical displacement δ_y of the upper metal plate) with the horizontal displacement δ_x in the direct shear test on "Toyura sand" in a dense state (based on the data of Shibuya et al.) is showing. According to Figure 8, soil behavior can be divided into 4 distinct parts:

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Quasi-elastic behavior (OA): Up to point A, the soil deforms quasi-elastically. The nonlinear behavior of the soil without any expansion is observed. δ_{xy} is the horizontal displacement at $\delta_y/\delta_x = 0$.

Hardening behavior (AB): From points A to B, the soil "yields" (enters the plastic zone) and expands. Point B corresponds to the peak shear stress and shows the hardening behavior of the soil. δ_{xp} is the horizontal displacement at $\delta_y/\delta_x = 0$.

Softening behavior (BC): From points B to C, the soil experiences softening behavior. Just after the peak point, a horizontal shear band extends through the middle of the sample. Softening is completed at point C. δ_{xf} is the horizontal displacement at $\delta_y/\delta_x = 0$.

Residual behavior (CD): shear accumulates along the entire length of the shear band.

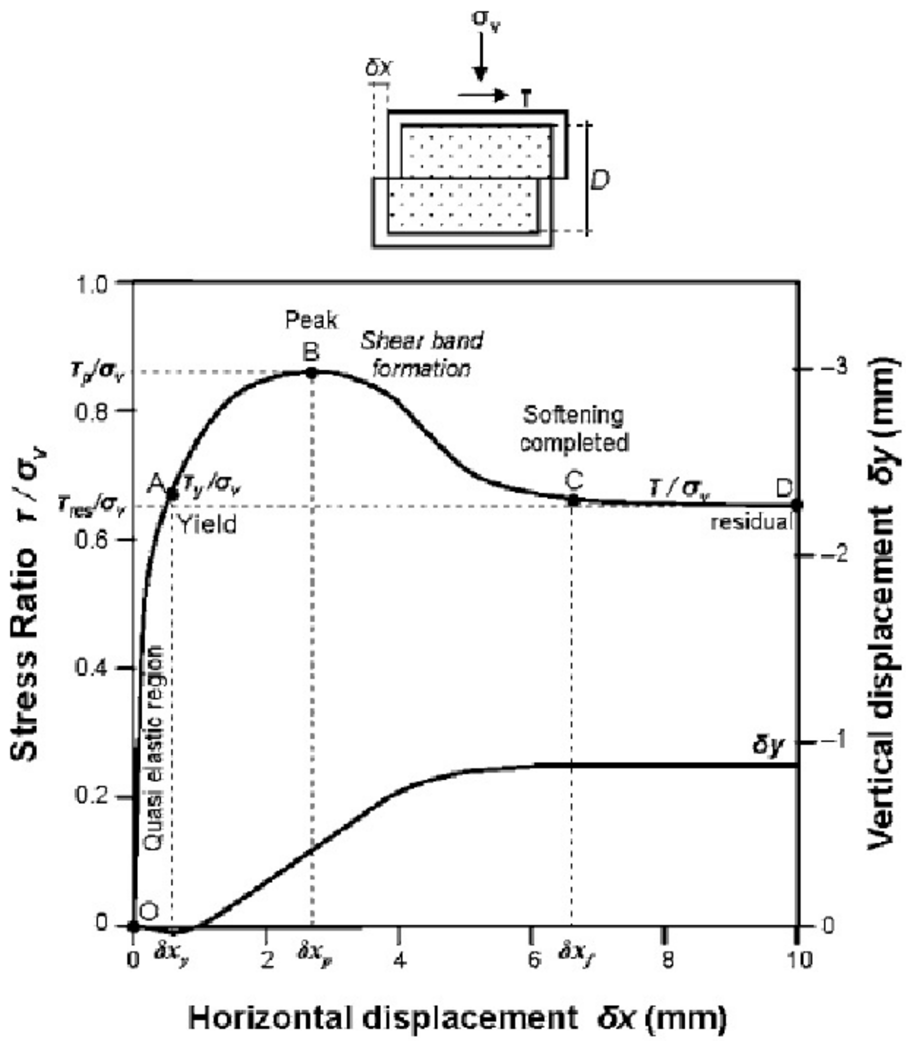

Figure 8. Changes in the ratio of stress and volume with horizontal displacement in the cutting test on Toyoura sand

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3.6. THE PARAMETERS OF THE BEHAVIORAL MODEL OBTAINED FROM THE EXPERIMENTS

The characteristics of the sand used in the research, such as modulus of elasticity, friction angle, and expansion angle, were extracted from the results of direct and triaxial cutting tests. In Tables 2-4, the properties of sand for three different relative densities of loose, medium, and dense are shown. In these tables, y_d, бn, тp, and тcr are dry density, applied normal stress, maximum shear stress, and critical shear stress, respectively. Also, φ_p, φ_{cr}, and Ψ are the peak friction angle, critical friction angle, and expansion angle, respectively, which were obtained directly from the results of the experiments. φ_{cor} is the corrected friction angle obtained from Equation (18) using Ψ and φ_{cr}. φ_{pl} is the plane strain friction angle used in the simulation and is obtained from Equation (19). δ_{xy}, δ_{xp}, and δ_{xf} are the horizontal displacements of the shear box at the yield, peak, and critical points, and the strains corresponding to yield points are peak and critical. For example, the diagrams related to the behavioral model and the changes in the internal friction angle and the expansion angle with plastic strain for a relative density of 25% are presented in Figures 9 to 11.

Table 2. Material properties from experimental tests for dense sand (Dr=92%).

No	Dr	Ψ	φcor (corrected)	φpl (plane strain)	γ_y	γ_p	γ_f
1	92	6.27	47.80	57.36	0.00	0.10	0.27
2	92	5.03	44.70	53.65	0.00	0.11	0.21
3	92	4.81	36.89	44.26	0.00	0.11	0.26
4	92	4.80	41.15	49.38	0.00	0.11	0.27
5	92	4.74	46.28	55.53	0.01	0.11	0.27
6	92	4.54	41.48	49.78	0.01	0.12	0.24
7	92	4.56	36.52	43.83	0.01	0.10	0.26
8	92	4.45	36.25	43.50	0.01	0.16	0.26
9	92	4.36	35.53	42.63	0.01	0.13	0.26
10	92	3.59	34.56	41.41	0.01	0.16	0.24

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Table 3. Material properties from experimental tests for sand with medium density (Dr=68%).

No	Dr	Ψ	φcor (corrected)	φpl (plane strain)	γ_y	γ_p	γ_f
1	68	6.92	45.45	54.55	0.00	0.26	0.35
2	68	6.63	45.20	54.24	0.00	0.22	0.28
3	68	5.47	42.00	50.40	0.00	0.16	0.24
4	68	4.04	43.83	52.60	0.00	0.14	0.22
5	68	3.85	43.86	52.63	0.01	0.16	0.29
6	68	3.01	36.87	44.24	0.01	0.11	0.27
7	68	2.53	41.04	49.25	0.01	0.15	0.24
8	68	2.04	39.31	47.18	0.01	0.14	0.32
9	68	1.74	39.81	47.77	0.01	0.14	0.28
10	68	0.70	38.51	46.22	0.01	0.14	0.22

Table 4. Material properties from experimental tests for loose sand (Dr=25%).

No	Dr	Ψ	φcor (corrected)	φpl (plane strain)	γ_y	γ_p	γ_f
1	25	8.87	40.07	48.09	0.00	0.22	0.30
2	25	7.41	35.13	40.54	0.00	0.24	0.29
3	25	7.33	34.08	38.87	0.00	0.21	0.31
4	25	4.22	30.60	34.63	0.00	0.17	0.27
5	25	2.47	38.97	51.48	0.01	0.22	0.29
6	25	1.81	35.71	44.69	0.01	0.17	0.29
7	25	1.05	34.61	42.97	0.01	0.19	0.32
8	25	0.51	33.93	41.97	0.01	0.17	0.31
9	25	0.82	33.05	40.14	0.01	0.27	0.32
10	25	0.10	32.17	38.93	0.01	0.32	0.42

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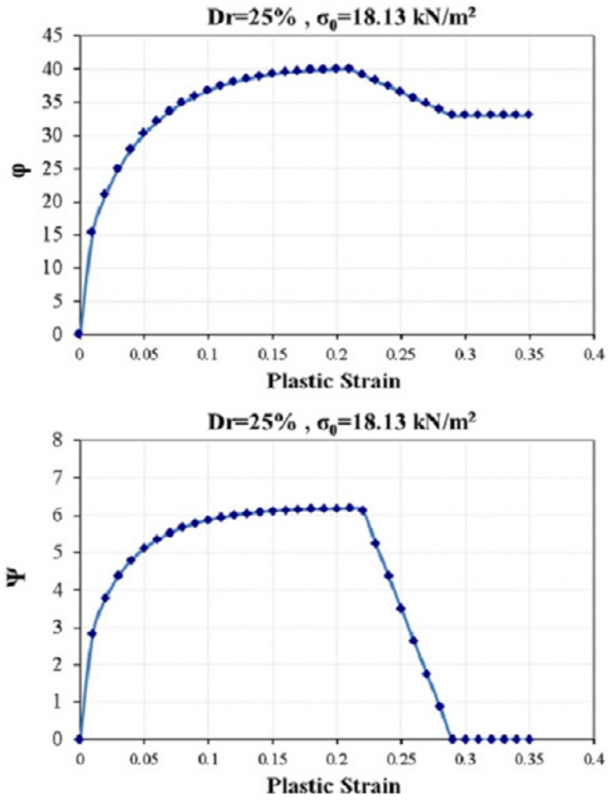

Figure 9. Changes of internal friction angle and expansion angle for relatively loose sand with low head load. (Dr=25%, ϭn=18.13KN/m3)

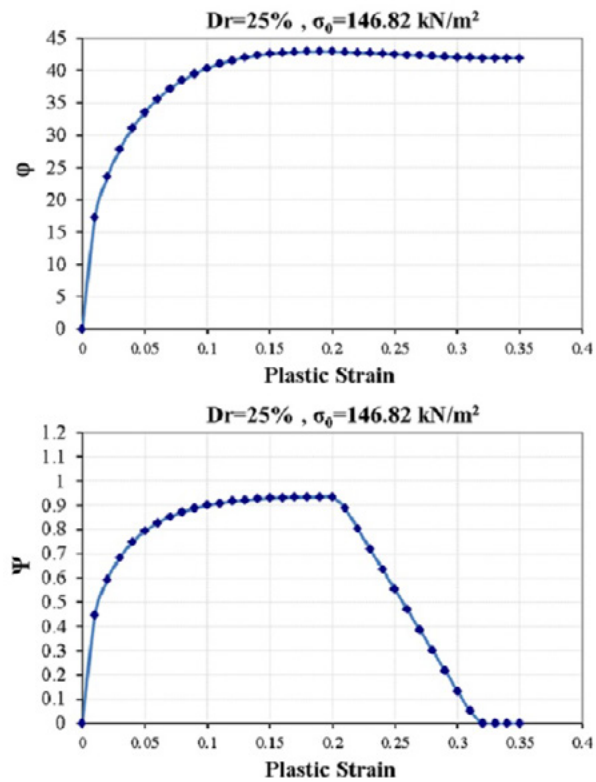

Figure 10. Changes of internal friction angle and expansion angle for relatively loose sand with medium overhead. (Dr=25%, ϭn=146.82KN/m3)

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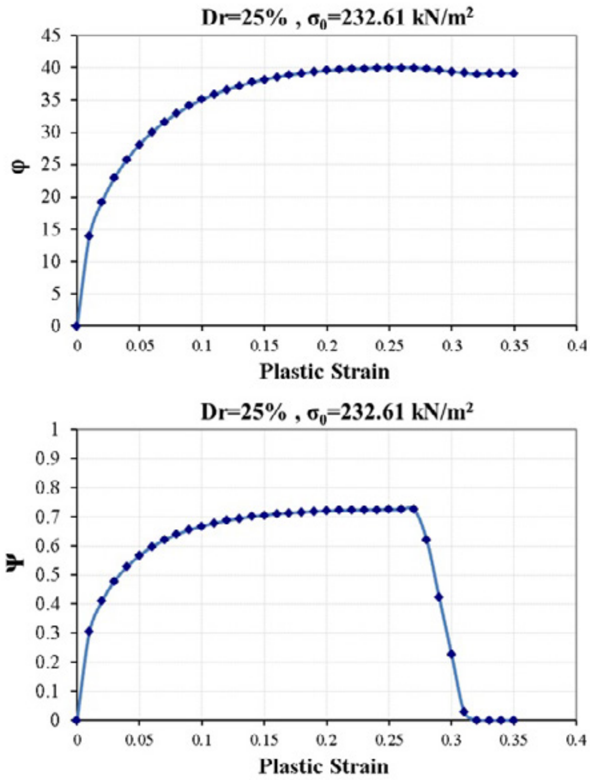

Figure 11. Changes of internal friction angle and expansion angle for relatively loose sand with high overhead. (Dr=25%, ϭn=232.61KN/m3)

3.7. CALIBRATION OF THE BEHAVIORAL MODEL

To calibrate the presented behavioral model, the direct cutting test was simulated in Abaqus software, and the obtained results were compared with the data obtained from the tests. In the simulation of the direct shear test, due to the lack of change in the stress level during a trial, the elastic modulus is defined as a constant value during the analysis, Still, in the simulation of different tests, the elastic modulus is changed based on the normal stress level. The finite element model and plastic strain gauge are shown in Fig. 12. As an example, Fig. 13 shows the graphs of shear stress and horizontal displacement as well as the vertical displacement and horizontal displacement in experimental tests and numerical modeling under different normal stresses for a relative density of 95%. The comparison between simulated and experimental curves shows their agreement. Therefore, the strain-dependent hardening-softening model should be used in simulating the behavior of granular soils in conditions where deformations are similar to direct shear tests.

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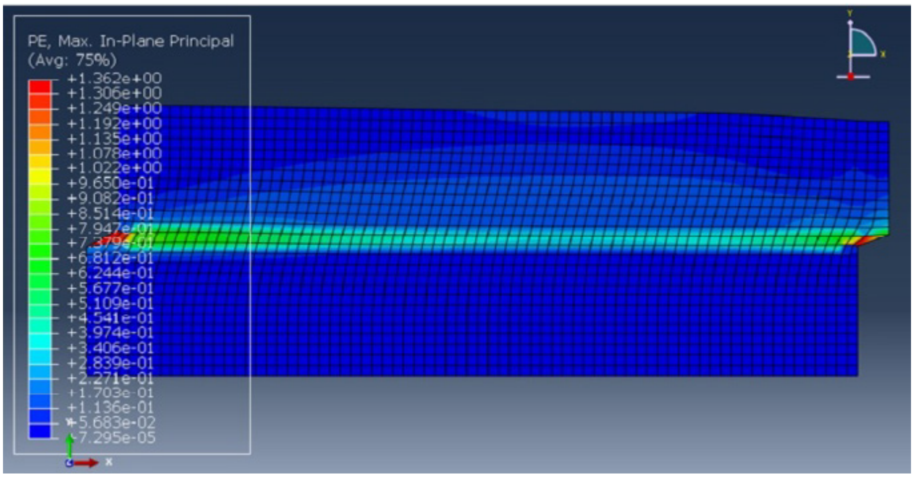

Figure 12. Meshing and plastic strain counters in the numerical model of direct cutting

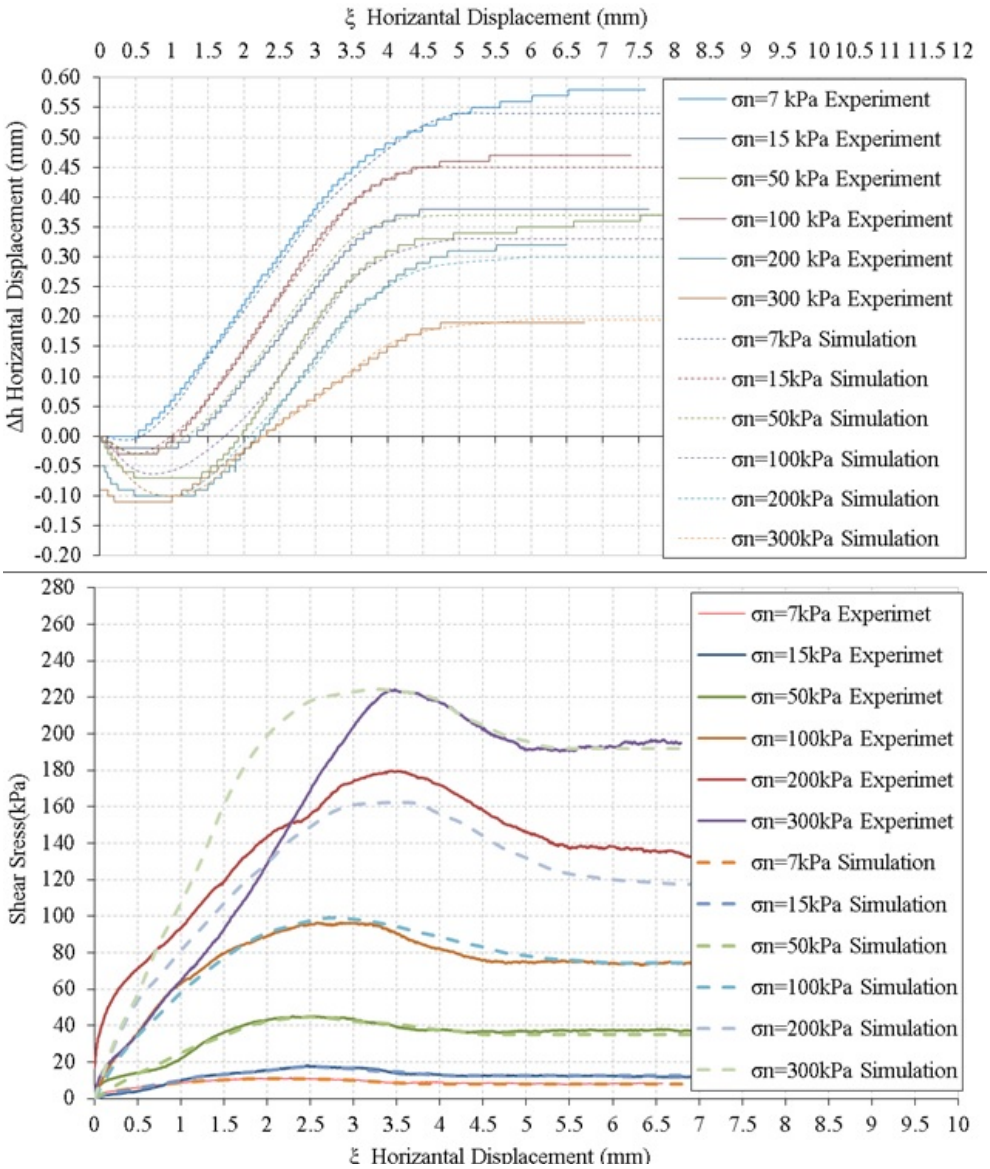

Figure 13. Comparison between shear stress-horizontal displacement and vertical displacement-horizontal displacement in the experiment and numerical results for dense sand (Dr=95%)

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3.8. NUMERICAL MODEL OF ARC PHENOMENON AND MODELING ASSUMPTIONS

Numerical modeling of the arcing phenomenon has been done in Abaqus software, 2012 edition. The numerical model was created in the graphical environment of the software in such a way that it accurately evokes the laboratory conditions. This numerical model includes three separate parts of the soil mass, tank, and valve, which are mounted together in the Assembly section of the software. The lateral boundaries include supports with degrees of freedom in the vertical direction, and the bottom part of the soil rests on the defined tank. The interaction between different elements is modeled according to actual conditions. In this way, the interaction between the tank and the soil is frictional for sliding movement and hard contact for motion perpendicular to the plane. The coefficient of sliding friction between the tank and the soil is considered equal to 0.3. This number is obtained from the tensile test of the painted metal plate buried in the test sand. A measurement of the rigid contact type leads to the soil elements not passing through the tank elements. Such an interaction is also considered for the soil and valve interaction. To remove the stress concentration in the sharp corner after lowering the valve, the sharpness of this part of the tank has been removed with the help of bending with a minimal radius.

Among the basic cases in modeling the phenomenon of arcing of elements, especially in the areas around the valve. The large size of the components leads to the occurrence of errors in the analysis and the failure of the flow phenomenon during the event of the arcing phenomenon, at the same time, the smallness of the elements also leads to the bulkiness of the analysis and the excessive increase of the analysis time. Therefore, choosing the right size for the details requires trial and error and comparing the results. Of course, the meshing was done according to the capabilities of the software in such a way that the size of the elements around the valve and places with higher strain is smaller and gradually towards the boundaries of the model, with a lower strain rate, the size of the elements increases.

The analysis has been done in two stages, which can be defined in the Step section of the software:

1. The stage of establishing the initial stress is defined as Geostatic in the model.

2. The opening stage of the valve and the beginning of the arcing phenomenon.

In the Abaqus software, it is impossible to define the modulus of elasticity and variable friction angle directly in the graphic part. Of course, the elasticity modulus depending on the stress level, can be determined through the Edit Keywords module. To apply frictional hardening and softening depending on the plastic strain, a program was written in FORTRAN space. This program is compiled through the Visual Studio interface and used in ABAQUS software. In this way, the variable internal friction angle and dependent on plastic strain can be defined in the software. Figs. 14 and 15, respectively show the numerical model along with the boundary conditions and the

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valve along with the reservoir defined with the curvature applied to reduce the stress concentration.

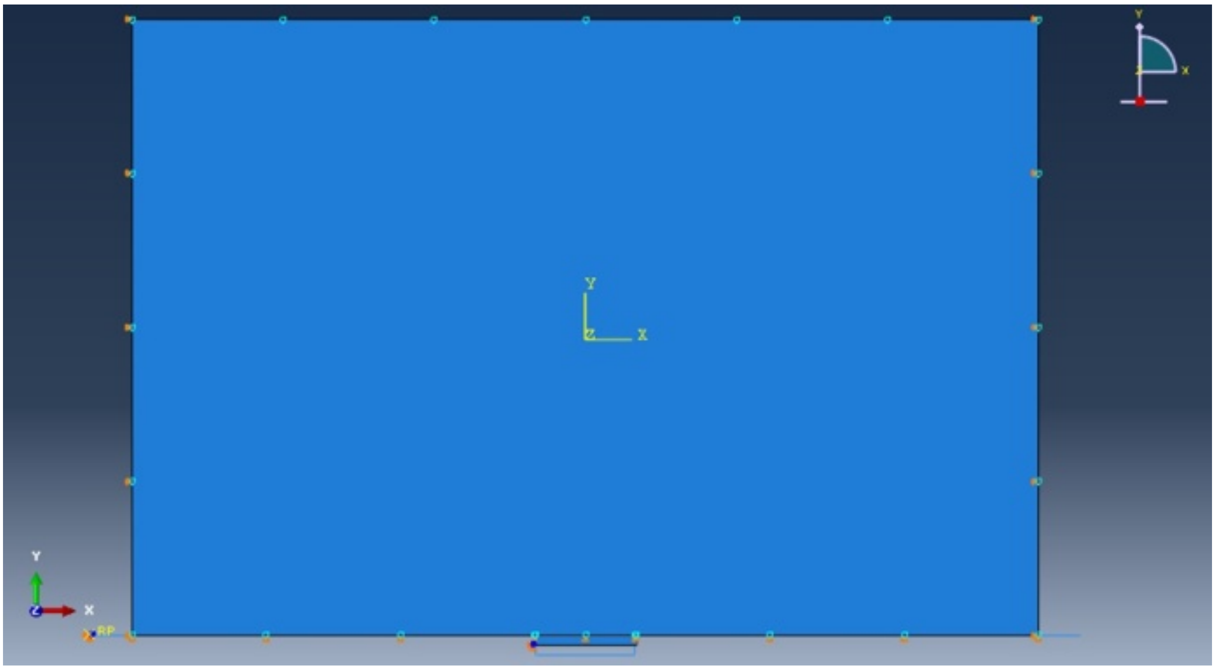

Figure 14. Numerical model and boundary conditions

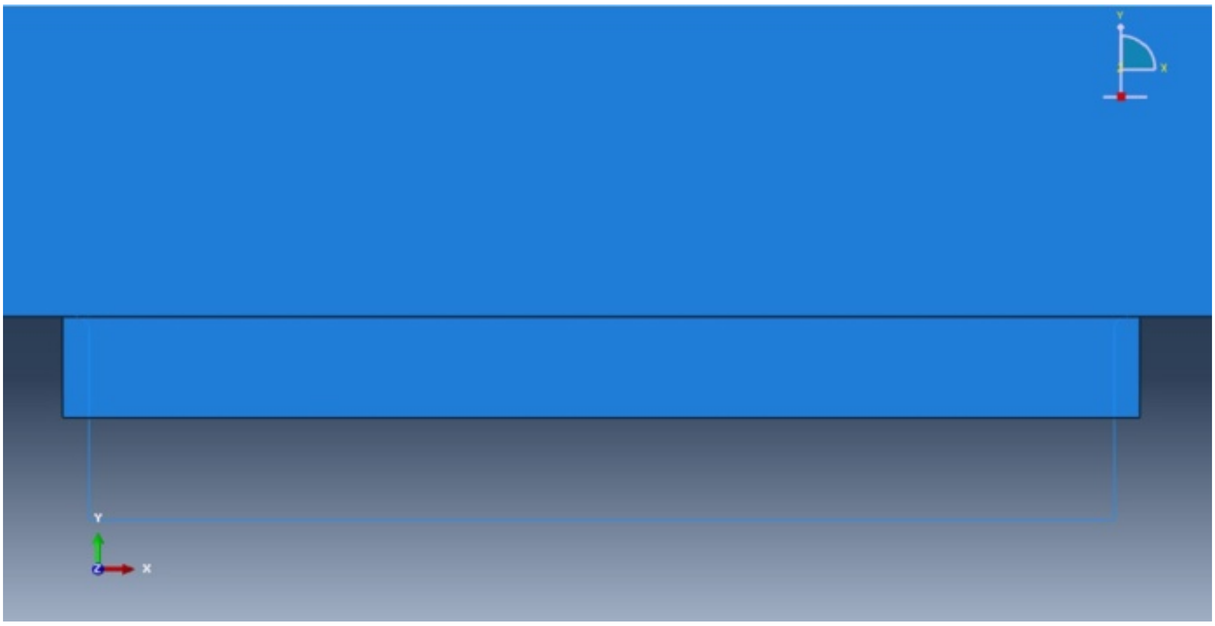

Figure 15. Numerical model and valve modeling details

3.9. ELIMINATING THE EFFECT OF THE ARC IN THE PLACE OF STRESS GAUGES

The research conducted on strain gauges and sensors installed in dams and roads shows an arc effect in their readings, which should be considered in the data used. Islam and his colleagues, in 2014, with finite element analysis and modeling of the strain gauge installed on the road, estimated the amount of arc effect in the strain gauge reading from 2.21 to 2.72 percent. In this research, by using two strain gauges installed in the middle part of the tank and comparing the initial stresses shown by the strain gauges with the calculated stress, the value of the arcing effect was obtained in about 2.5 to 2.8 percent, and the reading data has been modified accordingly.

4. EXPERIMENTS CONDUCTED ON THE PHYSICAL MODEL

Table 5 summarizes the conditions governing the experiments and the results obtained. In the first column of the table (Test No.), the number of the test is inserted in the order it was performed. In the second column (Trapdoor width), the width of the valve used in the experiment is shown. In the third and fourth columns (γ, γd), the amount of wet and dry density of sand in terms of kilonewtons per cubic meter is included in each test. In the fifth column, the relative density (Dr), and the sixth column (σ0), the value of the initial stress applied to the valve without any displacement to the valve or strain in the sand, i.e., γh where γ is the density of the sand and h is the height of the sand to its surface. In the eighth column (σmin), the value of the minimum stress applied to the valve, which was read on the strain gauge during the test, is entered. In the ninth column (Surcharge Pressure), the amount of overhead applied in different tests is presented.

In the following, the results obtained from the experiments are presented as graphs. In these diagrams, the stress applied to the valve, is measured in kilonewtons, is read from the strain gauge installed under the valves and plotted against the displacement of the valve. Because the graph in the direction of ΔH was very long and it was not possible to reach a conceptual and understandable diagram, therefore a logarithmic scale was used in the direction of ΔH. Also, in the direction of ΔH, the numbers read from the chart should be divided by 100 to get the actual displacement of the valve in millimeters.

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Table 5. Specifications governing each experiment and the results obtained

Test NO.	Trapdoor Diameter	γ (kN/m^3)	γ_d (kN/m^3)	Dr (%)	σ_0 (kpa)	Surcharge Pressure (kN/m^2)
1	10	13.80	13.16	25	8.23	---
2	10	15.60	12.75	68	7.95	---
3	10	16.90	14.21	92	8.88	---
4	20	13.80	14.88	25	8.01	---
5	20	15.60	14.88	68	9.3	---
6	20	16.90	12.75	92	8.01	---
7	30	13.80	12.83	25	8.01	--
8	30	15.60	14.88	68	9.35	---
9	30	16.90	14.97	92	9.35	---
10	35	13.80	12.7	25	9.35	---
11	35	15.60	13.68	68	8.54	---
12	35	16.90	13.68	92	8.54	---
13	35	15.60	14.02	68	8.76	128
14	35	15.60	14.09	68	8.8	212

4.1. THE RESULTS OF THE DATA OF THE STRESS GAUGE INSTALLED ON THE VALVE AND IN THE MIDDLE OF IT (S1).

In Fig. 16, the results of the tests performed in three relative densities of 25%, 68%, and 92% for the valve with a width of 10 cm are presented. As can be seen, after the start of valve movement, the stress immediately drops to about 4% of the initial stress. This minimum stress occurs when the valve moves about 0.06 mm. Then, as the valve continues to move, the tension is constant, and when the valve moves about 1 mm, the tension increases up to 6% of the initial tension and remains almost constant. With the change of the relative density, this stress ratio has changed, so the stress ratio is the highest in the relative density of 25% and the lowest in the relative density of 92%. In this case, it can be said that a stable arc is formed in all tests.

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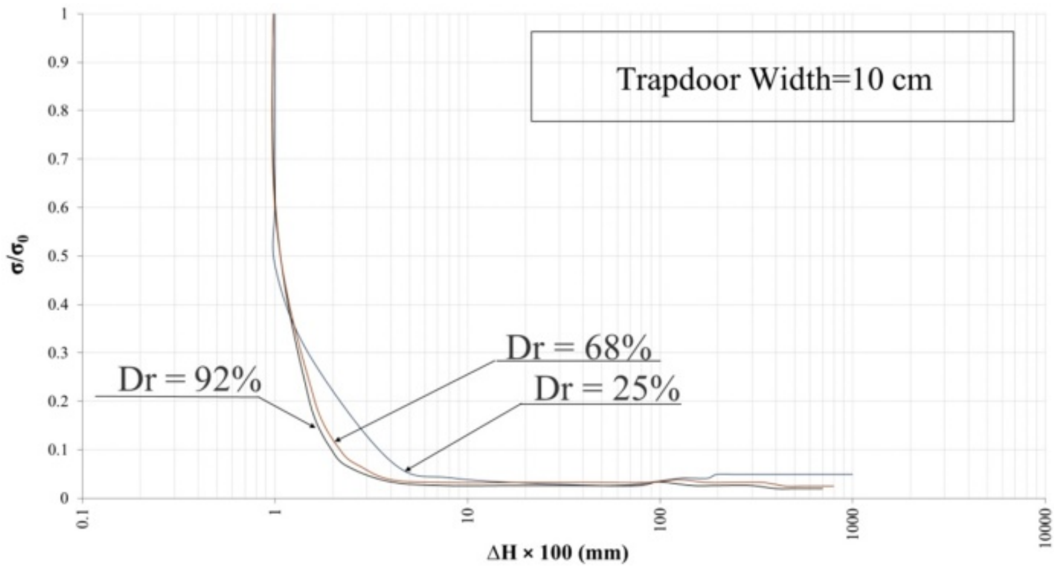

Figure16. Stress diagram in the middle of the 10 cm valve against the change in valve location

In all the graphs, the stress value has decreased sharply at low strains, and after reaching a minimum value, it has taken an upward trend. The minimum amount of stress applied to the valve occurred in the displacement of 0.02 to 0.3 mm of the valve.

As it is clear from these diagrams, four distinct phases can be distinguished in the arc phenomenon:

The first phase: This phase starts immediately after the start of the valve drop, so that the tension applied to the valve is immediately and strongly reduced and reaches the minimum value. In this phase, the soil behaves elastically, and the deformations are small, while the stress changes are huge. At the beginning and before moving the valve, the shear stress values in the sand mass and around the valve are zero, and the principal stresses are vertical and horizontal. As the valve begins to move around the arch area, the shear stress starts to increase, and as a result, the principal stresses deviate from the vertical and horizontal state and rotate. In fact, in this phase, in arc development, the principal stress plane turns by creating shear stresses. So that the value of the principal stresses is reduced to the minimum and the principal stresses are increased to the maximum. In other words, the diameter of Mohr's circle increases in the arched area. This process of changes in the plane of principal stresses continues until the formation of a stable arch.

The Second phase: This phase starts after the minimum stress point. This phase occurs in a wide range of valve displacement and the range of development of plastic strains. In the second phase, plastic strains and, finally, warping start from the side of the valve and proceed in the direction perpendicular to the two ends of the valve towards the surface. Convergence or divergence of this development of plastic strains and rupture depends on the density of the soil and the width of the valve, which determines the stable or unstable arch. In this phase, the phenomenon of flow

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occurs in the soil mass, so that despite high strains, there is no significant change in the applied stress on the valve.

The third phase: This phase begins with an increase in the applied tension on the valve. At this stage, the separation and formation of a stable arc take place. If there is no stable arc, the rising trend of tension continues.

The fourth phase: In this phase, the total weight of the stable arc is applied to the tension gauge, and the applied tension on the valve remains almost constant. In case of an unstable arc in this phase, the tension will be steady and increasing.

These separate phases are presented in Fig. 17 .

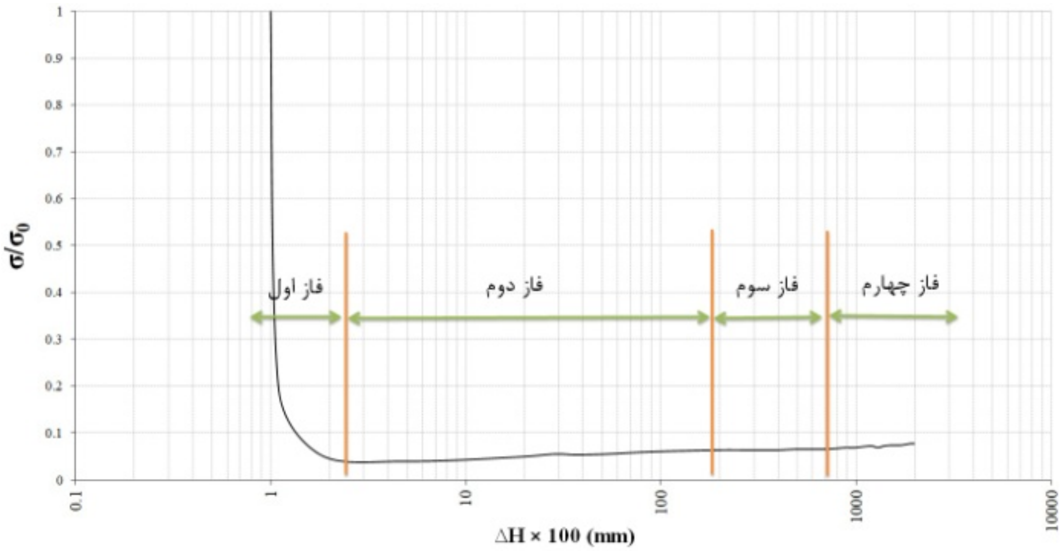

Figure 17. Four distinct phases of stress changes

4.2. COMPARISON OF THE LABORATORY RESULTS WITH THE NUMERICAL MODEL, TAKING INTO ACCOUNT THE DATA OF THE STRESS GAUGE INSTALLED ON THE VALVE AND IN THE MIDDLE OF IT.

The S16 strain gauge was installed in the middle of the valve and recorded the changes in tension during the movement of the valve. To compare the results obtained from the physical model and numerical modeling, the results have been drawn in a single diagram for the stress applied in the middle of the valve. In the numerical model, the element, such as the location of the stress gauge S16, is selected, and its results are presented. Fig. 18 shows an example of graphs obtained from laboratory data and numerical analysis results for a valve with a width of 10 cm and a relative density of 25%. As can be seen, the trend of changes in stress ratio with valve drop in both graphs obtained from experiments and numerical analysis is almost the same. Of course, there is a small difference of about 5% to 10% between the values of the stress ratios, which is caused by the error of the experiment and numerical analysis. It should be noted that with the increase in relative density, the difference between the results of experiments and numerical analysis has decreased. This is due to the reduction of the error caused by the uniformity of the sand, as well as the more excellent compatibility of the parameters obtained from the direct cutting tests and the arc mechanism. As can be seen, in the diagram related to the numerical model, as well as the physical model, the four regions defined in the previous section can be distinguished. Of course, to reduce the error in low relative densities, the size of the elements was increased so that the dimension of the component is as close as possible to the width of the cutting area. However, this reduced the slope of the elastic region and the rate of displacements and strains, especially in the part of the flow phenomenon. In other valves, the agreement between the results of the experiments in the physical model and the numerical model is evident.

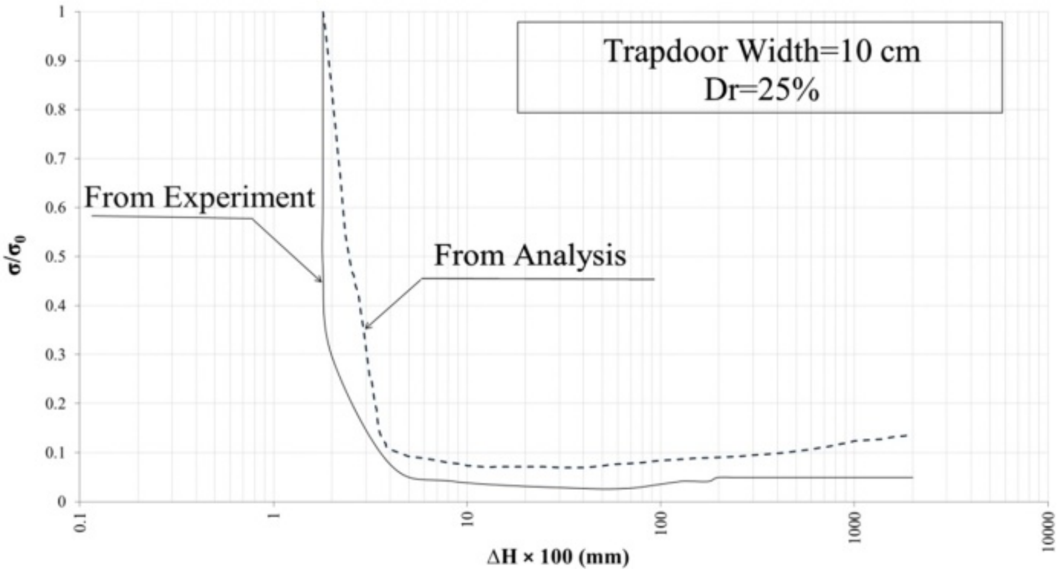

Figure 18. Comparison of the results of the physical model and the numerical model for a valve with a width of 10 cm and a relative density of 25%.

According to these results, it can be seen that by moving the valve downwards, the stress applied on the strain gauge drops drastically, and in the elastic range, this stress drop is very severe. As the valve moves, this drop continues with a gentler slope until it reaches a minimum value and an insignificant number near zero. Of course, this state occurs in a stable arc, and when an unstable arc occurs, the amount of increase in the stress applied to the strain gauge can be seen within the range of 10 mm displacements of the valve. Also, the agreement of the numerical modeling results with the results obtained from the physical model increases with increasing density.

4.3. THE RESULTS OBTAINED FROM THE PIV METHOD CONCERNING THE MEASUREMENT OF STRAINS DURING THE OCCURRENCE OF THE ARCING PHENOMENON

The PIV method has been used to measure the strains created during the arcing phenomenon. Fig. 19 shows an example of the results of the analysis of strains during the event of the arch phenomenon for a displacement of 10 mm of the valve. In this image, the upper and left figures are the color counters of the strains, and the upper right figures are the alignment lines of the strains. Also, in the diagram shown, the diagrams related to the strain changes corresponding to the location of stress gauges S18 to S23 (valve sides) are presented. As can be seen, the shear strain meters show a stable arc. Also, in these figures, the graphs related to the strain changes at 5 points where the strain gauge is installed, against the displacement of the valve, show that the relationship between the strain changes and the valve displacement is almost linear. Also, most strains are related to the sides of the valve. In the case of not creating a stable arch, the shape, and development of shear counters are different. Fig. 20 shows the shear strain counters of the unstable arch for a valve with a width of 30 cm and a relative density of 25%. The development of shear strains in this form is initially in the converging direction and towards the formation of a stable arch, still the continuation of the process of moving the valve, the shear strains developed towards the sand surface and led to the instability of the arc. While with the densification of the sand, the rate of formation of a stable arc is higher, and it does not allow the total rupture of the sand mass and a stable arc is formed. The development of shear strains first converged towards the formation of a stable arc, but at the same time, the vertical component of the shear strains developed towards the sand surface and led to the non-formation of a stable arc. Of course, with the densification of the sand, the strains are reduced, and the tendency to converge and form a stable arc is evident. Also, with the densification of sand, the growth rate of shear strains decreases.

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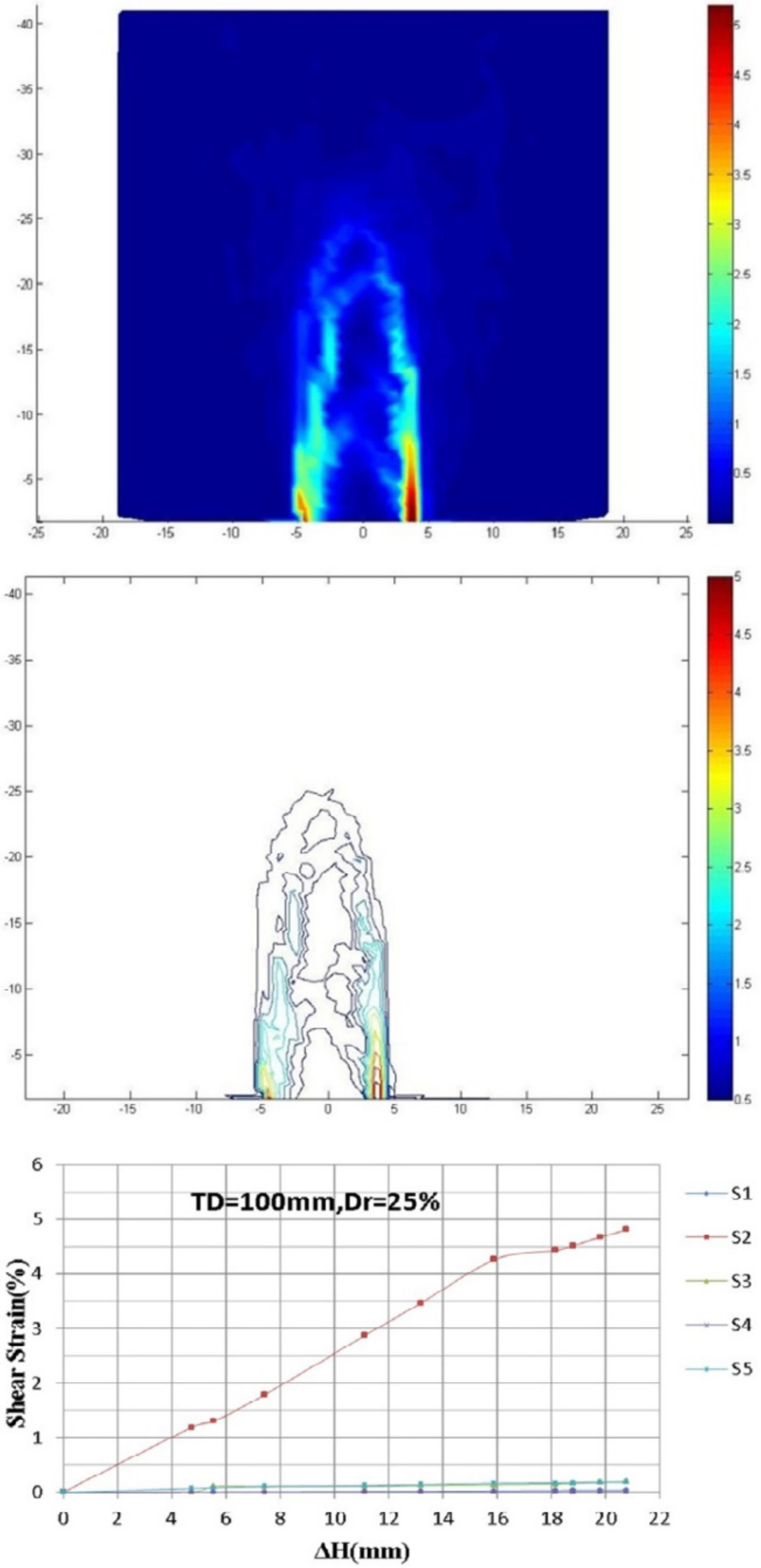

Figure 19. The results of PIV method for a valve with a width of 10 cm and a relative density of 25% .

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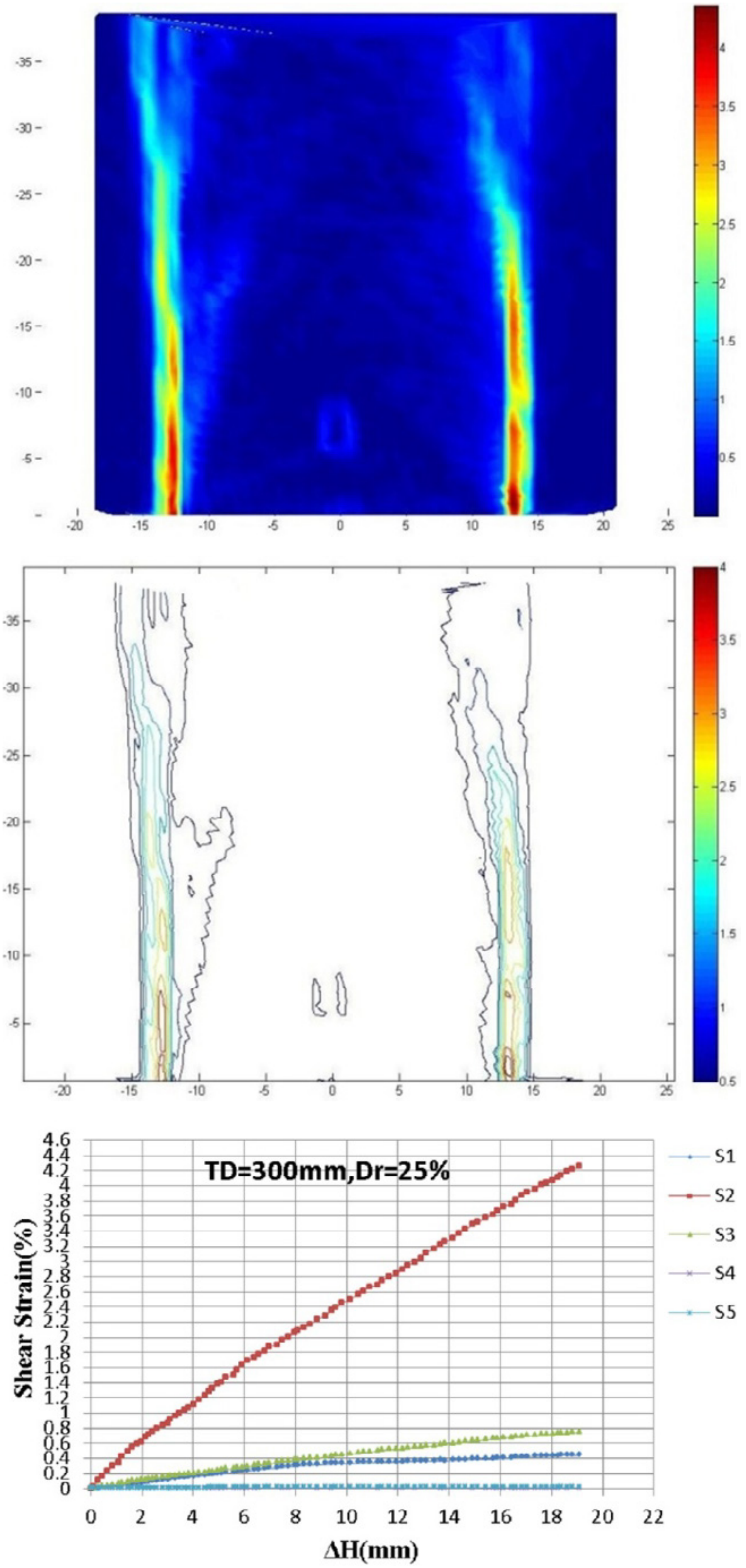

Figure 20. The results of the PIV method for a valve with a width of 30 cm and a relative density of 25%.

4.4. THE RESULTS OF STRAIN ANALYSIS

Based on the results of experiments and numerical modeling, after the occurrence of the arch phenomenon, four separate areas can be distinguished in terms of the behavior of the sand mass.

The first area: In this area, the soil mass behaves elastically, and the sand mass moves in general, and the particles do not have any relative movement to each other.

The second area: In the second area, a shear band is formed, and during the expansion of the arch phenomenon, it develops towards the crown of the arch, and the sand shows softening behavior.

The third area: the stresses in this area increased with the development of the arch phenomenon, and the sand mass shows hardening behavior. This area acts as a column to transfer stress to the foundation. Of course, this area is moved to the sides with the movement of the valve, and its position depends on the rate of motion of the valve.

The fourth area: This part has not been affected by the arching phenomenon, and the stresses and strains in this area remain almost constant during the arching phenomenon.

These four areas are shown in Fig. 21 .

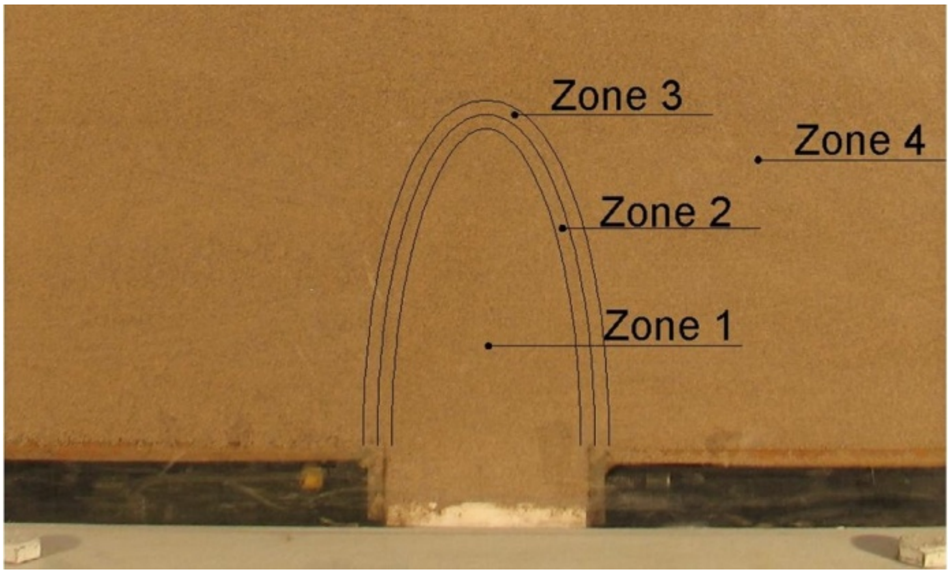

Figure 21. Four separate areas in terms of the behavior of the sand mass

5. THE NATURE OF THE FLOW PHENOMENON IN THE ARCING PHENOMENON

As mentioned, when the valve starts to move downward, a sharp and rapid drop in the amount of stress on the valve is immediately observed, which is due to the transfer of stresses to the fixed sides in the range of elastic strain. Then, by minimizing the stress on the valve by moving it more and applying more strains to the soil, the amount of stress on the valve does not change, and the stress remains constant in a wide range of plastic strains, especially at the edges of the valve. This phenomenon is called flow, which isn't associated according to the definition of the expansion angle dependent on plastic strain in numerical modeling and the acceptable agreement of the results of the numerical model with the results of the experiments. Also, the phenomenon of flow and application of large strains, which is the nature of the arch phenomenon in the sand, is well modeled in the finite element method, in Fig. 22, these large deformations in the elements can be seen well.

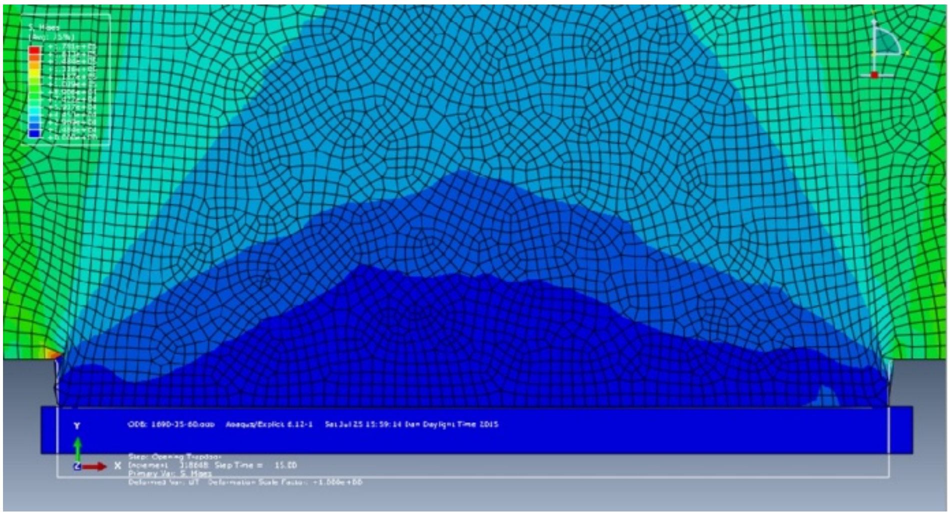

Figure 22. Large deformations applied to the elements in the finite element method

6. TENSION SPACE IN THE SELECTED BEHAVIORAL MODEL

The selected behavioral model for numerical analysis can be divided into two separate parts, elastic and plastic. In the flexible section, with the increase in the stress level, the modulus of elasticity increases until the sand reaches the yield point. When the sand comes to the yield point, the plastic stage begins, and the behavior leaves the elastic region. In the plastic area, depending on the plastic strain rate, there are two behaviors hardening and softening. According to the mentioned zoning, depending on the position considered for it, in each of the areas, the sand element can have a hardening or softening behavior or both behaviors. In the numerical model, according to the definition of the plane strain state, the stress path at different points is obtained using the following relations.

Plain Strain;

$$\varepsilon_2 = 0$$

$$p' = \frac{\sigma_1' + \sigma_2' + \sigma_3'}{3} \quad \text{and} \quad p = \frac{\sigma_1 + \sigma_2 + \sigma_3}{3}$$

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$$p' = p - u$$

$$q = q' = \frac{1}{\sqrt{2}}\left[\left(\sigma_1' - \sigma_3'\right) + \left(\sigma_1' - \sigma_3'\right) + \left(\sigma_1' - \sigma_3'\right)\right]^{1/2}$$

$$\varepsilon_p = \varepsilon_1 + \varepsilon_3$$

$$\varepsilon_q = \frac{2}{3}\left(\varepsilon_1^2 + \varepsilon_3^2 - \varepsilon_1\varepsilon_3\right)^{1/2}$$

As stated in the previous sections, four separate areas can be distinguished in the arcing phenomenon. These areas are shown in Fig. 17. To investigate the approach to stress in each area, a point has been selected, and the approach to stress in these points has been discussed. For example, numerical modeling results have been chosen for a relative density of 25% and a valve width of 10 cm.

6.1. THE STRESS SPACE OF AREA 1 (ELASTIC AREA)

In Fig. 23, the diagram related to the path of stress in the space of P and q is presented at a point located in zone 1 in a valve with a width of 10 cm and a relative density of 25%. Also, in Fig. 23, specific volume changes in P and v space are shown.

According to Fig. 22, P and q decrease rapidly at the beginning of the experiment. After reaching a minimum value, the reduction rate of q decreases, and the sand enters the flow phenomenon. In the range of occurrence of the flow phenomenon, the value of q has decreased much less, while the rate of decrease of p is very high. As the valve continues to go down, the average and shear stresses start to decrease again, this process continues until the end of the test, until it finally reaches a constant value in the shear stress. This is although the specific volume has not changed much during the trial and is almost constant. In the area of a mass of sand, it is entirely and without strain changed by the displacement of the valve, and the average and shear stresses are reduced at different rates depending on the amount of displacement of the valve. It can be said that Region 1 remains in the elastic range due to the meager amount of strains generated during the arch phenomenon, and only changes in the modulus of elasticity depending on the stress level are effective in this range.

In the graphs related to Figs. 23 and 24, the direction of the arrow represents the direction of changes in stresses and specific volume during the test.

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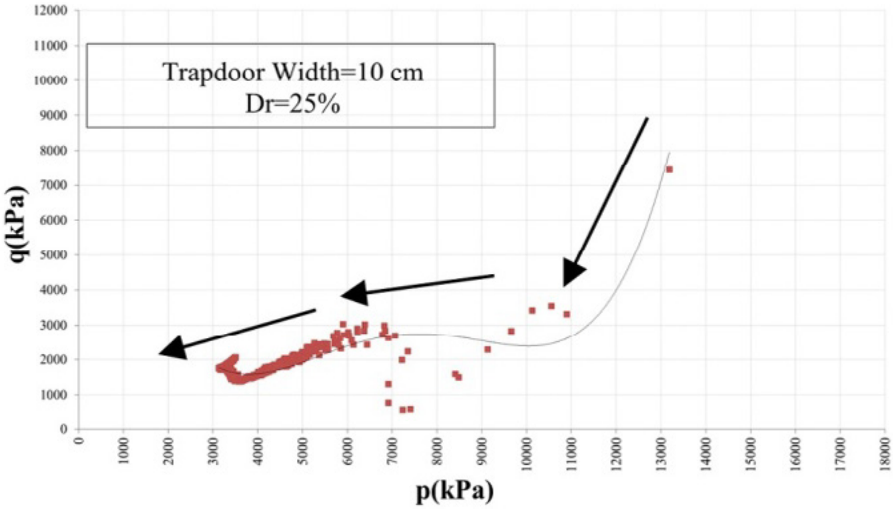

Figure 23. Diagram of stress path in p and q space for the point located in area 1

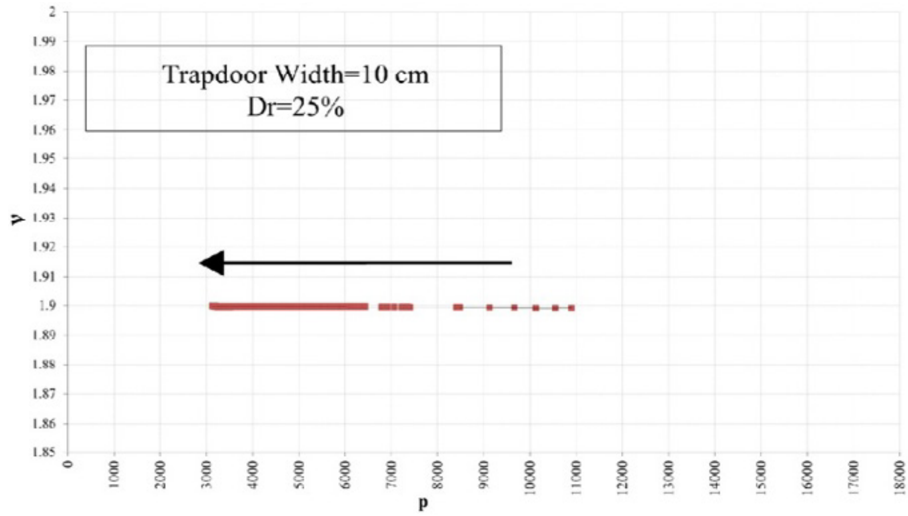

Figure 24. Diagram of stress path in p and v space for the point located in area 1

6.2. THE STRESS SPACE OF ZONE 2 (SOFTENING ZONE)

In Fig. 25, the diagram related to the path of stress in the space of P and q is presented at a point located in the expansion of the plastic points and the place of rupture (region 2) in the valve with a width of 10 cm and a relative density of 25%. Also, in Fig. 25, specific volume changes in P and v space are presented.

According to Fig. 25, P and q decrease rapidly at the beginning of the experiment. After reaching a specific value, the reduction rate of q is reduced due to the phenomenon of flow, the rate of extreme changes is related to the average stress. In the area where the flow phenomenon occurs, the value of q has decreased much less, while the rate of decrease of p is very high. As the valve goes down, the stresses continue in a straight line and on the critical line (CSL) until the end of the test. In this area, according to the diagram presented in the plastic strain range, the sand shows a softening behavior on the critical state line with an almost constant

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slope that can be calculated from the internal friction angle of the sand in the residual state, the path continues itself. In Fig. 26, with the beginning of the test and with the reduction of the average stress, the specific volume increases upon reaching the critical line, and the rate of growth in the particular volume increases until it reaches the maximum value. In fact, in this diagram, in the area where the flow phenomenon occurs, the specific volume change rate is much lower than in other areas.

In the graphs related to Figs. 25 and 26, the direction of the arrow represents the direction of changes in stresses and specific volume during the test.

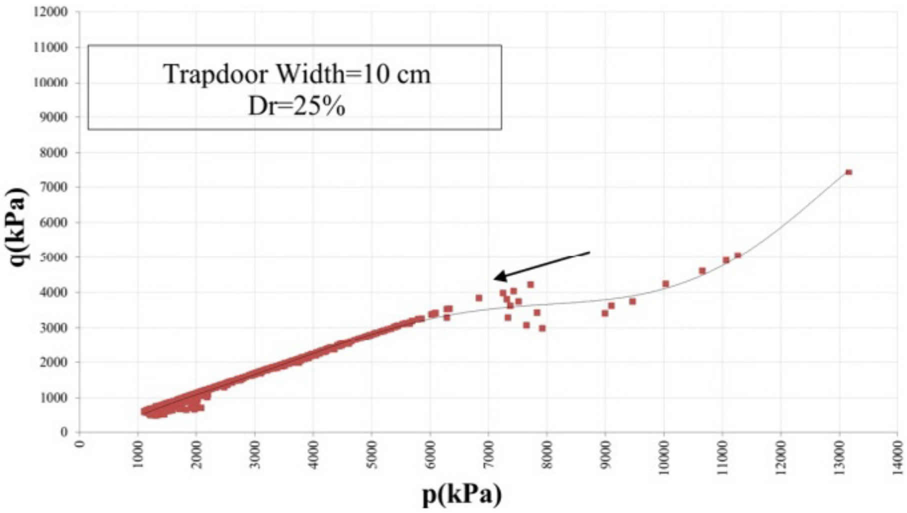

Figure 25. Diagram of stress path in p and q space for the point located in area 2

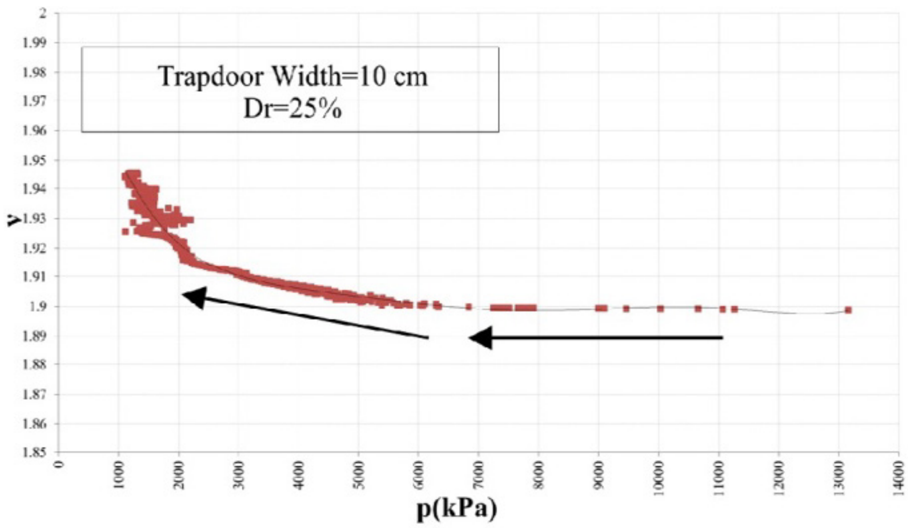

Figure 26. Diagram of stress path in p and v space for the point located in area 2

6.3. THE STRESS SPACE OF THE AREA NEAR THE VALVE (HARDENING AND SOFTENING EXPANSION AREA)

In Fig. 27, the diagram related to the path of stress in the space of P and q is presented at a point located in the area of expansion of hardening and softening (region 3 - areas near the valve) for a valve with a width of 10 cm and a relative density of 25%. Also, in Figure 28, specific volume changes in P and v space are shown.

In Fig. 27, with the start of the test and moving the valve, and transferring the stresses to the fixed parts of the model, the stresses P and q increase, this stress transfer leads to the occurrence of hardening behavior in the sand, and this process continues until reaching the ultimate point, after reaching the ultimate point, the average and shear stresses decrease, and the sand shows a softening behavior. It can be seen in Fig. 28 that the specific volume is almost constant at the beginning of the test, and near the maximum point of the average stress, the specific volume increases. After the ultimate point of moderate stress, the increase rate of specific volume increases as it decreases. In the graphs related to Figs. 27 and 28, the direction of the arrow represents the direction of changes in stresses and specific volume during the test.

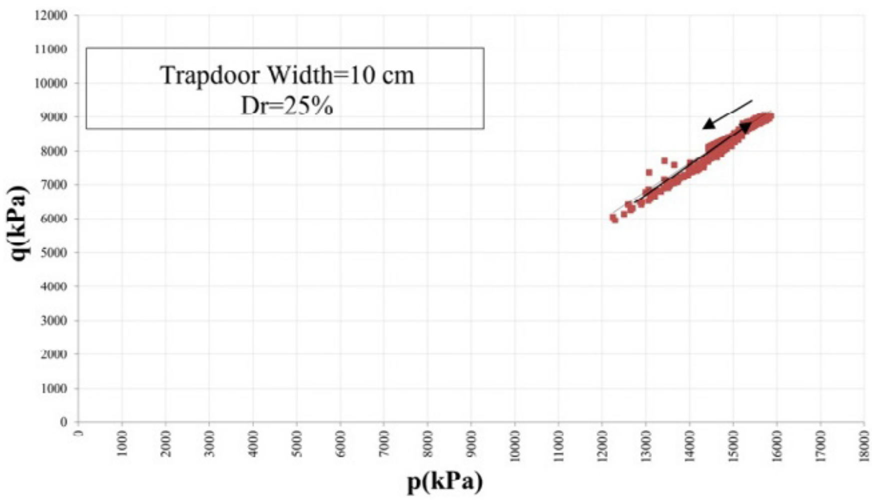

Figure 27. Diagram of stress path in p and q space for the point located in area 3 - areas near the valve

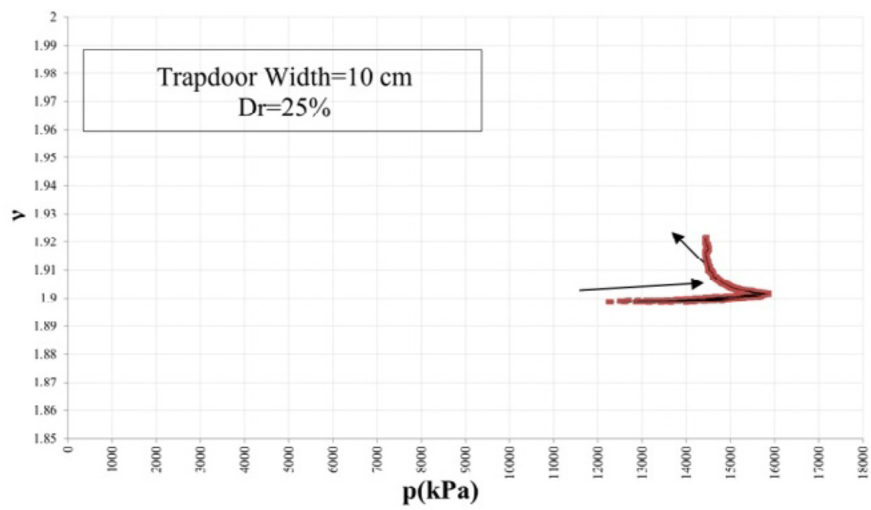

Figure 28. Diagram of the path of stress in p and v space for the point located in area 3 - areas near the valve

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6.4. THE STRESS SPACE OF ZONE 3 (HARDENING ZONE) - FARTHER FROM THE VALVE

In Fig. 29, the graph related to changes in the stress path in the environment p and q for the point located in the hardening area (area 3 - areas far from the valve) is presented. As you can see, as the valve goes down, the amount of average stress and shear stress increases. With the increase of moderate and shear stresses, the value of specific volume decreases (Fig. 30). Of course, this reduction in particular volume is minimal. In this area, sand exhibits elastic and plastic hardening behavior. So that in the flexible region, it is related to the hardening caused by the increase in the modulus of elasticity, which is dependent on the stress level, in the plastic region, it is related to the hardening caused by the increase in the internal friction angle, which is dependent on the plastic strain. In the graphs related to Figs. 29 and 30, the direction of the arrow represents the direction of changes in stresses and specific volume during the test.

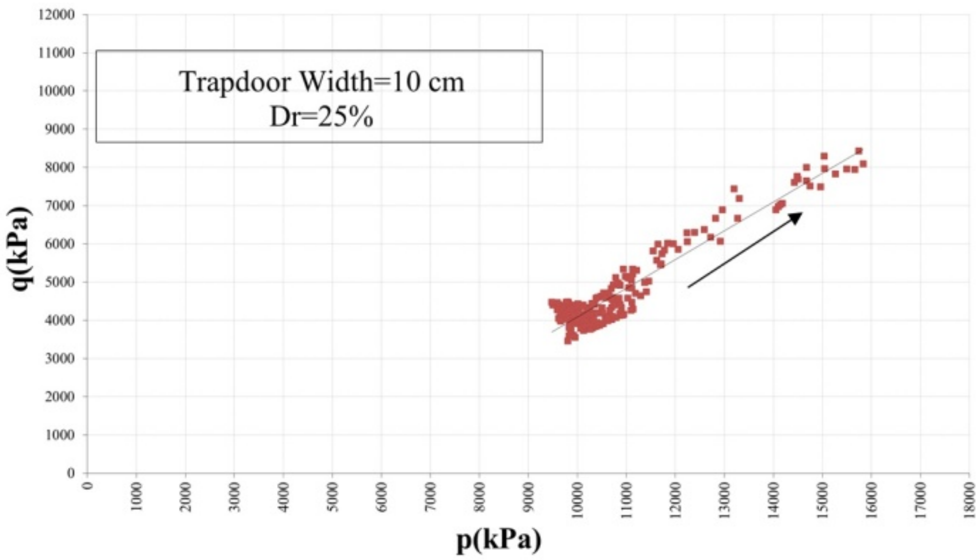

Figure 29. Diagram of stress path in p and q space for the point located in area 3 - areas far from the valve

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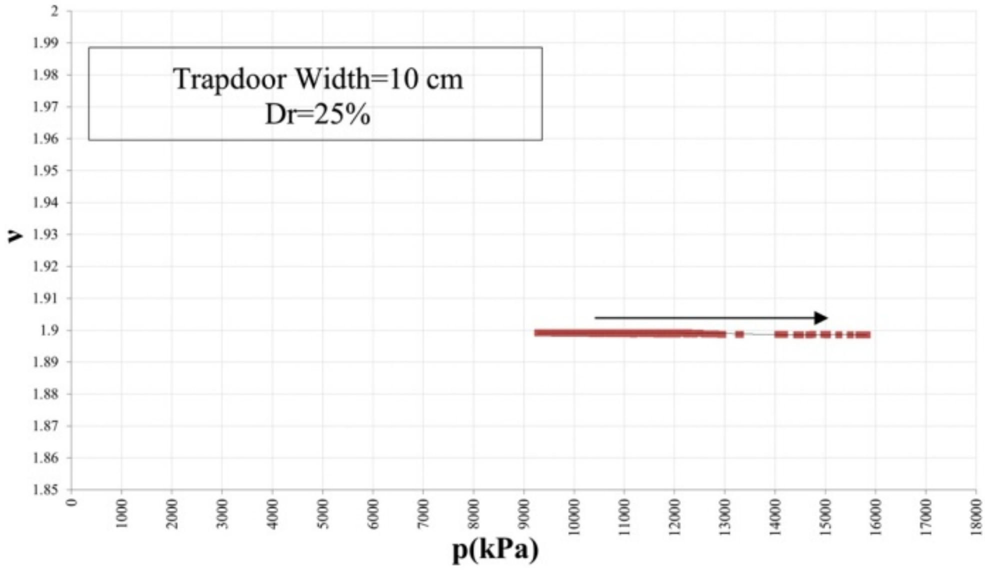

Figure 30. Diagram of stress path in p and v space for the point located in region 3 - regions far from the valve

7. CONCLUSION

Based on the studies conducted in this research, the following can be stated as the main results:

1. Four distinct phases can be distinguished in the arcing phenomenon:

• The first phase: This phase starts immediately after the start of the valve drop, so that the tension applied to the valve is immediately and strongly reduced and reaches the minimum value. In this phase, the soil behaves elastically, and the deformations are small, while the stress changes are huge. At the beginning and before moving the valve, the shear stress values in the sand mass and around the valve are zero, and the principal stresses are vertical and horizontal. As the valve begins to move around the arch area, the shear stress starts to increase, and as a result, the principal stresses deviate from the vertical and horizontal state and rotate. In fact, in this phase, in arc development, the principal stress plane turns by creating shear stresses. So that the value of the principal stresses is reduced to the minimum and the principal stresses are increased to the maximum. In other words, the diameter of Mohr's circle increases in the arched area. This process of changes in the plane of principal stresses continues until the formation of a stable arch.

• The second phase: This phase begins after the minimum stress point. This phase occurs in a wide range of valve displacement and the range of development of plastic strains. In the second phase, the plastic strains, and finally, the rupture starts from the side of the valve and proceeds in the direction perpendicular to the two ends of the valve

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towards the surface. Convergence or divergence of this development of plastic strains and rupture depends on the density of the soil and the width of the valve, which determines the stable or unstable arch. In this phase, the phenomenon of flow occurs in the soil mass, so that despite high strains, there is no significant change in the applied stress on the valve.

• The third phase: This phase begins with an increase in the applied tension on the valve. At this stage, the separation and formation of a stable arc take place. If there is no stable arc, the rising trend of tension continues.

• Fourth phase: In this phase, the total weight of the stable arc is applied on the tension gauge, and the applied tension on the valve remains almost constant. In case of an unstable arc in this phase, the tension will be steady and increasing.

2. Based on the results of experiments and numerical modeling, after the occurrence of the arch phenomenon, four separate areas can be distinguished in terms of the behavior of the sand mass :

• The first area: In this area, the soil mass behaves elastically, so that the mass moves as a whole and the particles do not have any relative movement with each other, that is, the amount of strains in this area is minimal.

• The second area: In the second area, a shear band is formed, and during the expansion of the arch phenomenon, it develops towards the crown of the arch, and the sand shows softening behavior.

• The third area: the stresses in this area increased with the development of the arch phenomenon, and the sand mass shows hardening behavior. This area acts as a column to transfer stress to the foundation. Of course, this area is moved to the sides with the displacement of the valve, and its position depends on the displacement of the valve.

• The fourth area: this part has not been affected by the arch phenomenon, and the stresses and strains remain almost constant during the occurrence of the arch phenomenon.

3. Due to the wide application of the simple straight-cut test and the ease of performing this test, the resistance parameters obtained from the simple straight-cut test can be used with acceptable accuracy for the numerical modeling of the arcing phenomenon.

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4. The best behavioral model governing the phenomenon can be defined as follows:

    • Elastic part: hardening depending on the stress level by defining the change of the modulus of elasticity against the stress change.

    • Plastic part: Hardening depending on the plastic strain up to the peak point (peak) by defining the increase of the internal friction angle up to the peak internal friction angle and softening depending on the plastic strain up to the critical limit point by defining the decrease of the internal friction angle up to the critical limit internal friction angle.

5. In the arched area, the lateral pressure coefficient of the sand is not constant and increases with the displacement of the valve. This rate of increase depends on the relative density of sand and shows an increase up to 2 times the initial value.

6. According to the definition of the expansion angle dependent on the plastic strain in numerical modeling and the acceptable agreement of the results of the numerical model with the results of the experiments, the flow in the arc phenomenon has no associated nature.

7. In examining the path of stress during the occurrence of the arch phenomenon, three separate areas can be identified in terms of changes in average and shear stress and specific volume :

    • Area 1: rapid decrease of p and q, approximate constancy of specific volume (elastic).

    • Area 2: reduction of p and q, flow phenomenon area, critical line (CSL), an increase of specific volume (softening area).

    • Area 3 and in the areas near the valve: increase and then decrease p and q, hard behavior and then softening, stability and then increase of specific volume (expansion area of hard and softening).

    • Area 3 and in areas further from the valve: increasing p and q, reducing the specific volume to a minimal amount (area of hardening) .

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RISK MEASUREMENT OF CHINA'S FOREIGN ENERGY INVESTMENT PORTFOLIO BASED ON COPULA-VAR

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ABSTRACT

Energy is an important resource for the development of the country, and investment in energy can promote the development of the national economy. Many scholars are currently using Copula models to predict the risk of energy investments to improve investment efficiency. However, most studies are not systematic enough and focus on countries outside of China. We use the Copula-VaR method with the Archimedean Copula function and the Copula-VaR method with the introduction of tail correlation to calculate the energy futures risk. The risk of six different percentages of China's foreign energy portfolio for three futures on natural gas, oil, and coal between January 3, 2015 and December 30, 2021 is calculated and compared to the traditional method. The results show that the risk values calculated using the improved Copula-VaR model are 0.00836, 0.00922, 0.00217, 0.00635, 0.00612 and 0.00827 higher under the 0.98 confidence level than under the 0.96 confidence level. It has a high accuracy compared with the traditional method. The research in this paper provides an idea for the design of energy investment programs in China

KEYWORDS

Copula- VaR method; energy investment; degree of confidence; portfolio risk; confidence level.

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1. INTRODUCTION

Energy is an important resource for national development. The development of industry and manufacturing industries cannot be separated from the supply of energy. With the development of economic globalization, each country cannot stay away from the development of energy [1-3]. At present, the world energy market is also suffering from an unprecedented impact with the spread of the economic globalization crisis. The world energy structure is currently undergoing a transformation, which brings a certain degree of impact on the economic trade and energy import and export of each country [4-6]. During World War II in the 19th century, the main conflicts in the world at that time were focused on the competition for resources and territories. Countries vigorously developed their industries. The Western countries successfully entered industrialized societies thanks in part to low energy prices [7-8]. But in the 21st century, there was a conflict over oil resources in the Middle East, which at once broke the world energy pattern. The increasing price of oil has led to an energy crisis in many countries and a gradual widening of the gap between countries' economic development [9-12]. Each country has its own energy advantages, for example, Russia has rich oil resources and China has rich coal resources. Figure 1 shows China's coal energy and crude oil energy production from 2011-2022. It can be seen that China's coal and crude oil resources have been increasing in the last decade, so it is important to be well-positioned for strategic energy investment.

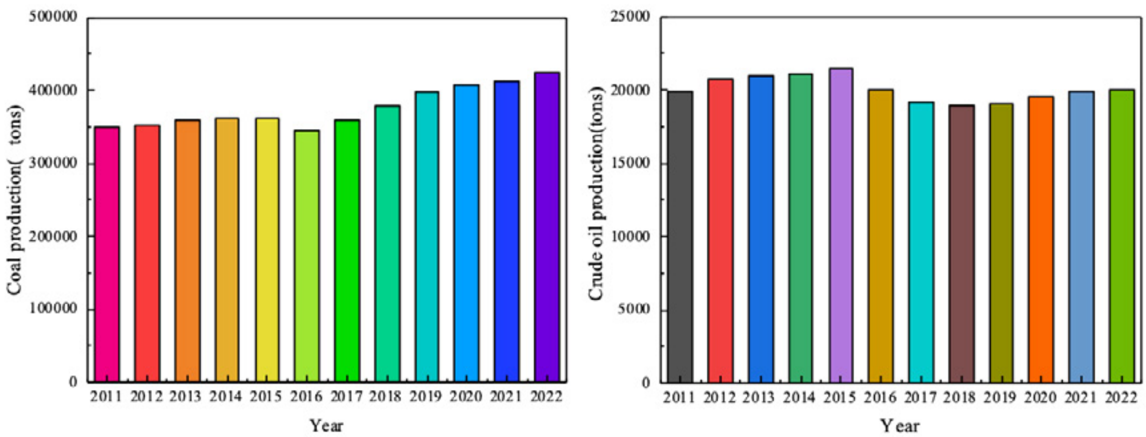

Figure 1. Coal and crude oil production 2011 - 2022

With the increasingly complex international situation, the price of energy is also changing. The recent conflict between Russia and Ukraine has caused an increase in the price of oil. Changes in energy prices can have a relatively large impact on a country's political economy. China is rich in energy, so it is necessary to make a good risk assessment of energy investments [13-16]. The Copula model, proposed in the 20th century, is well suited for the pricing of financial investments and the comprehensive measurement of investment risk, in which the investment risk is assessed by the magnitude of the VaR (Value at Risk) value [17-20]. Subsequently, some scholars used the Copula model to measure energy portfolio risk [21-24].

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HB Ameur et al. analyze the risk spillover benefits between oil and gas markets by measuring their risk dependence [25]. Combining market price data for oil and natural gas from 2014-2017 reveals that the risk premium from oil to natural gas markets is higher than the risk premium from natural gas markets to oil markets. It is also found that risk upward and downward spillovers are asymmetric, due to the stronger spillover effects from risk negative spillovers. Ji explores the impact of uncertainty on energy prices by measuring four types of Delta conditional value-at-risk (CoVaR) through six time-varying copula, considering uncertainty measures among economic policies, financial markets, and energy markets. The results show a negative correlation between energy returns and changes in uncertainty, with energy being more sensitive to the response of financial and energy markets, while economic policies have a relatively weak impact. The study provides informative recommendations for energy portfolios [26]. Qiang et al. used six time-varying copula models to analyze the dynamic dependence of WTI crude oil on China and the U.S., while taking into account the structural changes in their dependence [27]. The results show that there are breakpoints in the dependence on crude oil and the dollar index on a daily or monthly basis. There is a relatively large risk spillover from crude oil to the exchange rate markets in China and the United States. It is also found that the exchange rate markets in China and the United States are not as sensitive to the spillover effects of oil price turmoil. AK Tiwari et al. analyzed the dependence relationship between the Indian stock market and crude oil prices using the dependence transformation copula model [28]. Dependence and tail dependence are investigated for four states: oil price-rising-stock-rising, oil price-falling-stock-rising, oil price-falling-stock-rising, and oil price-falling-stock-falling. The results show that the gap between CoVaR and VaR for each domain is not significant. That is, the oil market does not add additional risk to the stock market when both the oil market and stock prices are in a downward spiral. Meanwhile, oil prices are falling and entering the carbon sector is the ideal hedge investment. Ren et al. studied the investment risk of U.S. crude oil, natural gas energy and heating oil futures using energy investment risk management as an entry point [29]. An energy futures portfolio risk measurement model based on BEKK-VaR and DCC-VaR methods was developed to calculate the value-at-risk of energy investments. The results show that the DCC-VaR has more accurate calculation results compared with the BEKK-VaR method, but the BEKK-VaR method works better in terms of the generalized error distribution. In general., the DCC-VaR method is better for measuring investment risk portfolios. Lv et al. proposed a copula-based stochastic multilevel planning (CSMP) method as a way to ensure a coordinated relationship between the energy economy and the ecosystem in China [30]. The results show that by the middle of the 21st century, China's tertiary and high-tech industries will account for 62.4% and 14.9% of the market, respectively. Energy and carbon dioxide consumption decreased by 45.1% and 56.9% respectively, which shows that the ecological relationship is developing towards economic energy saving and environmental friendly. Zhang et al. proposed a copula-based multivariate model aimed at analyzing the impact of oil price fluctuations on fuel and shipping prices [31]. Data is derived from the index relationship between oil prices and shipping in West Texas, the Baltic Sea region from 2008 to 2015. The results show that high oil prices

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are not significantly dependent on each country, and copula modeling can better identify the time-varying effects of the dependence between the two and help policymakers analyze energy investment markets effectively. Cai et al. proposed an integrated approach of system dynamics, orthogonal design, and copula analysis (IA-SOC) to assess the risk of coupling water and energy resources in cities in the Jinjiang region [32]. The results show that the system dynamics model constructed in the established paper is applicable to the prediction of water and energy resources. The water and energy scarcity risks are 0.938, 0.981 and 0.835, 0.936 for the government's planning period for the city of Jinjiang with water demand of 25.206, 29.07 billion cubic meters and 433.67, 477.02 million tons of standard coal equivalent (SCE), respectively. Jiang et al. narrow the risk gap between different countries by identifying the impact of specific political risk factors on foreign energy investments and exploring the significant political risk factors for foreign energy investments in 74 developing countries [33]. In addition, practical advice is given to foreign investors based on the national conditions of different countries and the differences between them. JC A et al. systematically review the literature of the last decade to summarize the interplay between stranded risk and capital allocation decisions of others in energy technologies [34]. Coal., oil and gas companies were found to be at risk of stranding asset owners due to misjudged energy price forecasts. Investors with illiquid assets are also found to be less exposed to risk and can hedge risk and manage assets through diversification strategies. In summary, the current prediction results of energy investment risk using the Copula model are satisfactory, but there is a lack of systematic research and shortcomings for quantitative analysis of risk assessment. Most studies have been conducted on countries outside of China, and there is still a lack of work on risk assessment of China's outbound energy investments.

Therefore, this paper calculates the risk of six different percentages of China's foreign energy portfolio for three futures of natural gas, oil, and coal for the period from January 3, 2015 to December 30, 2021 by using the Copula-VaR method. The values at risk of different proportional investment approaches were compared at confidence levels of 0.96 and 0.98, and the results calculated by the improved Copula-VaR method were compared with the traditional calculations. The research in this paper provides a reference for the formulation of China's outbound energy investment strategy.

2. COPULA-VAR MODELING

2.1. COPULA FUNCTION DEFINITION

The analysis of a single variable in financial risk analysis cannot correctly reflect the deep relationship between financial risk and investment behavior. Therefore, multiple variables need to be analyzed, and the analysis of multiple variables requires an in-depth analysis of the correlation of these variables. In this paper, we use the Cupula

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function to measure financial risk and time series and optimize the distribution function, and the Copula function is defined as follows:

Suppose there is a p element distribution function: $f(x_1, \cdots, x_p)$, where $x_i \in R,\ i = 1,\cdots,p$ with marginal distribution $F_i,\ i = 1,\cdots,p$. For $Copula\ C : [0,1]^p \rightarrow [0,1]$ such any $x_i \in R,\ i = 1,\cdots,p$ satisfies the following equation.

$$F\left(x_1, \ldots, x_p\right) = C\left(F_1\left(x_1\right), \ldots, F_p\left(x_p\right)\right) \quad (1)$$

The above theorem shows that for n marginal distributions and n elements of the Copula function, a distribution function consisting of n variables can be formed. The marginal distribution in this distribution function represents the distribution of each variable that has a correlation with financial risk. Copula function refers to the composite function composed of these variables fitted into a distribution function. The above theorem can confirm the existence of the Copula function, and through this theorem can show that the Copula function can describe the correlation of financial risk variables without considering the preconditions of the multivariate normal distribution function, which is more concise and convenient for us to study the existence of multivariate variables in the risk measurement of foreign energy portfolios.

With the above existence theorem of the Copula function, we can further introduce the definition of Copula, namely Sklar's theorem.

If the n element function $C : I^2 = [0,1]^n \rightarrow [0,1] = I$, if for all $t \in I^n$ the following four conditions are satisfied: $C(u) = 0$ if either component of t is 0; for $k \in \{1,2,\cdots,n\}$, $u_k \in [0,1]$, both have $C\left(1,\cdots,1,u_k,1,\cdots,1\right) = u_k$; The function $C\left(u_1, u_2, \cdots, u_k\right)$ is increasing; For any $0 \leq a_i \leq b_i \leq 1$, we have $\Delta_{a_n}^{b_n}\Delta_{a_{n-1}}^{b_{n-1}}\cdots\Delta_{a_1}^{b_1}C\left(u_1, u_2, \cdots, u_n \geq 0\right)$, then the function represented by C can be called a Copula function.

2.2. COPULA DISTRIBUTION FAMILY

Copula function has many distribution families, of which several are more important function families, including: the normal Copula distribution family, Archimedean Copula distribution family, t-Copula distribution family and elliptic distribution family, etc.. Several common families of Copula distributions are described below.

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2.2.1. NORMAL COPULA FAMILY OF DISTRIBUTIONS

The probability density function of the family of normal Copula distributions is shown below.

$$C\left(u_1, u_2, \ldots, u_p\right) = \phi_R\left(\phi^{-1}\left(u_1\right), \phi^{-1}\left(u_2\right), \ldots, \phi^{-1}\left(u_k\right)\right) \quad (2)$$

R in the above function equation represents a symmetric positive definite matrix, and the right-hand side of the equation represents the standard multivariate normal distribution function. $\Phi^{-1}(\cdot)$ is the inverse function of the standard normal distribution function. For the vast majority of cases, the data related to energy investment risks and returns show an asymmetric distribution, which is clearly different from the normal distribution. Therefore, the normal Copula family of distributions does not provide a valid analysis of the Chinese outbound energy portfolio risk measures we study.

2.2.2. T-COPULA DISTRIBUTION FAMILY

The probability density function for the family of t-Copula distributions is shown below:

$$C\left(u_1, u_2, \ldots, \quad u_k; R, v\right) = T_{R,v}\left(T_v^{-1}\left(u_1\right), T_v^{-1}\left(u_2\right), \ldots, T_v^{-1}\left(u_k\right)\right) \quad (3)$$

As with the probability density function of the family of normal Copula distributions, *R* is a symmetric positive definite matrix. The function $T_{R,v}()$ is a standard multivariate t distribution function, which R denotes the correlation matrix and v represents the degrees of freedom. $T_v^{-1}(\cdot)$ is the inverse function of $T(\cdot)$. Compared to the normal Copula family of distributions, the t-Copula family of distributions has a better fit in the tails of the financial risk and return distributions, but like the normal Copula family of distributions, it is less effective in characterizing asymmetry.

2.2.3. ARCHIMEDES COPULA DISTRIBUTION FAMILY

There are three types of probability density functions for the Archimedean Copula family of distributions, namely Gumbel Copula, Frank Copula and Clayton Copula, and their functional formulas are shown below.

$$C(u, v, \alpha) = \exp\left(-\left((-\log u)^{\alpha} + (-\log u)^{\frac{1}{\alpha}}\right), \alpha \in [1, +\infty)\right) \quad (4)$$

$$C(u, v, \alpha) = -1/\alpha \log\left(1 + \frac{\left(e^{-\alpha u} - 1\right)\left(e^{-\alpha v} - 1\right)}{e^{-a} - 1}\right), \alpha \in [-\infty, 0) \cup (0, +\infty) \quad (5)$$

$$C(u, v, \alpha) = \max\left(\left(u^{-\alpha} + v^{-\alpha} - 1, 0\right), \alpha \in [-\infty, 0) \cup (0, +\infty)\right) \quad (6)$$

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2.3. DEFINITION OF THE VAR METRIC

The traditional methods are ALM (Asset-Liability Management) and CAPM (Capital Asset Pricing Model), but each of these methods is overly dependent on the analysis of the data in the statements. As a result, the analysis results are not real-time and the risk measurement is too abstract to reflect the analysis results visually. These two traditional methods are unable to accurately analyze and measure investment risk because they can only show the volatility of assets and cannot incorporate other financial derivatives.

VaR (Value at Risk) is a method of measuring market risk proposed by the G30 Group in a report published in 1993, and the method has been widely promoted in the financial community. VaR means the maximum possible loss of a portfolio of financial assets under normal market volatility. It is the maximum possible loss of a portfolio of financial assets over the period from the present to a specific time in the future at a certain confidence level. The method is represented mathematically as follows.

$$\text{prob}\left(\Delta P_{\Delta t} \leq VaR\right) = \alpha \tag{7}$$

The definition of each variable in the above equation: P is the probability, representing the probability that the amount of loss of a financial asset is less than the maximum possible loss; $\Delta P_{\Delta t}$ is the loss amount, representing the loss amount of this financial asset during the holding time indicated by Δt. ; VaR represents the upper limit of possible loss at a certain confidence level α, which can also be the value at risk at that confidence level; α then represents the given confidence level.

2.4. CORRELATION METRIC

Correlation is a measure of the relevance of data attributes, and similarity is a measure of the similarity of data objects. Data objects are described by multiple data attributes, and the relevance of data attributes is described by the correlation coefficient. The similarity of data objects is measured by some distance measure. Because the correlation between different financial assets in a portfolio has a strong link to the overall portfolio investment risk, the analysis of correlation measures is a key part of the study of foreign energy portfolio risk.

The Kendall correlation coefficient is an important measure derived from the Copula function and is a statistical value used to measure the correlation of two random variables. the mathematical definition of the Kendall correlation coefficient τ is shown in equation (8). Suppose there are two mutually independent continuous random vectors (X_1, Y_1) and (X_2, Y_2), and these two vectors have the same joint distribution H. Then τ is defined as the difference between the positive and negative correlation probabilities, i.e.

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$$l = P\left(\left(X_1 - X_2\right)\left(Y_1 - Y_2\right) > 0\right) - P\left(\left(X_1 - X_2\right)\left(Y_1 - Y_2\right) < 0\right)$$
$$= 4\int_0^1 \int_0^1 C_2(u, v)dC_1(u, v) - 1 \quad (8)$$

It can be seen from the above equation that the calculation process of Kendall correlation coefficient τ is very tedious and requires the calculation of differentiation and double integration. However, under the calculation function of the Archimedean Copula family of distributions, it is only necessary to calculate its generating element φ first to calculate its Kendall correlation coefficient τ. Converting a two-dimensional problem to a one-dimensional direction greatly simplifies the computational process. According to the above method, we assume that there are two continuous random variables X and Y with Archimedean Copula family of distributions, and their generating elements φ are obtained by calculation, at which time the definition of Kendall correlation coefficient τ can be transferred from the above tedious formula as shown:

$$\iota = 1 + 4\int_1^0 \frac{\varphi(t)}{\varphi'(t)}dt \quad (9)$$

The Kendall correlation coefficient takes values between -1 and 1. When τ is 1, it means that the two random variables have consistent rank correlation; when τ is -1, it means that the two random variables have exactly opposite rank correlation; when τ is 0, it means that the two random variables are independent of each other.

3. ANALYSIS AND DISCUSSION

3.1. SELECTION AND DESCRIPTION OF DATA

The data selected for the empirical analysis in this paper are from Chinese industrial enterprise data for the period from January 3, 2015 to December 30, 2021, with a total of 1,498 sets of data for natural gas, oil, and coal futures as the data for the model analysis. The impact of price fluctuations between these three is studied by building a Copula-VaR foreign energy investment model. A comparative analysis of different foreign energy investment portfolio returns is conducted and the Kendall correlation coefficient is calculated to analyze the risk of the portfolio. The following variables are used in the Copula-VaR model calculation: (1) Vc is the coal futures price in USD/ton in the data of Chinese industrial enterprises; (2) Vo is the crude oil futures price in USD/barrel in the data of Chinese industrial enterprises; (3) Vg is the natural gas futures price in USD/mmBtu in the data of Chinese industrial enterprises.

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3.2. RISK METRICS FOR TRADITIONAL VAR METHODS

The analysis of single-asset risk measures is relatively simple and can be calculated using traditional methods. Table 1 shows the single-asset return VaR values calculated by traditional methods for natural gas, oil and coal futures.

Table 1. VaR values for each of the three futures

	Confidence level	Natural Gas	Oil	Coal
VaR value	0.96	0.01637	0.01357	0.03547
	0.98	0.02347	0.02367	0.03277

In a portfolio of foreign energy investments, the combination of different types of financial assets and the proportion of each financial asset in the portfolio in the overall portfolio are factors that affect the portfolio investment risk. Therefore, in this paper, three different energy futures are combined in different ratios: 0.2:0.2:0.6, 0.2:0.6:0.2, 0.6:0.2:0.2, 0.4:0.4:0.2, 0.4:0.2:0.4, 0.2:0.4:0.4, and 0.2:0.4:0.4. A total of six different combinations of ratios are used to calculate the data for in-depth analysis of the model. In this section, the VaR values of six different portfolios are calculated using the traditional VaR method at two different confidence levels, and the results are shown in Figure 2.

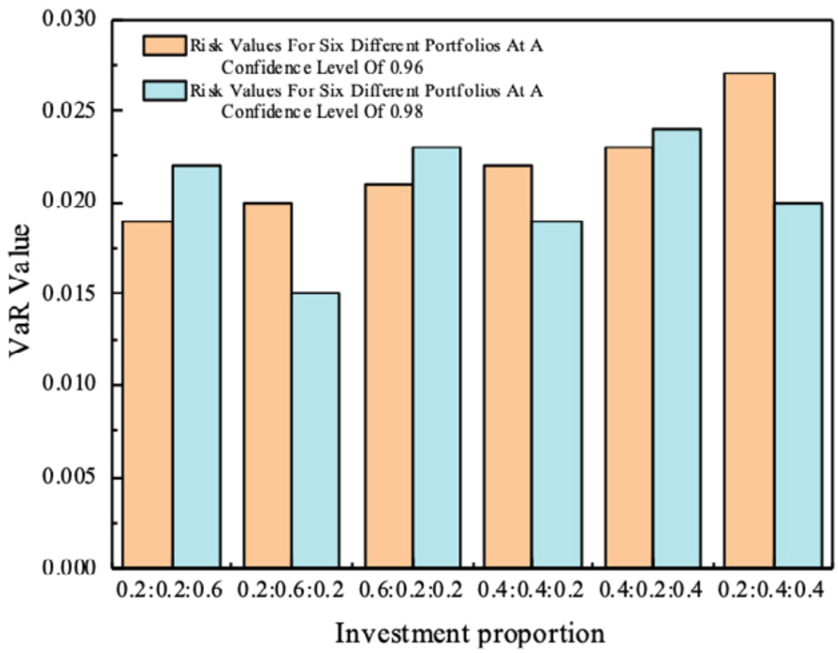

Figure 2. Coal and crude oil production 2011 - 2022

From Figure 2, it can be seen that there is a direct relationship between the investment risk value and the confidence level. When the confidence level is relatively high, it is accompanied by a greater investment risk. There is no obvious pattern of investment risk for the six portfolios with the same confidence level, and the highest risk value is when the investment allocation ratio is 0.2:0.4:0.4. At a confidence level

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of 0.98, the investment risk further increases when the 0.4:0.2:0.4 investment allocation brings a higher risk. Also, the risk values calculated using the traditional VaR method were 0.00434, 0.00462, 0.00167, 0.00870, 0.00193 and 0.00125 higher than those at the confidence level of 0.96, respectively.

Figure 3 shows the calculation of VaR for the single investment approach and portfolio investment approach, from the figure it can be seen that the VaR of the two investment approaches are different at different confidence levels. In general., the VaR values of natural gas and oil investment approaches are smaller, while the investment in coal has a greater risk, and the portfolio investment approach can reduce the risk value of coal investment to some extent.

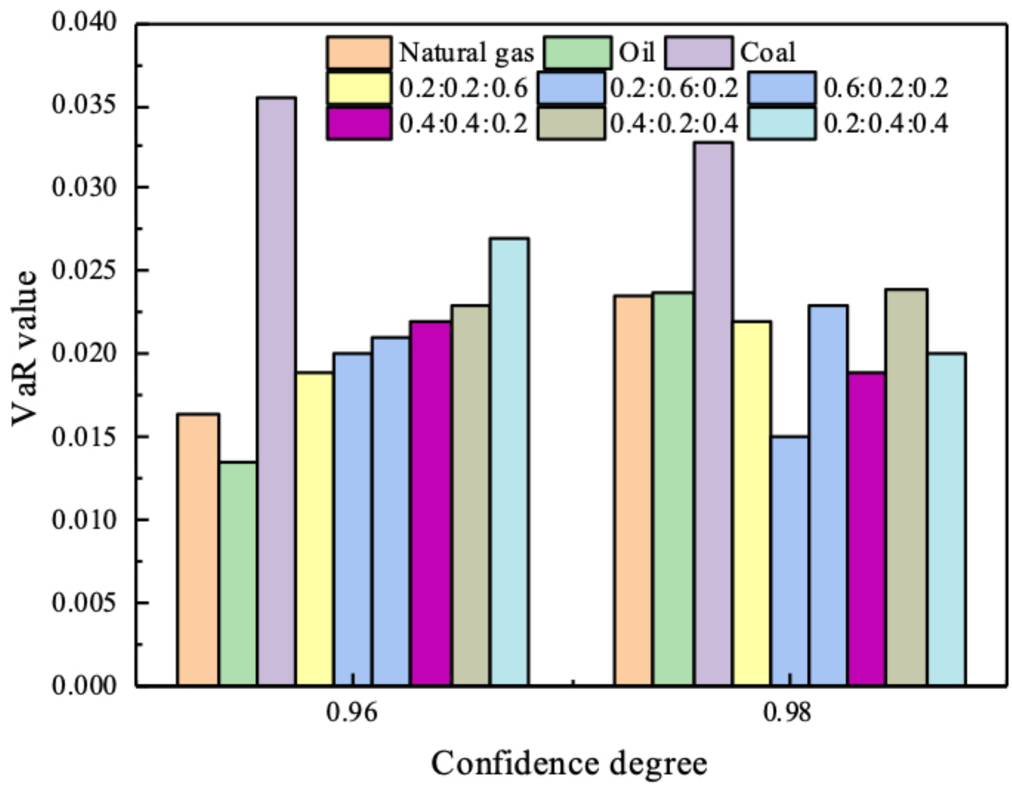

Figure 3. Risk measures for single investment approach and portfolio approach at different confidence levels

When the confidence level is 0.96, the risk of portfolio investment is greater than that of investing in natural gas and oil alone. When the confidence level is 0.98, the risk of portfolio investment is about the same as investing in natural gas and LPG alone, with a tendency to decrease in a given ratio. Therefore, when we do investment analysis, we have to divide the types of energy sources, and single and portfolio investments have different values of risk in specific conditions. There is no direct relationship between the two types of investments, which provides us with a way of thinking when doing energy investment planning.

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3.3. COPULA-VAR MODEL FOR RISK METRICS

From Section 2, we know that the introduction of Archimedean Copula function converts the two-dimensional problem into a one-dimensional direction for processing, which can make it easier to calculate the Kendall correlation coefficient τ. Using the Kendall correlation coefficient can improve the traditional VaR algorithm, and here we obtain $\tau = 0.692$ by calculating. Using the formula, the VaR values of natural gas, oil, and coal futures can be calculated for six different ratios of the portfolio, as shown in Figure 4

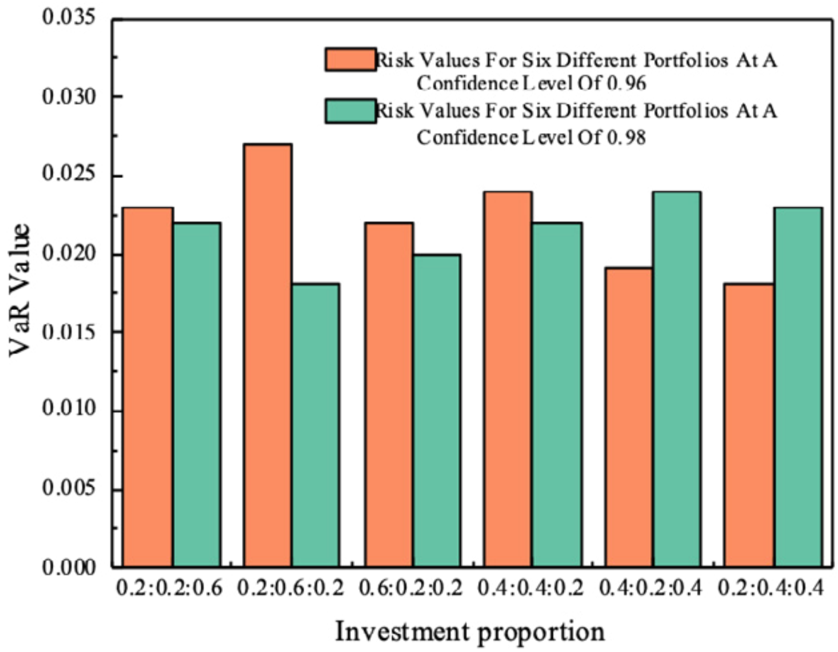

Figure 4. Risk values calculated by the Copula-VaR method at confidence levels of 0.96 and 0.98

As can be seen from figure 4, the value of investment risk is related to the confidence level, and different investment ratios have different risks at the same confidence level. This is consistent with the results calculated using the traditional method, where the 0.2:0.6:0.2 investment ratio has a higher risk when the confidence level is 0.96, while 0.4:0.2:0.4 has a higher risk when the confidence level is 0.98. The risk values under the confidence level of 0.98 are also higher than those under the confidence level of 0.96 by 0.00836, 0.00922, 0.00217, 0.00635, 0.00612 and 0.00827.

In addition to the improvement of the VaR measure of risk by introducing the Archimedean Copula function, the tail correlation carve-out can also enhance the method. The tail correlation coefficient consists of two parts, the upper tail correlation coefficient and the lower tail correlation coefficient, respectively. The tail correlation reflects the probability that the return of one asset is greater (less) than a certain threshold and the return of the other asset is simultaneously greater (less) than a certain threshold, i.e., the probability that two financial assets have extreme simultaneous same-directional returns. We can calculate the upper tail correlation coefficient $\gamma_u = 0.901$ and the lower tail coefficient $\gamma_1 = 0.843$ for the daily log returns of natural gas, oil and coal futures from the previous data. If the relationship between two assets is positively correlated and the higher the coefficient of correlation, the higher the risk coupling and the poorer the portfolio's ability to diversify risk; conversely, if the correlation coefficient between two assets is lower, the better the ability to diversify investment risk. These two correlation coefficients allow for the calculation of VaR values for the three futures at six different ratios of the portfolio, as shown in Table 2.

Table 2. VaR values for each of the three futures

			Different proportional portfolios of three futures					
VaR value	Confidence level	Correlation coefficient	0.2:0.2:0.6	0.2:0.6:0.2	0.6:0.2:0.2	0.4:0.4:0.2	0.4:0.2:0.4	0.2:0.4:0.4
	0.96	Upper tail	0.02143	0.02216	0.02165	0.02272	0.02411	0.02314
	0.98	Upper tail	0.02165	0.03156	0.03012	0.02684	0.02742	0.02812
	0.96	Lower tail	0.02514	0.02176	0.01982	0.01871	0.02187	0.02251
	0.98	Lower tail	0.03124	0.03417	0.02981	0.02318	0.02719	0.02154

The data in the table above shows that the value of risk varies for different percentages of investments. For investors, investing different amounts of money in different assets exposes them to different risks and yields different returns. To choose what portfolio proportions to invest in, the risk can be measured by a risk metric tool. The Copula-VaR model used in this paper can effectively improve the traditional VaR method, and the results of the test can give reference to the investment choice of investors. In the specific investment, the initial investment plan can be designed before the risk assessment, which can reduce the investment risk to a certain extent.

4. CONCLUSION

In this paper, the risk of foreign energy portfolios with six different ratios of natural gas, oil, and coal futures for the period from January 3, 2015 to December 30, 2021 is calculated by the traditional method, the Copula-VaR method that introduces the Archimedean Copula function, and the Copula-VaR method that introduces the tail correlation, respectively. Comparing the risk values of the six different proportions of the foreign energy portfolios, the following conclusions can be drawn.

1. The upper tail correlation coefficient $\gamma_u = 0.901$ and the lower tail coefficient $\gamma_1 = 0.843$ for the daily log returns of natural gas, oil, and coal futures indicate that if the relationship between two assets is positively correlated, and the higher the correlation coefficient is, the higher the risk coupling is and the worse the portfolio is for risk diversification; conversely if the correlation coefficient between two assets is lower, the portfolio is able to better diversification of investment risk.

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2. The risk of a single asset investment or portfolio is different at different confidence levels. From the data, it can be seen that the confidence level and the value of risk show a positive correlation. At the confidence level of 0.98, the value of risk calculated using the traditional VaR method is 0.00434, 0.00462, 0.00167, 0.00870, 0.00193 and 0.00125 higher than the value of risk at the confidence level of 0.96, respectively.

3. The data calculated using the modified Copula-VaR model also shows that the value at risk under the 0.98 confidence level is 0.00836, 0.00922, 0.00217, 0.00635, 0.00612 and 0.00827 higher than the value at risk at the 0.96 confidence level. most of the foreign energy portfolio values at risk are in between these three single The majority of the foreign energy portfolio is between the risk values of these three single energy assets. However, this approach is a good way to avoid a special situation where all investments are placed under the same asset and an accident causes a total loss of assets in the long run. There are different values of investment risk for different percentages of natural gas, oil and coal futures.

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/03/

DEVELOPMENT OF HIGH VOLTAGE ELECTRIC PULSE CHARGING AND DISCHARGING DEVICE BASED ON FUNCTIONAL MATERIALS

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ABSTRACT

As a relatively mature energy storage technology, charge/discharge devices are bound to develop significantly in the contemporary society among them energy is increasingly scarce. The traditional charging and discharging device is not smart enough, slow charging and discharging and other shortcomings have limited its further high-speed development. The application of functional materials and high-voltage pulse technology can drive the further development of charging and discharging devices. In this study, a safe, low-cost, functional material with high adsorption capacity was developed. At the same time, this functional material is applied to the charging and discharging device to improve the storage capacity and discharge efficiency of the device. In addition, we combine high-voltage electric pulse technology with charging and discharging technology to improve the charging and discharging rate of the charging and discharging device. It has certain guidance and reference values for the development of high-voltage electric pulse charging and discharging devices. According to the test results, the dynamic adjustment time of the charging module output current is only 20ms, and the dynamic adjustment response time of the discharging module input current is about 0.14s. The device provides a new idea for the development of high-voltage electric pulse charging and discharging equipment.

KEYWORDS

Functional materials; high-voltage pulses; charging and discharging devices; system design; electrochemical perform

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1. INTRODUCTION

With the scarcity of fossil energy and the great development of renewable energy, the demand for energy storage in power systems is becoming more and more urgent[1-3]. Charge discharge technology is widely used in electric power, railway transportation, automobile industry and marine industry. However, low efficiency, unfriendly environment and inconvenient operation limit the further development of charge and discharge technology to a certain extent[4]. The rapid development of productivity and increasingly serious environmental problems force people to put forward higher requirements for the performance of charging and discharging devices, so there is an urgent need to design an efficient, intelligent and reversible charging device[5-6].

Functional materials[7] mainly refer to those with excellent electrical, magnetic, optical, thermal, acoustic, mechanical, chemical, biomedical functions and special physical, chemical, biological effects, which can complete the mutual transformation of functions. These high-tech materials are mainly used to manufacture various functional components and are widely used in various high-tech fields[8-9]. With a wide variety of functional materials and a wide range of applications, a large-scale high-tech industry group is being formed, which has a very broad market prospect and extremely important strategic significance. All countries in the world attach great importance to the research, development and application of functional materials, which have become the hotspot and focus of new materials research and development in the world, as well as the hotspot of strategic competition in the development of high technology in the world[10-11]. Lu et al[12] developed a two-dimensional semiconductor functional material (CaP_3) with certain porosity and ultra-high carrier mobility. They found that this new functional material has a direct band gap of 1.15 eV and also has a very high electron mobility, which has great potential for applications in nanoelectronics. In addition to the above two characteristics, CaP_3 also exhibits good light absorption properties in the entire visible range. The innovative electronic and charge mobility as well as optical properties make such materials a potential army for future nanoelectronics and optoelectronics. xiao et al[13] designed and fabricated a functional material with excellent electrocatalytic properties and applied it in electrochemistry. Multifunctional cobalt hydroxide decorated homogeneous porous hollow carbon spheres (CoOOH-PHCS) can act as electrocatalysts to suppress the shuttle effect in lithium-sulfur batteries on the one hand, and accelerate the rate of redox reactions on the other. Moreover, thanks to the coordinated effect of these two materials, CoOOH and PHCS, the electrode exhibited an ultra-low capacity decay of 0.04% per cycle over 450 cycles at 1C. Their work explores and reveals the potential of CoOOH for electrocatalytic applications. Li et al[14] developed a CO_2 gas thermal conductivity sensor based on graphene oxide (GO) and α-Al_2O_3 and calculated the stability of this sensor by simulation. The results show that this sensor has excellent gas heat exchange rate and good stability, and also exhibits good linearity and zero-point stability with CO_2 gas. They developed a CO_2 gas thermal conductivity sensor with shorter response and response times and

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lower power consumption compared to conventional thermal conductivity sensors. Wang et al[15] reviewed the recent research on photonic devices based on functional material infiltrated photonic crystal fibers (PCF). They pointed out that PCFs have a unique arrangement of stomata in their two-dimensional orientation, and these stomata provide natural optofluidic channels for introducing materials, enhancing optical matter interactions, and extending transmission properties. This unique photonic device is widely used for compact and multifunctional integration as well as electromagnetic resistance. Compagnone et al[16] argued that although phytochemical products are starting to be widely used to assist in the exfoliation of 2D nanomaterials, there is a clear lack of research on the molecules involved and their ability to yield functional materials. They proposed a new green liquid phase exfoliation (LPE) strategy to analyze this, characterizing the morphological, structural and electrochemical properties of GF-CT by physicochemical and electrochemical methods. The results show that GF-CT exhibits good electrochemical properties without modification and also has high sensitivity at low overpotential.

High-voltage pulse technology is a technology with great development potential and also a key planning and development technology in China. Its products have high technical content, can provide very large peak currents, are advanced and highly reliable, and have a wide range of applications in the power industry, defense industry, and other high-tech fields[17-19]. Rao et al[20] used granite as an example to establish the electric pulse rock-breaking equivalent circuit, shock wave models in the electric channel plasma, and especially rock damage models. The results predicted from these models were used to analyze and reveal the rock destruction process under the action of high-voltage electrical pulses in order to evaluate and improve the efficiency of high-voltage pulse technology in geological drilling, tunneling, and other geotechnical applications. Dong et al[21] used a bipolar high-voltage pulse dielectric blocking discharge method for denitrification of exhaust gas in order to improve the removal rate of nitrogen compounds from automobile exhaust gas and reduce the environmental impact of automobile exhaust gas. The results showed that the use of a threaded copper rod as the discharge electrode and quartz glass as the medium had a better denitrification effect. Li et al[22] applied the high-voltage pulse technique to the field of hard rock construction drilling and breaking, and developed a prediction model for the discharge circuit based on Bayesian fusion. The results showed that this model reduced the average relative error by 25.5% compared with the traditional single model, which further improved the accuracy and reliability of the model prediction. Li et al[23] proposed the application of high pressure pulse technology to the coal industry in order to solve the challenges of coal desulfurization and ash removal. They showed that high voltage pulses can selectively breakdown minerals with higher conductivity or dielectric constants than coal, which are then separated by size differences to remove sulfur- and ash-bearing minerals containing pyrite. The results showed that after a single high-voltage pulse discharge, more than 75% of the high-density particles were broken up, while the low-density particles could still remain intact, resulting in more efficient desulfurization and ash removal from coal.

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In terms of charging and discharging devices, a reversible rectifier high-capacity charging and discharging power supply with SVPWM technology is necessary, characterized by an integrated charging and discharging main circuit that is both a charging circuit and a discharging inverter energy recovery circuit[24-26]. This allows for compact equipment, improved device utilization, and pulsed charging and discharging functions along with conventional charging and discharging. With SVPWM technology, high power factor and high efficiency of the device are achieved, and harmonic components are greatly improved and reduced. In addition, the fuzzy double closed-loop control of voltage and current is used in the control, which can ensure the steady-state accuracy of charging and discharging with constant current and voltage control, as well as the good dynamic response performance of the device[27-29]. Sodhi et al[30] proposed a numerical model for a horizontal conical shell-and-tube energy storage device to investigate its charging and discharging characteristics. The numerical results show that the innovative design by replacing the circular shell with a conical shell leads to an increase in the heat transfer rate of the whole energy storage device. Also the installation of fins outside the tube affects the performance of the device. Jaewon et al[31] proposed a fast charging system for wireless railroad trains using an input voltage sharing topology and a balanced control scheme. This system changes the traditional way of charging trains from roadside devices and uses on-board devices to store energy by fast charging during the train's inbound stop, which is convenient and efficient with a stable system. Choi et al[32] analyzed the charge and discharge characteristics of a hybrid electric propulsion system. They proposed a hybrid power system in which the ship is propelled only by the electrical energy stored in the battery at low speeds, while water jet propulsion is used in other operating conditions. From the analysis results, it is clear that this hybrid power system can help the ship achieve efficient, zero-emission and silent navigation.

In summary, functional materials, high-voltage pulses, and charging and discharging devices have great potential in their respective fields, but there are few studies combining all three of them. In this study, we aim to develop a safe, low-cost and efficient adsorption material with high adsorption capacity and low desorption rate, and obtain a functional material with high adsorption capacity and low desorption rate. Meanwhile, this functional material is applied to charge/discharge devices to improve the storage capacity and discharge efficiency of the devices. In addition, it is proposed to combine high voltage pulse technology with charging and discharging technology to improve the charging and discharging rate of the charging and discharging device.

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2. MATERIAL CHARACTERIZATION AND CHARGE/ DISCHARGE SYSTEM DESIGN

2.1. MATERIAL PROPERTY CHARACTERIZATION TEST

2.1.1. X-RAY DIFFRACTION ANALYSIS

The samples were prepared as thin layers on slides, and the characteristic diffraction peaks and crystallographic indices of the physical phases of the samples were measured at a rate of 2°/min at 5-80°(2θ) using an XRD-6000 diffractometer from Shimadzu, Japan, equipped with a Cu target for Kα radiation and an acceleration voltage of 30 kV.

$$2d\sin\theta = n\lambda$$

Among them d is the diffraction surface spacing of the sample, θ is the diffraction angle size, n is a non-negative constant, and λ is the wavelength value of X-ray diffraction.

2.1.2. FOURIER TRANSFORM INFRARED SPECTRAL ANALYSIS

The structure of the prepared samples was tested with a Fourier transform infrared spectrometer (FT-IR) model NICOLET 380 from Thermo Scientific, USA. An appropriate amount of powder specimen was mixed and ground well with KBr background material and placed in a mold for compression before testing (the sample was in the form of a thin film). The peaks were also observed at a resolution of 4 cm-1 covering the range of 400-4000 cm-1.

2.1.3. MICROMORPHOLOGICAL ANALYSIS

To study materials, we must study their morphology, and in order to clearly understand the morphology of materials, we usually use high-resolution transmission electron microscopes and scanning electron microscopes. Through these instruments, we can obtain photos up to the nanometer level, both of which can capture the internal structure of the material very clearly.

2.1.4. RAMAN SPECTRAL ANALYSIS

Raman spectrum is a kind of scattering spectrum, which is established according to the scattering phenomenon of light by substances. Different substances have different characteristic spectra, which can be qualitatively analyzed by Raman spectroscopy. Raman scattering does not require a change in dipole moment, but requires a change

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in polarization rate, unlike infrared spectroscopy, and it is by taking advantage of the difference between them that the two spectra can complement each other.

2.2. ELECTROCHEMICAL PERFORMANCE TESTING

2.2.1. CYCLIC VOLTAMMETRY (CV)

The CV method is performed by setting constants such as scan voltage window, scan rate and number of scans, and the electrochemical workstation scans the treated material with a triangular waveform of the relevant constants. The current-voltage curve is then obtained, and by analyzing it, the specific capacitance, redox peak intensity and position of the material can be obtained.

2.2.2. CONSTANT CURRENT CHARGE/DISCHARGE METHOD (GCD)

By setting the voltage window, the number of charging and discharging sections, current density level and other test information, the electrochemical workstation uses relevant parameters to charge and discharge the test materials. Then a triangular-shaped GCD diagram is obtained, which can be used to calculate and analyze the properties of the electrode material such as capacitance value and charge/discharge stability. The three-electrode-specific capacitance is calculated by the following equation.

$$C = \frac{I\Delta t}{m\Delta U} \tag{2}$$

Among them C is the specific capacitance of a single electrode, I is the charge/discharge current, Δt is the discharge time, m is the mass of the sample in a single electrode, and Δu is the change in voltage during the charge/discharge time.

2.2.3. ELECTROMAGNETIC WAVE ABSORPTION PERFORMANCE TEST

Paraffin-based mixtures are widely used in laboratory testing of electromagnetic wave absorption properties. In the test, the samples are first mixed well with paraffin wax in various mass ratios. Then, the mixed paraffin-based composites were pressed into circular samples with an inner diameter of 3.04 mm, an outer diameter of 7 mm, and a thickness range of 1.80 to 2.20 mm. The electromagnetic parameters consisted of complex permittivity and complex permeability, and a series of electromagnetic parameters were measured by a vector network analyzer in the frequency range of 2-18 GHz. The coaxial transmission reflection method was chosen to study the samples because of its advantages of small sample size (about 0.01-0.09 g) and wide

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test frequency range. The electromagnetic wave absorption characteristics of a material are highly correlated with its own complex permittivity and complex permeability, among them the real part represents the storage capacity of electrical and magnetic energy, and the imaginary part represents the loss capacity of electrical and magnetic energy.

2.3. CHARGING AND DISCHARGING DEVICE SYSTEM DESIGN

Charging and discharging device directly determines the comprehensive performance of the charging and discharging device system, and plays a very important role in the charging and discharging device system. There are two main technical indicators of charging and discharging equipment: one is to have higher performance indicators. Such as reliability, voltage and current stabilization accuracy, speed and pulsation coefficient of dynamic response, voltage and current stabilization accuracy, speed and pulsation coefficient of dynamic response. The second is a more complete self-test function, a high degree of intelligence and control, and the selection of the best parameters for charging and discharging is flexible to improve the capacity and the service life of the device.

The whole system consists of charging and discharging devices such as batteries, DC/DC converters, rectifiers, transformers and control systems. The transformer is connected to the grid on one side and the rectifier on the other side. the DC/DC converter and rectifier are controlled by the control system, which also controls some auxiliary equipment in the system, such as the monitor, power supply and fan.

2.4. FACTORS AFFECTING THE LIFE OF CHARGING AND DISCHARGING DEVICES

In some practical engineering applications, pulse charging and discharging technology basically need to operate at a certain repetition frequency. Under the repetitive charging and discharging conditions of the charging and discharging device, the internal electrodynamic damage and energy loss will be large, which will cause the device life to be reduced or even breakdown. Therefore, it is important to study the charge/discharge life of charge/discharge devices at repetitive frequency to manufacture high-performance, long-life charge/discharge devices and to promote the development of pulse power technology. At the same time, among the many performance parameters of charging and discharging devices, the charging and discharging life is also the most concerned index of some universities, research institutes and equipment manufacturers. When the high voltage pulse charging and discharging device is charged and discharged, its lifetime characteristics are affected by the following factors.

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2.4.1. CHARGING VOLTAGE

The life of a charging and discharging device is inversely related to the loss of electric capacity, while the loss of electric capacity is directly related to the working voltage of the charging and discharging device, the relationship between the life of a charging and discharging device and voltage can be expressed as:

$$\frac{L}{L_0} \propto \left(\frac{U}{U_0}\right)^{-m} \tag{3}$$

Among them L, L_0 is the lifetime when the operating voltage of the charging and discharging device is U, U_0, respectively, and m is the voltage acceleration factor.

2.4.2. ANTI-PEAK VOLTAGE

When the charging and discharging device is subjected to reverse peak voltage below 20%, the impact on its life is not obvious, when the reverse peak voltage reaches 50% or more, the capacity of the charging and discharging device will drop sharply. In the charge/discharge test of the charging/discharging device, the capacity loss caused by the reverse voltage during the test should be considered. When the charging and discharging device is subjected to reverse voltage, the voltage is superimposed on its internal slow polarization electric field, so that the internal medium is subjected to a higher electric field, which accelerates the deterioration of the medium, increases self-healing and reduces the life of the device. The relationship between charging and discharging device life and reverse voltage can be expressed as:

$$\frac{L}{L_0} \propto \left[\frac{\ln(1/\beta)}{\ln\left(1/\beta_0\right)}\right]^{-b} \tag{4}$$

Among them β, β_0 are the inverse peak coefficients, L, L_0 correspond to the lifetime when the voltage inverse peak coefficient is β, β_0 respectively, and b is the coefficient.

2.4.3. PEAK DISCHARGE CURRENT

Charging and discharging devices in the process of discharge generated by the pulse of high current will be in its internal electrodes between the formation of a large electrodynamic force. The device in the discharge process at its end of the gold spray flow through the current is the largest, a large electrodynamic force will make the spray gold damage, or even off. When the device is damaged inside the sprayed gold, its internal equivalent series impedance will increase. At this time, a high pulse current will generate high heat in the device, causing it to heat seriously, resulting in the

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deterioration of thin film dielectric, the reduction of breakdown field strength, the increase of self-healing and the decline of service life.

2.4.4. TEMPERATURE

When the ambient temperature is 20°C~40°C, the effect of temperature on the life of the charging and discharging device is very small. When the temperature is 40°C~65°C, the life of the charging and discharging device will be reduced by half for every 8°C increase. And when the temperature is above 65°C, the life of the device decreases sharply. Therefore, when conducting charge/discharge tests on the charging/discharging device, the influence of ambient temperature and the internal working temperature of the device on its life must be considered. The relationship between the life of the charging and discharging device and the temperature is as follows.

$$L \propto e^{-\gamma T} \tag{5}$$

Among them T is the operating temperature of the charging and discharging device, which is the sum of the ambient temperature and the temperature rise of the internal medium. L is the life of the charging and discharging device at temperature T, and γ is the material property index, which depends on the internal medium material.

2.4.5. OTHER FACTORS

This includes the number of charge/discharge cycles, charge/discharge frequency, charge voltage hold time, and first past zero time of capacitance-voltage are closely related to the lifetime characteristics of the charge/discharge device.

In this section, the methods of structural characterization of functional materials and the test methods of charge/discharge characteristics are elaborated. Then we describe the design of the entire high-voltage pulse charge/discharge device system and enumerate the devices involved in the system. Then we discuss and analyze the factors affecting the device life due to the frequent charging and discharging characteristics of the charging and discharging device, and lay the theoretical foundation for the subsequent discussion.

3. RESULTS AND DISCUSSION

The use method of the charging and discharging device is to first close the circuit breaker at the input end of the device and energize the whole device. The control program of the device starts to run, and checks the status of all parts of the device, including whether the cabinet door of the device is closed, whether the emergency stop switch is triggered, etc. If there is an error condition, the device's fault signal light will illuminate and the operator interface will have an error indication. If the system

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status is normal, the battery will be connected to the plug box of the charging and discharging device through the navigation plug. If the connection line is reliably connected, the standby signal light on the corresponding plug box and the standby signal light of the device will be on, otherwise, please check the connection line and reconnect. At this time, the control system will detect the battery voltage at the system output and display the battery power information on the device. If the battery voltage is too low or the connection cable is disconnected during the charging and discharging process, the system will enter the fault handling process.

3.1. CHARGING PROCESS

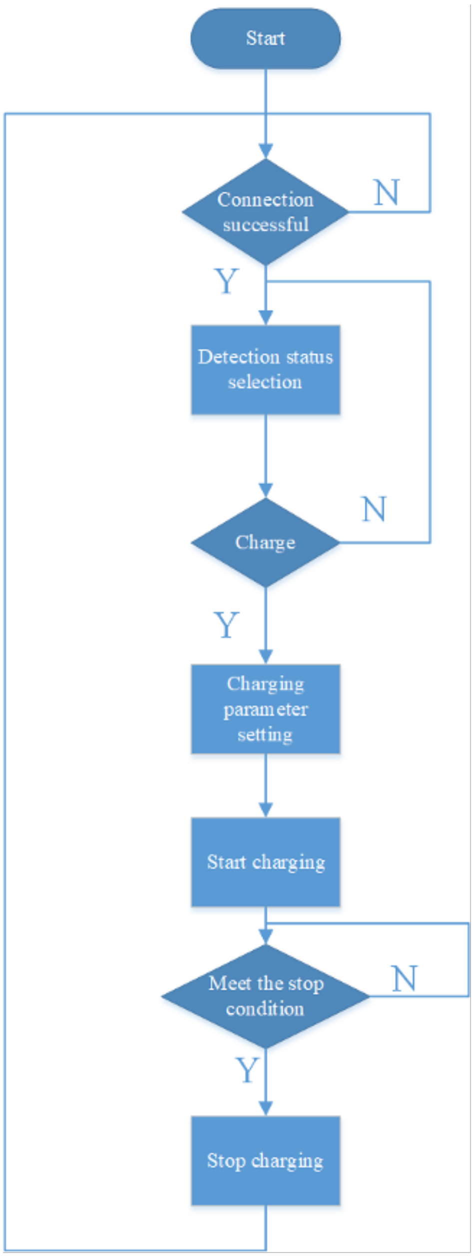

Figure 1. Charging flow chart

The charging control flow chart is shown in Figure 1. When the knob of the plug-in box selects charging, the device will jump to the setting interface of charging

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parameters, which can select the system default parameters or set the parameters manually. Selecting the system default parameters, the control system will control the charging module to charge according to the default command value, charging the battery at 150A in constant current and voltage limiting mode, and switching to constant voltage and current limiting mode when the battery voltage reaches 120V until the end of charging. Select manual setting parameters to set the constant current limit charging current value, constant current limit charging voltage value and charging time for lead-acid batteries, and stop charging when the battery is fully charged in constant current limit mode or when the charging time is over.

After setting the parameters, click the start button on the device interface to start charging. The control system of the device will send the parameter setting command to the charging module, and send the start command after the charging module returns the parameter confirmation information, and the charging module receives the start command and then opens the drive to start running.

When the equipment is running, the actual charging current, charging voltage, charging time, battery voltage, power state and other parameters can be observed on the operation interface, and there is a stop charging button to control the work of the charging module. During operation, the control system of the device will keep sending parameter query commands to the charging module via CAN communication and update the new data acquired into the device. At the same time, it will judge whether the charging module is normal or not based on the operating status of the feedback charging module, and if there is any abnormality it will stop charging and enter the fault handling process.

If there is no abnormality in the charging process of the device, when the charging end condition is met, the control system of the device will send a stop command to the charging module, and the charging module will stop the operation of the charging module after receiving the command. The operation interface will remind the user that the charging process is finished and please unplug the connection cable. During the whole charging process, the control system will also send the status and operation parameters of the whole device to the remote background, which is convenient for remote monitoring of the device.

3.2. DISCHARGE PROCESS

Figure 2 shows the discharge control flow chart of the charging and discharging devices. When entering the discharge mode, the operation interface will enter the discharge mode, in which the default parameters can be used to monitor and control the discharge process. You can also customize the control parameters according to your needs to achieve personalized control of the discharge process. When the default parameters are used, the control system will control the discharge module to discharge according to the default current command value of 80A. When the battery voltage is lower than 65V, the discharge will stop and the discharge time will be

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recorded to judge the battery life status. Select the manual setting parameter to set the discharge current and discharge time of the lead-acid battery, and stop the discharge when the battery voltage is lower than 65V or when the discharge time is over. After setting the operating parameters, click Run in the operation interface. During the discharge process, the current, voltage, running time of each work step and other parameters can be displayed on the screen, so that users can easily observe the discharge status. It is also possible to control the work of the charging module through this operation interface. The control system of the device will keep sending parameter query commands to the charging module through CAN communication during the operation process and update the new data obtained to the device.

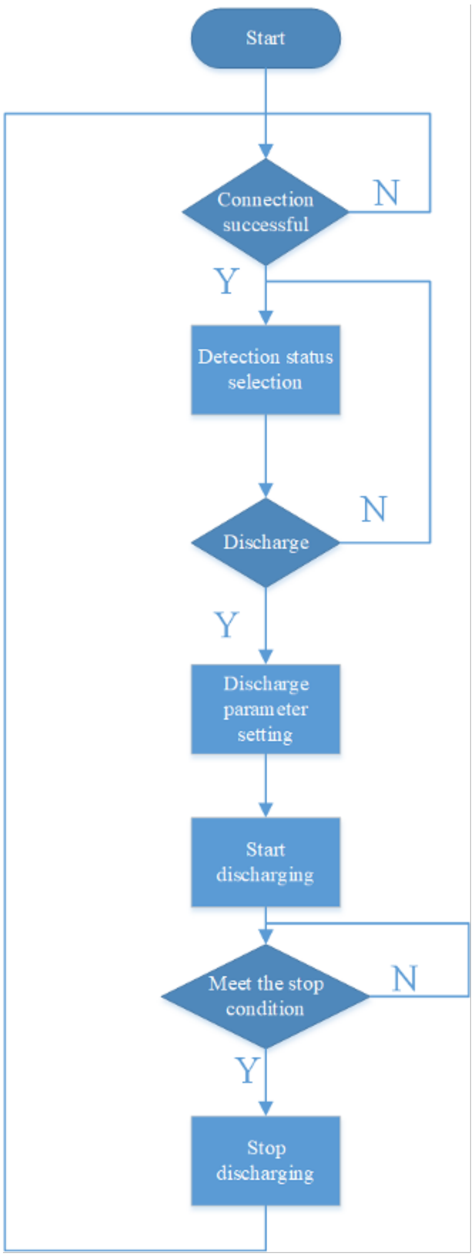

Figure 2. Discharge flow chart

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3.3. VERIFICATION OF CHARGING AND DISCHARGING FUNCTIONS

During the operation of the charging module of the device, when the user changes the setting value of the charging output current through the control device, the charging module should be able to respond quickly by adjusting the output current to the new commanded value. In this test, the charging module was adjusted from a steady-state output of 145A to a steady-state output of 75A in a dynamic process, and its output current dynamic regulation curve is shown in Figure 3.

As can be seen from Figure 3, the time required to regulate the charging module output current from steady-state output 160A to steady-state output 90A is 22ms under the design condition, and during the actual test, the regulation time of the charging module output current from steady-state output 145A to steady-state output 75A is only 20ms, which is 2ms less than the design condition. This is due to the fact that the DC/DC part of the charging module is operating in constant current and voltage-limiting mode. The maximum value of the output of the PI controller of the voltage outer loop is set to the value of the constant current limit charging current. When the charging module works in constant current limit mode, the voltage of the battery is lower than the constant current limit charging voltage, the PI controller of the outer voltage loop will be saturated and the output value is the constant current limit charging current value. At this time, the DC/DC part of the controller is equivalent to only the current inner loop single loop working. When the charging process transitions to the constant voltage current limiting mode, the outer voltage loop of the controller returns to the adjustable area and controls the output current of the module together with the inner current loop. Therefore, the charging and discharging device has good current dynamic regulation during the charging process.

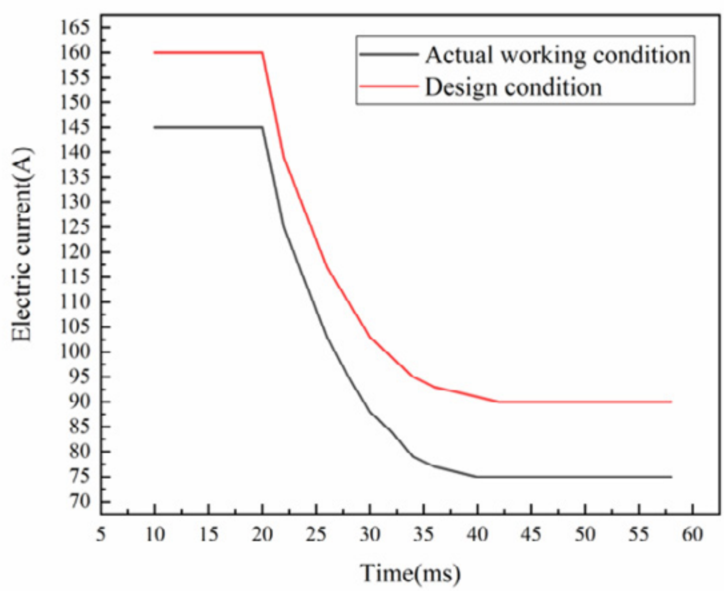

Figure 3. Charging state output current dynamic regulation curve

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3.4. DYNAMIC ADJUSTMENT OF THE INPUT CURRENT OF THE DISCHARGE MODULE

The dynamic adjustment of the discharge state input current is shown in Figure 4. When the user changes the set value of the discharge input current through the device during the operation of the discharge module of the device, the discharge module should be able to respond quickly by adjusting the input current to the new commanded value. Here, the dynamic process of adjusting the discharge module from a steady-state input of 60 A to a steady-state input of 40 A at an input voltage of 96 V is measured, and the response time of the discharge module is about 0.14 s. This is due to the introduction of a negative feedback link in the circuit, and the discharge circuit is a typical nonlinear system that cannot be parameterized with feedback links using methods such as frequency domain analysis of self-control theory. However, when the circuit is at a certain steady-state operating point, there is a linear relationship between the small disturbances of the state variables in the circuit. Therefore, the system has good performance in the dynamic regulation of the input current of the discharge module.

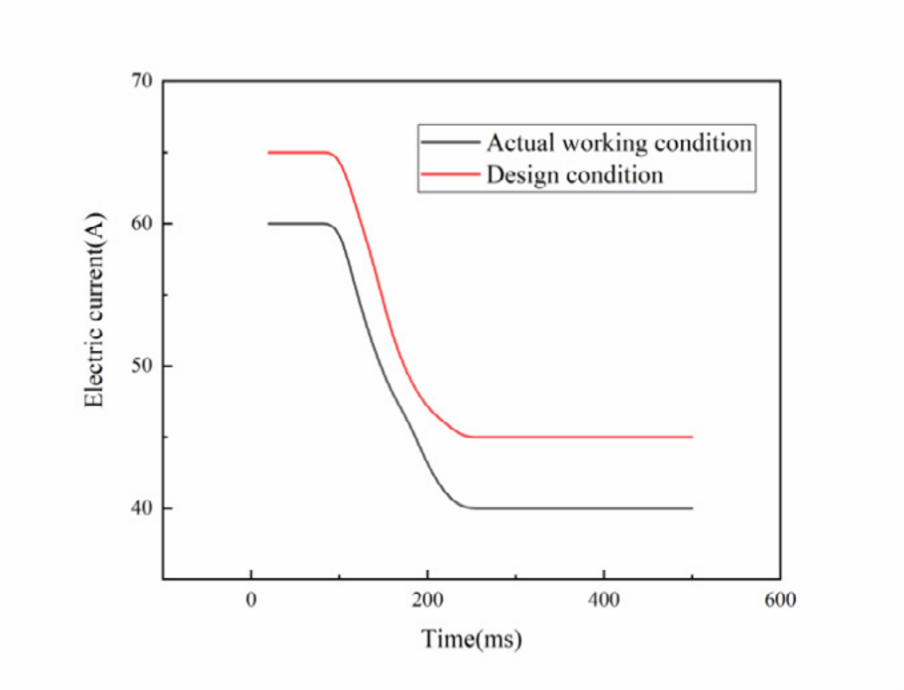

Figure 4. Discharge state input current dynamic regulation

In summary, this section firstly designs the charging and discharging process of this charging and discharging system, and tests the dynamic regulation performance of the charging module output current and the dynamic regulation performance of the discharging module input current for this functional material-based high-voltage electric pulse charging and discharging device.

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4. CONCLUSION

Based on the new functional materials, a new high-voltage electric pulse charging and discharging device is developed in this paper. The charging and discharging control process is designed in detail, and the dynamic regulation performance of the output current of the charging module and the input current of the discharging module is tested and verified. The specific research results are as follows.

1. Based on the technical specifications of charging and discharging the device, the topology of the discharging module was selected as a modified Buck circuit. The charging module uses a two-stage circuit topology of VIENNA rectifier plus a phase-shifted full bridge converter. The device is described at the system level and the workflow of each function of the device, such as the charging process and discharging process, is designed.

2. Through the dynamic adjustment of the charging module output current, during the test, the charging module output current is adjusted from steady-state output 145A to steady-state output 75A, and the adjustment time is only 20ms. therefore, the charging and discharging equipment has good current dynamic adjustment ability in the charging process.

3. In the dynamic adjustment test of the input current of the discharge module, the input voltage is 96V, and the dynamic process of adjusting the discharge module from steady-state input 60A to steady-state input 40A is measured, and the response time of the discharge module is about 0.14s. Therefore, the system has good performance in the dynamic adjustment of the input current of the discharge module.

In this paper, the input filter circuit is added in the front of the buck circuit, and the resonant peak is introduced into the Bode diagram of the discharge system, which is easy to causes the instability of the discharge system. In this paper, the method of reducing the amplitude-frequency gain of the system is adopted, so that the amplitude gain at the resonant frequency is less than 0, and the discharge system is stable, but the crossing frequency of the system is small, and the response time of the system is long. Therefore, the RC branch can be connected in parallel with the input filter capacitor in the future. When the capacitance C should be much larger than the value of the filter capacitance C 1, the specific impact and effect of this method can be studied.

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RESEARCH ON THE REALIZATION MECHANISM AND EVALUATION SYSTEM OF HIGH-QUALITY UNDERGRADUATE EDUCATION IN PRIVATE UNIVERSITIES BASED ON DEEP LEARNING

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ABSTRACT

Due to the new development stage, it is especially important to improve the education quality of private undergraduate universities. As a result, it is a new hot issue for the construction of a mechanism and assessment system for the quality improvement of private undergraduate education. In this paper, after analyzing and researching the quality of undergraduate education in present-day universities, the mechanism of deep learning is applied to the establishment of the assessment system. Finally, 1082 samples collected from the data center platform of a private university are analyzed as the research object. From the results, the final size of the combined weights of the seven evaluation items constituting the assessment system differed basically little. They were 12.81%, 15.78%, 15.28%, 14.38%, 12.83%, 12.81%, 15.01%, and 13.27%, respectively. In the comparison of this paper's method with FAHP+TOPSIS combined evaluation, euclidean map method, and genetic algorithm assignment, the difference between the seven weight values of the euclidean map method is larger, 5.56%. The evaluation times of the four methods were 41 s, 38 s, 47 s, and 118 s. Compared with the other three methods, the genetic algorithm assignment took the most time.

KEYWORDS

Deep learning; private universities; high-quality undergraduate education; realization mechanism; assessment system

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1. INTRODUCTION

Stepping into the new century, higher education in China has ushered in a new period [1]. With the continuous improvement of education methods, higher education has moved from the previous high growth rate to a new stage of high-quality development [2-4]. The improvement of teaching quality is not only for public undergraduate institutions. For private undergraduate institutions, seizing the opportunity to improve teaching quality is a decisive factor for their further development in the future. Most of the private undergraduate institutions are formed by upgrading local higher education institutions as the basis. They highlight their regional characteristics in terms of schooling characteristics while taking the needs of talents in the region as their own teaching orientation [5-7]. In the context of China's vigorous development of high-quality education, there are two aspects that need to be focused on. The first is how to seize the policies favorable to the development of private universities and add reliance to the development. The second is how to increase the kinetic energy within the school to comply with the development call and form a unified consensus. Creating private higher education institutions with certain influence as well as teaching strength should be placed at the top of the task list of the management of these universities [8].

In improving the quality of college education, numerous scholars have conducted research at various levels. Zeng Y [9] studied the influence of teachers' teaching ability and students' level on the effectiveness of college physical education. In order to further improve the accuracy of college physical education evaluation, he analyzed the course teaching quality evaluation system of college physical education. After analyzing the data mining techniques and the applicability of Hidden Markov in the evaluation of the teaching quality of college physical education, the corresponding mathematical model was proposed. The mathematical model was also validated by a series of experiments. heng Q [10] explored the role of 5G technology in reforming the quality of classroom teaching in colleges and universities under the accelerated development of information technology. In his study, he built the teaching quality system based on the B/S architecture model, using the SSM framework and MYSQL database development. He believes that this can improve the school's teaching quality evaluation system as a whole and make the system more objective and fair. Hong W [11] believes that computer teaching, as an important part of college student's education, can better promote students' all-around development for the improvement of students' computer ability application. However, there are more problems in computer education nowadays, and the teaching effect is not ideal. In his study, he focuses on analyzing the problems of computer teaching in colleges and universities in the environment of big data. Xu Z [12] believes that the construction of a practical teaching quality system and its optimization are especially important in improving the teaching quality of applied undergraduate institutions. In his study, the DEA model is used to construct the evaluation indexes of practical teaching in applied undergraduate institutions. Xue K [13] focused on analyzing the problems of teacher quality evaluation in higher education institutions and proposed a correct view of

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quality evaluation and an evaluation system with vocational and technical characteristics. He believed that a suitable teaching quality evaluation system should be reasonable and relevant. Only under the guidance of scientific evaluation methods can a correct and developmental teaching system be established. anzhao M [14] believes that the quality of practical teaching is the core competitiveness of private applied new undergraduate institutions. He believes that these types of institutions should focus on cultivating application-oriented talents. In order to achieve this goal, it is important to clarify the content of monitoring the quality of practical teaching. In his study, the focus is on the establishment of a practice teaching quality system. The sustainable and supervisable teaching model is explored.

At a time when high-quality development is advocated, undergraduate education in private universities should also join the flood of development. Apply the national policies as well as their own resource advantages to their own development [15, 16]. After examining their own strengths and weaknesses, they should integrate them into the new demands of development. It is also not negligible to find one's own position in the development. With these needs, an appropriate teaching evaluation assessment system is necessary to exist. Based on this evaluation system, it can play a role in monitoring and improving the management level of the school, the quality of teachers' teaching, and the development of students' abilities. It has a significant role in significantly improving the level of education and competitiveness of the school. This is the reason why this paper conducts a study on the mechanism and evaluation system for achieving high-quality undergraduate education in private universities.

2. THEORETICAL BASIS OF THE BLENDED EDUCATION MODEL BASED ON DEEP LEARNING

2.1. DEEP LEARNING

In the 1980s, Russell Ackoff's four-layer wisdom data framework bridged the gap between "technology" and "wisdom" for intelligent education in the information age. The framework demonstrates the evolutionary path of human intelligence from information to knowledge and from knowledge to intelligence. In this process, people build a knowledge network in their minds through active understanding of memory, establish interrelationships among things and between things, understand, connect, transfer, apply and create knowledge, and develop intelligence and wisdom. In the process of knowledge development, deep learning that focuses on knowledge internalization and transfer is crucial.

Deep learning theory has some similarities with deep learning of machines in the field of artificial intelligence [17, 18]. The idea of machine learning is to build a multilayer artificial neural network. During the training of the network, feedforward operations are performed layer by layer on the input data, the final result of the output operation is compared with the target, and the error is returned to each neuron to

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adjust the connection parameters of each neuron. Multilayer neural network connections can accurately represent the complex nonlinear mapping relationships between input and output data [19-21]. It is similar to the internalization and construction of knowledge in the human learning process. Among them, the functions of evaluation and feedback are very important. Artificial neural networks have self-identification and self-adaptive capabilities, and the performance of artificial intelligence in many fields has now surpassed human capabilities. In recent years, machine migration learning has become an important development direction, showing great commercial value. Compared with intelligent machines, the network structure of the human brain is more complex and profound, so it is equipped with better conditions for deep learning [22-24]. The purpose of human deep learning is also the transfer of knowledge. Therefore, this brings a profound insight into the realization of current high-quality undergraduate education in colleges and universities: deep learning is an important way to achieve the goal of current high-quality undergraduate education in colleges and universities, and it is a bridge between information technology and high-quality undergraduate education in colleges and universities.

2.2. BLENDED TEACHING

In the late 20th century, a blended learning theory was proposed in the West, and today's blended teaching is derived from the blended learning theory. 2003, Professor He of Beijing Normal University first proposed the concept of blended teaching in China. He believes that blended teaching combines the advantages of traditional teaching methods and online teaching. It not only plays a leading role in guiding, facilitating and monitoring the teaching process and fully reflects the initiative of teachers, but also shows the main features of students' enthusiasm and creativity in the learning process. Blended teaching is not a superposition of traditional offline and online teaching, but a rearrangement of teaching objectives, a reconfiguration of the knowledge system and a curriculum design using appropriate teaching methods based on a full analysis of their benefits in order to achieve the best teaching effect.

2.3. DELC MODEL

The DELC model is a deep learning route model proposed by American scientists Eric Jensen and LeAnn Nickelsen in their book "7 Effective Strategies for Deep Learning". The DELC model describes the entire design process of deep learning, from the initial "design of standards and curriculum" to the final "evaluation of student learning". It is a complete and clear pathway from lesson planning to implementation and evaluation, leading students to deeper learning step by step [25]. Blended teaching based on deep learning aims to make full use of the advantages of information and teaching technology to realize the organic combination of deep learning and blended teaching mode, to solve the problem of superficial learning to a certain extent, and to promote the realization of deep learning.

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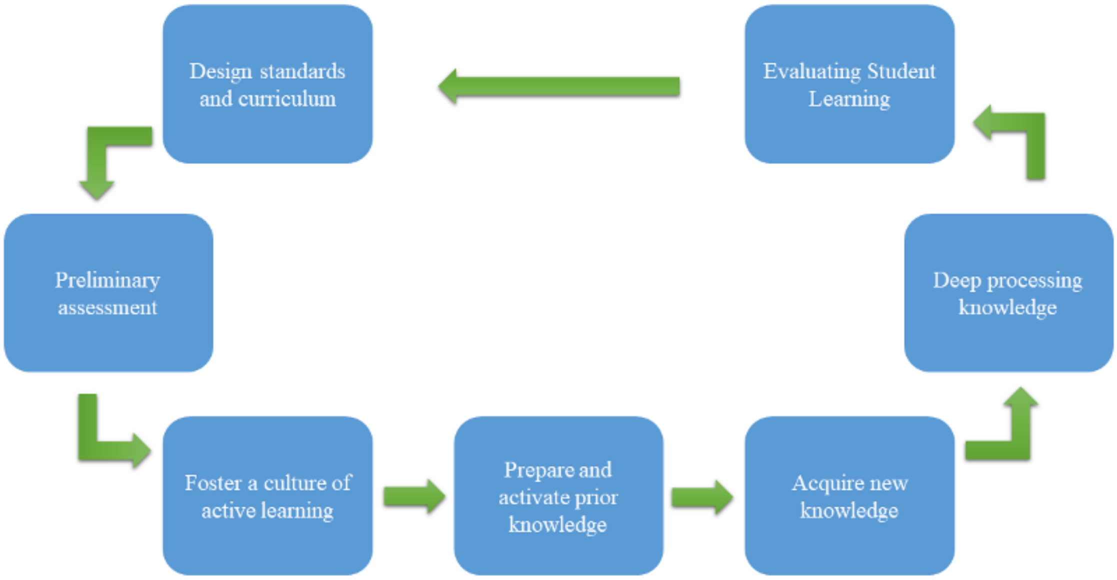

Figure 1. "Deeper Learning Cycle" (Deeper Learning Cycle)

3. MECHANISM FOR REALIZING HIGH-QUALITY UNDERGRADUATE EDUCATION IN PRIVATE UNIVERSITIES BASED ON DEEP LEARNING

3.1. PRE-COURSE SHALLOW LEARNING

In the pre-course shallow learning stage, according to the first stage of the DELC deep learning route "Designing Standards and Curriculum", i.e., the formulation of curriculum objectives, combining Bloom's classification theory of teaching objectives with the three-dimensional objectives of classroom teaching, the teaching objectives can be divided into knowledge objectives, skills objectives and emotional objectives. In deep learning, the goal of knowledge is not only the mastery of knowledge, but also the deep understanding of knowledge. Students actively construct their own knowledge system by activating their prior knowledge. Skill goals emphasize students' ability to use their knowledge flexibly, including the ability to learn independently, communicate collaboratively, and solve problems [26, 27]. Emotional goals, on the other hand, focus on students' emotional experiences throughout the learning process. Based on the mastery of knowledge and improvement of skills, students love learning and enjoy the whole learning process. Teachers can design lessons guided by clear teaching objectives. According to the characteristics of blended teaching, teachers should break the traditional textbook system, reorganize more meaningful teaching units, and collect, develop and adapt curriculum resources according to students' career orientation, curriculum features and student characteristics. Before the whole course starts, teachers can upload the syllabus, teaching plan and other relevant teaching materials on the teaching platform. Students can have a certain

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understanding and their own view of the classroom-related content by previewing the materials [28].

3.2. KNOWLEDGE FRAMEWORK CONSTRUCTION

When first building a knowledge framework, teachers should first complete the third step of the DELC Deep Learning Pathway, "Creating a Positive Learning Culture" and the fourth step, "Preparing and Activating Prior Knowledge. To create a positive learning culture, the first step is to establish a harmonious and reliable relationship between the teacher and the students. A good relationship between teachers and students will be further developed if teachers give students affirmation, encouragement and proper guidance; at the same time, students should develop harmonious and reliable interpersonal relationships between students through communication and collaboration. Thus, a positive learning culture can provide an emotional foundation for mastering new knowledge [29, 30]. Second, we should consolidate the basic knowledge base, i.e., teachers should "prepare and activate prior knowledge". In the process of pre-assessment, teachers learn about students' prior knowledge in various ways. During this phase, teachers can activate students' prior knowledge through tests, questions, surveys, discussions, and other methods. Since most students lack prior knowledge, teachers should add relevant knowledge to the curriculum so that students can connect old and new knowledge. This makes it easier for students to learn new knowledge so that they can deepen their understanding of it.

3.3. KNOWLEDGE DEPTH PROCESSING

In the early stages of knowledge construction, students' learning problems are often complex, both the same and different. Some problems can be solved through iterative research, while others require students to collect and analyze in different ways; other problems can be solved through discussion among students or comments by the teacher. No matter what the problem is and how it is solved, it lays a good foundation for the third stage of deep learning, which is "deep processing of knowledge". In the process of deepening knowledge, teachers should first answer the most common questions that students ask during the learning process. For important points, teachers should help students to reinforce their impressions of these points. For some difficult problems and tasks, teachers should further organize and guide students, such as ways to find information and problem-solving skills, to combine with various practical problems encountered in daily life, to develop logic, rigor and integrity of thinking in the process of problem solving, and to promote deeper processing of knowledge. After solving problems, teachers should summarize key knowledge and difficult knowledge to avoid the dispersion of knowledge caused by online learning, help students form a systematic knowledge system, reorganize the problem-solving process, and let students gain deeper learning experience and achievement experience.

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4. CONSTRUCTION OF ASSESSMENT SYSTEM FOR PRIVATE UNDERGRADUATE EDUCATION

4.1. EVALUATION MODEL

The traditional teaching evaluation model is mainly a quantitative superposition of individual indicators, which cannot reflect the hierarchical and systematic characteristics of indicators. In order to comprehensively evaluate the teaching level and educational success of high-quality undergraduate education in colleges and universities, help schools and teachers improve their teaching and identify problems, a systematic teaching evaluation model is established for this purpose according to the evaluation process and work requirements (see Figure 2). The evaluation model obtains evaluation index items from the training plan and course objectives, and then sets the values of each evaluation index by investigating and comparing them, and finally summarizes and analyzes the teaching effectiveness according to this evaluation system.

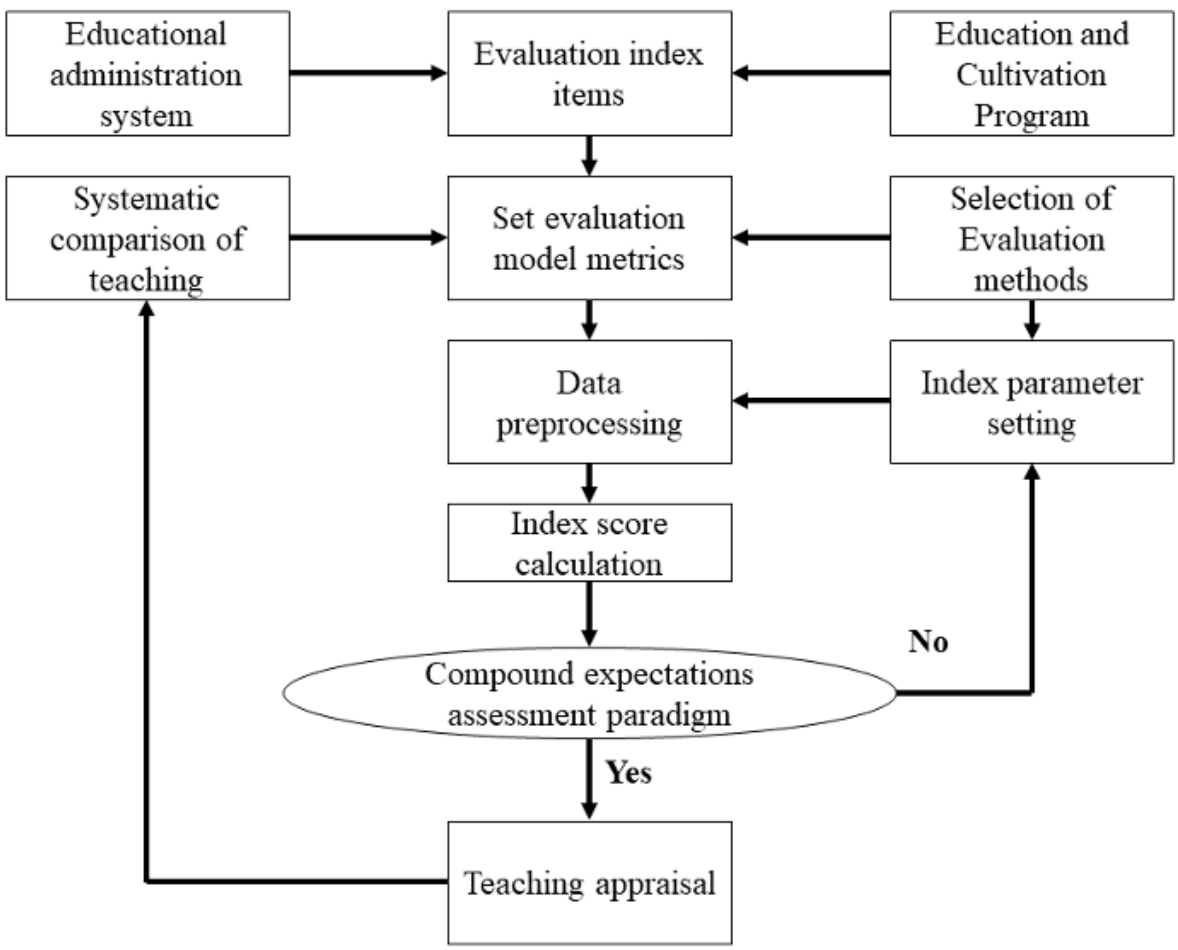

Figure 2. Diagram of teaching assessment processing model

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4.2. DATA ACQUISITION

Evaluation data can be obtained from the school's stored big data, and subsequently obtained in the infrastructure, business platform, teaching system and digital resource library according to the teaching evaluation objectives, with reference to the requirements of the index system of school route, teaching conditions, professional and curriculum construction, teaching management, academic style management and quality cultivation. With the help of third-party big data management platform tools, we collect and process various data, and evaluate the platform-generated teaching evaluation data with the content required by the evaluation index system in correspondence.

4.3. DATA PRE-PROCESSING

Let the level 1 index system set $I = \{I_1, \cdots, I_7\}$, dimensions i, j, k, w_{ijk} be the weight of the kth rated index at level 3, $w_{ijk} = \{w_{ij1}, \cdots, w_{ijK}\}$, and the appraisal sub-item score $s_{ijk} = \{s_{ijk}^1, \cdots, s_{ijk}^L\}, j \in J, l \in L, J, K, L \in Z^+$, then the evaluation value of a level is calculated as:

$$x'_{ijk} = \sum_{k=1}^{K} w_{ijk} \sum_{l=1}^{L} s_{ijk}^l \tag{1}$$

The initial data are de-quantified and then standardized. According to the algorithm model of the undergraduate education assessment index, the mean of the ith item $\bar{x}'_i = \frac{1}{J}\sum_{j=1}^{J} x'_{ij}$, standard deviation $S_i = \sqrt{\frac{1}{J-1}\sum_{j=1}^{J}\left(x'_{ij} - \bar{x}'_i\right)^2}$, and the mean is normalized to:

$$x^*_{ij} = \frac{x'_{ij} - S_i}{\max\left(x'_i\right) - \min\left(x'_i\right)} \tag{2}$$

Also standardized scores of:

$$x_{ij} = \frac{x^*_{ij} - \bar{x}_i}{S_i} \tag{3}$$

Thus each indicator within I_i will have m ratings $\left(m \in [1, M], M \in Z^+\right)$, and so the rating matrix X_i is obtained:

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$$X_i = \begin{bmatrix} x_{i1}^1 & x_{i1}^2 & \mathrm{L} & x_{i1}^M \\ x_{i2}^1 & x_{i2}^2 & \mathrm{L} & x_{i2}^1 \\ \mathrm{M} & \mathrm{M} & \mathrm{L} & \mathrm{M} \\ x_{ij}^1 & x_{ij}^2 & \mathrm{L} & x_{iJ}^M \end{bmatrix} \tag{4}$$

Also indicator weight $w_{ij} = \sum_{k=1}^{K} w_{ijk}, w_i = \sum_{j=1}^{J} w_{ij}, W = \sum_{j=1}^{J} w_{ij} = 1$ then the indicator score of :

$$S_i = \frac{\sum_m^M \sum_{j=1}^J x_{ij}^m w_{ij}}{M \sum_{j=1}^J w_{ij}} \tag{5}$$

4.4. VARIATIONAL CRITIC ASSIGNMENT METHOD

The CRITIC assignment method can objectively express the difference or correlation of m evaluations of indicator I_i, and its physical meaning is that the larger the standard deviation S is, the greater the role of the indicator; the correlation coefficient is used to express the degree of conflict between indicators, and if the correlation coefficient is higher, it indicates that the conflict between indicators is smaller. In order to speed up the big data computation, the correlation strength is calculated using the equivalent Pearson coefficient:

$$\rho_i^\mu(j,q) = \frac{1}{M-1} \sum_{m=1}^{M} \left(\frac{x_{ij}^m - \bar{x}_{ij}^m}{S_{ij}^m} \right) \sum_{m=1}^{M} \left(\frac{x_{iq}^m - \bar{x}_{iq}^m}{S_{iq}^m} \right) \tag{6}$$

Obtain the m evaluation correlation matrix $P_i = \left(\hat{\rho}_i\right)_{j\times q}$, where $j,q \in [1,j], j \in Z^+$, then there is indicator conflictive ness C_i:

$$C_i = \frac{\delta_i}{J-1} \sum_{j=1}^{J} \left(1 - \sum_{q=1}^{j} \left| \hat{\rho}_i(j,q) \right| \right) \tag{7}$$

$$\delta_i = r \frac{\left| x_i - \bar{x} \right|}{\bar{x}} \sqrt{\sum_{m=1}^{M} \left(x_i^m / \bar{x}^m \right)} \tag{8}$$

where the coefficient of variation δ_{ij} reflects the average variability and r is the adjustment factor to fit the integrated weight interval, generally $r = 2.5$, so that the I_i weight is obtained:

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$$w_i' = C_i / \sum_{i=1}^{I} C_i \tag{9}$$

4.5. IMPROVING THE ENTROPY WEIGHT METHOD

The entropy value can reflect the amount of information carried by an indicator, and the larger it is, the higher the variability among related indicators, and the greater the weight and role of an indicator in the whole evaluation system. Thus the process of calculating the weight of I_i the term:

$$P_{ij} = \sum_{m=1}^{M} x_{ij}^{m} / \sum_{j=1}^{J} \sum_{m=1}^{M} x_{ij}^{m} \tag{10}$$

Calculate the entropy value $e_i \left(0 \leq e_i \leq 1\right)$:

$$e_i = -\sum_{j=1}^{J} P_{ij} \ln p_{ij} / \ln J \tag{11}$$

If $p_{ij} = 0$, then $p_{ij} ln p_{ij} = 0$, followed by calculating the variance:

$$d_i = 1 - e_i \tag{12}$$

Obtain the entropy weights:

$$w_{ei} = d_i / \sum_{i=1}^{I} d_i \tag{13}$$

In the entropy value, expert assignment values $w_q^S (q \in [1, I])$ are introduced to improve the overall entropy weights:

$$w_i'' = \begin{cases} w_i^e & , i = q \\ w_i^e + \dfrac{w_i^e (w_q^e - w_q^s)}{\sum_{i=1}^{q-1} w_i^e + \sum_{i=q+1}^{I} w_i^e} & , i \neq q \end{cases} \tag{14}$$

4.6. COMPOUND WEIGHTS

In order to achieve a comprehensive and objective reflection of the teaching level and the subjective judgments of the parties in the evaluation, the closest combined weight w_i is calculated using the least squares method. $w_i', w_i'', i \in [1, I], I \in Z^+$ is known, and the shortest distance to w_i', w_i'' is calculated, then there exists:

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$$\begin{cases} \min\left(f(w_i)\right) = \sum_{i=1}^{1} \left(w_i - w_i'\right)^2 + \left(w_i - w_i''\right)^2 \\ \text{s.t.} \quad \sum_{i=1}^{I} w_i = 1 \end{cases} \tag{15}$$

When the $f\left(w_i\right)$ function is continuously differentiable, to simplify the calculation of large data weights, the inverse $f'(w_i) = 0$ of w_i is directly solved to obtain the optimal combination weights as:

$$w_i = \left(w_i' + w_i''\right)/2 \tag{16}$$

5. EXPERIMENT AND ANALYSIS

5.1. CREDIBILITY ANALYSIS

Of the 1082 samples collected from the data center platform of a private university, credibility analysis was first done and Cronbash's factor was introduced to test the level 1 teaching evaluation credibility of the samples:

$$a = \frac{n}{n-1}\left(1 - \frac{\sum_{i=1}^{n} S_i^2}{S^2}\right) \tag{17}$$

where the number of samples $n = 1082$, S_i^2 is the variance of the score of the ith sample, and S^2 is the total variance to obtain Figure 3. The specific data values are shown in Table 1. The variable weights and expected weights of the level 1 instructional evaluations of the different factors in the sample can be seen in Figure 3(a). The final combined weights obtained are shown in Figure 3(b), which consists of a combination of variable weights and expected weights. The specific results are calculated by equations (15)~(16). It is easy to see that the final size of the combined weights of the seven evaluation items differed basically little, 12.81%, 15.78%, 15.28%, 14.38%, 12.83%, 12.81%, 15.01%, and 13.27%, respectively. This reflects the fact that each item plays a similar role in the quality rating index. In terms of individual evaluation items, the difference between the variable and expected weights of instructional management is relatively significant compared to the other six items, reaching 0.90%. The reason for this situation is the excessive uncertainty in instructional management. This uncertainty makes it necessary to introduce correction factors appropriately for improvement in the subsequent evaluation of the assessment system. Meanwhile, the distribution of weights in Figure 3 (a) is not significantly different from the requirements in the book "Indicator System" published by the Ministry of Education, which proves the reliability of the algorithm proposed in this paper. And in Figure 3 (b), the reliability of the 7 items of Level 1 teaching evaluation are 0.89, 0.88, 0.90, 0.91, 0.87, 0.84, 0.89. Usually, α in indicates unreliable indicates reliable, and greater than 0.9 indicates very reliable. From Figure 3, it can be seen that the calculation results of the sample data can meet the accuracy requirements of the index, thus ensuring the reliability of the collection of large sample data.

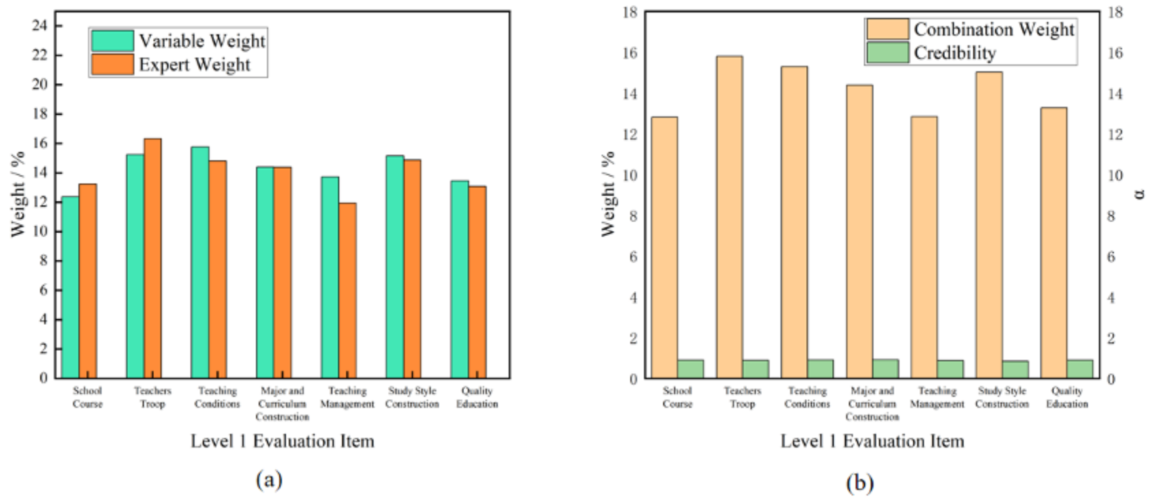

Figure 3. Weights of rating indicators and credibility of teaching evaluation of high-quality undergraduate education in colleges and universities

Table 1. Data values for each comparison of credibility of level 1 teaching evaluation

Evaluation Item / Contrast Item	School Course (%)	Teachers Troop (%)	Teaching Conditions (%)	Major and Curriculum Construction (%)	Teaching Management (%)	Study Style Construction (%)	Quality Education (%)
Variable Weight	12.37	15.24	15.79	14.39	13.73	15.16	13.46
Expert Weight	13.25	16.33	14.81	14.38	11.94	14.87	13.08
Combination Weight	12.81	15.78	15.28	14.38	12.83	15.01	13.27
Credibility	0.89	0.88	0.90	0.91	0.87	0.84	0.89

5.2. COMPARISON OF ALGORITHMS

In this paper, we also selected the more mainstream weight assessment algorithms for comparison, respectively, FAHP+TOPSIS combined assessment, superior order diagram method, and genetic algorithm assignment, using uniform samples and index coefficients, to obtain the weight of each index, and the results are shown in Figure 4. The specific values of the comparison items of the four algorithms are shown in Table 2.

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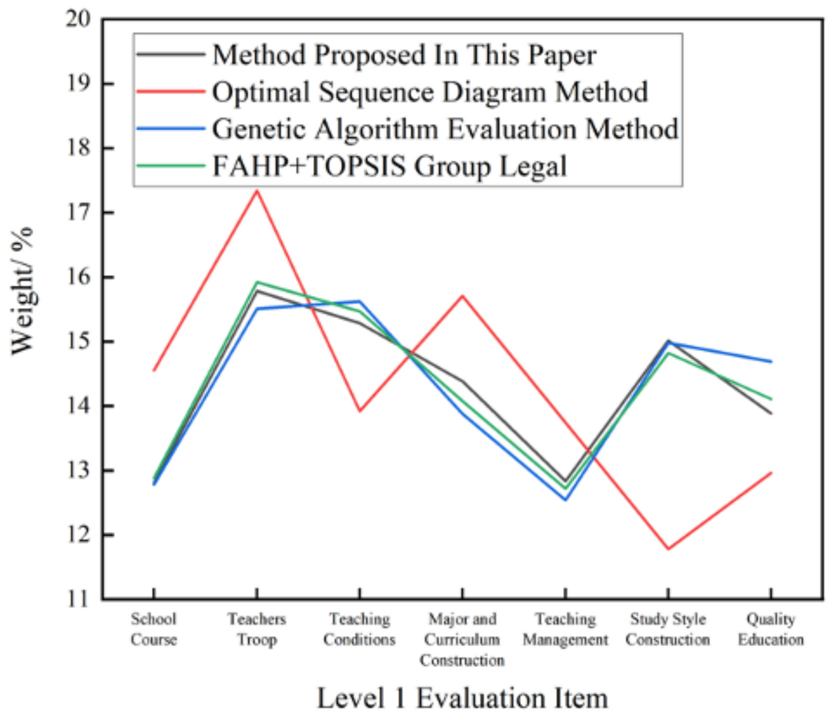

Figure 4. Comparison chart of various weighting algorithms

Table 2. Specific values of each comparison term for the four algorithms

Evaluation Item / Contrast Item	School Course Weight (%)	Teachers Troop Weight (%)	Teaching Conditions Weight (%)	Major and Curriculum Construction Weight (%)	Teaching Management Weight (%)	Study Style Construction Weight (%)	Quality Education Weight (%)	Evaluation Algorithm Time (S)
Method Proposed In This Paper	12.81	15.78	15.28	14.38	12.83	15.01	13.88	41
Optimal Sequence Diagram Method	14.55	17.34	13.92	15.71	13.74	11.78	12.96	38
Genetic Algorithm Evaluation Method	12.78	15.51	15.62	13.88	12.54	14.98	14.69	47
FAHP+TOPSIS Group Legal	12.88	15.92	15.47	14.08	12.72	14.82	14.11	118

The weighting of the indicator weights of the seven Level 1 teaching evaluations under different methods is reflected in Figure 4. Among them, the seven weight values of the Euclidean diagram method varied widely. Teaching tools have the largest weight in the Euclidean method with 17.34%, and teaching style construction has the lowest weight with 11.78%. The difference between the two was 5.56%. For the assessment system of FAHP+TOPSIS and the genetic algorithm, the index weights of each item are basically the same as the method proposed in this paper, and the

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differences between the items are small. For this kind of teaching evaluation system, too large or too small index parameters of each item are not good for the comprehensive construction of the evaluation system. Therefore, the method used in this paper with FAHP+TOPSIS combined assessment and genetic algorithm assignment can better provide suitable index weight values for the evaluation system of high-quality undergraduate education in private universities. In Table 2, the time consumption of the four evaluation algorithms for conducting one evaluation is compared. The time consumed by the method used in this paper, as well as the combined evaluation of FAHP+TOPSIS and genetic algorithm, is 41s, 38s, 47s, and 118s respectively, and it can be seen that the time consumed by the genetic algorithm is the largest compared with the other three methods, which is more than twice of the other methods. For the evaluation system, less elapsed time indicates higher operational efficiency. Although the method used in this paper, the elapsed time is about 3s slower compared to the combined FAHP+TOPSIS evaluation. However, the weights of its seven Level 1 teaching evaluations are more evenly distributed, and the comprehensiveness of the evaluation system is better than that of the FAHP+TOPSIS combination evaluation. Because of this, the difference of a few seconds is acceptable. In summary, the method used in this paper not only has a more even distribution of index weights but also takes less time to evaluate, which meets our requirements for the construction of an educational evaluation system.

6. DISCUSSION

For the future of high-quality undergraduate education in private colleges and universities, it should start from a macro perspective and look into the future. In response to a greater preference for local regional policy support, it should make better use of the economic development policies within its region to its advantage. Within the university, it should be more based on the reality of running schools, making reliable development plans, and striving to cultivate innovative and high-quality talents. Not only should they enhance their social responsibility obligations to increase the brand effect of the school, but they should also build up a high-level, high-quality faculty from within. It is a continuous process to figure out how to achieve an effective mechanism and assessment system for high-quality undergraduate education in private universities. In the establishment of the system, it is a continuous process of trial and error. In the assessment system, it is a continuous process of improvement with reasonable methods. The appropriate system and assessment system are not perfect at the beginning, and the research process should be a continuous advance.

7. CONCLUSION

In this paper, we analyzed the level 1 teaching evaluation reliability of the samples based on the deep learning method with 1082 samples collected from the data center platform of a private university. And subsequently, the method used in this paper was

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compared with three algorithms, namely, FAHP+TOPSIS combined evaluation, superior order graph method, and genetic algorithm empowerment, and the following conclusions were obtained:

1. In terms of the distribution of the weight parameters, the difference between the combined weights of the seven evaluation items is basically small, 12.81%, 15.78%, 15.28%, 14.38%, 12.83%, 12.81%, 15.01%, and 13.27%, respectively. In terms of individual evaluation items, the difference between the variable and expected weights of teaching management is more obvious, reaching 0.90%.

2. In the credibility evaluation, the credibility of the 7 items of the Level 1 teaching evaluation were 0.89, 0.88, 0.90, 0.91, 0.87, 0.84, and 0.89, respectively. The calculated results of the sample data of the 7 items were all greater than 0.8, and all of them could meet the accuracy requirements of the index.

3. Under the comparison of the algorithm of this paper with the combined assessment of FAHP+TOPSIS, the Euclidean map method, and the genetic algorithm assigned weights, the seven weight values of the Euclidean map method differed significantly. Among them, the teaching tools accounted for the largest weight in the Euclidean map method, reaching 17.34%, and the teaching style construction accounted for the lowest, 11.78%, with a difference of 5.56%. The four algorithms took 41 s, 38 s, 47 s, and 118 s. The genetic algorithm took the most time to assign weights compared to his three methods.

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/05/

SEQUENCING THE CARBON EMISSION CYCLE OF GREEN BUILDINGS IN CHINA BASED ON AN ECOLOGICAL CITY PERSPECTIVE

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ABSTRACT

As people's basic material living standards continue to rise, the demand for a better living environment and a better life is becoming increasingly strong. Since the 18th and 19th National Congresses of the Party proposed to carry out ecological civilization construction and build a beautiful China, carrying out ecological city construction has become one of the effective ways to solve the current urban development problems. In this paper, we summarise the latest research on green building assessment systems, life-cycle carbon emissions and life-cycle costs of buildings. We find that China's green building assessment system still has many shortcomings compared to the world's advanced green building assessment systems. Based on this, we have conducted a sequencing analysis of the life cycle carbon emissions of green buildings in China, so that buildings can meet the green building rating and at the same time achieve energy and carbon savings. The results of the study show that the building use phase has the highest carbon emissions in the building life cycle, accounting for 77% of the life cycle carbon emissions.

KEYWORDS

Ecological cities; green buildings; carbon emissions; cycle sequencing; accounting

INDEX

ABSTRACT

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4. DISCUSSION

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1. INTRODUCTION

The city is a living organism, and the construction of an eco-city is aimed at achieving the harmonious development of man and nature and establishing a virtuous cycle of urban ecology. It emphasises the harmonious development and overall ecology of society, economy, culture and nature [1,2]. For a long time, China's urban construction has mainly been based on the model of rough and loose growth, which has led to the incompatibility between urban development and ecology and subsequently to the emergence of many urban problems. Against this background, urban ecological civilisation has emerged as an urgent solution to urban problems and a healthy, green living environment for human beings [3-5]. In addition, as the global climate problem continues to be serious, people are paying more and more attention to the issue of greenhouse gas emissions [6,7]. As the construction sector accounts for about one-third of global greenhouse gas emissions, reducing greenhouse gas emissions in the construction sector is a major concern worldwide. Among the necessary ways to reduce low carbon emissions in the building sector are not only improving building energy efficiency and reducing building energy consumption, but also increasing research and investment in clean energy and renewable energy technologies [8-10].

In recent years, theoretical and practical research on ecological cities has gradually become a new direction for urban construction in the new era. In urban construction, planners and city builders must adhere to the principle of eco-friendly construction, strictly adhere to the 'ecological bottom line', form a rational structure of production, living and ecological space, and improve the efficiency of land use. Supriana et al[12] argue that a city's knowledge management system is important to encourage people to create, share and use knowledge. Dai et al.[13] summarised different urban lighting projects in the context of eco-city construction. They found that there are currently three main indicators for urban lighting projects, which are energy saving, environmental protection and intelligence. Then, based on the above research summary, they provide an outlook on the application of artificial intelligence technology in urban lighting engineering and put forward ideas related to the construction of intelligent infrastructure. shu et al [14] analysed the current status of eco-city development in China, taking the Sino-Singapore Tianjin Eco-city as an example. They analysed the daily lifestyle of the city's residents based on the results of several interviews and potential field observations, and found that China is gradually beginning to pay attention to environmental protection and is striving to find a path that harmonises economic and environmental protection. Drawing on the experiences of international countries, China has gradually explored an eco-city development path with Chinese characteristics. xu et al[15] studied the relationship between urban environmental image and urban eco-efficiency and innovatively used a national garden city image scheme to examine the improvement of eco-efficiency. The results showed that this programme significantly improved the eco-efficiency of the city by expanding the green area of the city, optimising the industrial structure and bringing in talented residents. This impact was significant for western China, but

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somewhat marginal for developed eastern cities.Azambuja et al [16] found that rapid population growth and urbanisation caused problems such as environmental pollution and shortage of natural resources. The existence of these problems has driven a shift from traditional urbanisation models to eco-smart cities. Based on the UN Sustainable Development Goals, they proposed a new conceptual framework of smart sustainable cities and elaborated on smart governance approaches to ultimately achieve coordinated and sustainable development of economic development, ecological civilisation construction and environmental protection. li et al[17] pointed out that building circular economy eco-cities is the most effective way to solve the problem of sustainable urban development. They assessed the sustainability of these cities using an energy value approach through a study of daylighting in coastal Central and Eastern European countries. The study shows that the utilisation rate of non-renewable resources has a significant impact on the economic development of a city. As the recycling rate of these non-renewable resources increases, the energy value sustainability index and the development index first decrease and then increase, which helps to resolve the contradiction between environmental superiority and economic backwardness.

The construction industry is a major contributor to China's carbon emissions, accounting for 30% to 50% of society's total carbon emissions each year. In order to achieve the goal of carbon neutrality, the construction industry is bound to face a huge transformation challenge. Green buildings, as a sustainable building type, are an effective way to achieve carbon neutrality in buildings [18-22].Fan et al [23] established a multi-objective optimisation scheme for green building modelling. The multi-objective optimisation of the construction effect of the project was carried out by combining the resource allocation and weather condition factors such as temperature, humidity and precipitation of the project site. The results show that this optimisation approach can reduce the total cost of the project and provide new ideas for the development of unconstrained optimisation. pu et al [24] applied BIM technology to the field of green building. bim technology can quantify and manage the life cycle of green buildings, thus stepping out of the traditional model and making the design and construction process more accurate. They summarised the current situation and advantages and disadvantages of using green building and BIM in the actual construction process, and analysed the prospects for the application of BIM technology in the construction field. The results show that combining BIM technology with green building and applying it in the construction field is a green path that can make the construction process more standardised and increase the life cycle of green buildings. yu et al [25] applied deep learning neural networks to green building energy consumption in order to avoid problems such as local pole skewing, slow convergence and incomplete data collection brought by traditional neural network models data model. A generative adversarial network-based model for building energy consumption data generation in green buildings was finally implemented. They found that the model can learn hidden patterns in the original data and generate some virtual data. They then validated this model with real building energy consumption data. Ferrari et al [26] argue that in order to improve the sustainability of buildings, it is

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necessary to rate green buildings. They point out that the Level(s) proposed by the EU in 2018 have become a common framework for assessing the sustainability continuation of buildings across Europe, becoming a uniform standard for the European building industry. The proposed rating system can promote competition among those in the construction-related industries and enable the construction industry to flourish. Ykj et al [27] developed a two-stage data mining model based on 354 building profiles and a neural network prediction model in Taiwan to analyse the types, grades, and technologies of these buildings. The results showed that different green buildings have different construction processes. For example, high-grade residential communities focus more on the indoor air environment as well as the surrounding living environment. Chen et al [28] used building-integrated photovoltaic (BIPV) technology to reduce CO_2 emissions from buildings. BIPV low-carbon design involves five major aspects: energy, materials, environment, management and innovation, with the first two being the main influencing factors. Accordingly, they proposed a framework of indicators related to carbon emission control to guide the low carbon design approach for buildings. Lu et al [29] summarised their research on carbon emissions in the green building construction industry from three aspects: policy, technology and management models. They found that current research hotspots focused on life cycle modelling, energy efficiency and the environment, which have limitations. They concluded that combining decarbonisation design into building design is a feasible path, which can be optimally analysed by establishing a multi-objective decision model for decarbonisation design and renewable energy.

To sum up, in order to better achieve energy saving and emission reduction in the construction industry, the development of green buildings is comprehensively promoted. Green building evaluation standards are a tool to measure the energy and carbon reduction capacity of green buildings, and the higher the green building rating, the more energy and carbon efficient the building is. However, the actual research process has found that some buildings are obsessed with the pursuit of green building rating, making their building carbon emissions increase instead [30-32]. In response to the problems found, this paper injects the concept of 'eco-city' into the green building industry. Through the study and understanding of existing eco-cities, the research focuses on the renewal of land use in eco-cities, emphasising the importance of the 'ecological' concept. The aim is to evaluate the current state of green buildings from an ecological perspective, without being limited to traditional evaluation methods and renewal strategies, so that buildings can meet green building ratings while saving energy and reducing carbon.

Table 1. Main modes of green ecological agriculture

Agricultural model	Features
space-time structure	According to the biological, ecological characteristics and a rationally formed ecosystem of mutually beneficial symbiotic relationships between organisms
food chain	A virtuous cycle agro-ecosystem designed according to the energy flow and material cycle laws of the agro-ecosystem
Integrated spatiotemporal food chain	The organic combination of space-time structure type and food chain type is a mode type with moderate input, high output, less waste, no pollution and high efficiency

2. LIFE CYCLE CARBON ACCOUNTING MODEL FOR GREEN BUILDINGS

2.1. GREENHOUSE GAS ACCOUNTING

The contribution of different greenhouse gases to global warming varies, with carbon dioxide at 76%, methane at 14.3%, nitrous oxide at 7.9%, and other overall contributions of less than 2%. The Intergovernmental Panel on Climate Change (IPCC) uses the GWP of carbon dioxide as a benchmark for converting the GWP caused by other greenhouse gases over a period of time (usually on a 100-year basis) into carbon dioxide equivalents, using the following formula:

$$CO_2eq_i = GM_i \times GWP_i \tag{1}$$

Among them, CO_2eq_i is the carbon dioxide equivalent of the i greenhouse gas, GM_i is the emission of the i greenhouse gas, and GWP_i is the GWP value of the i greenhouse gas.

2.2. METHODOLOGY FOR CALCULATING CARBON EMISSIONS AT VARIOUS STAGES OF THE LIFE CYCLE OF A GREEN BUILDING

The formula for calculating carbon emissions at each stage of the full life cycle of a green building is as follows:

$$C = AD \times EF \tag{2}$$

Where C denotes the carbon emissions at each stage of the full life cycle of a green building, AD denotes data on the level of direct or indirect activity throughout the life cycle of the building, and EF denotes the carbon dioxide equivalent generated per unit of building activity data, also known as the carbon emission factor.

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The total carbon emissions for the life cycle of a green building are the sum of the carbon emissions at each stage and the mathematical expression is calculated as follows:

$$E_{\text{sum}} = E_d + E_{pt} + E_c + E_{om} + E_{end} \qquad (3)$$

Of these, E_d are carbon emissions from the design decision phase, E_{pt} are carbon emissions from the production and transportation of building materials, E_c are carbon emissions from the construction phase, E_{om} are carbon emissions from the operation and maintenance phase and E_{end} are carbon emissions from the demolition and disposal phase.

The annual carbon emission per unit of floor area, GE is selected as the evaluation index of life-cycle carbon emission of green buildings, and its expression is as follows.

$$GE = \frac{E_{\text{sum}}}{Y \times A} \qquad (4)$$

Where Y is the full life cycle time of the building and A is the floor area.

2.3. CALCULATION OF CARBON EMISSIONS AT THE DESIGN DECISION STAGE

In this paper, two main aspects are considered when calculating the carbon emissions at this stage: on the one hand, the carbon emissions resulting from the energy consumption of the designers in using the relevant equipment for the design of the architectural drawings; on the other hand, the carbon emissions resulting from the project-related activities occurring during the travel of the designers for the construction project. Therefore, the formula for calculating carbon emissions at the design decision stage is

$$E_d = P_e + P_b \qquad (5)$$

Where P_e is the design equipment's carbon emissions and P_b is the travel carbon emissions.

$$P_e = \sum_{i=1}^{n} DM_i \times T_i \times EF_c \qquad (6)$$

Where n is the number of designer categories, DM_i is the number of designers in category i, T_i is the average number of computer hours used by designers in category i, and EF_c is the carbon emission factor for computer operation.

$$P_b = \sum_{i=1}^{n} \sum_{j=1}^{z} D_{ij}' \times EF_{i,j}' \qquad (7)$$

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Where n is the number of business trips, z is the number of types of transport taken, D_{ij}' is the distance traveled by the i business traveler in the j mode of transport, and $EF_{i,j}'$ is the carbon emission factor per unit distance for a single person in the j mode of transport.

2.4. CALCULATION OF CARBON EMISSIONS DURING THE PRODUCTION AND TRANSPORTATION PHASES OF BUILDING MATERIALS

The building material production and transport phase can be further divided into material production and material transport phases. Namely

$$E_{pt} = P_p + P_t \tag{8}$$

Where P_p is the material production carbon emissions and P_t is the material transport carbon emissions.

$$P_p = \sum_{i=1}^{n} m_i \times EF_{m_i} \tag{9}$$

Where n is the number of building material types, m_i is the amount of building materials used in category i and EF_{mi} is the carbon emission factor for category i.

$$P_t = \sum_{i=1}^{n} \sum_{j=1}^{z} m_{ij} \times D_{ij} \times K_y \times EF_{i,j} \tag{10}$$

Where z is the number of transport mode categories, m_{ij} is the mass of building materials of category i transported by the jth transport mode, D_{ij} is the average transport distance of building materials of category i transported by the j transport mode, K_y is the empty vehicle correction factor, and $EF_{i,j}$ is the carbon emission factor per unit mass per unit transport distance of the j transport mode.

2.5. CALCULATION OF CARBON EMISSIONS DURING THE CONSTRUCTION PHASE OF BUILDING

During the construction phase, site formation begins and people, machinery and materials enter the site one after another. The carbon emissions during this phase mainly come from the carbon emissions generated during the use of machinery and equipment on site. Therefore, the formula for calculating carbon emissions during the construction phase is as follows

$$E_c = P_c + P_r \tag{11}$$

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Where P_c is the carbon emissions from construction machinery and P_r is the carbon emissions from construction personnel.

$$P_c = \sum_{i=1}^{n} TB_i \times EF_{e,i} \tag{12}$$

Where n is the number of machinery and equipment categories, TB_i is the number of machinery and equipment shifts in category i, and $EF_{e,i}$ is the carbon emission factor per unit shift of machinery and equipment in category i.

$$P_r = \sum_{i=1}^{n} T_i \times EF_{r,i} \tag{13}$$

Where n is the number of construction personnel, T_i is the number of man-days and $EF_{r,i}$ is the manual carbon emission factor.

2.6. CALCULATION OF CARBON EMISSIONS DURING THE OPERATION AND MAINTENANCE PHASE

The operation and maintenance phase can be subdivided into an operation phase and a maintenance phase, so the carbon emissions from the operation and maintenance phase are made up of these two components, as in the following equation.

$$E_{om} = P_o + P_m \tag{14}$$

Where P_o is the operational phase carbon emissions and P_m is the maintenance phase carbon emissions.

$$P_o = \left(\sum_{i=1}^{n} E_i \times EF_{e,i} + W \times EF_w + P_l - \sum_{i=1}^{n} R_i \times EF_{e,i} - GS \right) \times Y \tag{15}$$

Where n is the number of energy types, E_i is the annual consumption of the i energy type, $EF_{e,i}$ is the carbon emission factor of the ith energy type, W is the annual consumption of water systems, EF_w is the carbon emission factor of water, P_l is the annual carbon emission of land development and use, R_i is the annual saving of the ith energy type, GS is the annual carbon reduction of greening systems, and Y is the life of the building.

$$P_l = \sum_{i=1}^{n} S_i \times EF_{l,i} \tag{16}$$

Where n is the number of land use types, S_i is the area of land type i and $G_{e,i}$ is the carbon sequestration factor for land type i.

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$$GS = \frac{\sum_{i=1}^{n} G_{e,i} \times A_{e,i} - 600 \times R \times A_s}{40} \tag{17}$$

Where n is the different planting methods in the greening system, $G_{e,i}$ is the 40-year carbon sequestration per unit area for the ith planting method, $A_{e,i}$ is the green area for the ith planting method, R is the green space ratio and A_s is the total building site area.

2.7. CALCULATION OF CARBON EMISSIONS DURING THE MAINTENANCE PHASE

Carbon emissions from the maintenance phase include carbon emissions from the production of building materials and the energy consumption of machinery and equipment used for transport and maintenance, resulting from the aging of building materials or components.

$$P_m = \sum_{i=1}^{n} \left(m_{s,i} \times EF_{m,i} + P_{t,i} \right) \times k_i + \sum_{k=1}^{q} TB_k \times EF_{e,k} \tag{18}$$

$$P_{t,i} = \sum_{j=1}^{z} m_{ij} \times D_{ij} \times K_y \times EF_{t,j} \tag{19}$$

$$k_i = \frac{Y}{Y_m} - 1 \tag{20}$$

Where n is the type of maintenance material, $m_{s,i}$ is the mass of maintenance material of category i, $EF_{m,i}$ is the carbon emission factor of maintenance material of category i. k_i is the transportation carbon emission of maintenance material of category i, TB_k is the maintenance factor of maintenance material of category i. is the number of maintenance equipment shifts of category k, $EF_{e,k}$ is the carbon emission factor per unit shift of category k maintenance equipment, $m_{i,j}$ is the transport quality of the jth transport mode of the maintenance material of category i. $D_{i,j}$ is the transport distance of the jth transport mode of the maintenance material of category i, K_y is the empty vehicle correction factor, $EF_{t,i}$ is the carbon emission factor of the j transport mode, Y is the service life of the building design, and Y_m is the service life of the building material.

2.8. CALCULATION OF CARBON EMISSIONS DURING THE DISMANTLING AND DISPOSAL PHASE

$$E_{end} = Q_c + Q_t + Q_h + Q_m \tag{21}$$

Where Q_c is construction demolition carbon emissions, Q_t is construction waste transportation carbon emissions, Q_h is construction waste disposal (including landfill

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and incineration) carbon emissions and Q_m is construction waste recycling carbon emissions.

This section establishes a life cycle carbon accounting model for green buildings based on the life cycle assessment (LCA) approach. The purpose and scope of accounting for green building life-cycle carbon emissions, system boundaries, and functional units are firstly determined. This is followed by an analysis of the sources of green building carbon emissions in five stages of the building life cycle: design decision, production and transportation of building materials, construction, operation and maintenance, and demolition and disposal, and the establishment of a carbon emission calculation method for each stage. A theoretical model is established for the subsequent discussion.

3. RESULTS AND DISCUSSION

This paper analyses a typical case of a residential community in a city in China, which covers an area of 28,000 square metres, with a building area of 76,500 square metres and a green space ratio of 48%. There are eight high-rise residential buildings in it.

In this paper, we analyse one of the green buildings in the context of an eco-city, and analyse its carbon emission cycle sequencing. The residential building is 18 storeys above ground, with a building height of 55.35m; reinforced concrete shear wall structure, seismic intensity 8 degrees; there are 4 units, each with one staircase and two households. Each unit has a floor area of 101.4 square metres, with a total of 144 residences and a total floor area of 16,432 square metres. The building has a total floor area of 5,658 square metres and 2,320 square metres of green space (densely planted bushes). The carbon emissions of the building were calculated for the entire life cycle of the building by separating the building phase, the building use phase and the end-of-life phase of the building. The highest carbon emissions were analysed to provide theoretical guidance for energy saving and emission reduction in green buildings.

3.1. CARBON EMISSIONS DURING THE BUILDING PHASE

The residential building was completed as a rough building, so the main statistics are for the materials used in the civil construction and installation of the building. The carbon emissions per unit area produced at each stage of the building, including the extraction of raw materials, production of building materials, on-site processing of components, construction and installation, land use and the buildingisation stage, were also counted. The statistical results are shown in Table 1 below.

According to the definition of greenhouse gases, greenhouse gases from the combustion of fossil fuels and land use during the on-site processing of components, construction and installation sub-stage of the physical phase are classified as direct

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emissions. The greenhouse gas emissions from the use of electricity in the on-site processing of components, construction and installation sub-stage and the greenhouse gas emissions from the extraction of raw materials and the production of building materials are classified as indirect emissions. Based on the calculations, it can be concluded that the sub-stage with the highest proportion of carbon emissions in the physical phase of the building is the land use, followed by the production of building materials and the extraction of raw materials, which account for 94% of the physical phase, while the construction phase only accounts for 6% of the total carbon emissions. Direct carbon emissions in the physical phase account for about 41%; indirect carbon emissions account for about 59%.

Table 2. Carbon emission statistics per unit area for each sub-stage in the physical phase of the building $(kgCO_2e/m^2)$

Stage	CO_2	CH_4	N_2O	Total calculation
Raw material extraction	185	5.08	5	195
Building material production	253	633	1.03	254
On-site machining of structural components	8.34	263	176	8.78
Construction and installation	42.9	1.36	904	45.2
Land use	317	0	0	317
Building materialisation phase	806	7.33	7.11	820

3.2. CARBON EMISSIONS DURING THE USE PHASE OF THE BUILDING

Carbon emissions from the day-to-day operation of buildings include greenhouse gas emissions directly or indirectly from the (1) use phase of buildings due to the consumption of energy such as fossil fuels, electricity and heat, (2) the use and discharge of water resources, and (3) the leakage of refrigerants. In residential buildings energy consumption specifically includes elements such as heating, air conditioning, lighting, lifts, other appliances, natural gas for cooking and domestic hot water.

The residential building is heated in winter by a natural gas wall-hung stove as the heat source and radiant floor heating as the end; in summer the cooling is by split type air conditioning. The thermal efficiency of the natural gas fireplace is 91% and the electrical power of the circulating water pump is 130 W. The split air conditioner is energy efficiency class 2 with an energy efficiency ratio of 3.4. The heating period is from November 15 to March 15 and the air conditioning period is from June 15 to August 31. The electricity consumption of lighting equipment accounts for a significant

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proportion of the life-cycle energy use of a home, and the energy consumption of lighting equipment is closely related to the choice of lighting and usage habits. The power consumption of lighting equipment can be calculated as the product of building lighting power density and lighting time. According to the Building Lighting Design Standard GB 50034-2004, the annual lighting energy consumption of the residential building can be calculated as the remaining carbon emissions of each building's daily use as shown in Table 2.

Table 2 shows that air conditioning and heating are the largest contributors to carbon emissions, with a combined total of 42%; refrigerants, although smaller in mass, account for 25% of carbon emissions during the building use phase due to their large GWP values; and water supply and drainage also contribute 5% of carbon emissions and cannot be ignored. According to the definition of greenhouse gases, carbon emissions from the combustion of natural gas and refrigerant leakage during the daily use phase of the building are direct emissions, while carbon emissions from electricity and water supply and drainage are indirect emissions. According to the calculations, direct emissions are 30% higher than indirect emissions.

Table 3. Greenhouse gas emissions during the use phase of residential buildings

$$(kgCO_2e/m^2)$$

Projects	CO_2	CH_4	N_2O	HFC	Total
Heating	599	262	1.03	0	600
Refrigeration	377	0.0988	1.69	0	379
Elevator	110	0.0289	493	0	111
Lighting	271	71	1.21	0	273
Other household appliances	157	0.0411	701	0	158
Domestic gas	126	0.0627	0.0974	0	126
Drainage	85.6	0.00794	135	0	85.7
Refrigerant	0	0	0	587	587
Total	1730	573	5.35	587	2320

3.3. CARBON EMISSIONS AT THE END-OF-LIFE STAGE OF THE BUILDING

According to the national standard, the carbon emissions of building demolition, recycling/reuse of building materials/equipment and waste disposal can be calculated separately. The total carbon emissions from the demolition of the building are 40.7

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$kgCO_2e/m^2$, the total carbon emissions from the recycling/reuse phase are 41.3 $kgCO_2e/m^2$, and the total carbon emissions from the waste disposal phase are 8.32 $kgCO_2e/m^2$. Therefore, it can be found that the carbon emissions from the end-of-life phase of the building mainly come from the demolition and recycling/reuse phases of the building.

3.4. BUILDING LIFE CYCLE CARBON EMISSIONS

The carbon emissions of the residential building in each sub-stage of its life cycle are shown in Table 3. The life-cycle carbon emission of the building is about 4000 $kgCO_2e/m^2$, and its carbon footprint is 80 $kgCO_2e/m^2$. From Table 3, it can be seen that the highest carbon emission in the whole life-cycle of the residential building is the daily operation stage of the building, which reaches 2320, accounting for 58.03% of the whole life-cycle carbon emission. This is followed by the land use, building repair, building materials production and building renovation phases, which generate 7.93%, 6.60%, 6.35% and 6.30% of the carbon emissions of the whole life cycle, respectively.

Table 3. Carbon emissions of residential building life cycle sub-stages ( )

Stage	CO_2	CH_4	N_2O	HFC	Total
Raw Material Mining	185	5.08	5	0	195
Building materials production	253	633	1.03	0	254
On-site processing of structural parts	8.34	263	176	0	8.78
Construction and Installation	42.9	1.36	904	0	45.2
Land Use	317	0	0	0	317
Daily operation of the building	1730	573	5.35	587	2320
Building Maintenance	48.9	733	711	0	50.3
Building Restoration	257	3.85	3.73	0	264
Building Updates	196	2.93	2.84	0	201
Building renovation	244	3.66	3.56	0	252
Demolition of buildings	38.7	1.22	814	0	40.7
Recycling/reuse	36.2	941	4.15	0	41.3
Waste disposal	8.3	0.00772	0.0207	0	8.32
Full Lifecycle	3360	21.2	28.3	587	4000

The proportion of carbon emissions from each sub-stage of the building's life cycle is shown in Figure 1. It can be seen from the figure that the proportion of carbon emissions from the daily operation of the residential building is the largest, reaching

58%, while the whole building use phase accounts for 77% of the life-cycle carbon emissions, reaching 3087 $kgCO_2e/m^2$. Carbon emissions from the physical phase of the building account for 20.5% of the life-cycle carbon emissions, at 820 $kgCO_2e/m^2$. The carbon emissions from the end-of-life phase of the building account for 2.2% of the life-cycle carbon emissions, at 91 $kgCO_2e/m^2$.

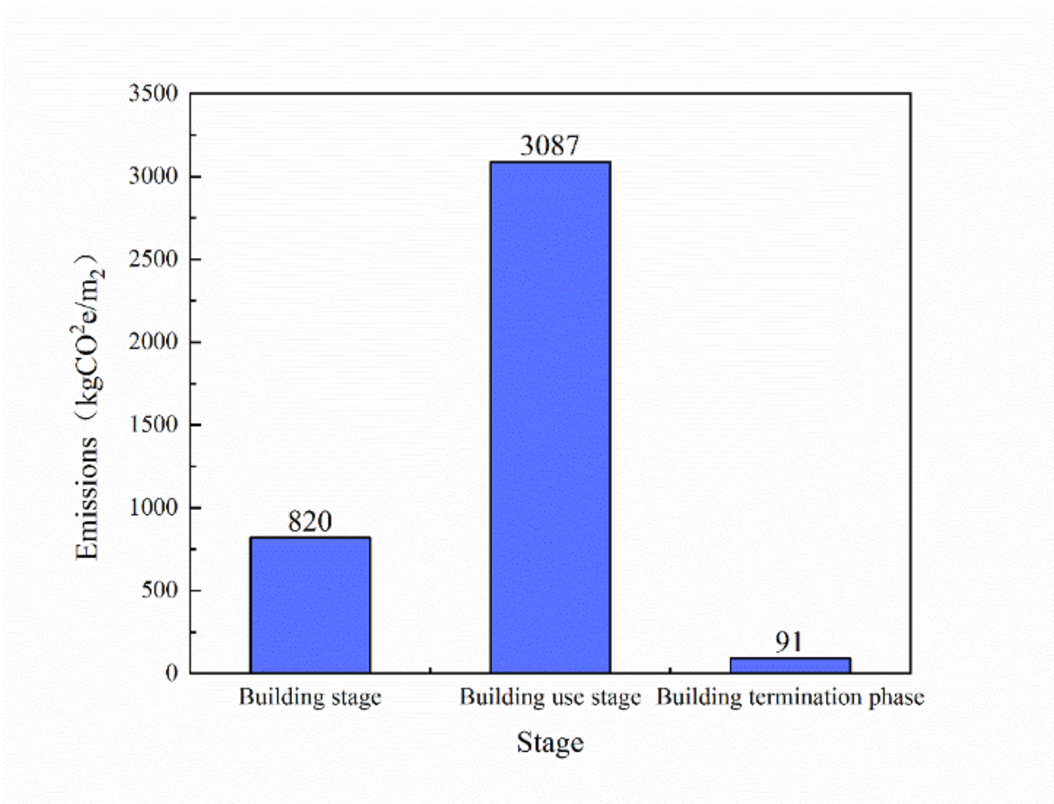

Figure 1. Carbon emissions in the three main stages of the life cycle of a residential building

In summary, the carbon emissions of this residential building were calculated for the three phases of building construction, building use and building end of life, and the highest carbon emissions were found in the building use phase, accounting for 77% of the life cycle carbon emissions. Therefore, in order to reduce carbon emissions, we can start from the use phase of the building.

4. DISCUSSION

In this paper, a typical case study of a mobile high-rise building in a residential community in a Chinese city is analyzed in the context of eco-city. The carbon emissions of the building are calculated in the building construction phase, the building use phase and the building end-of-life phase, and thus the carbon emissions of the building throughout its life cycle are calculated. The highest carbon emissions were analyzed to provide theoretical guidance for energy saving and emission reduction of green buildings. The results of the study are as follows.

1. In the building materialization stage, the sub-stage with the highest proportion of carbon emissions in the building materialization stage is land use, followed

by building materials production and raw materials extraction, which account for 94% of the materialization stage, while the total carbon emissions in the construction stage account for only 6%.

2. In the building use phase, the most carbon emissions are generated by air conditioning and heating energy, the sum of which reaches 42%; although the refrigerant mass is small, the proportion of carbon emissions generated by it accounts for 25% in the building use phase due to its large GWP value.

3. In the end-of-life stage of the building, the total carbon emission from the demolition of the building is 40.7 $kgCO_2e/m^2$, the total carbon emission from the recycling/reuse stage is 41.3 $kgCO_2e/m^2$, and the total carbon emission from the waste disposal stage is 8.32 $kgCO_2e/m^2$. Therefore, the carbon emissions in the end-of-life stage of the building mainly come from the demolition and recycling/reuse stages of the building. In addition, the carbon emissions from the building use phase are the highest in the building life cycle, accounting for 77% of the life cycle carbon emissions.

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STUDY ON THE APPLICATION OF DEEP LEARNING TECHNOLOGY AND BIM MODEL IN THE QUALITY MANAGEMENT OF BRIDGE DESIGN AND CONSTRUCTION STAGE

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ABSTRACT

The development of the transportation industry can effectively accelerate the speed of economic development, in which bridges occupy an important position in transportation. The safety of the bridge design and construction process is a key part of bridge construction, and relying on human resources to investigate safety hazards greatly affects efficiency. In this paper, we combine deep learning technology and BIM model to explore the synergistic effect of both on the quality management of bridge construction phase and analyze the measured data. The results show that the application of BIM model can improve the efficiency by 35% compared with the traditional 2D CAD drawings, and the accuracy of data analysis can be improved by 12.51% and 14.26% for DNN and DBN models based on deep learning, respectively. The addition of the GSO algorithm leads to a further 19.19% improvement in the training accuracy of the coupled model. Finally, the optimization model was used to analyze the load factors and force majeure factors that affect the safety of the bridge, and to find the structural factors that affect the safety of the bridge design, which provides guidance to ensure the quality of the bridge during the construction process.

KEYWORDS

BIM model; CATIA modeling; deep learning; bridge construction; quality and safety

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1. INTRODUCTION

With the continuous development of China's economy, transportation modes are showing a trend of diversification. The establishment of a well-connected transportation network is of great importance for the development of national transportation, the promotion of inter-regional economic exchanges and the flow of talents [1,2]. Among them, bridge construction is the core link in the transportation network, which can effectively solve the problem of inconvenient traffic on both sides of the river basin. The safety of bridges is a key consideration in the design and construction process of bridges, which can cause very serious traffic accidents if the quality is not up to par [3-5]. Safety problems not only cause national economic losses, but also have a destructive effect on the ecological environment to some extent [6-8]. The safety issues of bridges should have a preliminary prediction during the construction phase and also throughout the construction phase of the project, where data from all aspects of bridge construction should be collected, processed and analyzed. Bridge quality and safety monitoring mainly include two aspects of data acquisition as well as safety index evaluation [9,10]. BIM technology is a technology that integrates the data in the construction process through a building information model. By integrating a large amount of data and information, it can read the key information and realize data interoperability. It enables information transfer and resource sharing in the pre-project preparation, process implementation and quality control stages at the end of the project. It plays an important role in quality inspection, safety management, budgeting, and progress monitoring of the construction process [11-14]. BIM technology can effectively improve efficiency, increase calculation accuracy, shorten construction cycle time and scientifically maintain equipment. Neural network deep learning is a modern tool for data interpretation and result prediction, which can quickly read information and extract data feature values, and input calculation results after training with embedded algorithms. This learning approach is currently combined with various fields, and the use of a deep learning approach can help us to quickly make predictions about the results and greatly improve efficiency [15-19]. If the deep learning approach is applied to the quality inspection in the bridge construction process, not only the rate of problem solving can be improved but also the accuracy of calculation results will be enhanced. Currently, some scholars have conducted studies on the use of BIM technology and deep learning methods in bridge construction and obtained desirable results [20-24].

Pan [25] et al. investigated a clustering-based log mining method for building information modeling (BIM), while combining a novel clustering algorithm with an efficient fuzzy Kohonen clustering network (EFKCN) to classify information with different characteristics. The data were analyzed using regression prediction method and the results showed that the model can be better for model building. D Forgues et al [26] used the BIM model to reduce the cost of project completion and shorten the project cycle by classifying the data through linear regression. The results showed that the use of the BIM model can effectively discover the causes affecting the quality of bridge construction and improve efficiency. R Edirisinghe [27] developed a safety

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life cycle BIM prediction model with high maturity and analyzed the factors affecting the model by data from real cases. As a result, five main factors affecting the BIM model were found, and the model was improved to propose a life cycle BIM maturity model (LCBMM) supported by actual data. Liang et al [28] proposed a novel deep learning model based on a three-stage image training strategy to analyze the bridge design structure, and in order to train and analyze the data effectively focused on the model's robustness of the model was focused on in order to train and analyze the data effectively. The results show that the robustness of the model is very good and the accuracy of the prediction is more than 90%. T Abbas [29] et al. used a neural network (ANN) model to predict and analyze the aerodynamic phenomena around the bridge design process. In the paper, the neural network and the structural model were combined and trained on bridge data with different interfaces and different geometric features. The results show that artificial neural networks can predict the bridge construction process more accurately, and this method can provide ideas for the design of bridges with larger spans. Qz A [30] proposed a vision-based method for the detection of cracks in concrete bridge decks, which is a one-dimensional convolutional neural network (1D-CNN) and long short-term memory (LSTM) method in the image frequency domain. The method is trained using a large number of cracked or uncracked bridge deck images with high efficiency and accuracy. The results show that the developed model can reach 99.25% accuracy with respect to the test data. Moreover, the 1D-CNN-LSTM model can effectively reduce the computation time compared with other neural network deep learning approaches. Ma [31] et al. proposed a data-driven method for strain data detection and differentiation of vehicles for detecting vehicle operation in large-span bridges. A neural network deep learning approach is used to track and identify vehicles to ensure traffic safety on bridge pavements. The results show that this detection method is relatively robust and accurate and is able to predict traffic conditions well despite the presence of noise. Dinh K [32] et al. proposed a coupled algorithm combining traditional image processing techniques and deep convolutional neural networks for the localization and detection of steel reinforcement during the construction of bridge construction. The images are first processed by offset and normalization methods for locating the pixels containing potential rebar peaks. The results obtained in the first step were then classified by a convolutional neural network (CNN) and a total of 26 bridge data were analyzed. The results showed that the average accuracy of the model's calculation results exceeded 97.75%, and the overall accuracy of the whole bridge test was about 99.60%. Kim [33] et al. proposed a vision sensor-based UAV bridge inspection method to troubleshoot the deterioration of bridges over a long period of time to ensure the quality and safety issues of bridges. The test first used a UAV to fly around and obtain a point cloud-based background model. A regional convolutional neural network (R-CNN) model was then used to detect the crack structure on the bridge surface and calculate the thickness and length of the cracks. A new network is generated from the pre-trained network and used to collect 384 crack images with 256 × 256 pixel resolution. The results show that the model is highly accurate in the identification and detection of bridge quality. Yang [34] et al. proposed a deep learning model to evaluate the stability and safety of bridge structures, and the model maps a network of large data into a very small volume of eigenspheres. Where the data in the spheres are normal values and the abnormal data are outside the eigenspheres. The results show that this model learning approach is effective and the computed practical results are superior compared to other advanced methods. In summary, the application of BIM technology and deep learning neural networks for monitoring the management of safety issues in bridge construction has ideal results in terms of both data resources and access integration and project outcome prediction. However, the two technologies are separate in the research work so far, and the combined use is relatively rare.

Therefore, this paper explores the synergistic effect of coupled models in the application of bridge construction stage quality management based on the BIM model, combined with a deep learning approach. Firstly, the bridge structure is parametrically modeled by CATIA software, and the potential problems in the bridge construction process are identified through the BIM model. Then the information is input into the neural network through the input layer, while comparing the deep learning approach with the traditional calculation method, and evaluating the accuracy of the deep learning approach according to the calculation results. Further, the GSO algorithm is used to optimize the deep learning method, and the validity of the computational results of the optimized algorithm is analyzed. Finally, the structural factors affecting safety and stability, including load factors and force majeure factors, are analyzed by this optimization algorithm. It provides an idea for the bridge construction process monitoring and the bridge quality and safety prediction.

2. DESIGN OF THE MODEL

2.1. PARAMETRIC MODELING OF THE BRIDGE STRUCTURE

At present, BIM models are more widely used in all stages of engineering design, construction and maintenance, among which the application in the transportation industry is the most. Various urban transportation fields in China have made application requirements for the application of BIM technology, and strict standards have been set for the accuracy of the results. The standardized regulations are important to ensure the construction quality and safety of the project, and all aspects of bridge design should be carried out in strict accordance with the standards. the key aspect of BIM application lies in the construction of the initial model, and the efficiency and quality of the modeling directly affect the project. CATIA software is a good modeling tool, which is a software developed by Dassault Systèmes, France, mainly used for the construction of mechanical structure models. the most important feature of CATIA is that it can model according to parametric spatial points, spatial curves and surface features, and has a good effect on the parametric modeling of large bridges (arch bridges, T-bridges, etc.).

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CATIA is an integrated software with CAD/CAE and CAM, which can provide a set of mature technical solutions from product design and final product landing. CATIA has the functions of 3D parametric design, dimensional constraints, parametric modification, etc. The specific connotations of parametric include the following.

1. Custom parameters: Users can input specific parameters according to their actual needs during the modeling process, and there are various types of parameters to meet different types of customers.

2. All-round dimensional constraints: This is the advantage of CATIA. Dimensional constraints refer to the specific constraints on the dimensions of each drawing that are mandatory for users in the modeling process. If the markup is missed, the modeling process cannot proceed. Also, the user has to give a global dimension so that the accuracy can be effectively controlled during the modeling process.

3. Dimensional parameter modification: In the process of parametric modeling, there must be constraints on the overall dimensions. But the detail part may exist with the subject management, the size can not be completely determined. CATIA can give the drive size modification function to this part, to achieve size modification and change.

4. Structural logic: In the design process respect the top-to-bottom concept, specifically expressed as a loop. In the setting or modification link soft solutions are made to record, the user can check or modify again.

5. Standardized design: For the frequently used structure, the software provides a parametric template. That is, the software can save this part of the design in the inventory, and the same is defined in accordance with the standard size. Users can transfer in and out from the library in the process of use, to facilitate the work of users.

2.2. DEEP LEARNING MODEL

In recent years, deep learning (DL) and artificial intelligence have been very closely integrated and have penetrated into many industrial fields. DL has unique advantages in extracting feature values from big data and processing data, and therefore has a wide range of applications in computer systems, speech idiosyncratic recognition and language expression. The input is generally located at the lower level. The input transmits the data further to a higher layer. The layers of transmission finally reach the output layer, which is the highest layer. It is important to note that the data is mined step by step during the transfer process, and finally, the data is obtained with some distribution pattern. The bridge structure is composed of many different small parts, and each part is related. Therefore, many details need to be considered when evaluating construction safety and quality, and the amount of data is relatively large. To address this problem this paper uses the DL model for analysis, and adds the deep

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neural network (DNN) model and the deep belief network (DBN) model to the DL model, aiming to further improve the accuracy of the model prediction results. Which can be transformed into an output matrix when extracting the feature values, as shown in Equation 1.

$$R = \begin{pmatrix} r_1 & r_2 & \cdots & r_{1,n} \\ r_{1,1} & r_{2,2} & \cdots & r_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{n,1} & r_{n,2} & \cdots & r_{k,n} \end{pmatrix} \tag{1}$$

Where k denotes the fault information and r_{nk} denotes the fault parameters. By constructing a mixture model about the features, the distribution expression of the features of the faults can be obtained as follows.

$$R_i = \frac{\sum_{i=1} R + r_{n,k}}{m_i} \tag{2}$$

Where m_i denotes the frequency of the fault wave and the subscript i expresses the number of faults. According to the deep learning method, the dynamic components of the faults can be obtained by the distribution probabilities of the visible and implicit layers corresponding to the initial detection and model reconstruction of the bridge as shown in the following equation.

$$T = \frac{R_i(n+1) + R}{m_i} \tag{3}$$

Where n denotes the fusion transfer parameter containing the fault features, and based on the above-extracted eigenvalues, combined with the spectral analysis, the density component of the monitoring fault phase coupling is obtained as shown in the following equation.

$$R_x = \frac{v_x}{T + R_i} \times \sum_{i=1} R \tag{4}$$

Where v_x represents the peak of the bridge fault state. The joint analysis method is applied to it, and the expression of energy distribution can be obtained as follows:

$$M = \frac{N_x}{R_i + R_x} + \sum_{i=1} R \tag{5}$$

Where N_x denotes the dimensionless parameter for equipment failure in the bridge monitoring process, and analysis of the data yields the output of automatic fault tolerance for bridge equipment failure monitoring as:

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$$G = 2T + \frac{N_g + N_x}{m_i} \tag{6}$$

From the above analysis, it can be seen that when a bridge fails, the extraction of fault feature values can help engineers quickly determine the cause of the failure and find the location of the failure. The bridge fault tolerance model constructed can improve the fault tolerance of the device.

DNN is an artificial neural network composed of the input layer, implicit layer and output layer, DNN is mainly through the learning behavior to solve the mapping relationship between the input layer and output layer. DNNs can achieve more satisfactory results for both feature value extraction and computational result prediction.

DBN is a generative model with multiple hidden layers because it is composed of multiple restricted Boltzmann machines (RBMs) cumulatively, which is a model with random probability distribution consisting of a set of visible units as well as hidden units. DBN is able to retain data features and on this basis, the computational process can be simplified by reducing the dimensionality as much as possible. Therefore, the effective learning method of DBN can be thought of as reducing the complex model to a combination of many simple models, and learning the input parameters by passing them in layers. The DBN is more accommodating and can input different kinds of data. And the data transfer is iterative, i.e., the previous data calculation result will be used as the next input data, so DBN has an efficient learning method as well as scientific classification performance.

3. ENGINEERING APPLICATION RESEARCH

Deep learning technology and BIM models have a role in the quality management of bridge design and construction phases that should not be underestimated. Among them, BIM technology and the CATIA software module available in recent years have a guiding role in the design of the bridge in the early stage and the subsequent construction problem ranking, which can reduce the manual input. Deep learning technology, on the other hand, can be used to troubleshoot bridge quality problems that occur during the construction phase and to monitor the bridge quality monitoring system, which can provide statistical analysis efficiency by excluding invalid data. This section will detail the specific application of the BIM model and deep learning approach in bridge construction.

3.1. SPECIFIC APPLICATION OF THE BIM MODEL IN THE DESIGN AND CONSTRUCTION OF BRIDGE ENGINEERING

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For the bridge project, the bridge design and construction and bridge engineering feasibility links, through the application of BIM technology, can more effectively accelerate the progress of the bridge project design. the advantages of BIM technology applied to bridge design are mainly the following two points, one is that through the use of the technology, you can check out in advance whether there are defects and deficiencies in the project, timely improvement and processing, for the later bridge engineering project The first is that by using this technology, the defects and shortcomings of the project can be identified in advance, and timely improvements can be made to bring more convenience to the later bridge projects. The second is that the application of BIM technology helps designers and constructors to have a deeper understanding of the project, and can accurately analyze and judge the different cost situations involved in the project to facilitate further reduction of bridge project costs. the main contents of the four main steps of BIM technology application are:

1. In the design and construction of bridge projects, the first step of BIM technology application requires that the designer should continuously improve the model according to the requirements of different periods and the actual needs of the project so as to ensure the accuracy of the model. The construction process mainly has the following three steps: the first is to establish the relevant parameter library, the second is to build a scientific and accurate model, and the third is to reasonably set the corresponding reinforcement module. Among them, the establishment of the relevant parameter library and the next step of building the model can use Dassault's CATIA software to achieve parametric modeling. CATIA 3D model can pass management object data, index data, etc. to the construction stage, which can make the modeling process more convenient with higher accuracy.

2. After constructing an accurate parametric model of the bridge project in the early stage, to develop a perfect construction strategy, advanced BIM technology needs to be further applied. By means of simulation, the link is clearly presented, and the construction differences are compared, so that the simulated construction process is visualized and dynamic. This step will enable the designer to make a more scientific and accurate judgment on the safety and economy of the bridge structure.

3. Volume statistics, refers to the application of BIM technology application statistics to obtain accurate volume calculation values in the bridge engineering design period. Compared with the traditional method of calculating the points, lines and surfaces of the two-dimensional plane, the calculation task is completed with Excel tables. Using BIM technology, in building an accurate three-dimensional model of the bridge, it is possible to scientifically select the design components and suitable materials, and use the automated measurement function to achieve the purpose of determining the bridge volume. This method, in addition to reducing the calculation time, improves the accuracy of calculation by about 35% on average and saves the energy input

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of design staff. In addition, for the modeling of complex curves under linear engineering, it is also possible to accurately determine the twisted part and accurately measure the length, area and volume of the bridge by using the CATIA software in BIM technology.

4. In the design and construction of bridge projects, after completing the above work, Navisworks and other related software can be further used. For the construction of the BIM model for collision analysis, to complete the preliminary check, proofreading and audit and other different work. At the same time, it helps to find out whether there are defects and deficiencies in the construction drawings, and further correct them. In addition, the use of BIM technology can also achieve the task of comparing procurement lists and determining what needs to be procured.

3.2. SPECIFIC APPLICATION OF DEEP LEARNING TECHNOLOGY IN BRIDGE ENGINEERING QUALITY MONITORING

It is necessary to monitor the health system data in the design and construction of bridges. Compared to most traditional test and analysis methods that rely on statistical theory and require extensive domain knowledge, monitoring systems based on deep learning techniques are more suitable for large-scale data sets. The main work of the deep learning technique monitoring system is to perform health monitoring and data characterization of bridge structures. Its main purpose is to study the different distribution characteristics of the data for subsequent processing of the data. One of the bridge quality monitoring devices for monitoring bridge structure data is an important device for monitoring faults and status, and the reliability of bridge quality monitoring devices is to be ensured in performing bridge quality monitoring. However, the reliability of the bridge quality monitoring device cannot be guaranteed due to the bridge's own structural factors that easily affect the bridge quality monitoring device. In order to guarantee the reliability of monitoring data, this paper proposes an intelligent bridge quality monitoring device fault tolerance system automatically based on deep learning technology, and carries out hardware design and application testing.

Establish the communication module of bridge quality monitoring equipment in the fault-tolerant system of the upper computer, and carry out the interface interaction design of bridge quality monitoring equipment fault judgment through reset control and Internet networking control technology. Set the dual ports as RAM, apply the Internet of Things networking technology to obtain the PCI protocol of the dual ports, and obtain the bus control parameter analysis model for fault-tolerant judgment of bridge quality monitoring equipment according to the PCI protocol control signal. Set the operating main frequency of the system to 180MHz/MIPS, and carry out the joint multi-channel control of bridge quality monitoring equipment fault judgment by PCI protocol. The bridge quality monitoring sensor module with data bus set to LD[16:0] signal is used for VXI transmission of bridge quality monitoring equipment fault

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tolerance system automatically to build a network monitoring model for bridge quality monitoring equipment fault tolerance judgment. To reduce the error of fault information, the register initialization process is carried out, and finally, the monitoring information of bridge quality monitoring equipment fault automatic fault tolerance system sends data to the main control computer through the bus.

4. RESULTS AND DISCUSSION

4.1. ANALYSIS OF TEST RESULTS

A part of the data from the China Construction Project Database was used as the experimental data set for the experimental testing of the bridge quality monitoring device fault automatic fault tolerance system designed based on deep learning. The output curve of fault feature monitoring of the bridge quality monitoring device is shown in Figure 1.

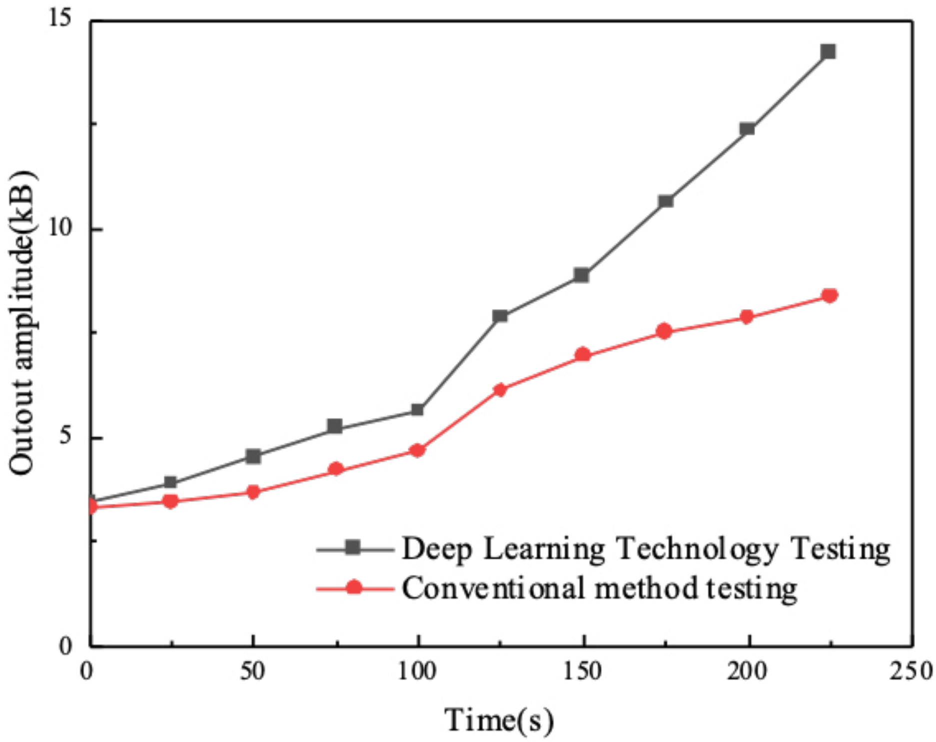

Figure 1. Monitoring output amplitude change curve

As can be seen from Figure 1, the deep learning technique-based test method for bridge quality monitoring equipment fault monitoring has a high level of sample fusion. In addition, compared with the traditional test method without troubleshooting, the highest output value of the deep learning technique test is 28.64% higher in the first 125S and 69.97% higher in the second 250S, which greatly improves the fault

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tolerance level of the bridge quality monitoring equipment and the reliability of the measured data. The fault tolerance level of the bridge quality monitoring equipment is greatly improved and the reliability of the measured data is also greatly enhanced. On this basis, the bridge quality monitoring equipment fault judgment was implemented, and the fault tolerance convergence level evaluation results were obtained as shown in Figure 2.

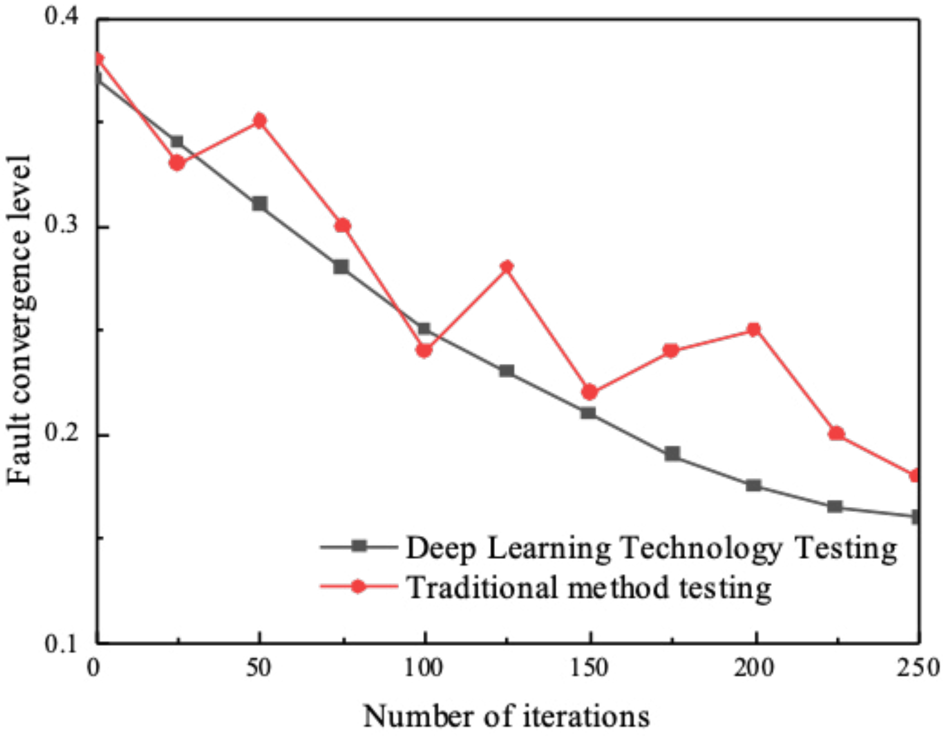

Figure 2. Monitoring convergence level curve

From the convergence curve comparison, it is known that the convergence curve of the method designed in this paper for bridge quality monitoring equipment fault monitoring is smooth and of high quality, with small overall changes and reliable data measured by side feedback. In contrast, with the data obtained from the traditional method test, the data reliability cannot be guaranteed due to the failure of the monitoring equipment and automatic error reporting is not excluded. Although the highest convergence level and the lowest convergence level of the test method based on deep learning technology are smaller than the traditional test method by about 0.01-0.02, the overall level change rate is only 2.1% per 25 iterative steps, the fault reliability is large, the judgment ability is high, and the overall fault tolerance convergence is high.

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4.2. DATA VALIDITY ANALYSIS

After excluding the bridge quality monitoring equipment fault monitoring data, the validity analysis of the measured monitoring data is performed. The prediction results of decision-tree, random-forest, SVM, DNN, DBN and other machine learning classification methods were compared. For the same dataset collected, the DBN model can improve the accuracy by 14.27% compared with the decision tree. The experiments prove that the deep learning model has stronger data analysis capability and is more suitable for validity analysis of bridge quality monitoring data obtained from monitoring.

Although deep learning models such as DNN and DBN have a great improvement for data analysis accuracy, but because there are more parameters in the two models and the initial values of the parameters are set randomly, it is easy to lead to local optimum during the training process of deep learning, which affects the training results of network models and reduces the testing accuracy. For this reason, a firefly swarm optimization algorithm, combined with artificial GSO, is used to further optimize the DBN model. Since GSO has a strong ability to solve local optimization problems, its objective function can be a loss function, and the initial parameters of the model are optimized through GSO to improve the model's applicability and test accuracy. the DBN-GSO model represents a random initialization of parameters to the original DBN-R model, and the results show that the data accuracy obtained from testing through the DBN-GSO optimized model is higher than that of the initial model by The accuracy is improved by 19.19% compared with the initial model, indicating that the GSO optimization algorithm can further optimize the DBN model and improve the training test accuracy.

4.3. STRUCTURAL SAFETY ANALYSIS

Based on the above analysis, it is clear that the optimized DBN algorithm has improved the model prediction accuracy, so this subsection further analyzes the structural parameters affecting bridge safety by the optimized DBN algorithm. The bridge construction process is fixed by the connection between the piers, the bridge body and the bridge deck, and its structural integrity is an important factor affecting the stability of the bridge. This paper focuses on the structural analysis of bridges, including the bearing of bridges under overload conditions of use and force majeure factors. These factors include mainly pedestrian and vehicle loads (lateral and longitudinal), ambient temperature, typhoons and seismic natural disasters, and the input layer data of the influencing factors under certain criteria are imported into DL, as shown in Table 1.

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Table 1. Input layer parameter characteristics

No.	Load Type	Load design limit value		
		Base value setting basis	Minimal value	Maximum value
1	Vehicle load /（$kN\cdot m^{-2}$）	Consider the overload situation	0	1.3
2	Crowd Load /（$kN\cdot m^{-2}$）	Number of people in large events	0	2.8
3	Temperature /（°C）	Meteorological statistics temperature maximum value	-15	40
4	Windward load（$m\cdot s^{-1}$）	Category 10 typhoon	0	27.6
5	Upwind load（$m\cdot s^{-1}$）	Category 10 typhoon	0	27.9
6	Transverse vehicle load /.kN	Consider the overload situation	0	45000
7	Longitudinal vehicle load /kN	Consider the overload situation	0	18000
8	Seismic load /g	8 magnitude earthquake	0	0.24

For the input parameters, the DL model is calculated iteratively to obtain the output results as shown in Table 4. The output layer results represent the structural influences on the safety and stability of the bridge, highlighting the most jointed areas. This is because of the large and complex structure of the bridge and the high degree of correlation between the internal structures. Relying solely on the engineer's experience to make judgments about safety issues at design time would slow down the project schedule on the one hand, and there is no guarantee that the experience is accurate and that any safety-threatening issues in the bridge design must be eliminated. The structure obtained from the DL model can help engineers find the key aspects of the construction problem and provide guidance for the bridge design. Table 2 lists the force problems during the use of the bridge. The main sources of force are load and wind, and the parts that are subject to the greatest axial force, bending moment, and shear can be obtained from the input results. The offset is then the stability problem of the bridge in the presence of stresses. The same analysis was carried out for different parts to get the sensitive areas affecting the main girders, piers and towers.

Table 2. Output layer parameters and characteristics

No.	Type		
	Major Categories	Minor Categories	position
1	Inner Strength	Axial force	Tower main beam
2			Tower Root Section
3		Bending moment	Bridge pier main girders
4			Tower Headquarters (Yokohama direction)
5		Shear force	Bridge pier main girders
6			Tower root (longitudinal bridge direction)
7	Offset degree	Main beam	Middle of main beam
8		Bridge pier	Left side of the bridge pier
9		Bridge Tower	Tower top (cross-bridge direction)

5. CONCLUSION

This paper is based on the definition and role of both deep learning technology and the BIM model, and discusses the significance of both in the quality management of bridge design and construction stage, systematically analyzes the guidance significance of the BIM model in bridge design and construction, describes the application process of deep learning technology and its role in monitoring experimental test in bridge quality monitoring equipment failure, and obtains the following conclusions.

1. The application of the BIM model in bridge engineering design and construction mainly through the construction of models, the development of construction strategies, statistical engineering volume and fault monitoring and material statistics during construction, compared to the traditional two-dimensional CAD drawings BIM model has more aspects of bridge engineering design and construction, improving the efficiency of about 35%.

2. Deep learning techniques applied in bridge quality management monitoring can improve the reliability of measurement data and analysis efficiency. The bridge quality monitoring equipment fault monitoring and troubleshooting system designed in this paper can improve up to 69.97% in 250S iteration time compared with the data obtained from the traditional method testing, while the

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level value of the convergence curve is high, with a change rate of only 2.1% per 25 iterative steps.

3. The validity analysis of the measured data after the bridge quality monitoring equipment fault monitoring and elimination, the DNN model and DBN model in the deep learning technique can improve the accuracy of data analysis by 12.51% and 14.26%, respectively, and the DBN-GSO model combined with the GSO optimization algorithm can also avoid the local optimization results and improve the training accuracy by 19.19% compared with the original model. The optimized model is further analyzed for load-stress analysis and safety issues of force majeure factors for bridge structures. Based on the imported parameters, the specific structural parameters affecting the bridge quality and safety were obtained by iterative learning.

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RESEARCH ON THE PROTECTION AND DEVELOPMENT OF HISTORICAL AND CULTURAL RESOURCES IN THE YELLOW RIVER BASIN FROM THE PERSPECTIVE OF ECOLOGICAL CIVILIZATION

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ABSTRACT

In building the ecological civilization of the Yellow River basin, it is of extraordinary importance to preserve and develop the historical and cultural resources of the Yellow River basin to ensure the economic and cultural prosperity of its surroundings. Based on the need to better protect and develop the historical and cultural resources of the Yellow River Basin, we have developed a research system for the conservation and development of the natural and cultural resources of the Yellow River Basin. It covers both the conservation of the natural resources and the development of the cultural heritage of the Yellow River Basin. The assessment results show that in the Yellow River travel assessment score, the score in 2018 was 67.12, and in 2021 the score rises to 76.23, an increase of 13.57%. In the exploitation of the natural and historical resources of the Yellow River Basin, the scores of related travel, books, and transportation have improved significantly. Yellow River-related history books scored only 63.21 in 2018 for books and increased by 16.04% to 73.35 in 2021. In the transportation sector in the Yellow River Basin, the score was 65.37 in 2018, rising to 75 in 2021.

KEYWORDS

Historical and cultural resources protection; historical and cultural resources development; ecological civilization construction; Yellow River Basin; intangible culture

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1. INTRODUCTION

The ecological environment is the basis of our survival [1, 2]. Ecosystems are difficult to repair when damaged because they are irreplaceable [3]. The development model that follows the law of natural development with equal emphasis on the economy and environment is the most valuable [4, 5]. Therefore, the protection of ecological civilization deserves high priority and we must follow a green and sustainable development path. [6]. In carrying out the construction of ecological civilization, his core issue is to correctly deal with the relationship between man and nature and promote the harmonious development of man and nature [7, 8]. The hallmark of a new stage in the development of human civilization is ecological civilization. Ecological civilization is a symptom of the harmonious development of man and nature. The sum of material and spiritual results achieved as a result of this objective law [9]. The construction of ecological civilization is related to the high-quality development and modernization of China's economy [10, 11]. Environmental protection and economic development go hand in hand and will generate transformative forces. In the construction of ecological civilization, there are numerous watersheds within China. The ecological civilization construction of watersheds is crucial to the construction of ecological civilization in China.

In China, the major watersheds include the Yangtze River basin [12, 13], and the Yellow River basin [14, 15]. The Yellow River basin, the second largest basin in China, has a good vegetation cover in most of its upstream parts. The upper main streams have many canyons and are rich in hydraulic energy resources [16]. Below the gorges are the river plain, irrigated and accessible to shipping. In the middle reaches, there are also abundant hydro-energy resources. The banks are loess plateaus with little vegetation and severe soil erosion, which is the main source of flood sediment in the Yellow River [17, 18]. In the lower reaches, most of the dikes are built on both banks, and the sediment accumulation makes the riverbed generally 3-5m above the ground level on both banks, and as much as 10m, so it is called a hanging river [19]. In China's 5,000-year-long history corridor, numerous cultures and historical civilizations have been born in the Yellow River basin. Because of the very harsh natural conditions and climate change in the Yellow River Basin, the Yellow River Basin civilization is quite different from other ancient civilizations. Therefore, when carrying out ecological construction in the Yellow River Basin, it is necessary to focus on the protection and development of historical and cultural resources.

Many scholars all over the world have conducted relevant studies on ecological civilization construction and historical and cultural resource protection and development in watersheds [20-27]. Zhu, Li [28] conducted ecological civilization prospect prediction based on a factor map distributed algorithm. They constructed an evaluation index set based on the connotation of the ecological civilization construction evaluation system and established a factor graph distributed ecological civilization construction evaluation model. They collected relevant data from 15 Chinese cities at different levels and standardized the input learning matrix. Their findings suggest that China's economic development needs further transformation and

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the corresponding resource output rate needs to be improved. Shen B [29] discussed the attractiveness of an urban ecological environment to Chinese job seekers. They studied the relationship between the urban ecological environment and labor mobility decisions from a micro-individual perspective. They found that job seekers were more willing to move to cities with better ecological environments during job transactions, and their study illustrated the importance of ecological civilization construction. Wang D [30] established an integrated model of urban ecological civilization and its barrier factors evaluation system. They constructed an extended index system of ecological civilization to reflect the interaction between humans and nature. And they combined the index variable weighting method, similarity to the ideal solution ranking technical model and barrier degree model to evaluate and diagnose regional differences and barrier factors. Liu T [31] believed that how to cope with the contradiction between the protection and development of ancient villages and towns in the process of new urbanization and rural revitalization is the key point in the protection and development of historical and cultural resources. They argued that the planning of tourist destinations in new urbanization can be carried out in an orderly manner within the framework of landscape information chain theory. Bonazza A [32] developed an interaction matrix to collect data on their needs and to identify the main gaps in data and information. In addition, they provided recommendations on implementing infrastructure solutions to improve access to data and information on Copernicus services for cultural heritage users. Their research shows that when conducting ecological civilization, it is important to consider the planning of construction, economic development, etc. In addition, in conducting the conservation and development of historical and cultural resources, it is necessary not to be uniform, but to combine local characteristics to form a distinctive cultural landscape.

In addition, due to the superior climate, fertile soil and other excellent geographical conditions of the Yellow River basin, it led to the socio-economic development of China in early China. In previous research work, people tend to consider purely ecological civilization construction without considering the impact of the preservation and development of historical and cultural resources in the Yellow River Basin on the economic and cultural prosperity around the Yellow River Basin. Therefore, in the study of this paper, we have established a research system for the protection and development of historical and cultural resources in the Yellow River Basin. The research mainly contains two aspects ecological construction and historical and cultural resources protection and historical and cultural resources development in the Yellow River Basin. We systematically analyzed and discussed these two aspects, and systematically evaluated the historical and cultural resources protection, and historical and cultural resources development by scoring. We hope that our research can bring new hope to the ecological construction and historical and cultural resources protection and development of the Yellow River basin.

2. HISTORICAL AND CULTURAL RESOURCES OF THE YELLOW RIVER BASIN

Yellow River Basin historical and cultural resources can be divided into naturalized Yellow River Basin historical and cultural resources and socialized Yellow River Basin historical and cultural resources, materialized Yellow River Basin historical and cultural resources and immaterialized Yellow River Basin historical and cultural resources in terms of their properties and existence forms [21-23]. The so-called naturalized Yellow River Basin historical and cultural resources are the elements that widely exist in nature and can be used by human beings; the socialized Yellow River Basin historical and cultural resources are the elements created by human beings themselves through labor and can serve the survival and development of human beings. Materialized Yellow River Basin history and cultural resources are embodied in kind and can be seen, and touched, in the tangible existence of the Yellow River Basin history and cultural resources. The non-materialized Yellow River basin history and cultural resources are the Yellow River basin history and cultural resources that can be used by humans but exist in non-physical forms, such as Yellow River history knowledge, Yellow River history concept, Yellow River history creativity, etc. Naturalized Yellow River historical and cultural resources are generally materialized Yellow River historical and cultural resources, while socialized Yellow River historical and cultural resources include both materialized Yellow River historical and cultural resources and related human resources as well as immaterialized Yellow River historical and cultural resources.

2.1. PROTECTION OF HISTORICAL AND CULTURAL RESOURCES IN THE YELLOW RIVER BASIN

The conservation of the natural historical resources and cultural heritage of the Yellow River Basin consists of two aspects: governmental conservation measures and technical remedial measures. The governmental conservation measures mainly enhance the relevant policies promulgated by the Yellow River Basin Historical and Cultural Resources Conservation Bureau and local government organizations in the Yellow River Basin to protect the historical and cultural resources of the Yellow River Basin. Further establishment of the Yellow River Basin Historical and Cultural Resources Protection Site. Technical remedy mainly refers to the adoption of various measures and techniques to prevent historical and cultural resources. Specifically, the current protection of historical and cultural resources in the Yellow River Basin involves firstly the relevant policies and regulations of China on the protection of historical and cultural resources in the Yellow River Basin. Secondly, the Yellow River's historical archaeology, museums, ruins relics and ancient modern architectural relics protection, ancient books protection, intangible cultural heritage protection, oral history and culture of the Yellow River basin, etc. Finally, there are related legends of river management figures, promotion of the importance of the history and culture of

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the Yellow River Basin, and protection of the environment management related to the Yellow River Basin.

The protection of the intangible Yellow River Basin historical and cultural resources mainly includes its governmental organizational structure, related policies on the protection of the Yellow River Basin historical and cultural resources, the main body of the protection of the Yellow River Basin historical and cultural resources, and the main body of the protection and transmission of the intangible Yellow River Basin historical and cultural heritage. The current organizational structure of the government for the conservation of intangible historical and cultural resources of the Yellow River Basin is mainly a joint domestic and foreign UNESCO and Chinese civil organizations. The main bodies of the heritage conservation of the intangible Yellow River Basin are government departments, universities, research teams, public cultural institutions and supporting organizations such as civil society organizations, and the public. The Yellow River Basin's historical and cultural intangible heritage bearers are the main body of the Yellow River Basin's intangible historical and cultural resources heritage protection and transmission, and therefore the most important aspect of the Yellow River Basin's intangible historical and cultural heritage protection is the identification of intangible cultural heritage bearers. The adoption of economic support, recognition and awards to support the protection of the intangible Yellow River historical and cultural heritage inheritors plays an important role in the protection of the inheritance of the intangible Yellow River historical and cultural resources. The principles of heritage protection of intangible Yellow River historical and cultural resources are mainly people-oriented, living and innovative, sustainable development, and holistic principles, etc.

2.2. HISTORICAL AND CULTURAL DEVELOPMENT OF THE YELLOW RIVER BASIN

The rise of the history and culture of the Yellow River Basin in China has also contributed to the popularity of books related to the history and culture of the Yellow River Basin among many consumers. The publication of books on the natural history of the Yellow River Basin is an important part of the development of the natural history of the Yellow River Basin, based on which we can better understand the trends in the ecological resources of the Yellow River Basin region. In contrast to sightseeing, reading books on the natural history of the Yellow River makes it easier to understand the historical mysteries and folklore of the Yellow River region. Although the older generations have handed down much of the history and culture of the Yellow River Basin, the historical and cultural illustrations provide a deeper understanding of the historical origins of the Yellow River Basin.

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3. EVALUATION SYSTEM

3.1. CONSERVATION AND SYSTEM DEVELOPMENT OF HISTORICAL AND CULTURAL RESOURCES IN THE YELLOW RIVER BASIN

This section constructs a structural model for the evaluation of the conservation and development of historical and cultural resources in the Yellow River Basin as shown in Figure 1, consisting of two primary indicators and five secondary indicators.

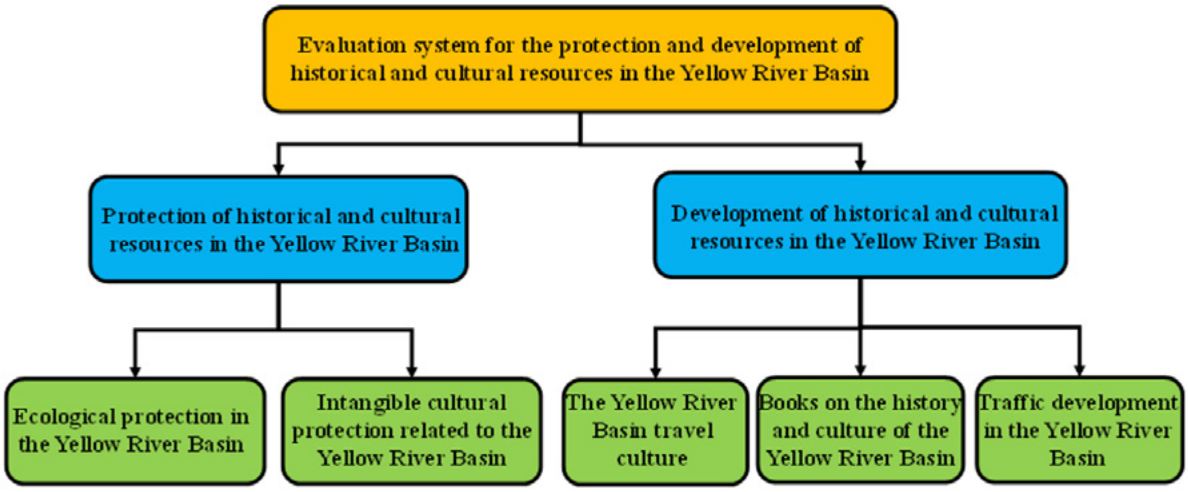

Figure 1. Evaluation system for the protection and development of historical and cultural resources in the Yellow River Basin

1. Protection of historical and cultural resources in the Yellow River Basin: An objective reflection of the degree of protection of historical and cultural resources in the Yellow River Basin, mainly including

    - C1 Ecological protection of the Yellow River Basin: Geological research and environmental protection of the area where the Yellow River Basin is located.

    - C2 Intangible culture protection related to the Yellow River Basin: Display of the non-traditional culture of the Yellow River Basin, as well as the overall presentation of cultural forms such as Huanghuang culture, Hailuo culture, Guanzhong culture, and Qilu culture.

2. Development of historical and cultural resources of the Yellow River Basin: A reflection of the development status of historical and cultural resources of the Yellow River Basin, mainly including

    - C3 Yellow River Basin travel culture: presenting to visitors the deep historical and cultural atmosphere of the Yellow River Basin.

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- C4 Yellow River Basin history and culture-related books: record related Yellow River Basin history mysteries.
- C5 Transportation development in the Yellow River Basin: including the convenience of transportation in the Yellow River Basin.

To ensure the reasonableness of the conclusions obtained by the hierarchical analysis method, the three judgment matrices obtained need to be tested for consistency. Therefore, the three judgment matrices will be tested using the consistency test formula, and the specific calculation process is as follows.

$$CR = \frac{CI}{RI} \tag{1}$$

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{2}$$

Where, CR is the random consistency ratio; CI is the judgment matrix consistency index; RI is the average random consistency index; n is the order of the judgment matrix, and λmax is the maximum eigenvalue of each matrix.

3.2. PSR MODEL

As a classical model of a dynamic analytical process, the PSR model not only reflects the pressure and impact on the ecological environment under human activities and behavior, but also facilitates people to visualize the changes in the natural ecology and motivates people to protect the ecological environment in various ways, to achieve a harmonious relationship between man and nature as well as the sustainable development of human society." The 'Pressure (P)', 'State (S)' and 'Response (R)' indicators. The "Pressure (P)" indicator reflects the negative impact of human activities and behavior on the natural environment during the interaction between human society and the natural environment, i.e. the "pressure" exerted by humans on the natural environment; the "State (S)" indicator reflects the changes in the natural environment over some time in response to the negative impact of human activities, i.e. the "state" of the natural environment; the "Response (R)" indicator reflects the remedial measures and actions taken by human beings to improve the carrying capacity of the environment and ecological environment in the face of the negative impact of human activities on the environment and the "state" of the natural environment, i.e. the "response" made by human society.

The questionnaire of these five indicators was sent to the panel members for consultation, and then the panel members submitted their opinions by letter in an anonymous manner. After several iterations of solicitation and feedback, the opinions of expert group members gradually converged and agreed, and finally a collective judgment result with a high accuracy rate was obtained.

4. ANALYSIS AND DISCUSSION

The Yellow River is not only a magnificent natural river but is also a long-standing culture of the river. The long history of Chinese civilization over thousands of years has been nurtured by the Yellow River and the Yangtze River together. They have not only given birth to the great Chinese nation but also to the glorious Chinese culture. Among the historical and cultural resources under the Yellow River Basin, the Yellow River culture is mainly agrarian and has characteristics such as pluralism and integration. In Table 2, we can observe the richness and diversity of the cultures of the Yellow River basin, and so in analyzing its ecological civilization, we need to take into account its many different features.

4.1. PROTECTION OF HISTORICAL AND CULTURAL RESOURCES IN THE YELLOW RIVER BASIN

There are many historical and cultural aspects of the Yellow River, and in the protection of cultural resources in the Yellow River basin, we mainly consider two aspects: the ecological protection of the Yellow River basin and the protection of intangible culture related to the Yellow River basin. The ecological protection of the Yellow River basin includes regional geological research and environmental protection. The protection of intangible culture related to the Yellow River Basin includes the protection of non-heritage culture and the overall presentation of cultural forms such as Huanghuang culture, Hailu culture, Guanzhong culture, and Qilu culture. We scored the protection and development of historical and cultural resources in the Yellow River basin by distributing questionnaires. The scores were used to calculate the assessment accordingly. The survey of the perceived value questionnaire of historical and cultural tourists in the Yellow River basin started on September 10, 2018, and the formal survey began on October 11, 2018, during which two surveys were conducted, as shown in Table 1. 200 questionnaires were distributed on October 20, 2018, and 181 questionnaires were returned, of which 155 were valid; on December 11, 2018, 300 questionnaires were distributed and 286 were returned, with 155 valid questionnaires A total of 500 questionnaires were distributed and 467 questionnaires were collected in the 2 surveys, of which 441 were valid, with an efficiency rate of 88.2%.

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Table 1. Questionnaire survey on the perceived value of historical and cultural tourists in the Yellow River Basin

Survey time	Distribution of questionnaires	Receive the questionnaire	Valid questionnaire
October 20, 2018	200	181	155
December 11, 2018	300	286	259
Total	**500**	**467**	**441**

We analyzed and processed the scores of C1, and C2 in the questionnaire to obtain the scores of ecological conservation in the Yellow River Basin and intangible cultural conservation related to the Yellow River Basin. We analyzed the scores and predicted the data of historical and cultural resource conservation in the coming years. As shown in Figure 2, in 2018, the scores of ecological conservation and intangible cultural conservation in the Yellow River Basin were 65.32 and 67.82, respectively. This indicates that the protection of historical and cultural resources in the Yellow River basin in 2018 is not sufficient and does not satisfy local people and tourists. In the process of carrying out the construction of ecological civilization, the related ecological protection of the Yellow River basin and the related intangible cultural protection of the Yellow River basin show signs of climbing up. This shows that China is paying more and more attention to the protection of historical and cultural resources while carrying out the construction of ecological civilization. In 2021, the scores of ecological protection of the Yellow River Basin and intangible cultural protection related to the Yellow River Basin increased to 73.52 and 77.39. Compared with 65.32,67.82 points in 2018, the scores increased by 12.55% and 14.11% year-on-year. In addition, it is worth mentioning that we have also predicted the ecological protection of the river basin from 2023 to 2025, and the score of intangible culture protection related to the Yellow River basin. According to the prediction results, the ecological protection score of the Yellow River basin increased to 79.85, 80.23, and 85.22 points between 2023 and 2025, respectively. Compared with 2018, it increased by 22.24%,22.82%,30.46%. This indicates that the ecological protection of the Yellow River basin has been further improved. The score of intangible culture protection related to the Yellow River Basin will be 83.65, 87.56, 89.5, compared with 2018, up 23.34%, 29.11 %, 32.01%, which indicates that while ecological protection, intangible culture related to the Yellow River Basin has also been improved accordingly, and China is more and more attentive to the protection of historical and cultural resources in the Yellow River Basin.

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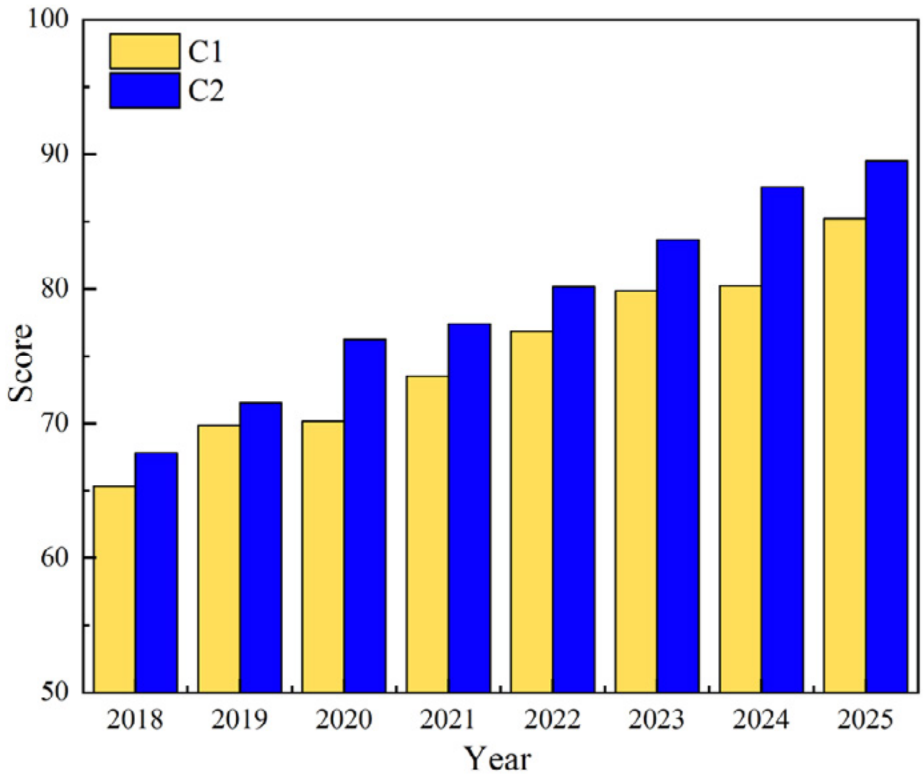

Figure 2. Trend and prediction of corresponding score changes for the protection of historical and cultural resources in the Yellow River Basin

4.2. DEVELOPMENT OF HISTORICAL AND CULTURAL RESOURCES IN THE YELLOW RIVER BASIN

The development of historical and cultural resources in the Yellow River Basin, in short, means using various methods to make full use of the historical and cultural resources in the Yellow River Basin to make them effective and gain benefits. In fact, in history, the development of historical and cultural resources has existed for a long time, mainly for government, social education, and intellectual enlightenment, as well as to learn or preach and exchange historical and cultural knowledge as a form of recreation. At present, the development of historical and cultural resources is mainly based on the development of cultural tourism and cultural relics exposition industry. In our study, we mainly evaluate three aspects of the Yellow River travel, related history books and the development of transportation within the Yellow River basin. Travel culture of the Yellow River basin: presenting tourists with a deep historical and cultural atmosphere of the Yellow River basin. Books related to the history and culture of the Yellow River Basin, recording the historical mysteries related to the Yellow River Basin. Transportation development in the Yellow River Basin, which includes the accessibility of transportation within the Yellow River Basin. In the questionnaire, the related score results are shown in Figure 3. In Figure 3, we can see that the scores in the three aspects of travel on the Yellow River, related history books and transportation development within the Yellow River basin have a large increase. In the

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Yellow River travel, the score in 2018 was 67.12, and in 2021 the score increased to 76.23, up 13.57%. In addition, by forecasting the Yellow River travel score, the associated score increases to 83.69, 89.69, and 90.53 between 2023 and 2025. Compared to 2018, the predicted Yellow River travel scores increased by 24.69%, 33.18% as well as 34.88%. The score on the Yellow River-related history book aspect is then slightly lower than the travel aspect. In 2018, the score for books was only 63.21, in 2021, the score increased by 16.04% to 73.35. In the subsequent projections, the scores obtained were 80.66, 83.52 and 85.86, with an increase of 27.61%, 32.13% and 35.83% compared to 2018. This indicates that the development of historical books of the Yellow River is steadily progressing. In the area of transportation within the Yellow River basin, the score was 65.37 in 2018, rising to 75 in 2021. In the predicted years 2023 to 2025, the scores are 81.15, 85.36, and 89.53, with an increase of 24.14%, 30.58%, and 36.96% compared to 2018. This indicates a significant increase in the development of historical and cultural resources in the Yellow River basin, related to travel, books and transportation.

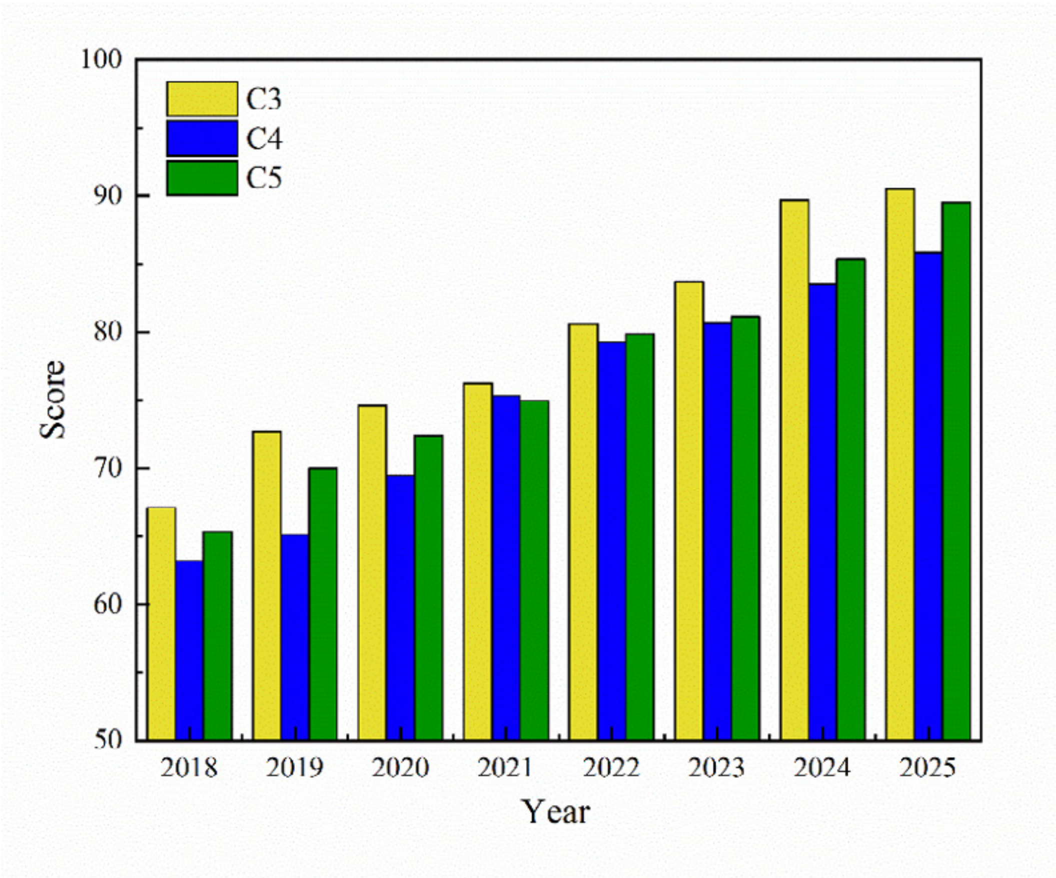

Figure 3. Trend and forecast of corresponding score changes in the development of historical and cultural resources in the Yellow River Basin

5. cONCLUSION

The Yellow River is the mother river of the Chinese nation, and the Yellow River culture rooted in the Yellow River basin is the most representative and influential main

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culture in Chinese civilization. In our research, we have established a research system for the protection and development of historical and cultural resources in the Yellow River Basin, which mainly contains three aspects: ecological construction and historical and cultural resources protection in the Yellow River Basin, and historical and cultural resources development. And the following conclusions are drawn.

1. By analyzing the scores of C1 and C2 in the questionnaire, in 2018, the scores of ecological protection of the Yellow River Basin and intangible cultural protection related to the Yellow River Basin are 65.32 and 67.82 respectively. in 2021, the scores of ecological protection of the Yellow River Basin and intangible cultural protection related to the Yellow River Basin increased to 73.52 and 77.39 respectively. This indicates that China is paying more attention to the protection of historical and cultural resources while building ecological civilization.

2. This paper focuses on three aspects of travel on the Yellow River, related historical books, and transportation development within the Yellow River basin. In Yellow River travel, the score was 67.12 in 2018 and increased to 76.23 in 2021, an increase of 13.57%. In the development of historical and cultural resources of the Yellow River basin, the scores of related travel, books and transportation have improved significantly. Yellow River-related history books scored only 63.21 in 2018 for books and in 2021, the score increased by 16.04% to 73.35; in the field of transportation within the Yellow River basin, the score was 65.37 in 2018 and increased to 75 in 2021.

3. This paper predicts five aspects of the Yellow River Basin: ecological conservation, intangible cultural conservation related to the Yellow River Basin, travel on the Yellow River, related historical books and transportation development within the Yellow River Basin from 2023 to 2025, and the scores of the Yellow River Basin all increase significantly in the coming years. By 2025, the scores related to ecological conservation in the Yellow River Basin and intangible cultural conservation in the Yellow River Basin are predicted to increase by 30.46% and 32.41%. The scores for Yellow River travel, related history books and transportation development in the Yellow River basin are predicted to increase by 34.88%, 35.83% and 36.96%.

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RESEARCH ON THE INTEGRATION STRATEGY OF MUSIC TEACHING AND ENVIRONMENTAL EDUCATION UNDER THE PERSPECTIVE OF ECOLOGICAL CIVILIZATION

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ABSTRACT

With the gradual deterioration of today's ecological environment, there is an urgent need to improve the quality of environmental education. The current environmental education has grown somewhat with the increase in government investment. However older teaching methods seem inadequate to deal with the current situation. The integration of music teaching into environmental education, as explored in this paper, can be a good solution to this problem. This fun and educational approach is a good way to enhance students' interest in learning. After the corresponding discussion on the value of integration, the article used hierarchical analysis to conduct a fuzzy comprehensive evaluation of the combined utility. After stratifying the corresponding influencing factors, the weights were assigned and satisfactory evaluation results were obtained. An example was used for the analysis in this paper. The results showed that third graders with appropriate education got a significant improvement in their scores than sixth graders with no education. Both their median and mean scores improved from 66 and 60 to 70, respectively. More students are also concentrated in the high-score segment. In terms of the direction of focus, the percentages of the four areas of saving food, saving water, saving electricity, and separating garbage all changed. The values of the corresponding numbers for the third and sixth grades are 29%, 20%, 23%, 28% and 29%, 15%, 21%, 35%, respectively.

KEYWORDS

Ecological environment; environmental education; music teaching; integration value; comprehensive evaluation.

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1. INTRODUCTION

In the present time of rapid social development, the lack of material life has been gradually solved [1-3]. However, it is a very troubling problem how to solve the deteriorating ecological environment around us. Raising people's awareness of environmental protection can better help us alleviate the increasingly severe environmental dilemma [4,5]. In recent years, the level of quality education in China has been improving year by year. It is an important task to better penetrate the concept of environmental protection into the students' minds. The current ecological environment, such as emissions, wastewater discharge, and other issues directly affects our lives [6-8]. Correspondingly, our investment in this part of education has been strengthened. However, it is not enough to use environmental education only as a means of propaganda, which does not achieve our ultimate goal [9-11]. From an educational point of view, unlike other traditional disciplines, environmental protection education is not limited to a discipline [12-14]. This advantage shows that it is possible to combine and integrate it with any discipline. Among these, the music classroom has shown its great advantages [15,16]. In this regard, many scholars have conducted research at various levels.

Brennan M [17] investigated whether music communities in Scottish communities can address environmental protection issues. The project examined how music festival communities are constructed, with the focused dimension of concern being how music festivals can help address environmental issues. Using a variety of research methods, the researcher asked members of the music community about their perceptions of environmental protection and obtained positive results. Batt-Rawden KB [18] conducted a study of music as a quality of environmental intervention in a Norwegian system of welfare institutions. The survey was conducted at a local medical center, where subgroups of people were surveyed for their cultural situation. During a two-day passive observation, it was found that the use of music as a beneficial aspect of environmental intervention increased among the students. This is a testament to the tremendous effect that occurs when the two are integrated. After the 2018 Global Climate Risk Index ranked Haiti as a country with extreme weather, scholarly research in various countries concluded that the planet is in a dangerous state of imbalance. Dirksen R [19] investigated the efficacy of using musical means to develop environmental awareness, focusing on how human responsibility for the environment is expressed interactively through song. Publicover JL [20] investigated whether adding an artistic element can add a certain emotional component to environmental education. He argued that environmental education is a key tool in human efforts to address environmental issues and that the arts can help provide some of the emotional components of environmental education. After studying a group of environmentally conscious musicians, the results were coded and analyzed. The analysis revealed four artistic dimensions and five qualitative dimensions that participants considered when sharing their environmental values through music. Qiang G [21] investigated the role of music itself in ecological influence and transmission. He argued that the trend of the times has led to the diversified

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development of various musical cultures and that this development can be applied to ecological theories. He also analyzed the current ecological problems in China based on the ecological development theory. m. Prior H. [22] was keenly aware of the power of music. Music is often used to help solve specific problems, especially in the areas of health and well-being. The issue of climate change is increasingly established in public discourse, but individuals often fail to act in environmentally friendly ways. In the field of environmental psychology, a number of empirically based theories have been developed. Focusing on a selection of relevant theories, he attempts to identify the role that music plays in influencing beliefs and behaviors related to the environment. In light of the current ecological posture, it makes sense to integrate music instruction into environmental education [23-25]. In order to survive and thrive in the long run, it is important to focus part of education on environmental protection. It is possible to use music classes to teach environmental conservation. This is because the teachers themselves can incorporate some of the characteristics of music teaching in the music classroom to protect the environment. In addition, it is possible to use the psychological characteristics of the students to select suitable environmental protection themes to add to the lesson plan. In a relaxed and cheerful atmosphere, students are not learning environmental protection knowledge in boring text teaching. The relaxed atmosphere of music teaching with music can allow more environmental protection knowledge to permeate to students and make them enhance their own environmental protection awareness while communicating and learning about music [26,27]. Specifically, we can try to incorporate many songs about environmental protection into music teaching materials. When teachers are conducting lessons, they should not only confine themselves to teaching the text but should also convey this context to their students. In addition, it makes sense to incorporate environmental awareness into diverse musical activities. For example, when a teacher teaches a unit of music knowledge, he or she can design a drama based on the content of the song and let students perform it in their own preferred way [28,29]. This can not only stimulate the interest in learning music knowledge but also make students understand the importance of protecting the environment in a more immersive way.

In the current environment, the issue of environmental protection has been a point that cannot be ignored more and more. Environmental protection education is also something that should be invested more [30]. At this stage of the music classroom, a corresponding combination of environmental protection knowledge can make students understand the importance of protecting the environment to a greater extent. This is of great significance for today's environmental education. This paper discusses in detail the specific value of the integration of the two, discussing their effectiveness using a fuzzy integrated evaluation of the utility of hierarchical analysis. It is hoped that the effectiveness of the integration can be verified by using concrete examples to enhance environmental education.

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2. THE VALUE OF INTEGRATING MUSIC TEACHING WITH ENVIRONMENTAL EDUCATION

2.1. IMPROVE THE EFFECTIVENESS OF CLASSROOM TEACHING

Integrating environmental awareness into music teaching can help improve the impact of music teaching in the classroom. In elementary school music classes, the teacher's classroom teaching affects the effectiveness of students' music classroom learning and thus the quality of classroom teaching [31]. Meanwhile, teachers should focus on students in music teaching to promote effective development of music teaching and ensure students' mastery of music knowledge. Teachers combine music content with real-life environmental awareness to carry out elementary school music lessons in depth, improve the quality of classroom music lessons, enhance students' classroom learning effects, comprehensively cultivate students' basic music quality, and improve students' music appreciation ability.

2.2. SUBLIMATION OF STUDENTS' EMOTIONS

By showing students images, audio, video, and environmental behaviors from everyday life, teachers present students with musical compositions that allow them to interact with the music and sublimate their emotions. When conducting elementary music instruction, teachers provide music content that should enhance students' interest in teaching music in the classroom. Under the influence of traditional techno-economic conditions, the form of music instruction is individualized and fails to convey rich musical content to students, leaving them unable to feel the beauty of music. Therefore, teachers should use daily exposure to show students representative music classics, use new methods of presentation to increase interest in teaching appreciation and motivate students to actively participate in music appreciation activities.

2.3. IMPROVE STUDENTS' HANDS-ON SKILLS

Empty cans, used newspapers and other recyclable trash are common in students' daily lives. By creating and transforming these items in music class, students can turn them into treasures and create more fun for them. For example, teachers can ask students to add different amounts of sand to different empty cans and then seal the filler plugs with tape so they can turn the used cans into new percussion instruments. Allowing students to play their instruments in class gives them mental satisfaction. In addition, teachers can allow students to scatter their ideas through their own creations by transforming their household scraps into various decorative items for performance, which not only effectively improves students' practical skills, but also helps to raise their environmental awareness. The three values brought by integrating music

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teaching and environmental education are described in Figure 1. The three values are the improvement of teaching effectiveness, the sublimation of students' emotions, and the better development of students' practical skills.

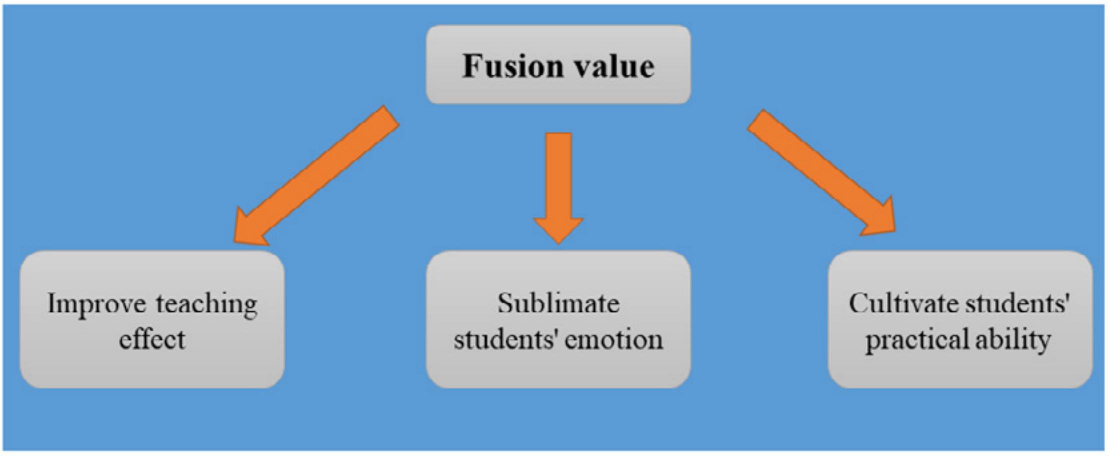

Figure 1. The value of integrating music teaching and environmental education

3. STRATEGIES FOR THE EFFECTIVE INTEGRATION OF MUSIC TEACHING AND ENVIRONMENTAL EDUCATION

3.1. CREATE A MUSIC-TEACHING ATMOSPHERE

Teachers should incorporate environmental knowledge to create a positive classroom atmosphere. In music classes, teachers can use multimedia to teach students or show pictures or videos related to music content and environmental knowledge to stimulate students' senses, so that they can actively learn music knowledge and meet the needs of classroom music learning. In music classroom teaching, teachers should pay attention to the subjective learning nature of students, so that students have initiative in learning, thinking, exploring, and reflecting, and encourage students to realize their emotions effectively in their work to improve the classroom effect [32]. For example, when appreciating music related to the suburbs, teachers can show students videos or images that teach them the concept of "going out" and suggest ways to be more environmentally conscious when leaving, such as cleaning up trash. Since students are usually from urban areas and are not familiar with the concept of suburbia, teachers can show them videos or images related to suburbia so that they can better understand the concept of "suburbia" and avoid misunderstandings due to lack of life experience or experience and lay the foundation for students to deeply understand the emotions inherent in the relevant works. In addition, teachers can ask students questions to better integrate this teaching context. What recreational activities can I do in the suburbs? What should I do after the recreational activities are over? What do we do if we see recyclable trash in the suburbs? and have students answer this question, allowing them to enter a fun and

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powerful teaching atmosphere with the teacher's guidance so that the overall teaching effectiveness is greatly enhanced. In particular, it puts students in a happy learning atmosphere. Because the teacher can use the visual effects of the video to teach the students, it enhances their musical experience and improves their learning in the classroom.

3.2. ENRICH THE CONTENT OF MUSIC TEACHING

In music classes, teachers should dig deeper into the content of music materials, enrich classroom teaching with the help of environmental knowledge, strengthen the close connection with music students' lives, and enhance the cultivation of music quality and ability. First, enjoy nature, from infection to care. Teachers can combine multimedia modern tools with teaching materials to let children enjoy natural landscapes and appreciate the beauty of natural and artificial environments under the influence of a lot of audiovisual information so that students can care about their world and habitat. Learn about the impact of human activities on the environment and show the landscape through songs. Second, appreciate the work and understand it from the perception. It has an important impact on the development of children's musical aesthetics and environmental awareness. Teachers can use a variety of methods to apply to the explanation process. This allows children to feel the beauty of the natural and human environment while providing them with a deep understanding of the negative effects of environmental destruction. Everyone on the planet must care about the world and the place we live in, bridging the gap between people and nature and making them interact with each other. At the same time, teachers must constantly update classroom content to improve students' basic music quality. In music classes, teachers should pay attention to music culture, make students aware of various musical instruments, and improve their artistic qualities. By developing environmental awareness and enriching classroom content and modes, students' understanding of music and musical content can be deepened [33,34]. By continuously studying the musical knowledge in the textbook, teachers can help students understand the connotations and abstract concepts of musical culture more easily and accurately, and develop environmental awareness more easily. On the basis of improving students' music appreciation ability and cultivating their self-confidence in music learning, attention should be paid to improving the learning efficiency of students' music classes. Teachers should make full use of the music classroom to deepen students' understanding of environmental protection, deepen their absorption of environmental knowledge, and allow students to appreciate the charm of music education and teaching combined with the protection of the environment.

3.3. OPEN UP THE SECOND CLASSROOM

We can use the music class time to open up the second classroom and change the situation of "sitting and listening" in the classroom so that students can "come out". Translate environmental awareness into environmental protection measures and improve students' environmental performance. Elementary and middle school students often have a wealth of knowledge but need to learn more deeply and extensively. Teachers should encourage students to conduct more outdoor investigations and enhance environmental education through extracurricular activities.

If you live with pollution, everyone is a victim, but on the other hand, anyone can be a destroyer of the environment. So encourage students to do small environmental tasks every day, things like whether the classroom is clean or has no messy waste and domestic wastewater disposal. Students should be taught that they should work as a family to protect the environment and change their existing habits. They should also promote green consumption and use cloth bags when going to the supermarket to reduce white pollution. Garbage as another kind of wealth, set up a garbage sorting area and recycle cans and plastic bottles in order to turn waste into treasure. When traveling, one should travel in a civilized manner so as not to pollute picturesque places. Establishing an environmental association for students can enable them to participate in an organized way to protect the environment, such as collecting white trash on campus. If there is a traffic jam, then parents can be encouraged to turn off the engine and wait, because if the traffic jam is prolonged, the car cannot burn completely and the exhaust gases can directly harm the people around the road. We can't just talk about theory, but we must put environmental protection into practice every time. Students will understand that "environmental protection is everyone's responsibility" is not just a slogan, but also a way for every citizen to follow orders. Young people can lead the whole society and promote social participation in environmental protection. Figure 2 illustrates the progression of students' environmental awareness. Through these sessions, the student's participation in environmental protection follows the state of "can protect the environment" - "want to protect the environment" - "will protect the environment " - "adhere to environmental protection" change. From the exhortation to build on the basis of good development of self-confidence, we have the motivation to protect the environment, then we find ways to protect the environment, environmental protection into our own habits, and finally to form a firm will and perseverance.

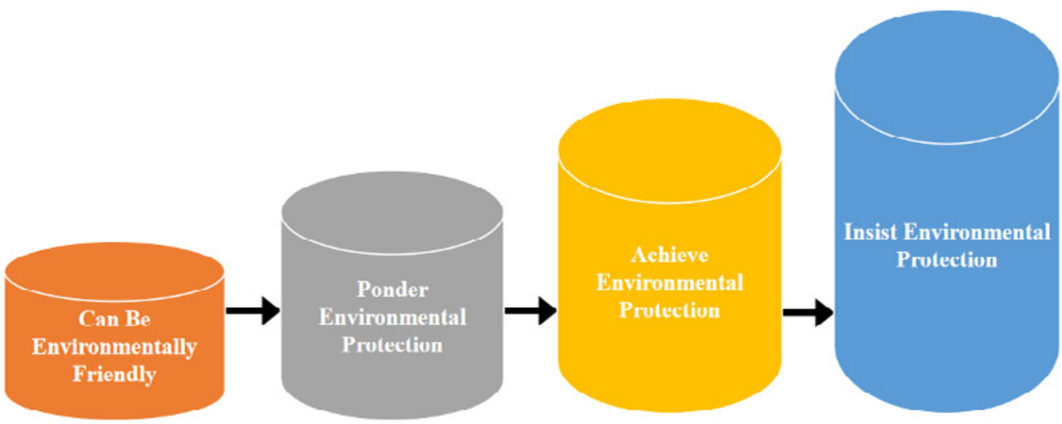

Figure 2. Progressive process of students' environmental awareness

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4. FUZZY COMPREHENSIVE EVALUATION OF THE UTILITY OF MUSIC TEACHING AND ENVIRONMENTAL EDUCATION

4.1. EVALUATION INDEX SYSTEM FOR THE UTILITY OF INTEGRATING MUSIC TEACHING INTO ENVIRONMENTAL EDUCATION

Referring to relevant literature, 10 utility factors affecting music teaching and environmental education were analyzed using hierarchical analysis. The first factor was musical ability enhancement. This is specified as the assessment of students' musical ability through a vocal test, which is rated by the teacher after identification. The second factor is the improvement of environmental awareness. The specific content is the use of small games to assess students' environmental cognitive ability, and the content is mainly simple environmental knowledge. The third factor is students' satisfaction with the classroom-. The specific content is the distribution of questionnaires to find out the students' satisfaction with the classroom. The fourth factor is the execution of the teacher's teaching. The main content is to randomly check the classroom to find out the active atmosphere and students' motivation. The fifth factor is the increase in the number of teachers, and the main content is to count the number of music teachers in the school. The sixth factor is the increase in classroom teaching tools. The specific content is to count the tools and money invested by teachers in conducting music teaching. The seventh factor was the richness of the classroom content. The specific content is the classroom content of the class by distributing questionnaires. The eighth factor is students' satisfaction with the teacher. This is done by distributing questionnaires to students to rate the teaching style of the teacher. The ninth factor is the students' attraction to the course content. The ninth factor was the attractiveness of the content of the music class to the students. The last factor was the length of the lesson, which was determined by asking the instructor for the length of the lesson.

These indicators were divided into 2 orders and 3 levels to assess the utility of music teaching and environmental education in four aspects: students' perceptions of their own abilities, reliability of teaching, teaching expenditures, and overall quality of teaching. The finalized evaluation index system for the utility of music teaching integrated into environmental education is shown in Figure 3.

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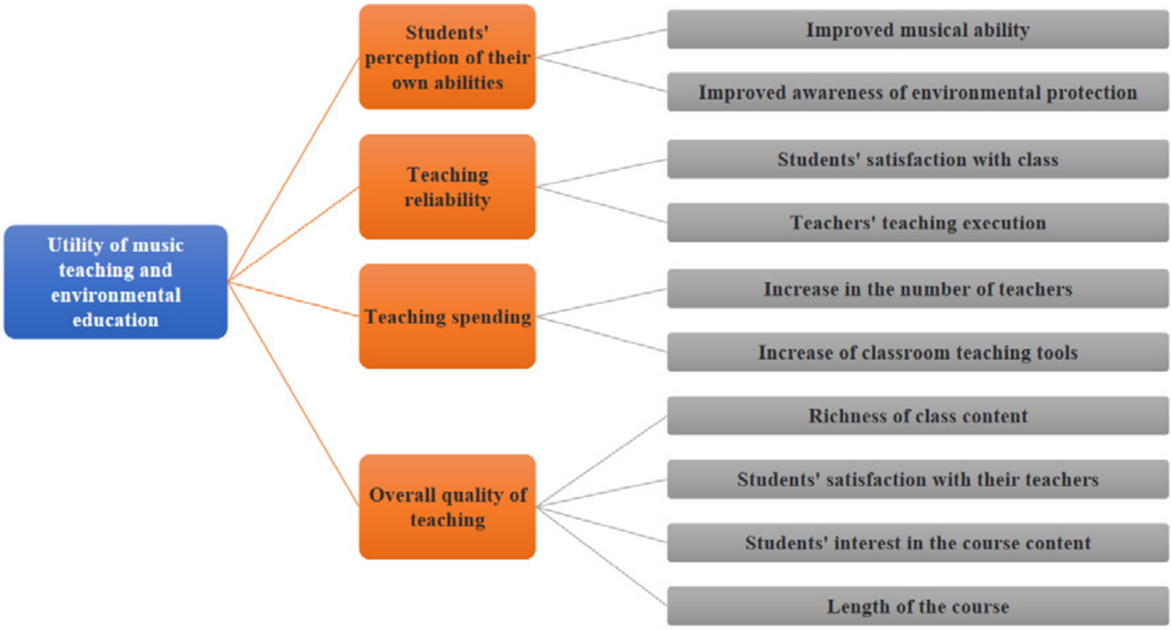

Figure 3. Evaluation index system of the utility of integrating music teaching in environmental education

4.2. FUZZY COMPREHENSIVE EVALUATION OF THE UTILITY OF COMBINING MUSIC TEACHING AND ENVIRONMENTAL EDUCATION

Firstly, for the weights of indicators at all levels of this teaching, the hierarchical analysis method was used to analyze and calculate them. By reading other literature and referring to the weights of each indicator of the indicator system developed by other scholars, the weights of rating indicators for the utility of combining music teaching with environmental education were finally determined as shown in Table 1. The weight value of each indicator is based on the importance of each item in the indicator evaluation system in teaching and the data from the comprehensive survey of teachers and students.

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Table 1. Evaluation index weights of the utility of combining music teaching and environmental education

Target layer	Weighting of primary indicators	Secondary indicator weights
The utility of music teaching and environmental education（U）	Students' perceptions of their own abilities（0.43）	Music ability improvement（0.42）
		Enhancement of environmental awareness（0.58）
	Reliability of teaching（0.22）	Students' satisfaction with the classroom（0.37）
		Execution of teachers' teaching（0.63）
	Teaching expenses（0.09）	Increase in the number of teachers（0.25）
		Increase in classroom teaching tools（0.75）
	Overall quality of teaching（0.26）	Richness of classroom content（0.31）
		Students' satisfaction with teachers（0.24）
		Students' level of attraction to the course content（0.19）
		Duration of the course（0.26）

The weight vector matrix can be derived as follows, respectively

$$A_1 = (0.42, 0.58) \tag{1}$$

$$A_2 = (0.37, 0.63) \tag{2}$$

$$A_3 = (0.25, 0.75) \tag{3}$$

$$A_4 = (0.31, 0.24, 0.19, 0.26) \tag{4}$$

In order to construct an evaluation affiliation matrix, 253 students were invited to evaluate the utility of music teaching and environmental education teaching according to the utility evaluation system of combining music teaching and environmental education in Table 1 by distributing questionnaires online and offline, and according to five equal ratings of very dissatisfied, dissatisfied, half, satisfied, and very satisfied. According to statistics, 253 questionnaires were distributed and 217 valid questionnaires were collected, with a valid recovery rate of 85.77%. Through the statistics of the evaluation results, the evaluation affiliation matrix of the utility of combining music teaching and environmental education can be obtained.

$$R_1 = \begin{pmatrix} 0.067 & 0.095 & 0.127 & 0.297 & 0.348 \\ 0.098 & 0.049 & 0.081 & 0.422 & 0.335 \end{pmatrix} \tag{5}$$

$$R_2 = \begin{pmatrix} 0.052 & 0.112 & 0.037 & 0.362 & 0.359 \\ 0.067 & 0.075 & 0.098 & 0.397 & 0.388 \end{pmatrix} \quad (6)$$

$$R_3 = \begin{pmatrix} 0.066 & 0.123 & 0.159 & 0.243 & 0.407 \\ 0.092 & 0.064 & 0.035 & 0.350 & 0.398 \end{pmatrix} \quad (7)$$

$$R_4 = \begin{pmatrix} 0.073 & 0.064 & 0.123 & 0.447 & 0.496 \\ 0.111 & 0.085 & 0.061 & 0.452 & 0.364 \\ 0.090 & 0.052 & 0.135 & 0.472 & 0.348 \\ 0.042 & 0.048 & 0.103 & 0.535 & 0.331 \end{pmatrix} \quad (8)$$

To perform the first-level fuzzy evaluation, the model $\mathrm{M}(\cdot,+)$ is used for the synthetic operation, and the results of the first-level fuzzy evaluation are obtained as follows.

$$B_1 = A_1 \wedge R_1 = (0.054,0.098,0.082,0.405,0.362) \quad (9)$$

The same reasoning leads to:

$$B_2 = (0.082,0.079,0.017,0.364,0.358) \quad (10)$$

$$B_3 = (0.061,0.064,0.116,0.362,0.379) \quad (11)$$

$$B_4 = (0.121,0.107,0.157,0.307,1.308) \quad (12)$$

Subsequently, the second-level fuzzy evaluation was carried out, and the same model M(-,+) was used for the synthetic operation to obtain the results of the second-level fuzzy evaluation.

$$B = A \wedge R = (0.111,0.107,0.154,0.317,0.309) \quad (13)$$

The fuzzy evaluation result is calculated, and the fuzzy vector is further mono-valued, and each evaluation level in the evaluation domain is assigned as V-1=1, V-2=2, V-3=3, V-4=4, and V-5=5. The final weight values of the five sets of comments are analyzed, which are 0.117, 0.101, 0.144, 0.308, and 0.315. The highest weight value (0.315) in the five sets of comments, combined with the rule of maximum affiliation, shows that the final comprehensive evaluation result is "satisfactory". This shows that the effectiveness of music teaching and environmental protection is significant.

5. SPECIFIC EXAMPLE ANALYSIS

5.1. COMPREHENSIVE SCORE COMPARISON ANALYSIS

In the fourth section of the fuzzy comprehensive evaluation, a hierarchical analysis was used to assign weights in a stratified manner, and a final satisfactory result was obtained. After this, after communication and consultation, this paper applied the

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integration of music teaching and environmental education to a third-grade student for one semester. Questionnaires were distributed to parents to understand the students' environmental awareness focus while having the current students compete with the sixth graders in an environmental awareness knowledge contest. In this quiz, there are 45 students in both the third and sixth grades. This paper reflects on the gap in environmental awareness between the students who have received the integration strategy of music teaching and environmental education and the average students.

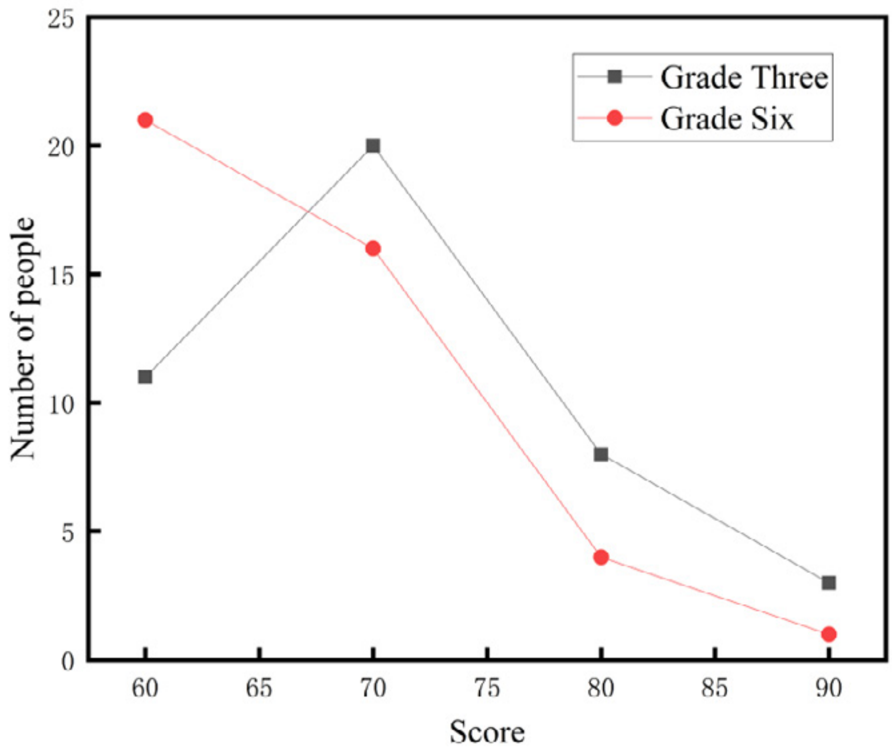

Figure 4. Number of scores in each section of the knowledge contest

In Figure 4, an exhaustive comparison of the number of scores in each segment of the knowledge competition is presented for both grades. In general, the general trend in the overall scores for both ages is a high number of students in the low-scoring range and a low number in the high-scoring range. However, the majority of the sixth graders, who did not have an integrated education, were concentrated in the 60 and 70-point range. The majority of the third graders who had the appropriate education were in the 70 and 80 range. The difference between the two reflects the overall improvement in the quality of the students. Within the high scoring range of 80 to 90, the number of third graders is also much greater than the number of sixth graders. In terms of specific values, the overall median and mean scores of third graders who have received music integration education also improved compared to sixth grade. This is a significant increase from 60 and 66 to 70. The number of low scores in the third grade has been reduced compared to the sixth grade, thanks to the adaptation of teaching strategies. More numbers are gradually moving towards the higher end of the scale. Although the overall improvement is not drastic, it is important to understand that this comparison was made between two different grade levels. There

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is still a large difference in learning ability between the two grade levels. If the strategy was applied to all grades, I believe the sixth grade would have scored higher in the competition. This shows how effective it is to combine music instruction with environmental education. Elementary school is the beginning of quality education when students are in a state of mind and values to be shaped. At this time, better educational strategies can be useful in shaping students' values. Therefore, providing students with a way to combine music and environmental education at this stage is a good way to ingrain environmental values in their minds. This approach is necessary in today's environment, which is deteriorating. In addition, the results of the knowledge competition also showed that the speed of knowledge reserve is not divided into age groups. Younger students can also quickly form a knowledge system with appropriate training. Therefore, this once again confirms that the cultivation of environmental protection knowledge should be as early as possible.

5.2. FOCUS ON DIRECTION ANALYSIS

Another issue is reflected in Figure 5 for the two grades' environmental awareness focus. The chart shows that the third grade has the following environmental emphasis from the largest to the smallest: saving food, saving water, saving electricity, and separating garbage. The overall trend is also consistent for the sixth grade. In terms of the percentage of people, the percentages of people who associate environmental protection with these four dimensions in third grade are 29%, 20%, 23%, and 28%, respectively. In grade 6, the percentages were 29%, 15%, 21%, and 35%, respectively, from the largest to the smallest. Although the trend of the two is close, the overall level of third graders is improving from the median and average. From these two points, it can be seen that after the integration of music teaching and environmental education teaching, the third-grade students have a higher number of students focusing on each point. The sixth graders, on the other hand, had a significantly lower focus on trash sorting than the other three points. This is largely due to the fact that the conservation of basic resources and the protection of the ecology have been deeply rooted in the past. However, there is a lack of awareness of waste separation as a means to protect the ecological environment and conserve resources, which has emerged in recent years. This again demonstrates how well the teaching of new integration strategies can impart current advanced environmental concepts to students. In today's ecological environment, many environmental issues are gradually coming to the forefront. Issues such as metal pollution, offshore oil spills, etc. are all issues that need attention. The integration of these topical environmental issues into today's music teaching can better shape the values of students. This is a great help for the subsequent quality education in China to train students who have the right values to protect the environment.

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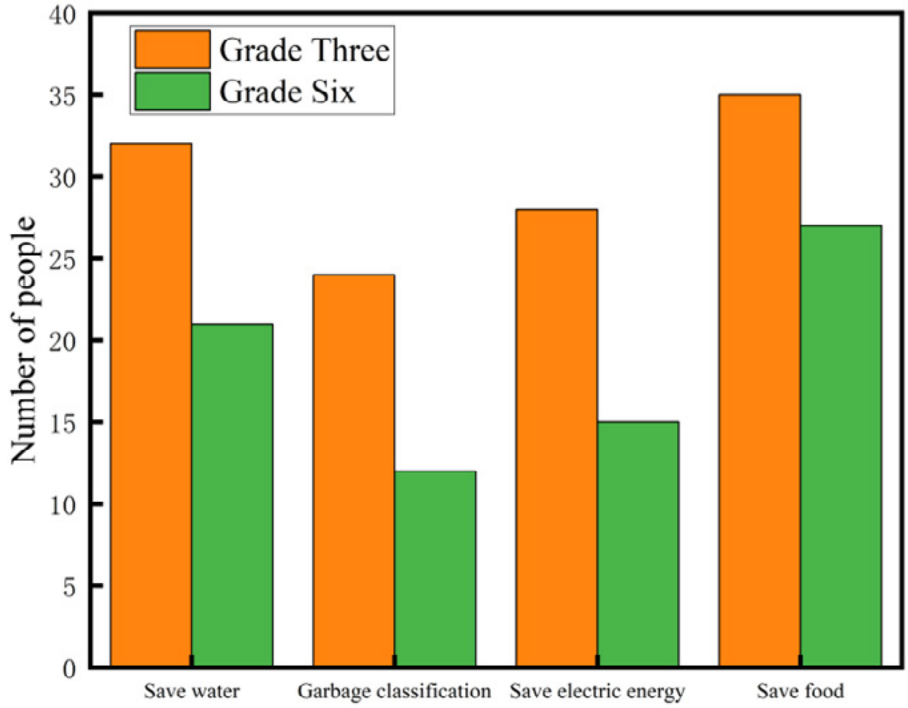

Figure 5. Environmental awareness focus

6. DISCUSSION

Research on the integration strategies of music teaching and environmental education in the context of ecological civilization has been conducted at different levels both at home and abroad. Quality education for the protection of the ecological environment can be said to have been developed early in China. The protection of water resources, the greening of the environment, and so on have been long-standing observations in students' textbooks. However, with the development of the times, both the students and the educational environment have changed significantly. It is not helpful to use old educational strategies for environmental education. Music teaching, like the one mentioned in this article, is a new educational vehicle. However, it is not limited to the combination of new educational methods with music teaching. Other methods that can effectively stimulate students' interest and make them aware of new environmental protection methods and situations should be promoted. In today's world of technology and educational thinking, good environmental education methods should be constantly proposed.

7. CONCLUSION

This paper analyzes the research on how to develop strategies for integrating music teaching and environmental education in the context of ecological civilization. After a background introduction to the study, the paper describes the value of integrating music teaching and environmental education accordingly. After that, a

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fuzzy comprehensive evaluation study of the effectiveness of combining music teaching and environmental education was conducted to obtain the results of integrating the two with significant efficacy. Subsequently, the teaching approach was applied to a third-grade student. After this, the students of this time were put into an environmental awareness knowledge contest with the sixth-grade students and the following results were obtained.

1. In the analysis of the number of scores in each segment of the knowledge contest, the third-grade students who were taught the integration strategy scored higher overall than the sixth-grade students who were not taught it. The majority of the third-grade students scored in the 70 to 80 range, with 68% of the scores. Sixth graders scored mostly in the 60 to 70 range, with 89% of the scores.

2. In the specific analysis of the scores, the mean scores of the third grade have improved significantly. In terms of median scores, the median scores for the sixth and third grades were 60 and 70, respectively, but in terms of specific trends, both showed a gradual decrease in the number of high scores. In both cases, the majority of the scores are concentrated in the 60s and 70s.

3. In the description of the environmental awareness focus of the two grades, the distribution of the focus from major to minor was the same in both grades. From the largest to the smallest, they are: saving food, saving water, saving electricity, and separating garbage. However, the specific percentages of the two differ. For the third graders, the percentages were more even, 29%, 20%, 23%, and 28%, respectively. The sixth graders, on the other hand, focused less on the level of waste conservation. The percentages of the four items were 29%, 15%, 21%, and 35%, respectively.

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RESEARCH ON TEACHING REFORM OF PETROCHEMICAL COURSES IN UNIVERSITIES IN THE CONTEXT OF CARBON NEUTRALITY

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ABSTRACT

The increasing pollution caused by carbon emissions has led to a growing call for emission reduction. With China's current goal of carbon neutrality, how to innovate the petrochemical industry has become a hot issue. As a higher education institution that delivers talent for the petrochemical industry, it is in line with this trend to carry out teaching reforms of professional courses. In this paper, we collect data extensively for the evaluation of course attainment in the petrochemical industry and carry out the weight allocation of factors. Two classes of a university's 2018 class of petrochemical industry majors were used as the comparison objects. One of the classes was taught in a reformed manner while the other class was taught in a traditional manner. The results showed that the overall score of the class subjected to reformed instruction was 78.9, which was greater than the 74.6 score of the class taught using the traditional approach. In addition, when surveyed for feedback on course content, it was found that a whopping 92% of students showed identification with their major. Only 2% of the students felt that the new teaching style was a waste of their time.

KEYWORDS

Carbon neutrality; petrochemical industry; professional courses; teaching reform; higher education institutions.

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ABSTRACT

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3. **EVALUATION ANALYSIS OF THE DEGREE OF ACHIEVEMENT OF PETROCHEMICAL PROFESSIONAL COURSES**
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1. INTRODUCTION

With today's goal of carbon neutrality, how to harmonize petrochemicals and ecology has become a hot issue that needs to be addressed urgently [1-3]. The goal of achieving carbon neutrality by 2060 was first proposed by Chinese President Xi Jinping at the United Nations General Assembly on September 22, 2020. The introduction of this target not only shows China's great power role but also brings opportunities and challenges for the transformation and upgrading of China's petrochemical industry. In this context, how to use the carbon neutrality target to force oneself to reduce carbon awareness is something that should be taken seriously by the industry [4-6]. Actively developing energy-saving and low-carbon processes and participating in the construction of a carbon emission trading market are important means to achieve carbon neutrality [7-9]. As a higher education institution providing talents for the petrochemical industry, how to adapt teaching to the new environment is also one of the means to accelerate the achievement of carbon neutrality [10,11]. In the new era, social development and economic construction need suitable talents. At present, all universities are in full swing to cultivate new engineering technical talents. As a pillar industry of the national economy, petrochemical products cover a wide area and are closely related to people's life [12-14]. The corresponding teaching reform for it should not only take into account the complexity of its knowledge system but also the changes of industry standards brought by the reform. As a long chain of industries, the huge impact of drastic changes is unforeseeable. Various reasons make the corresponding pedagogical reform difficult, and the small number of reference examples leads to no standards to follow.

Amin M S [15] studied the impact of providing students with appropriate carbon reduction materials and presenting scientific explanations to a new generation of students. Gamarra A R [16] conducted an in-depth assessment of how well five public schools were performing in their school environments as they transitioned to a low-carbon economy and a sustainable social model. Du J [17] investigated the effectiveness of a psychosocial approach to teaching and learning to foster carbon reduction behaviors such as energy conservation in dormitories. A questionnaire survey of 290 students was conducted and found that this approach was effective in increasing the body of knowledge about energy-saving behaviors. Students were able to better understand energy use behaviors by identifying the role of ethical beliefs. Mazhar M [18] explored the barriers encountered in carbon management in UK universities and highlighted the main challenges that need to be addressed. In his study, a mixed-method approach was used to conduct a content analysis of carbon management approaches, which led to the exploration of barriers. These barriers can help to establish some theoretical support for carbon emissions. Sippel M [19] explored the lifestyle characteristics of campus students at a time when universities are taking on increasing responsibility for climate protection. After collecting data on students' lifestyles and emission patterns through questionnaires, a web-based carbon calculator was used to perform calculations. An attempt was made to identify appropriate ways of living with low carbon emissions on campus. Udas E [20] in his

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study shared an institutional process aimed at a gradual transition towards carbon neutrality. In order to achieve the goal of carbon neutrality, he argues that three major transformational strategies are adopted: carbon reduction, carbon offsetting, and mainstreaming of sustainable actions through teaching and research can be done. He has successfully developed a locally adapted sustainability institutional framework to facilitate change in day-to-day operations. Also implementing interdisciplinary research, integrating sustainability into teaching and education, and strengthening outreach programs. From the studies of various scholars above, it is easy to see that as the concept of carbon neutrality takes hold, more and more scholars are happy to combine it with pedagogical reform [21,22]. This combination will allow the concept of carbon reduction to be ingrained in students and later applied in the fields they are subordinated to. This is of great help to achieve the goal of carbon reduction.

In order to adapt to social development as well as the needs in the context of carbon neutrality, it is necessary to reform the teaching of current university petrochemical courses according to the needs. The study of the original teaching form and connotation will help to specify how to make linked adjustments and reforms to the petrochemical industry [23-25]. In addition, the construction of a new curriculum and teaching system should be oriented to the needs of society and the core of students' competence development. Universities not only have a supporting role in today's economic development and industrial transformation and upgrading but also are of great help to the cultivation of new talents and the construction of new teaching theories. This paper analyzes the teaching evaluation system based on the OBE (Outcome-Based Education) concept and applies it to petrochemical students in a university for example analysis. We try to explore whether we can cultivate high-quality petrochemical industry talents in the new situation under the new reform teaching.

2. REFORM OF PETROCHEMICAL EDUCATION IN THE CONTEXT OF CARBON NEUTRALITY

Petrochemical technology is one of the typical focuses of traditional energy engineering majors, mainly concentrating on drilling and completion engineering, subsurface fluid flow laws, development technology theory, process technology, and oil and gas reservoir management. Under the current carbon-neutral background, the reform of petrochemical technology education and teaching is an important way to achieve the goal of high-quality carbon neutrality. Specific reform ideas mainly include the following aspects.

2.1. TRAINING OBJECTIVES AND CURRICULUM

With the goal of carbon-neutral-oriented education, students are motivated and interested in carbon-neutral related industries according to their professional development needs. Understanding the close relationship between carbon neutrality

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and the oil and gas industry will enable students to better participate in engineering design and production construction in the petroleum engineering field after graduation. In addition, students can be involved in the design of strategic requirements for "decarbonization" goals in the oil and gas sector, and then engage in carbon neutral management and research and development [26,27].

To do this, it is necessary to optimize the existing teaching programs. In petrochemical technology, on the one hand, carbon capture is achieved through various measures such as carbon storage in abandoned oil and gas reservoirs and CO2 oil drives. On the other hand, carbon substitution is achieved by replacing conventional oil and gas resources with unconventional resources (shale oil and gas, geothermal energy, natural gas hydrates, etc.). Finally, the clean utilization of energy is achieved and the conversion rate is improved [28,29]. On this basis, in terms of curriculum, the traditional petroleum engineering-related courses should be retained, and appropriate elective courses on clean energy such as "carbon capture and storage" and "energy conservation and emission reduction" should be added. At the same time, courses on geothermal energy, natural gas hydrate, and hydrogen production should be introduced. The professional curriculum of the old and new teaching modes is shown in Figure 1. In the teaching process, we should focus on cultivating students' interdisciplinary awareness and establishing the concept of green, low-carbon, and clean energy, so as to lay the foundation for the carbon-neutral industry after graduation.

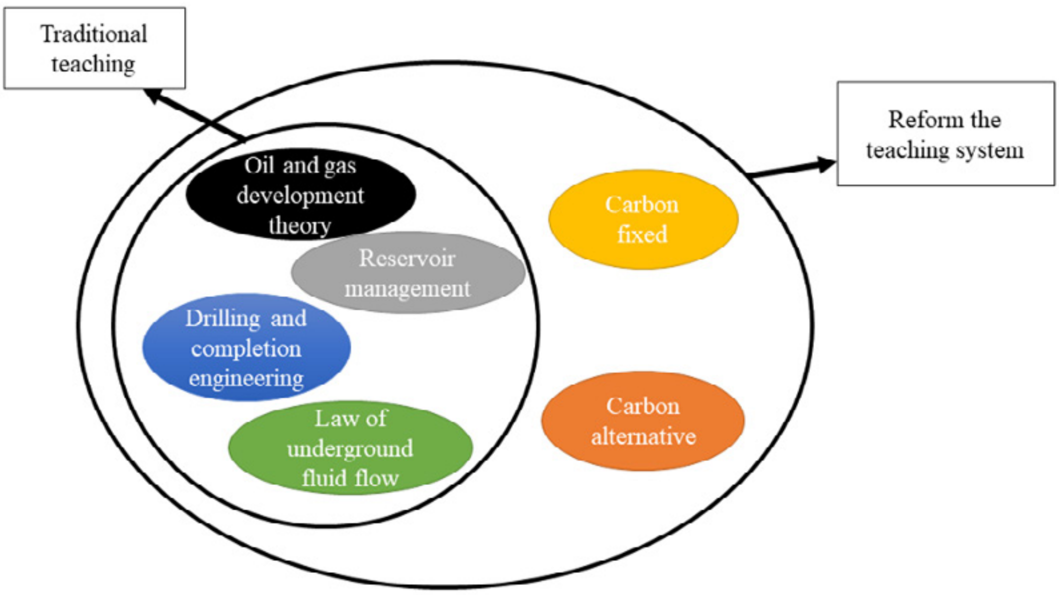

Figure 1. The curriculum of the petrochemical industry in the context of carbon neutrality

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2.2. COURSE IDEOLOGY AND TEACHING CONTENT

Using mobile devices for online teaching is an important measure to improve teaching effectiveness. From the perspective of teaching, we should make full use of online teaching resources and pay attention to the diversity of teaching methods. We should make good use of online teaching resources, shared classrooms, and other high-quality online teaching tools, pay attention to the guidance and inspiration of students' ideas, let students actively participate in classroom teaching, and improve their active learning ability and learning efficiency [30,31]. In addition, classroom teaching should also cultivate students' patriotic emotions through various typical examples, focus on the organic combination of course teaching and ideological and political education, and strengthen ideological and political leadership. The synergistic effect is brought into play to cultivate students' ideals and beliefs, moral sentiments, and other good moral qualities.

With the development of modern technology, interdisciplinarity is becoming increasingly important. Interdisciplinarity is the way to achieve the goal of high-quality carbon neutrality [32,33]. By thinking laterally, it helps to effectively solve industrial bottlenecks and promote technological development. In addition to relevant basic theories and basic skills, petrochemical students should be able to think in the cross direction of chemistry, physics, mechanics, materials, and other disciplines, and apply their knowledge flexibly to achieve the goal of carbon removal.

3. EVALUATION ANALYSIS OF THE DEGREE OF ACHIEVEMENT OF PETROCHEMICAL PROFESSIONAL COURSES

3.1. TEACHING EVALUATION SYSTEM BASED ON THE OBE CONCEPT

Curriculum evaluation is one of the important links of the modern teaching system, which plays a pivotal role in the development and improvement of teaching. A scientific and reasonable curriculum evaluation method can optimize teaching management science, promote the improvement of teaching quality and efficiency, and ensure the effectiveness of the curriculum system. In the teaching system pointed by OBE, course evaluation is one of the most basic closed-loop quality evaluations, and also an important dimension in building the teaching quality control system of universities.

The course evaluation based on the OBE concept can be summarized into three main points. The first point is to clarify the relationship between the professional training objectives, graduation requirements, and the curriculum system. The determination of course objectives must meet the students' skill development requirements in the graduation requirements. The establishment of the curriculum

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system must cover all index points of graduation requirements and establish a close connection between courses and curriculum. The teaching and learning process is based on the course objectives, and deriving the course evaluation results will allow us to accurately track course attainment as well as graduation requirement attainment, ultimately creating a closed-loop, results-oriented assessment system. The second point is to reflect the degree of course completion through course grade evaluation, reduce the weight of final exam results in course evaluation, and increase the weight of teaching process evaluation. Add various evaluation items to the teaching process evaluation, including students' daily assignments, classroom exams, learning performance, and emotional attitude. As the main body of course learning, students need to pay attention to their emotions, which can help to adjust students' learning status in time and stimulate their enthusiasm and subjective initiative. The last point is not only limited to the evaluation of classroom teaching effect but also increases the evaluation of students' practical ability, including course experience, enterprise internship, competition, etc. Students should be encouraged to participate in Internet innovation and entrepreneurship competitions, Challenge Cup, etc. to improve their innovation ability. It is also necessary to combine classroom theoretical knowledge with practical activities and integrate practical skills into the course evaluation to promote students' overall development.

3.2. EVALUATION ANALYSIS OF THE DEGREE OF ACHIEVEMENT OF PETROCHEMICAL PROFESSIONAL COURSES

In this paper, we will take the graduation requirements of a university's petrochemical industry major as an example, and establish a support system for the cultivation of high-quality technical skills talents. For the division of specific index points, the division content is shown in Figure 2. The content of the first-level index includes whether one can operate and maintain the petrochemical unit equipment, whether one can control the operation of the petrochemical production unit, and whether one has the ability to analyze the production operation and deal with abnormal conditions. The secondary indexes mainly consist of core courses in oil formation physics, seepage mechanics, rock mechanics, oil recovery engineering, drilling engineering, and petroleum engineering big data. The specific weighting parameters of each index are detailed in Figure 2.

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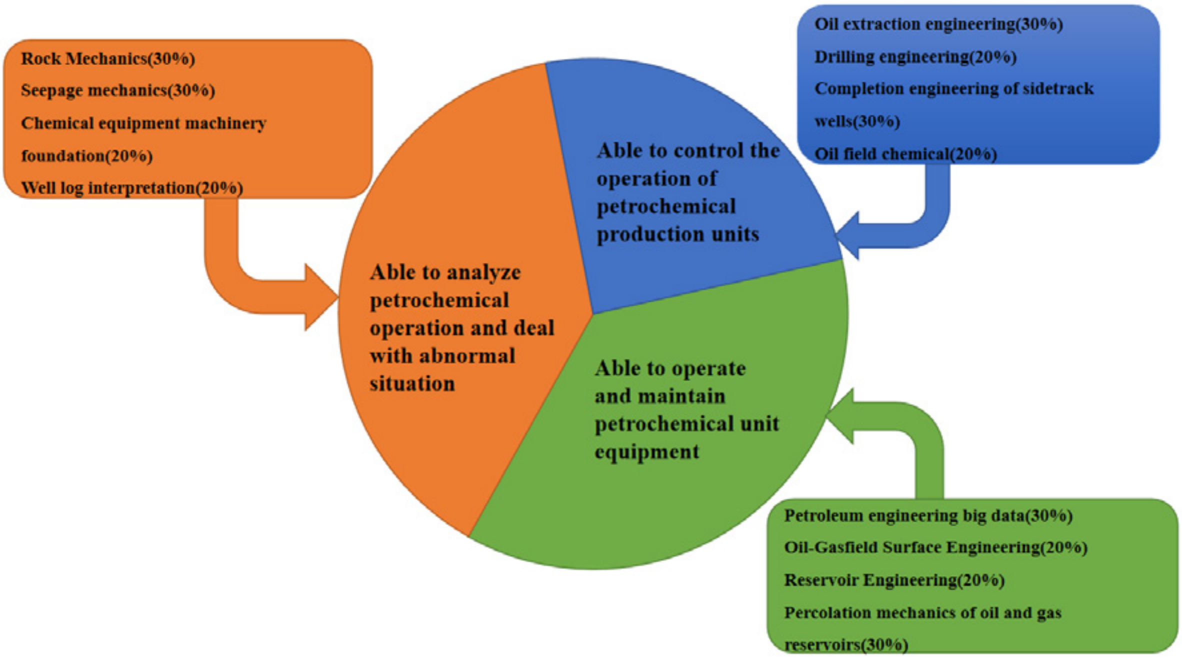

Figure 2. Example of correspondence between indicator points and supporting course system

According to the weight coefficients set for different courses, the degree of achievement of each graduation requirement index point can be calculated by weighted summation, as shown in equation (1).

$$Z = \sum_{i=1}^{m} a_i Y_i \qquad (1)$$

Where: Z is the degree of achievement of each graduation requirement index point; Yi is the evaluation of course achievement; ai is the weight coefficient of the course to the index point; m is the number of courses corresponding to the index point.

The calculation method of course attainment is shown below.

The evaluation value of the petrochemical course on the index point attainment is calculated according to the formula shown below.

$$y_1 = Q_1 \times \frac{\bar{x}}{x} \qquad (2)$$

Where: is the final assessment weight; x is the total score of the test questions related to the index point in the sample; is the average score of the test questions related to the index point in the sample.

Appraisal assessment evaluation value.

$$y_2 = Q_2 \times \frac{\bar{n}}{n} \qquad (3)$$

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Where: is the process assessment weight; n is the total score of the class process assessment score; is the average score of the class process assessment score.

Practice assessment evaluation value.

$$y_3 = Q_3 \times \frac{\bar{p}}{p} \tag{4}$$

Where: is the weight of practical assessment; p is the total score of class process assessment results; is the average score of class process assessment results.

Course Attainment Rating Value.

$$y = y_1 + y_2 + y_3 \tag{5}$$

4. EXAMPLE ANALYSIS

4.1. ANALYSIS OF COURSE ATTAINMENT EVALUATION SCORES

This paper analyzes and compares students in Class 1 and Class 2 of the 2018 petrochemicals program at a university, where Class 1 underwent a reform of professional course teaching in the context of carbon neutrality in the current academic year, and Class 2 was taught by traditional teaching methods. The number of students in both classes is 50. The evaluation of course attainment of petrochemical industry majors used the course performance analysis method to quantitatively analyze the assessment results. The course attainment consists of three parts, which are course process assessment evaluation value, end-of-course evaluation value, and practical assessment evaluation value. The corresponding evaluation weights are 30%, 40%, and 30%, respectively. The specific size of the weight comes from the data reference in the research of the teaching system and the evaluation and analysis of the degree of curriculum achievement. The next course achievement evaluation analysis was conducted for Class 1 and Class 2, and the achievement evaluation values are shown in Figure 3.

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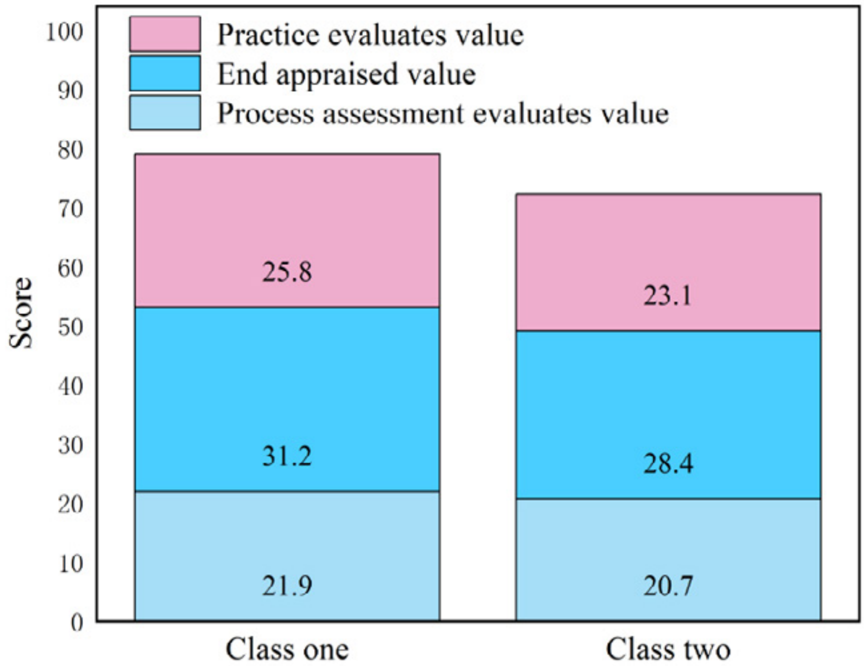

Figure 3. Course attainment evaluation scores of the Class of 2018 in petrochemicals

The evaluation scores of the two classes can be obtained from Figure 3, in which Class 1, which received the reformed instruction, has an overall score of 78.9, while Class 2, which did not receive the corresponding instruction, has an overall score of 74.6. It can be seen that the student's course attainment scores have improved after receiving the reformed instruction. For the three components that make up the score, the scores have improved to different degrees after the implementation of the reformed teaching program. For the course process evaluation score, the score increased from 20.7 to 21.9, an increase of 5.79%. The end-of-course evaluation score increased from 28.4 to 31.2, an increase of 9.85%. The practical assessment score increased from 23.1 to 25.8, an increase of 11.69%. It is easy to see from the increase of the three, that the increase of the practical assessment value is the largest among the three. The specific reason for this situation is to a large extent due to its composition. From the description above, we can find that the practical assessment value is composed of course experience, enterprise practice, and competition projects. Compared with the other two parts, this part pays more attention to the cultivation of students' practical abilities. As the practice is close to reality, students can be better exposed to cutting-edge development and broaden their insight. In addition, the extensive project participation and competition preparation provide practical experience that is not available in the previous classroom. As the course process assessment evaluation value with the smallest increase, it is only half the increase of the practical assessment evaluation value. This part is mainly composed of traditional teaching evaluation contents such as attendance, homework, class tests, and learning attitudes. Even if the corresponding reform teaching is carried out, the basic content still cannot jump out of this framework, which is the reason for the small increase. For the end-of-course evaluation value, the increase is within the two. This part of the course attainment score is basically a student assessment of the content and structure of the course, so the score depends on the student's self-perception of the course. The increase in this part of the score is not insignificant because of the greater optimization brought about by the curriculum reform.

Since the end-of-course assessment value is weighted at 40%, more attention should be paid to this aspect in the curriculum reform. However, the analysis above also reflects a very important point. Although the weight of the practical assessment evaluation value is relatively small, it has a high score increase. If more reforms are put into this point, good results may be achieved.

4.2. ANALYSIS OF COURSE CONTENT FEEDBACK

After the class, a questionnaire survey of teaching feedback was conducted for the Petrochemicals 1 class that had conducted the teaching reform of the professional course in the context of carbon neutrality, and the results are shown in Figure 4.

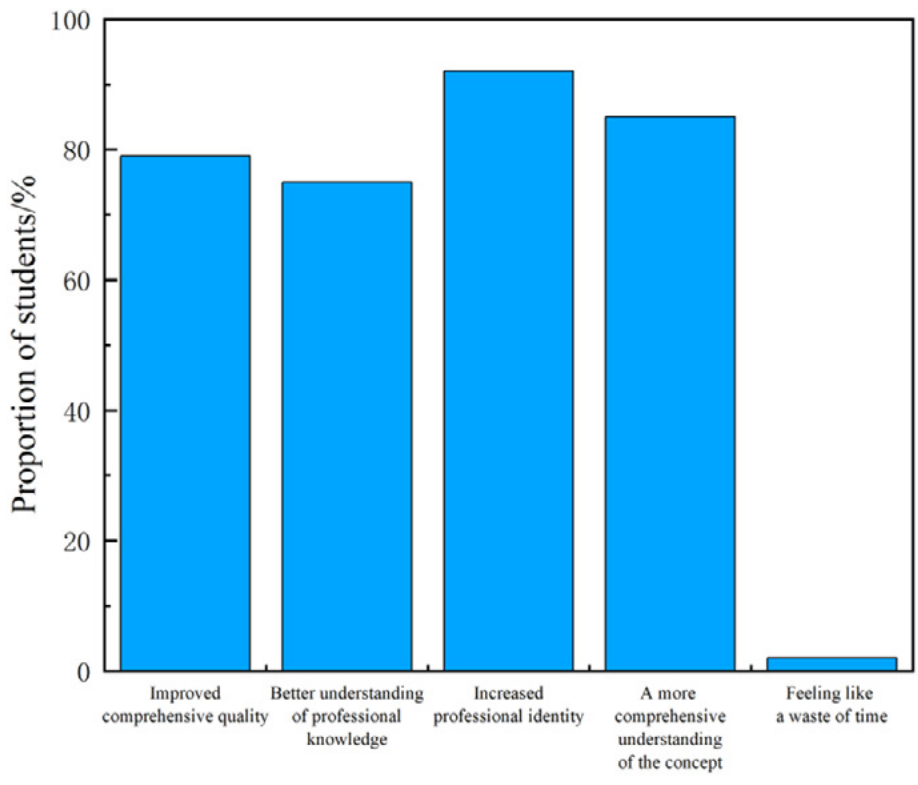

Figure 4. Students' feedback on course content in the context of "carbon neutrality"

In this questionnaire, it is very intuitive to see the students' views on the content changes with the curriculum reform. The survey consists of five main parts: for the improvement of their general quality, whether there is better help to understand the professional knowledge, for the increase of the professional identity, for the more comprehensive understanding of the concept, and whether they feel that they have wasted their time. For these five items, a high 92% of students expressed their approval in terms of increased professional identity. With the development of recent years, unlike the rapid development of various science and technology brought about

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by the upgrading of status, the status of the traditional petrochemical industry can be said to be in decline. This situation has actually indirectly led to a sense of extreme disapproval among petrochemical industry students in their own professional fields. However, it can be found that the new reformed teaching has led to a significant increase in student recognition. This is because the carbon-neutral context of the reform has allowed students to better understand the current state of their profession and to understand that innovations in their industry can contribute significantly to the achievement of carbon reduction goals. These increased perceptions are what increase the increased recognition of their profession. At the same time, it can be found that only 2% of the students feel that they are wasting their time, which can also reflect the satisfaction of the students with the course content under the teaching reform.

The approval ratings of 79%, 75%, and 85% for improving one's overall quality, better understanding of professional knowledge, and a more comprehensive understanding of concepts, respectively. Although not as high as the professional recognition, it is still a good level. Even so, it should be noted that nearly 20% of the students still think that they have not done enough to improve their overall quality and to help them better understand their professional knowledge. The reform of teaching has introduced a number of new methods, but not all of them are helpful. Any change in teaching methods should be based on the principle of improvement through trial and error, with positive adjustments based on student feedback. The 20% of the students who did not approve of the teaching method was the basis for subsequent changes. In the follow-up, it is necessary to provide better solutions to improve the overall quality of the students and to provide a better system of answers for the understanding of professional knowledge.

5. DISCUSSION

Under the current carbon-neutral background, there has been some progress in the curriculum teaching reform of the petrochemical industry in colleges and universities. On the one hand, the trend of the future direction of the industry in the new environment is explained in depth in the course, which can help students to recognize the current situation. On the other hand, strengthening the practical exercise for students has a certain guiding effect on students to find their own positioning in the industry. The development of these two aspects has largely led to a certain improvement in the backward teaching mode of the petrochemical industry. The newly trained talents can use more specialized knowledge to accomplish the goal of carbon neutrality.

Although various attempts and reforms are in full swing in various universities, not all new teaching theories are applicable to the reform of the petrochemical industry. The reform for such traditional engineering subjects should be a combination of theoretical innovation and enhanced practice. The new theoretical knowledge is taught in a way that is acceptable to the students and is really absorbed into their own

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knowledge system. For the expansion of the practical content, whether the students can accurately find the industry and their own positioning. Only when these things are really done can teaching reform be considered effective. In the current teaching environment, it takes a huge investment of time and cost to really achieve these elements, and it is not something that can be accomplished overnight. How to develop an effective program and follow a schedule to advance steadily should also be taken seriously by universities. Although carbon neutrality is a long-term goal, effective improvements in the petrochemical industry can accelerate the accomplishment of the goal. As a higher education institution that provides talent for the industry, it is important to carry forward the teaching reform of the petrochemical industry effectively with a great sense of responsibility.

6. RESULTS

In this paper, under the guidance of the teaching evaluation system based on the OBE concept, the students of Class 1 and Class 2 of a university's 2018 petrochemical class were investigated. Among them, Class 1 accepted the reformed teaching method, while Class 2 kept the existing teaching mode unchanged. Finally, the assessment results were analyzed quantitatively to obtain the professional course attainment evaluation scores and feedback on course content for both classes. After the analysis, the following conclusions were made.

1. In the distribution of the weights of the professional course achievement evaluation scores, the weights of the course process assessment evaluation value, the end-of-course evaluation value, and the practical assessment value are 30%, 40%, and 30%, respectively. When making improvements to the focus direction of the reform, the weighting percentage should be considered appropriately.

2. In the evaluation score, the combined score of class 1, which was subjected to reformed teaching, was 78.9, which was greater than the 74.6 of class 2, which maintained the existing teaching method. for the three components with the constituent elements, all three had some degree of increase. The practical assessment value increased the most, from 23.1 to 25.8, an increase of 11.69%. The course process assessment value increased the least, from 20.7 to 21.9, an increase of 5.79%. The end-of-course evaluation value increased moderately, from 28.4 to 31.2, an increase of 9.85%.

3. In terms of student feedback on the course content, 92% of the students expressed their approval in terms of increased professional identity, which is the maximum of the five components. In terms of improving their overall quality, better understanding of professional knowledge, and more comprehensive understanding of concepts, 79%, 75%, and 85% of the students approved respectively. Nearly 20% of the students thought that the reform was not enough in terms of improving their overall quality and helping them understand

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the concepts better. Only 2% of the students agreed with this opinion on whether they felt that they had wasted their time.

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EXPLORATION OF THE CONSTRUCTION PATH OF ARTIFICIAL INTELLIGENCE BIG DATA "INTEGRATED" INNOVATION AND ENTREPRENEURSHIP ECOSYSTEM FROM THE PERSPECTIVE OF LAND USE ECOLOGICAL SUITABILITY

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ABSTRACT

Ecological environment has always been an important prerequisite while reflecting people and nature. The construction reflects the degree of development and civilization of a country as a whole, so it is related to the future of mankind. The deep integration of land use is a major breakthrough in solving the complex problems in the process of ecological civilization development and transformation. By establishing a "fusion" innovation and entrepreneurship ecological civilization system, this paper applies artificial intelligence and big data in the construction path of innovation and entrepreneurship ecological system from the perspective of land use and ecological suitability. Simulation studies were conducted in parasitic mode, biased symbiosis mode, asymmetric symbiosis mode, and symmetric symbiosis mode respectively through Matlab software. According to the results of the study, the subject size of the relevant subjects in the parasitic mode is only 70.43% of the subject size of the entrepreneurial enterprise. In the biased symbiosis model, the subject size of the relevant subject is 87.82% of the subject size of the entrepreneurial enterprise.

KEYWORDS

Land use; artificial intelligence; big data; ecological civilization construction; innovation and entrepreneurship.

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ABSTRACT

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1. INTRODUCTION

Innovation and entrepreneurship is the main theme of the current society and is an important engine to promote China's economic development. In the process of ecological system construction, all sectors should meet the needs of social and ecological development. In addition, it is a new way to combine the "fusion" innovation and entrepreneurship approach with system construction in the context of artificial intelligence, combined with the rational use of land. To build an innovation and entrepreneurship ecosystem that "continuously deepens the reform of the ecological system and integrates entrepreneurship whole ecological civilization construction" is the goal of current development.

Land use change is a core area of contemporary global environmental change research, and scholars in China and abroad have been advancing their research work in both depth and breadth over the past 30 years [1-3]. Driven by human economic and social activities, land use change always has its "reasonable" and "unreasonable" sides [4-6]. Reasonable land use change means that land users can obtain better economic and ecological benefits by correctly choosing land use according to the inherent suitability of the land [7,8]. An unreasonable land use change means that people violate the law of land suitability, which will cause serious consequences in terms of ecological degradation [9,10]. We need a reasonable calculation method to explore the path of ecosystem construction from the perspective of land use and ecological suitability.

Artificial intelligence. This describes the action form. Artificial intelligence is a complex category that includes multiple disciplines [11-13]. Big data is also called a huge amount of data, which refers to the collection of data that cannot be extracted, summarized, and processed in a short period of time due to the huge and cumbersome content of the data[14-16]. Later, other methods can be used to integrate these disorganized data and transform them into our use [17-19].

In the long history of human development, the human and the natural environment are interrelated and inseparable. Its value system profoundly affects the development direction and degree of ecological civilization [20-23]. Ecosystem construction is a non-independent systematic project, and the “integrated” innovation and entrepreneurship ecosystem is to build a benign and intelligent ecosystem that integrates ecologically suitable land use and artificial intelligence big data [24,25]. As ecological civilization is closely related to territorial spatial planning, regional spatial planning from the perspective of ecological civilization is becoming more and more popular. Lu et al. [26] took Yongan, Chengdu as an example, and discussed the development path of territorial space planning. Finally, the corresponding development strategy and planning are put forward for Yongan Town. They practice the concept of conservation in the planning of land and space. In addition, they have formulated measures and specific planning schemes for the ecological compensation system, hoping to provide certain theoretical guidance for the national land and space planning of other cities and towns. Ma et al. [27] sorted out the relevant policies. The

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research shows that the protection policy is sufficiently perfect, but the correlation between marine policy points and marine support policies is not high. These influence the coupling of marine ecological civilization and ecological society to a certain extent. Yang et al. [28] studied the civilization pilot city policies emissions based on the pollution discharge of multiple cities in China. They found that this of cities, especially for small cities. Xie et al. [29] studied the relationship between quality and economics. They found that while economic growth has risen steadily in recent years, environmental pollution, as measured by emissions of wastewater and air pollutants, is still decreasing, and at a markedly faster rate. This can provide a practical and effective path for the construction of ecological civilization in other countries. Meng et al. [30] first combined the evaluation framework of the ecological civilization pilot area with academic research to build a comprehensive framework and index system. Then, they calculated the coupled coordination number (CCD) for each experimental plot based on the entropy weights. Finally, they used relative development coefficients to measure ecological and economic development and studied different development patterns of cities. The results show that the regional economy and CCD are closely related, which shows that the relationship between economy and ecology is complementary.

To sum up, the advanced ecological ethics concept is the value orientation, the developed ecological economy is the material basis, and the perfect ecological civilization system is the incentive and restraint mechanism. At present, from the ecological perspective of land use, there are still some vacancies "integrated" system. Combined with the topic of " drives the construction of ecosystems in our province and countermeasures - based on the perspective of innovation reefs", this paper takes artificial intelligence and big data as the background, combines intelligent algorithms with the construction of ecological civilization system, and proposes. This kind of "integrated" innovation and entrepreneurship ecological civilization system construction path. By creating an immersive and integrated intelligent environment, improving the intelligent literacy of human-human synergy, achieving the intelligent integration required by the whole ecology, and exploring the practical path of building an innovative ecological system.

2. THEORETICAL MODEL

A neural network is an information processing system formed by studying the structure and function of the human brain through physical and mathematical methods. A neural network has many nodes called neurons, each node is connected with each other, and each node is connected by a connecting line. When data is fed into a neural network, it spreads among the nodes, each of which then processes the data. In this case, the nodes in the ANN will find an optimal state, and this process is called training. From its basic working mechanism, if you find suitable training data to train the neural network model, you can easily deal with some problems that cannot be solved at present. Due to the particularity of neural network structure and processing methods, it has been widely used in many aspects such as image processing, robotics, and data mining.

2.1. BP NEURAL NETWORK ALGORITHM

BP has good adaptive ability, regularity, and high parallel processing information ability. It is a multi-layer feed-forward backward transfer that has excellent high-dimensional function mapping ability and can handle complex classification problems and overcomes the problems of exclusive or (XOR) that cannot be handled by simple perceptrons and the learning of hidden layer connections in multi-layer neural networks. Through long-term research and exploration, the BP neural network can solve problems such as prediction, classification, and evaluation.

Taking a simple BP neural network as an example, set the number of node neurons, single-layer hidden layer, and to be [2, 3, 1], respectively, and the activation function is the $\tan sig$ function, that calculates the output value of the output layer. The mathematical expression is as follows:

$$\begin{aligned}\text{simy} = {} & w_{11}^{(2,3)} \times \text{tansig}\left(w_{11}^{(1,2)} \times x_1 + w_{21}^{(1,2)} \times x_2 + b_1^{(2)}\right) \\ & + w_{21}^{(2,3)} \times \text{tansig}\left(w_{12}^{(1,2)} \times x_1 + w_{22}^{(1,2)} \times x_2 + b_2^{(2)}\right) \\ & + w_{31}^{(2,3)} \times \text{tansig}\left(w_{13}^{(1,2)} \times x_1 + w_{23}^{(1,2)} \times x_2 + b_3^{(2)}\right) + b_1^{(3)}\end{aligned} \tag{1}$$

Where, x, w, b are variables.

The $\tan sig$ activation function is as follows:

$$f(u) = \frac{2}{1 + e^{-2u}} - 1 \tag{2}$$

The weight between nodes i and j is set to w_{ij}, b_j is the threshold of node j, x_j is the each node, and the specific calculation method value of each node is as follows:

$$S_j = \sum_{i=0}^{m-1} w_{ij} x_i + b_j \tag{3}$$

$$x_j = f\left(S_j\right) \tag{4}$$

Where, f is an activation function, usually the $sigmoid$ function is chosen.

Assume that the full result of the output layer is w, and the error function is as follows:

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$$E(w,b)=\frac{1}{2}\sum_{j=0}^{n-1}\left(d_j-y_j\right)^2 \tag{5}$$

Using the gradient descent method, the gradient at the current position is proportional to the correction of the weight vector, so the j output node is:

$$\Delta w(i,j)=-\eta\frac{\delta E(w,b)}{\delta w(i,j)} \tag{6}$$

Assume that the chosen activation function is as follows:

$$f(x)=\frac{A}{1+e^{-\frac{x}{B}}} \tag{7}$$

Self-feedback network, as a widely used network model in BP neural network, transmits the error signal of its output layer to the connection weights between its other layers, so that the error tends to the minimum value. The expression is as follows:

$$E=\frac{\sum_1\left(T_1-y_1\right)^2}{2} \tag{8}$$

Where, T_1 is the expected output, y_1 is the output layer output, and E is the error signal.

In view of the characteristics of the transfer function and in order to meet the training requirements, the samples need to be normalized between $[-1,1]$, and the $\min-\max$ algorithm is used:

$$y=\left(y_{\max}-y_{\min}\right)\times\frac{\left(x-x_{\min}\right)}{\left(x_{\max}-x_{\min}\right)}+y_{\min} \tag{9}$$

Where, x is the original data, and y is the normalized data.

2.2. RANDOM FOREST

Random forest is one of the most widely used machine learning models, and it is also an ensemble learning method. Random forest improves the output without increasing the amount of computation and is not sensitive to multivariate collinearity. This algorithm is robust to missing data and unbalanced data, and can effectively predict thousands of different explanatory variables.

Random forest contains several decision trees, and there is no correlation between these decision trees. Random forest uses the different characteristics of multiple subsamples to construct multiple decision trees to make similar predictions for the

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same phenomenon. A random forest is a forest composed of multiple decision trees using the Bagging idea. Each decision tree is a weak classifier. In the classification problem, the result of each decision tree is voted to obtain the final result, thus forming a strong classifier.

Random forest uses random samples and random features, that is, random rows and columns, which reduces the correlation of the base model, that is, each tree, and can directly deal with categorical and numerical features, avoiding the occurrence of overfitting to a certain extent. The anti-overfitting and stability characteristics of Bagging allow random forests to trade-off between bias and variance by adjusting parameters. These characteristics of random forests make random forests unnecessary for feature selection. It is suitable for high-dimensional data and can perform parallel computing, which also makes the selection of effective factors more simple, efficient, and high-precision in this paper.

2.3. GAUSSIAN PROCESS REGRESSION ALGORITHM

It is suitable for dimensionality and nonlinearity and has good generalization ability.

$$f(x) \propto GP\left(u(x), k\left(x, x'\right)\right) \tag{10}$$

$$y = f(x) + \varepsilon \tag{11}$$

Where, x, x' are arbitrary random variables, ε is noise, obey a Gaussian distribution with mean 0 and variance σ_n^2. $u(x)$ is the mean function and $k\left(x, x'\right)$ is the covariance function. Since $f(x)$ follows a Gaussian distribution that is independent of ε, y follows a Gaussian distribution:

$$y \propto N\left(0, K(X, X) + \sigma_n^2 I_n\right) \tag{12}$$

where I_n is an n dimensional unit matrix and given an input variable x^*, the corresponding output is y^*, the joint distribution of the algorithm's prediction set y^* and training set y is, according to Bayes' principle:

$$\begin{bmatrix} y \\ y^* \end{bmatrix} = N\left(0, \begin{bmatrix} K\left(X, X + \sigma_n^2 I_n\right) & K\left(X, x^*\right) \\ K\left(x^*, X\right) & k\left(x^*, x^*\right) \end{bmatrix}\right) \tag{13}$$

So the expression for the prediction set y^* is as follows:

$$y^* \mid X, y, x^* \propto N(\mu, \Sigma) \tag{14}$$

Where,

$$\mu = K\left(x^*, X\right)\left[K(X, X) + \sigma_n^2 I_n\right] \tag{15}$$

$$\sum = k\left(x^*, x^*\right) - K\left(x^*, X\right)\left[K(X, X) + \sigma_n^2 I_n\right]^{-1} K\left(X, x^*\right) \tag{16}$$

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For the covariance function, this paper uses the most commonly used square exponential covariance kernel function:

$$K\left(x_i, x_j\right) = \sigma_f^2 \exp\left(-\frac{\| x_i - x_j \|^2}{2l^2}\right) \tag{17}$$

2.4. INPUT VARIABLE SELECTION METHOD

The Pearson correlation coefficient describes the degree of correlation between two spaced variables, generally represented by r, and its calculation formula is:

$$r = \frac{N\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{N\sum x_i^2 - \left(\sum x_i\right)^2}\sqrt{N\sum y_i^2 - \left(\sum y_i\right)^2}} \tag{18}$$

Where, N is the number of samples, x_i, y_i are the current variables, $i \in N$. The larger the absolute value of r, the stronger the correlation between the two variables, and the closer the correlation coefficient is to 1 or -1. The weaker the correlation, the closer the correlation coefficient is to 0.

2.5. HYPERPARAMETER OPTIMIZATION METHODS

The choice of the number directly determines the quality of the model: if there are too many, the model will be over-fitted and the generalization will be poor. If the number is too small, it is difficult to complete the fitting of the samples.

In this paper, root mean square error (RMSE), mean error (MAE), mean absolute error (MAPE) and coefficient of determination (R^2) are used as model evaluation indexes to evaluate the effectiveness and generalization of the model.

Root Mean Square Error:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\hat{y}_i - y_i\right)^2} \tag{19}$$

Average error:

$$MAE = \frac{1}{n}\sum_{i=1}^{n}\left|\hat{y}_i - y_i\right| \tag{20}$$

Mean absolute error:

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$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{\hat{y}_i - y_i}{y_i}\right| \times 100\,\% \tag{21}$$

Decisive factor:

$$R^2 = \frac{\sum_{i=1}^{n}\left(\hat{y}_i - \bar{y}_i\right)^2}{\sum_{i=1}^{n}\left(y_i - \bar{y}_i\right)^2} \tag{22}$$

Where, $y, \hat{y}$ represents the actual predicted model, n is the number of test samples, and $\bar{y}_i$ is the average value of the sample y_i.

This section describes how to process the original dataset, how to choose input and output variables, and how to optimize hyperparameters for best predictions when using machine learning methods. Provide theoretical guidance for follow-up work.

3. ANALYSIS AND DISCUSSION

3.1. MODEL SIMPLIFICATION

The $logistic$ growth function model can well describe the growth process of ecological populations in the ecosystem. The growth of population size is subject to external environmental factors such as resources, technology, policies, and institutions. In the entrepreneurial ecosystem, resources are limited, and the growth of entrepreneurial enterprises, large enterprises, investment institutions, intermediary service institutions, universities, and research institutes will be constrained by resources. With the increase in the population density of the subject, the growth of the subject will slow down, and the growth process of the subject conforms to the evolution process of the ecological population.

1. Participants in the entrepreneurial ecosystem include entrepreneurial enterprises, large enterprises, investment institutions, intermediaries, and universities and research institutes. Any type of subject other than start-up enterprises can be a relevant subject.

2. The scale changes of entrepreneurial enterprises and related entities represent the growth process of the entities. As the entrepreneurial ecosystem evolves, the size of each entity represents its growth process. The larger scale of the subject, the greater the number and types of resources in the entrepreneurial ecosystem, and the better the growth. Conversely, the smaller the scale of the main body, the less the number and types of resources in the entrepreneurial ecosystem, and the worse the growth.

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3. The scale changes of various entities affect each other, and their growth processes all serve the growth law of $logistic$. Due to the limited number of resources, the growth of subjects is constrained by resources, so in the model of this paper, the growth of one type of subject will be affected by the density of another type of subject. The increase in the density of another type of main body will bring about a decrease in the growth rate of this type of main body.

4. the subject is growing and enters a stable state.

3.2. SIMULATION CALCULATION

Through Matlab software, under the same parameter background, when setting the relevant subjects, it is found that the of entrepreneurial enterprises, entrepreneurial enterprises, entrepreneurial enterprises and intermediaries, entrepreneurial enterprises and universities and scientific research institutions is consistent. Due to space reasons, this paper takes the symbiotic evolution path of entrepreneurial enterprises and investment institutions as an example to simulate. The maximum scale between start-ups and related entities under specific resource constraints is 1000. The initial size of both types of entities is 100. The evolution cycle is 800 simulation times. By exploring the relationship between different A and B, we can obtain the evolution process, and path.

1. Parasitism. Taking A as -0.15 and B as 0.15, respectively, the parasitic evolution results, when A takes a negative value, the entrepreneurial enterprise belongs to the party with increased interest in the parasitic relationship, and the related enterprises play a positive the growth of the entrepreneurial enterprise, and the steady state value exceeds its maximum capacity for independent growth. B takes a positive value, the relevant subject is on the side of the parasitic relationship with impaired interests. The startup plays a negative role in weakening the growth of the size of the relevant subject, and the steady state value is less than its maximum capacity for independent growth. After stabilisation, the subject size of the entrepreneurial enterprise reaches 1150 and the subject size of the related subject is only 810, which is only 70.43% of the subject size of the entrepreneurial enterprise.

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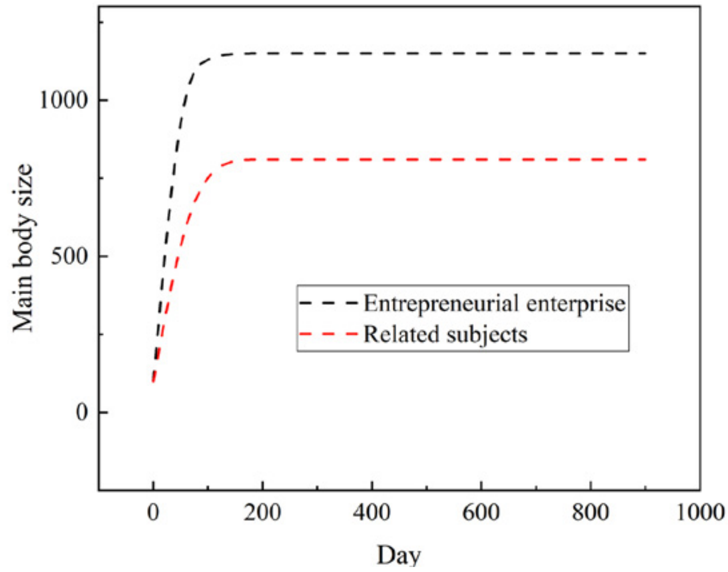

Figure 1. Symbiotic evolution results in a parasitic mode

2. Symbiosis of partial benefit. Taking A as -0.15 and B as 0, respectively, the result of partial benefit, when A takes a negative value, the entrepreneurial enterprise belongs to the party with increased interests in the symbiotic relationship of partial interests. The steady-state value exceeds the maximum capacity of independent growth. When B is 0, the relevant subject belongs to the party whose interests are not affected by the symbiosis of partial interests. Entrepreneurial enterprises have no effect on the growth of the scale of related entities, and the steady state value is equal to the maximum capacity of independent growth. In the stable simulation stage, the main body scale of entrepreneurial enterprises has reached 1150, and the main body scale of related entities is 1010, which is only 87.82% of the main body scale of entrepreneurial enterprises.

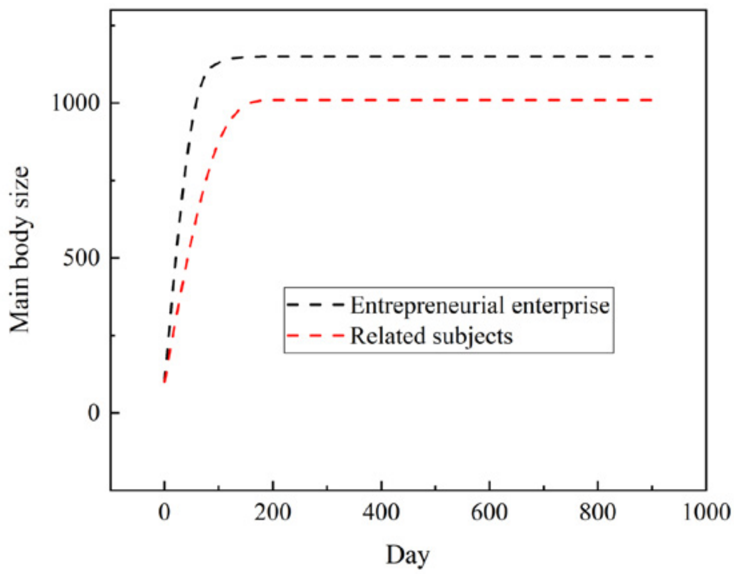

Figure 2. Symbiotic evolution results under the partial benefit symbiosis model

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3. Asymmetric mutualism. Taking A as -0.35 and B as -0.15, respectively, the results of asymmetric reciprocal A and B have negative values, and the scale growth of start-ups and related entities benefited from the other entity. The scale growth of start-ups and related entities is positively promoted by each other, and the steady state values of the two types of entities both exceed the maximum capacity of their independent growth. However, when |A|>|B|, it means that the relevant subject has a greater influence on the entrepreneurial enterprise. In the stable simulation stage, the main body scale of entrepreneurial enterprises has reached 1400, and the main body scale of related entities is 1250, which is only 89.28% of the main body scale of entrepreneurial enterprises. Therefore, the steady-state scale of entrepreneurial enterprises is larger than the steady-state scale of related entities.

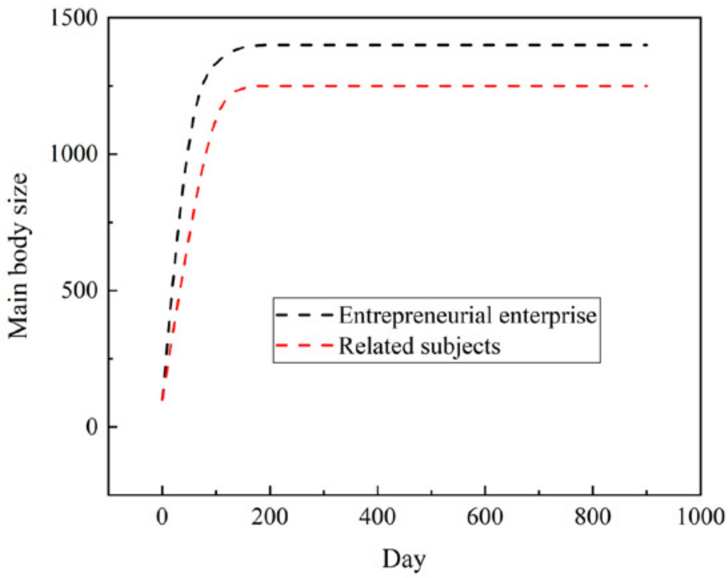

Figure 3. The results of symbiotic evolution under the asymmetric symbiotic model

4. Symmetrical mutualism. Take -0.35 for A and -0.35 for B, respectively, to obtain the symmetrical reciprocal. Both A and B take negative values, and |A|=|B|, the scale growth of entrepreneurial enterprises and related entities both benefit from the other entity and are affected to the same extent. The steady-state scale of entrepreneurial enterprises is equal to the steady-state scale of related entities, and both are larger than the maximum scale of their independent growth. In the late stage of simulation, the scale of the main body of entrepreneurial enterprises has reached 1570, and the scale of the main body of related entities has also reached 1570, but the simulation time is slightly longer.

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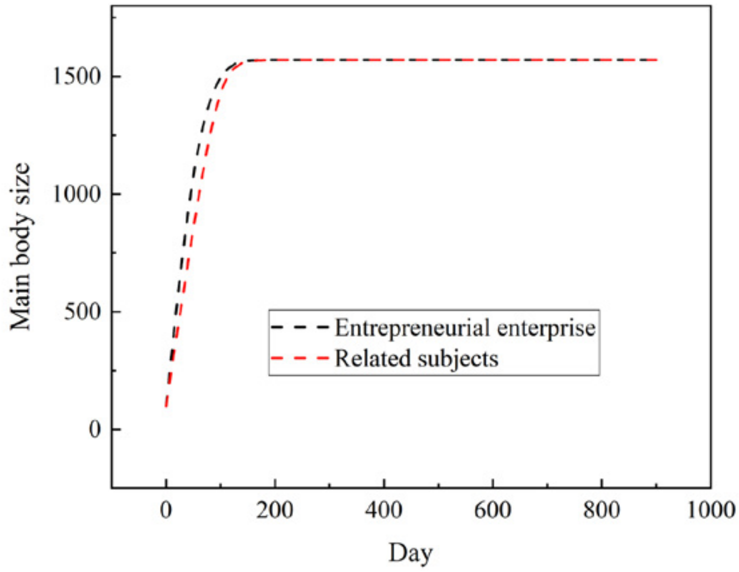

Figure 4. Symbiotic evolution results under the symmetrical symbiosis model

Through the above simulation results, it can be found that of A and B represent different symbiosis modes. Different symbiosis modes affect the stable equilibrium point, ultimately leading to different evolution paths of the subjects. It can be concluded that the path is affected by the symbiotic mode among multiple types of subjects. Observing Figures 1-4, it is found that different symbiosis coefficients represent different symbiosis modes. Under different symbiosis modes, the evolution equilibrium point of the main body is different, and the final stable scale of the main body is different.

4. RESULTS AND ANALYSIS

In the context of dual innovation, the entrepreneurial ecology of major cities in China is developing well and is becoming a world-leading entrepreneurial ecosystem. In this paper, we establish a "convergent" innovation and entrepreneurship eco-civilization system and apply it in the construction of the innovation and entrepreneurship eco-system from the perspective of land use and ecological suitability. Simulation studies were conducted in parasitic mode, biased symbiosis mode, asymmetric symbiosis mode, and symmetric symbiosis mode by Matlab software, respectively, and based on the results, the following conclusions can be drawn:

1. Different values are taken to represent different symbiosis patterns, and different symbiosis patterns affect the stability of symbiotics, which eventually leads to different evolutionary paths of the subjects. In the parasitic mode, the subject size of the relevant subject is only 70.43% of the subject size enterprise.

2. The steady state scale is related to its symbiosis coefficient and maximum scale and has nothing to do with initial population size and natural growth rate.

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Under the partial benefit symbiosis model, the scale of the main body of entrepreneurial enterprises has reached 1150, and the scale of the main body of related entities is 1010, which is only 87.82% of the scale of the main body of entrepreneurial enterprises.

3. Under the symmetrical symbiosis model, the main body scale of the relevant entities also reaches the optimum, reaching 1570, which is consistent with the main body scale of entrepreneurial enterprises. From this, it can be concluded that the equilibrium point is related to the symbiotic coefficient.

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THE APPLICATION OF BIG DATA TECHNOLOGY IN THE PREDICTIVE ANALYSIS OF ENTERPRISE CAPITAL OPERATION RISK

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ABSTRACT

The background of the big data era makes enterprise tax management face many opportunities and challenges, in order to improve the management of enterprise capital operation risks and promote the enterprise to take the road of sustainable development. This paper firstly indexes risk names with the help of web crawler technology, establishes data sources, and then circulates the crawler to obtain the required information. Secondly, a hashing algorithm is applied to compress the massive data into a unique and extremely compact section of hash values by means of constant mapping. Then association rules are used to determine the set of frequent risk items, and the values of the two are continuously changed to derive the final predictive analysis. Finally, a capital operation risk prediction and analysis platform is built by combining the above processes. In this paper, the effectiveness of the proposed platform is verified, and the practical results show that the accuracy of the proposed platform for risk prediction discovery is as high as 97%, and the time spent for risk discovery is controlled within 30 minutes. The relevant data results verify that big data technology improves the accuracy of enterprise capital operation risk prediction and analysis while accelerating the speed of risk discovery.

KEYWORDS

Web crawler; hashing algorithm; hash value; association rule; frequent risk item set.

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1. INTRODUCTION

Under the premise of continuous development of the economic market, enterprises must continuously expand their own business scope as well as business scale and management mode in order to gain a foothold in the market competition [1]. Therefore, enterprises often use capital operation to promote the efficient operation of capital and lay the foundation for the improvement of enterprise efficiency. The opportunities and risks faced by enterprises in capital operation are increased due to the influence of internal and external environment [2-4]. Therefore, it is necessary to study how to prevent the risk of enterprise capital operation and countermeasures.

Corporate capital operations have long been a hot topic of research in the industry [5-6]. The literature [7] states that firms with high social capital exhibit higher levels of risk-seeking behavior. Moreover, the relevant actions of firms lead to greater volatility in stock returns and earnings. Thus, it is clear that firms should conduct capital operations to generate returns while preventing risks from causing greater losses. The literature [8] constructs a minimum risk versus capital and risk diversification strategy for investment portfolios, taking into account the most frequent capital risks in various industries today. Risky capital is placed separately from risk-free capital, so that the benefit obtained is a weighted average of risk-free assets, while the risk is not a weighted average of risky assets, spreading the capital risk. The literature [9] used Bayesian network models in big data technology to calculate the risk of water pollution and assess the impact of contaminants in water, which identified the critical causes and thus the risk of adverse accidents. A new model for risk assessment was proposed in the literature [10]. Preliminary estimates are made with the help of reference scenario prediction methods and optimistic bias enhancement is performed. Uncertainties are introduced in the cost-benefit analysis. Thereafter, a quantitative risk analysis is provided using Monte Carlo simulation. Although the above-mentioned literature proposes a series of new methods for risk prediction, the proposed methods do not fully take into account the large size of the risk data, the data storage system is more settled, and the analysis of the data is not thorough enough, and the conclusions obtained are not representative.

Therefore, this paper builds an enterprise capital operation risk prediction and analysis platform based on big data technology. Firstly, with the help of the web crawler technology in big data collection technology, the capital operation risk is indexed and relevant data is obtained through continuous cyclic crawling. Secondly, the hash algorithm in big data storage technology is used to compress the massive data into unique and extremely compact hash values, and then realize the storage of massive data. Finally, the set of frequently occurring risk items is determined by using the confidence and support degrees in the association rules, and the values of both are continuously adjusted to derive the final capital operation risk prediction analysis data. In order to verify the effectiveness of the enterprise capital operation risk prediction and analysis platform built based on big data technology, this paper analyzes the accuracy and time required for enterprise capital operation risk prediction and analysis in the simulation experiment and verifies that the enterprise

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capital operation risk prediction and analysis can be achieved quickly and accurately based on big data technology.

2. CORPORATE CAPITAL OPERATION

2.1. CAPITAL OPERATION

Capital operation as a business concept has a long history and has been developed and perfected with the formation of a commodity economy and market economy. Capital operation is becoming an important way for enterprises to enhance economic efficiency and realize self-value appreciation. By capital operation, it means that the enterprise operator takes all the tangible or intangible assets and production factors owned by the enterprise, through flow, fission, combination, optimal allocation and effective operation in various ways, to gather a large amount of capital in a short period of time, and make the capital increase rapidly through capital expansion, in order to achieve the maximum capital appreciation [11-12]. The process of capital operation is also the concrete implementation process of capital management strategy and capital movement.

The various aspects of capital operation are interlocked to form a closed loop. Capital operation requires an all-around control of financing, investment and assets, etc. The object of capital operation is property rights in the form of stock assets, or physical capital that can be operated according to securitization and valuation, and is a capital-oriented enterprise operation mechanism. The capital operation usually leads to a transfer of ownership or a significant change in the original shareholder structure. The core issue of capital operation is how to optimize the structure of production factors to improve the efficiency of capital operation, which includes the optimization of resource allocation structure, the optimization of industrial capital, financial capital and property rights capital structure, the optimization of speculative capital and incremental capital and the optimization of capital operation process.

However, capital operation is a risky economic activity, which can bring great risks to the enterprise while bringing rapid development opportunities to the enterprise.

2.2. CAPITAL OPERATION RISK

Capital operation risk refers to the possibility of failure of capital operation or failure of capital operation activities to achieve the expected goals and losses due to the complexity and variability of the external environment and the limited cognitive ability of the capital operation subject in the process of capital operation. In simple terms, capital operation risk refers to the possible loss of the enterprise due to the occurrence of unfavorable events in the process of capital operation, which is mainly caused by the uncertainty of the environment.

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According to the definition of capital operation risk, it can be seen that the direct bearer of capital operation risk is the capital operation subject, i.e., the capital operation enterprise rather than the owner of the capital, although it also brings losses to the owner of the capital. Capital operation risk mainly comes from the complexity and variability of the environment, i.e. the uncertainty of the environment. The relatively limited cognitive ability of the capital operation subject to the environment is also an important factor leading to the capital operation risk. There are two consequences of capital operation risk: failure of capital operation and failure of capital operation activities to achieve expected goals. Failure of capital operation refers to the suspension of capital operation activities, while failure of capital operation activities to achieve the expected goal means that the capital operation activities are successful but do not achieve the desired efficiency. For example, the merging firm is forced to terminate the merger due to the anti-merger resistance of the merged firm.

In general, enterprise capital operation risk mainly contains the following aspects, namely, operational risk, information risk, management risk, legal and regulatory risk, etc.

Business risk refers to the occurrence of business risk due to the lack of comprehensive understanding of market information in the actual management process and the lack of countermeasures for problems in internal management, which creates problems in the operation process and thus affects the normal operation of the enterprise [13-14]. Financial risk, on the other hand, refers to the fact that enterprises do not have scientific planning for financial management work, the use of funds is more arbitrary, and operational risks are increasing, which leads to financial risk [15]. In the context of the information age, the processing of market information by enterprises is not scientific and reasonable enough, which leads to the phenomenon of information asymmetry and adversely affects the business decisions of enterprises. As enterprises are subject to state regulation of capital operation, the phenomenon of inefficient operation and unreasonable setting of capital structure still exists in the actual operation of enterprises. In addition for the internal management of enterprises, the deviation of management concept and the mistake of operation within the enterprises can cause management risks. In addition, capital operations in other countries can also spill over into the development of developing economies [16]. The development of the market economy must be based on the relevant national laws and regulations, and the macroeconomic regulation of the state will be adjusted, which will have a certain impact on the M&A behavior of enterprises, thus making the operating costs of enterprises higher.

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2.3. CHARACTERISTICS OF CAPITAL OPERATION RISK

2.3.1. OBJECTIVITY OF CAPITAL OPERATION RISK

Objectivity is the essential characteristic of capital risk, as can be seen from the definition of capital risk. Like all other risks, capital risks do not exist at the will of the operator. It exists objectively regardless of whether the operator acknowledges it or not, or whether he is aware of it or not. Capital operation risk exists not only in the preparation stage and the operation stage of capital operation but also in the commodity operation stage after capital operation.

2.3.2. VARIABILITY OF CAPITAL OPERATING RISKS

Capital operation risk can change under certain conditions. The probability of occurrence, the degree of impact, and even the scope of impact of capital operation risks are different in each period and each link of capital operation and under various conditions. This requires the capital operating entity to make full use of various methods and means to identify and prevent risks in the process of capital operation risk prevention.

2.3.3. PREDICTABILITY OF CAPITAL OPERATION RISK

Although capital operating risks are variable highly contingent and uncertain, capital operating risks can also be identified and predicted. While the occurrence of a single risk may be contingent and uncertain, the occurrence of a large number of risks is inevitable. In fact, the occurrence of risks before, during, and after the operation of capital operation will have certain characteristics. As long as the capital operation subject of the enterprise can capture such information, it is possible to detect the risks in time and prevent and avoid them early through prediction and analysis. However, in order to accurately anticipate risks and take effective preventive measures, it is necessary for capital operators to have risk awareness and accumulate experience in identifying and preventing risks.

Thus, it is very necessary to study and explore the risk of capital operation. In the new development period, enterprises should establish capital operation risk early warning mechanisms based on national and industry norms, based on laws and regulations, based on their own capital operation needs, etc., and use the early warning mechanism to timely discover, identify prevent, and control all kinds of risks in the process of capital operation, so as to fundamentally improve the security of capital operation. However, the current era is the information age, and big data technology has become the core weapon of each enterprise, which will play an important role in the transformation and development of enterprises and risk prevention and control. Therefore, enterprises wanting to conduct risk prediction and analysis of capital operations need to rely on big data technology.

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3. RISK PREDICTION UNDER BIG DATA TECHNOLOGY

Big data technology refers to a new type of information processing technology in which people and objects upload data between them through a third-party medium, the computer, and the computer categorizes, fuses, and processes the data uploaded into the network. The strategic significance of Big Data technology does not lie in the mastery of huge data information but in the specialized processing of these data containing meaning [17-19]. In other words, if big data is compared to industry, the key to the profitability of this industry lies in improving the processing capability of the data and realizing the value-added and prediction of the data through processing.

3.1. DATA ACQUISITION

Data acquisition is data mining, i.e., extracting high-value data information from inside massive data resources, and is an important method used to obtain association rule attributes to filter data. Data acquisition belongs to a decision support process, mainly based on artificial intelligence, machine learning, and pattern recognition, and can also interact with users or knowledge bases. The mining object is also not limited to a certain type of data source but can be a relational database, data warehouse, text, multimedia data, and other data sources containing semi-structured data or even heterogeneous data [20]. More common is the web crawler technique.

Web crawler technology is a technology based on the Internet that automatically crawls a specific web page. Its implementation mechanism is similar to the human click operation on web pages, and it can complete the interaction between the client and the server without human intervention to achieve automatic, accurate, and large-scale extraction of web data. According to the different crawling tasks, web crawlers can be classified into various types such as general-purpose, focused, priority, incremental, deep, etc. Meanwhile, users can also build custom web crawlers according to their actual needs.

Web crawler technology is used to collect information related to enterprise capital operation risk, the specific steps are as follows:

Firstly, collect data requirements according to predefined. Establish the data source website with the name of enterprise capital operation risk as the index. Use web crawler technology to crawl enterprise basic data and related information, such as national enterprise credit system, judicial system, Tian-eye search, enterprise search, Qixinbao, etc., focusing on asset data, trademark data, public litigation data, public opinion data and deep mining and crawling of enterprise relationship.

Next, the seed initialization crawler is constructed. Using the name data of existing corporate capital operation risks, we construct the initialization crawler based on the characteristics of each website. Then, we obtain the source documents of the web pages. The source document of the web page is parsed and the required text content is stored in the database, or the required data is extracted and put into the queue to

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be crawled and then entered into the cycle of crawling. Finally, the data obtained by the crawler is stored in the database.

3.2. DATA STORAGE

At this stage, the most commonly used system for data storage is a distributed electromechanical system. Distributed electromechanical systems can store massive amounts of data on multiple spatial and temporal scales. However, as the service time of the equipment becomes longer, the amount of data for remote monitoring of distributed electromechanical systems grows exponentially. At this time, the use of distributed storage systems for data storage may suffer from load-balancing imbalance. The use of a hashing algorithm can achieve distributed data storage with minimal and stable system changes, as shown in Figure 1.

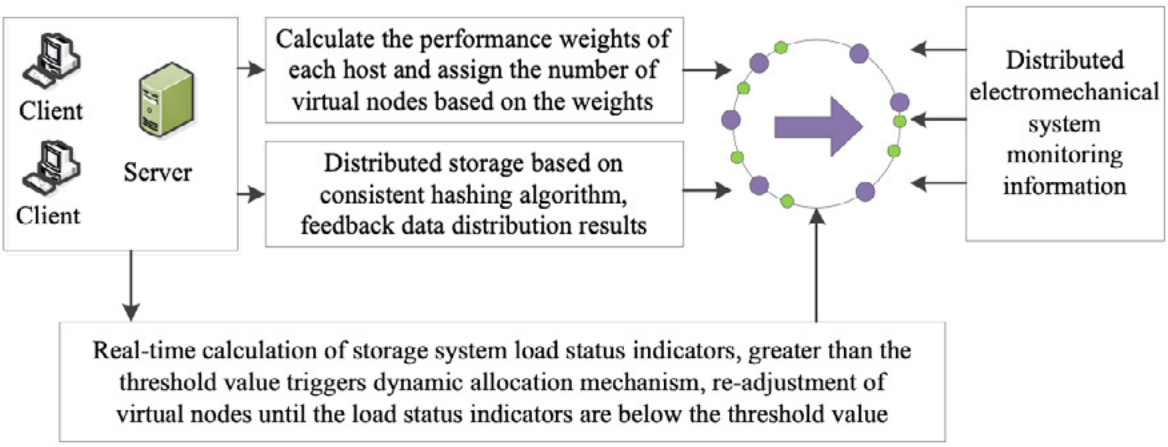

Figure 1. Distributed storage under hash algorithm

As can be seen in Figure 1, using hashing algorithms to store enterprise capital operation risk data, the entire risk data storage space can be abstracted as a ring of fixed length, and then storage nodes are assigned to this ring. In this way, the nodes on the ring all have a fixed hash value, and this ring is called a hash ring. The same hashing algorithm is used to find out the hash value of the keys of the stored data and they are mapped on the same hash ring as well. Finally, the storage node is found clockwise from the position of the data mapping, and the data is stored on the first found storage node. In this way, the enterprise capital operation data information becomes a unique and extremely compact hash value of the data, which facilitates the storage of information.

3.3. ASSOCIATION RULE PREDICTION ANALYSIS

In order to efficiently predict the risk of capital operations, we need to process and analyze the large amount of data generated during capital operations. Eighty percent of the data generated during capital operations is unstructured and grows exponentially by 60% every year. This corresponds to the data processed by big data

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technology. There are three main categories of data processed by Big Data technology, namely structured data, semi-structured data, and unstructured data, and unstructured data is becoming a major part of data.

In big data processing and analysis, correlation analysis is one of the simplest and most practical analysis techniques, which can be used to better handle unstructured data and generate frequent patterns and correlation models at the same time. The so-called association reflects that an event is dependent or related to other events to some extent and can be predicted according to the relevant rules. Association rules are a widely used pattern recognition method, which can be applied to enterprise capital operation risk prediction to effectively identify the risk factors involved.

Let the possible risks in the capital operation of an enterprise be set, and each risk in it can be regarded as a subset. Each risk subset and the whole risk set are logically implicitly related. If the probability of two risk subsets appearing simultaneously in the whole association rule is small, it is proved that the relationship between the two risks themselves is not significant. If the probability of the simultaneous occurrence of two risk subsets is very frequent, it indicates that the two risk subsets are related to each other, and this probability of simultaneous occurrence can also be called support. The probability of two risk subsets occurring simultaneously is the confidence level, and when the confidence level is 100%, then the two risk subsets are proved to be relational and intimate. When one of the risk subsets appears, the other risk subset also appears in a bundle.

The risk dataset stored by the hashing algorithm is used as input data, and the frequent item set is obtained by setting the minimum support, and then the next process proceeds. According to the confidence threshold, the strong association rules that meet the requirements are inferred from the results generated in the previous step and are aggregated and verified, and the whole mining process is finished. In the process, we can set different parameters to guide the mining process according to the actual needs, and the final results of risk prediction analysis factors are derived by continuously changing the values of both.

3.4. PREDICTIVE ANALYTICS BUILDING PLATFORM

Using the web crawler technology, hash algorithm, and association rule analysis in big data technology, we can achieve optimization in the accuracy and analysis speed of risk prediction, and better improve the process and results of capital operation risk prediction analysis. Accordingly, this paper builds an enterprise capital operation risk prediction and analysis platform based on the above algorithms, as shown in Figure 2.

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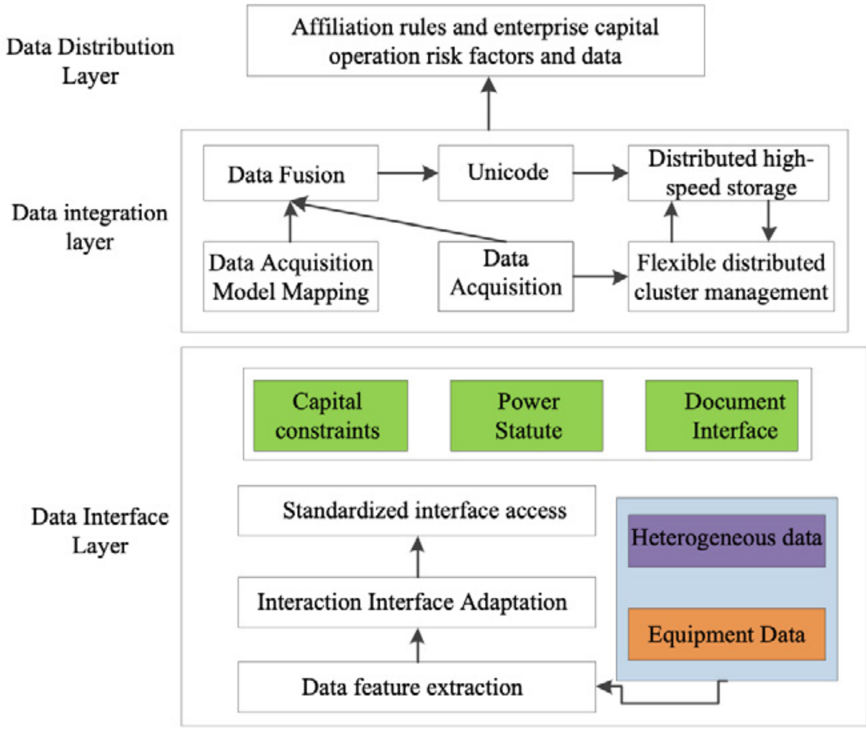

Figure 2. Enterprise capital operation risk prediction and analysis platform

As can be seen from Figure 2, the built enterprise capital operation risk prediction and analysis platform includes three modules: data interface layer, data integration layer, and data distribution layer. The data collected in the major platforms by relying on web crawler technology are input to the data interface layer and feature extraction of the data to extract high-risk data. Through the interface with the data integration layer, the high-risk data is connected to the data integration layer. In the data integration layer, the hash value of the keys of the stored data is derived by the hashing algorithm and mapped on the same hash ring. Finally, the storage node is looked up clockwise from the location of the data mapping, and the data is stored on the first found storage node. The data and hash ring are uniformly encoded to achieve distributed high-speed storage and flexible management of data. Finally, the stored data are analyzed by correlation rules to derive the most likely operational risks of the final enterprise when conducting capital operations. The platform has powerful data storage and processing capabilities in all aspects, which can effectively alleviate the problem of information asymmetry.

4. APPLICATION OF ENTERPRISE CAPITAL OPERATION RISK PREDICTION ANALYSIS

4.1. INCREASED ACCURACY OF PREDICTIVE ANALYSIS

The most fundamental purpose of applying big data technology to enterprise capital operation risk prediction and analysis is to improve the accuracy of enterprise capital operation risk prediction and analysis. Accordingly, in this paper, the platform was put

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into use in 10 companies in a city, denoted by letters A, B, C, D, E, F, G, H, I and J, to compare the predictive analysis accuracy of the 10 companies before and after using the platform. The results obtained under the same conditions are shown in Figure 3.

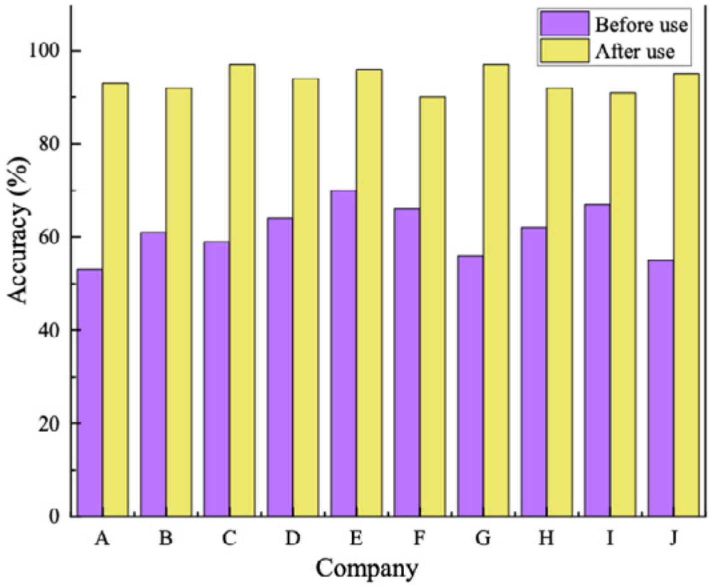

Figure 3. Comparison of accuracy rates of sample companies

As can be seen in Figure 3, before the use of big data technology, the accuracy of capital operation risk prediction analysis of Company A was only 53%, and after the use of Company A, the accuracy of capital operation risk prediction of Company A has increased by 40% to 93%. Company B's capital operation risk prediction accuracy increased from 61% to 91%, an increase of 31%. Both Company C's risk forecast accuracy and Company G's risk forecast accuracy peaked at 97%, an increase of 38% and 41%, respectively, from the previous levels. Before using the built platform in this paper, the risk prediction analysis accuracy of Company D was only 64%, while after using the built platform, the accuracy rate was 94%. Before applying the built platform to the whole process of capital operation, Company E had the highest accuracy rate of 70% in the risk prediction analysis of enterprise capital operation. Company F's risk prediction accuracy rate also improved significantly, lower than other companies, but also increased by 24% compared with that before. Company H and Company I improved their risk forecasting accuracy by 30% and 24%, respectively, compared to their pre-platform performance. Company J had the lowest risk prediction accuracy of 55%, but after applying the built platform, it improved to 95%, ranking third.

It can be seen that the introduction of big data technology in enterprise capital operation risk prediction and analysis has achieved a significant increase in the accuracy of enterprise capital operation risk prediction and analysis, which can help enterprises reduce unnecessary waste of resources and recover a lot of unnecessary losses.

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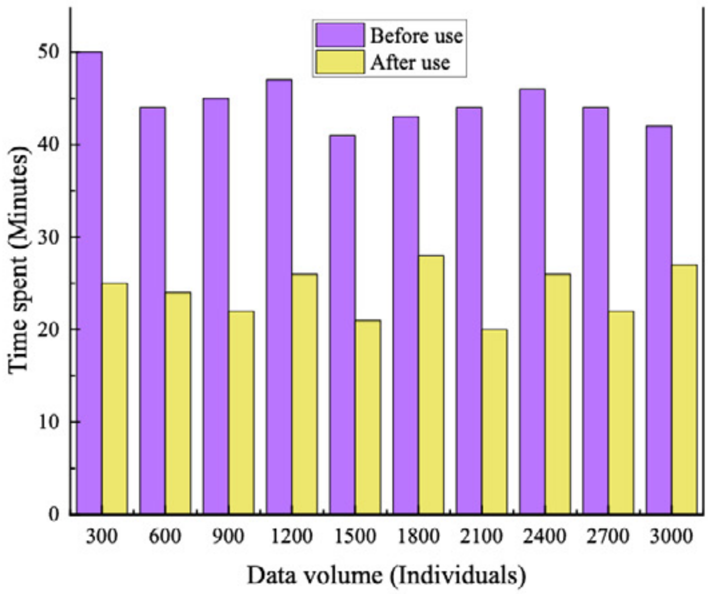
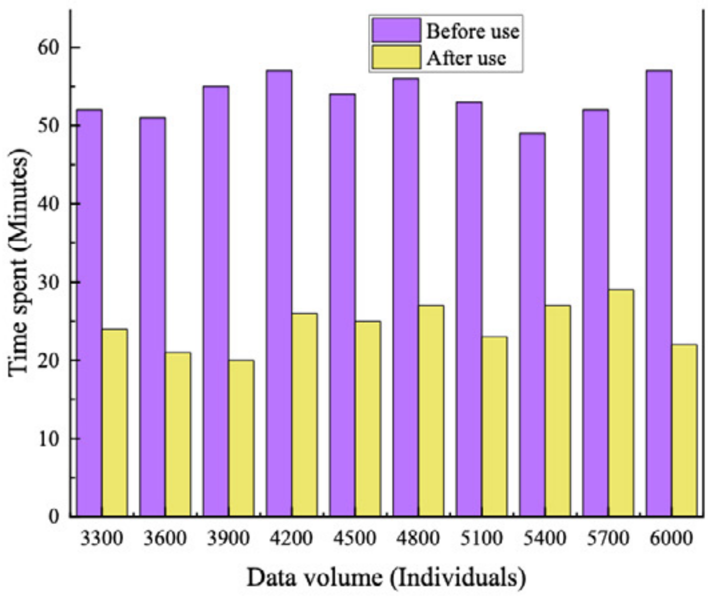
4.2. INCREASED SPEED OF PREDICTIVE ANALYSIS

Enterprise capital operation risks often occur in a split second, while the losses caused by the risks are infinite. The improvement of the speed of risk prediction and analysis is also based on big data technology in building prediction and analysis platforms needs to be considered. The speed of analysis should not decrease with the increase in the amount of information such as data. To verify the analysis speed of the platform built in this paper, 3,000 data, and 6,000 data were input into the platform to derive the platform risk prediction time and compare it with the time required before the enterprise uses the built platform, and the results are shown in Figure 4.



(a) Time required to analyze 3000 data



(b) Time required to analyze 6000 data

Figure 4. Time required to analyze the predicted risk of corporate capital operations

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As you can see in Figure 4(a), before using the platform, it took 50 minutes for companies to identify capital operation risks when analyzing data of up to 300. However, after using the platform, it only takes 25 minutes to identify potential capital operation risks, which is one-half of the time saved. When the data reached 600, the built platform took only 24 minutes to identify risks, a reduction of 20 minutes from the previous 44 minutes. When analyzing 900 pieces of data, it took 45 minutes to identify risks before the enterprise used the platform, while after the application, risk discovery took less than half the time. When the data was 1200, the time for risk discovery was reduced by 21 minutes compared to the original. When the number of data is 1500, the risk discovery time is reduced by 20 minutes. When the data reached 1,800, the built platform took only 28 minutes to discover the risk, a reduction of 15 minutes from the previous 43 minutes. As the data increased, the platform still took less time to discover risks than it did before use. When the data was 3000, the time for risk discovery was reduced by 15 minutes from the previous 42 minutes to only 27 minutes.

As can be seen in Figure 4(b), the risk analysis speed of the platform built in this paper remains at a high level as the data volume increases. When the data volume reaches 3300, the time taken by the built platform drops by 28 minutes. When the data volume was 3600, the time for the platform to discover risks was 21 minutes, which was 30 minutes less than before using the platform. Before using the platform, it took 55 minutes to discover capital operation risks when analyzing 3900 data. However, using the platform, companies can identify potential risks to capital operations in just 20 minutes, saving nearly one-third of the time previously. When analyzing 4,200 pieces of data, it took 57 minutes to identify the risk, but with the platform, it took only half the time to identify the risk with 5 minutes remaining. When the data reaches 4,500 to 5,700, the platform takes up to 27 minutes to identify potential risks, compared to a minimum of 49 minutes before use, a reduction of 22 minutes. When the data volume is as high as 6,000, the platform takes only 22 hours to discover risks, nearly a quarter of the time it took for the original enterprise.

By comparing the time spent on the same amount of data, it can be found that the time required for the capital operation risk prediction and analysis platform based on big data technology is controlled within 30 minutes, with a minimum of 20 minutes. With the increase of data and other information, the prediction and analysis accuracy rate can still be maintained at a high level. Thus, the application of big data technology to the prediction and analysis of enterprise capital operation risk is helpful to help enterprises quickly identify the existence of risks, and then take timely measures before the occurrence of risks, so that losses can be controlled within affordable limits.

5. CONCLUSION

In order to promote the benign development of enterprise capital operation, this paper uses web crawling technology to index the enterprise capital operation risk and

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then obtain the required data through cyclic crawling. Using a hashing algorithm, the relevant numbers of the massive enterprise capital operation risks are compressed through constant mapping, so that the massive data can be stored effectively. The frequent risk items are identified through association rules to derive the final capital operation risk prediction analysis data. Finally, an enterprise capital operation risk prediction and analysis platform is built based on the above big data technology. The accuracy of the built predictive analytics platform is 97%, and the risk prediction time is as low as 20 minutes and does not decrease as the amount of information increases. From the accuracy and speed of risk prediction analysis, it can be seen that the enterprise capital operation risk prediction analysis can be well achieved by relying on big data technology.

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/12/

RESEARCH ON THE FUNCTIONAL GAME INDUSTRY EXPANDABLE BASED ON VR REALISTIC TECHNOLOGY

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ABSTRACT

In order to make the game industry chain be developed structurally, this paper designs a functional game industry expansion path based on VR realistic technology to enhance the interactivity of functional game industry expansion. The interactive 3D model is used to integrate the professional game engine and design the functional game expansion process. The motive of game expansion is guided by the ARCS model to support the construction of functional games. According to the VR realistic game experience, analyze the expandable paths from the modules of technological innovation and industrial integration in order to enhance the realistic experience of integrated industries in functional games. The simulation analysis of the expansion path of the functional game industry based on VR realistic technology shows that VR realistic technology improves the signal-to-noise ratio of functional games by 50% on average, height and cross-roll angle changes by 6.65f/ms and 6.79f/ms respectively, and the number of textures is up to 16.68MB. Therefore, VR realistic technology is beneficial to promote the transformation of the functional game industry it can ensure that the functional game industry steps into a sustainable and expandable track of transformation and upgrading.

KEYWORDS

VR real-world technology; interactive 3D model; ARCS model; game industry; signal-to-noise ratio.

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1. INTRODUCTION

As a branch of the video game industry, the functional game industry can integrate the knowledge and skills of different industries into games, so that they have the dual attributes of entertainment function and learning function [1]. Functional games mainly adopt the form of fun and educational games, allowing users to receive information and gain a personalized new learning experience in the process of playing, thus stimulating the creativity and innovation of learners [2-3]. The functional game industry is actually a cross-border concept, that integrates the knowledge and skills of different industries into the game, which can make the participants acquire knowledge and master skills while relaxing and entertaining, and improve their abilities in a subtle way.

With the rapid development of information technology, the chain of functional games has been systematically supported. For example, the literature [4] stimulates the cognitive processes of mathematical learning through functional game challenges in order to increase students' effectiveness in mathematical learning. In an experimental setting, the surprise condition was set as an emergent condition and the non-game characters that characterized the problem were changed. The experiment combined the intensity of expectation with the surprise condition and demonstrated that surprise conditions can play a key role in mathematics learning by comparing the overall difference between the surprise and control conditions in the student population. The literature [5] applies cognitive load to the contextual setting of functional games and proposes a concept of workload predictors. Functional games were used to reflect the predictors of game participants, to observe the proportional relationship between attention attraction time and the total time consumed by the task at hand, to simulate real-time-critical situations with gamified scenarios, and to assess individual performance. The literature [6] uses functional games to provide talent development for school communities, using a systematic review approach in experiments to increase gamers' social learning opportunities. In functional games, gamers explore different climatic risks in an interactive manner, build the ability to cope with complex challenges and socialize the adaptive matters of the game. The literature [7] reviews the current state of learning analytics, and data standards in functional games, examines how functional games distill technical indicators from player interactions, and analyzes the data collection standards currently used in the field. Based on this review, an interaction model was designed to lay the groundwork for the application of learning analytics in functional games. The literature [8] evaluates the effectiveness of empirical support for functional games. The experimental search strategy included categories such as: gamification and functional games, home energy consumption, and relevant vocabulary combinations, and more comprehensive selection criteria were used throughout the selection process. The results indicate that gamified and functional games have a higher value in terms of energy consumption, conservation, and efficiency. In summary, the current research level of the functional game industry in the academic field is relatively shallow, and all of them are researched mainly on game principles, without considering the industrial development effect at the technical level, lacking design thinking exploration, and not realizing the benign combination of game industry and technical development.

Based on this, this paper applies VR realistic technology to the expandability study of the functional game industry and designs a functional game industry expansion path based on VR realistic technology. In the design process, firstly, the real world is realistically restored to the game through three-dimensional virtual space. The process of functional game expansion is designed by using the interactive 3D model to integrate a professional game engine. Secondly, the ARCS model is used to stimulate the learning motivation of functional game industry expansion, so that the expansion links such as virtual environment, learning content, and interaction means can directly support the meaningful construction of VR realistic functional games, and the expansion path of interactive functional games is designed through VR realistic technology. Finally, the feasibility of the functional game industry expansion path is verified by comparing strong noise points, interactive 3D scene frame rate, and the number of model textures.

2. THE VR TECHNOLOGY-BASED GAME INDUSTRY CAN EXPAND THE PATH

2.1. ENHANCE USER EXPERIENCE

Functional games pursue virtual reality and are dedicated to providing the most sensible experience for players. From the first simple text games to later massively multiplayer 3D games, games have been developed to provide users with a better sense of realism and interactivity to perceive the virtual world. The development of VR realistic game optimization technology is mainly aimed at improving players' combat morale, focusing more on the core optimization settings of the online game world rather than ignoring players' gaming experience. The functional games based on VR realistic technology have a different design concept from traditional video games, through the headset device and somatosensory technology, players can map their own movements to the game world simultaneously. There are two main impact perspectives of VR realistic technology for user experience enhancement.

One is to enhance the interactive effect between game players and the game environment so that functional games can break through spatial constraints. Early functional games in the design can only take the light gun mode to broaden the game content. But along with the continuous development of VR real-world technology, the virtual sex environment can restore the player's sense of immersion in the functional game to the greatest extent.

The second is the shaping of the game environment. The reason why VR real-world technology is so desirable to game companies is that it can provide players with a different game experience without any change in the game content. For the direction

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of industrial expansion of functional games, VR real-world technology is very suitable for a series of functional games such as role-playing, reasoning, etc. to expand to the social industry, and the expansion content includes the game itself, peripherals, and all other products related to the game.

2.2. IMPROVE GAME FLUENCY

The interactive 3D model provides multi-faceted opportunities for the industrial development of games by integrating various professional game engines. VR realistic technology divides the expansion of the functional game industry mainly into the processes of resource management, scene construction, and game release to ensure the flow of game scenes after expansion. Resource management can realize resource presetting and processing functions, and after adding resources to the game scene, multiple files need to be fused to aggregate and integrate the added resources, which is called game scene construction. Game scene construction is to restore the real world in the game by using the three spatial dimensions of the three-dimensional longitudinal direction through the performance principle of three-dimensional virtual space [9-10]. The smooth construction of game scenes using VR realistic technology requires a modular management method so that the particle modules cooperate with the particle curve editor to create various colorful and complex particle effects. The particle system can be intuitively controlled in terms of duration, cyclic mode, and rhythm control so that the particle effects can play a role in rendering the environment atmosphere in the game scene and improving the smooth quality of the game.

2.3. MOTIVATION TO LEARN

ARCS (design motivation) model is a model that aims to stimulate users' motivation to learn [11]. Based on the characteristics of human psychology and physiology, motivating learning is a continuous work, so the ARCS model is also an important factor throughout the expansion process of the game industry [12]. As shown in Figure 1, the ARCS game guide motivation model contains an association strategy, confidence strategy, and satisfaction strategy.

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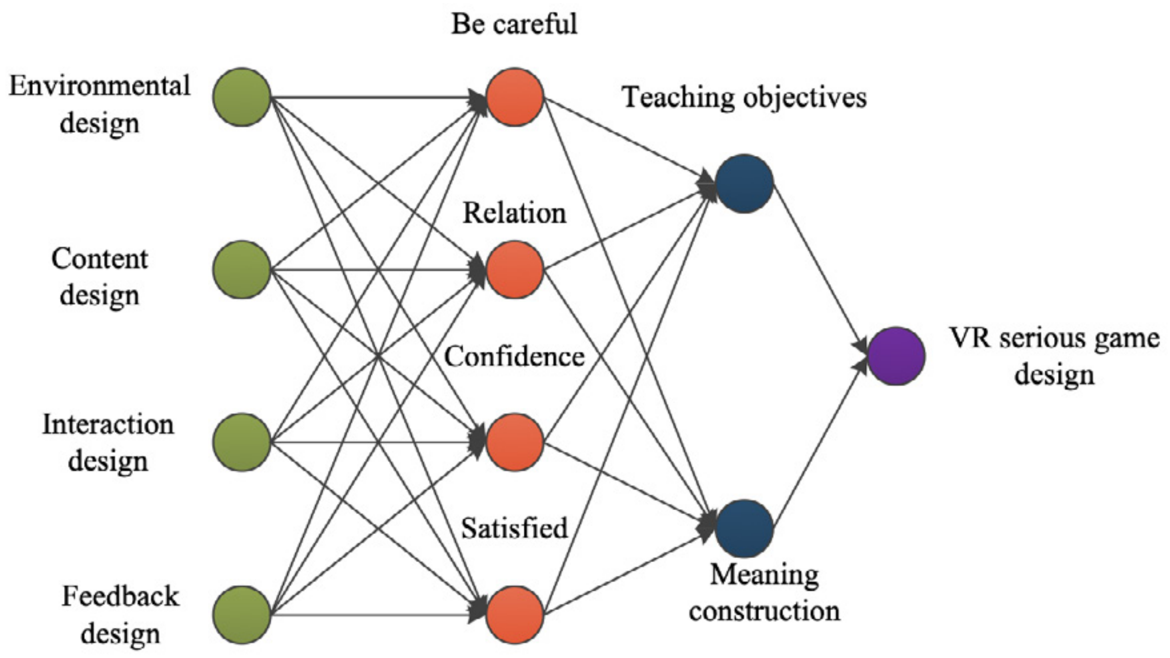

Figure 1. Guided tour motivation model for ARCS game expansion

The association strategy in Figure 1 means that the functional game industry should have clear self-knowledge in the process of expansion, with a view to gaining the experience of industrial upgrading in the expansion, helping to solve certain problems that arise at present or in the future, and transforming the experience into its own management skills in the process of experience.

Confidence strategy encourages functional game companies to develop interest into positive expectations to achieve their goals and helps functional game companies to build confidence in upgrading during the process of expansion. It also provides rich and diverse ways to present resources and educational activities for related industries to sustain the interest in industry transformation.

Satisfaction strategy provides both external and internal reinforcement for functional game enterprises. When game enterprises complete certain stages of goals in the process of expansion, the satisfaction strategy provides functional game enterprises with appropriate rewards to help them gain expansion satisfaction and further enhance the motivation of upgrading.

In the actual expansion process of functional game industry, the expansion of virtual environment, learning content, interaction means and learning feedback all reflect the motivation of ARCS at all times, which directly supports the ultimate expansion purpose of VR realistic functional game industry, i.e. learning objectives and meaning construction.

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3. INTERACTIVE INDUSTRY EXPANSION PATH

3.1. GAME DEVELOPMENT TECHNOLOGY INNOVATION

In the expansion path of functional game industry, improving the innovation ability of game technology is one of the important ways to realize the upgrade of functional industry [13-14]. Unlike traditional functional games, VR realistic functional games can provide force feedback and haptic feedback to the user's hands to create more realistic simulations in the virtual world through sensing technology. A variety of tactile feedback is given to the gamer's body through electronic pulses, and data is collected on various biometric parameters of the game user. It not only provides gamers with the ability to observe and experience virtual reality, but also empowers users to feel their own behavior in the virtual world to produce perceptual changes, improving the functional gaming experience for gamers.

Game development technological innovation is a techno-economic activity that can promote the expansion of functional industrial structure to the rest of the industry. Game technology innovation affects the structure of production technologies, production processes and market demand conditions in the industrial sector, thus providing mechanisms that can effectively trigger industrial expansion and have a profound impact on the changes in the industrial structure [15]. Innovations in game development technology will enable the emergence of new technologies, and along with the birth of new industries, promote the qualitative evolution of the industrial structure.

The technological breakthrough of functional game industry and the widespread application of VR real-world technology will cause structural changes in this industry and related industries, and drive the development of a series of other related industries through forward, backward and sideways correlation. For example, in the process of expanding into the social industry, functional games can promote the technological change of the social industry through the diffusion and penetration of VR real-world technology. Integrating functional games into social software can provide players with the opportunity to meet and interact with others in the virtual world. Players express themselves through movements and gestures by choosing or creating an avatar to support the communication of full-body movements. And the difference in the level of functional games determines the number of downloads of social software. After the functional game industry enters the maturity period, the results of technological innovation drive the game dominant industry to carry out sequential turnover until it becomes a significant feature and sign of industrial structure upgrade. Among the many categories of industry expansion, the leading game industry with advanced technology can absorb a large number of innovative achievements, which leads to the increase of the integration rate of game industry.

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3.2. DRIVE-RELATED GAME INDUSTRY

The upgrading of related expansion industries is driven by strengthening the high technology transformation efforts of the functional game industry [16]. The high growth of the game industry itself cannot bring about substantial adjustment of industrial structure and structural upgrading of related expansion industries, but only when the industry has great industrial correlation and can produce integration, penetration and diffusion effects through correlation with other industries, the game industry has high structural growth effects. The high-tech connotation of the functional game industry determines that it can be expanded to the sports and athletic industries, and the way to expand to the sports and athletic industries is mainly reflected in the following two aspects:

First, increase the investment of VR real experience transformation in sports and athletic industries, and use VR real technology to transform the technical equipment and processes related to sports and athletic industries in order to improve labor production efficiency and product quality, and rapidly improve the industrial base and enhance economic strength.

Second, the use of VR game's realistic operation to upgrade sports and athletic products, prompting the development of sports and athletic products in the direction of multiple types and multiple experiences. Through the upgrading of VR realistic products, the vitality and vigor of the sports and athletics industry will be rejuvenated. Accelerating the separation of the functional game industry and the formation of the game industry system promotes the relevant development of the modern industrial system. Introduce the operation experience of VR realistic games in sports athletics, enhance the smoothness of sports game scenes by updating the operation of gamepads and keyboards, make weak performance processors load high-quality resource content, improve the endurance while reducing costs, and promote the development of functional games in the direction of scale.

3.3. ACCELERATE INDUSTRIAL INTEGRATION

Industrial integration refers to the dynamic development process in which different industries or different industries within the same industry interpenetrate and intersect with each other, eventually merging into one and gradually forming new industries [17-19]. Industrial fusion is a form of industrial innovation, and the proliferation of this industrial innovation method drives the adjustment and upgrading of the related industrial structure [20-23]. The directionality of the change in the industrial structure of functional games is the effective accumulation of industrial expansion innovation within a certain industry.

Technical elements such as information technology, network technology and digital technology in the functional game industry sector are being integrated into the education-based industry sector one after another, putting it on the path of informatization and network development. It has profoundly changed the production and service methods of traditional education-based industries and promoted the upgrading of their industrial service structures [24]. The expansion of the functional game industry based on VR real-world technology to the education-based industry aims to improve students' motivation and participation in learning and sublimate them from passive receivers to active participants. Through the effective combination with online information resources, the delivery of educational contents is realized in a more approachable way to provide students with better and broader educational information. In addition, the continuous renewal of game products and educational services drives the upgrading of the demand structure of educational commodities, which in turn pulls the upgrading of the structure of education-related industries.

4. THE FUNCTIONAL GAME CAN BE TOPOGRAPHIC INDUSTRY SIMULATION RESULTS ANALYSIS

In order to verify the feasibility of the design path of this paper, the results of strong noise points, interactive 3D scene frame rate and model texture quantity are now analyzed, and the feasibility of functional game industry expandable based on VR realistic technology is analyzed by comparing with the 3D game industry transformation model for mobile terminals.

4.1. STRONG NOISE POINT DISTRIBUTION

When the static feature parameters in the 3D scene remain unchanged, while the angular velocity and rotation angle in the dynamic feature parameters change at the same time, the 3D game industry transformation model for mobile terminals is compared with the functional game industry expansion path based on VR real-world technology, and the display of strong noise on the client side is shown in Figure 2.

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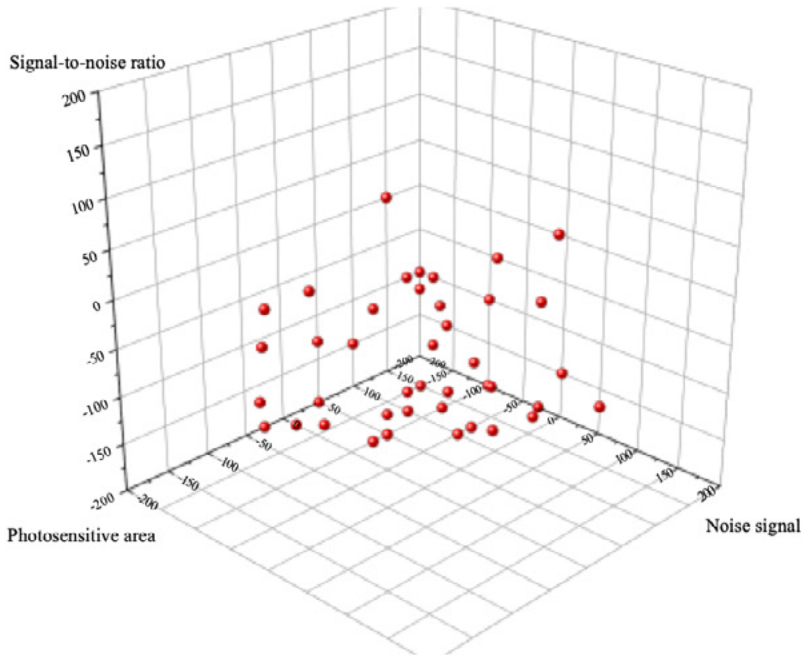
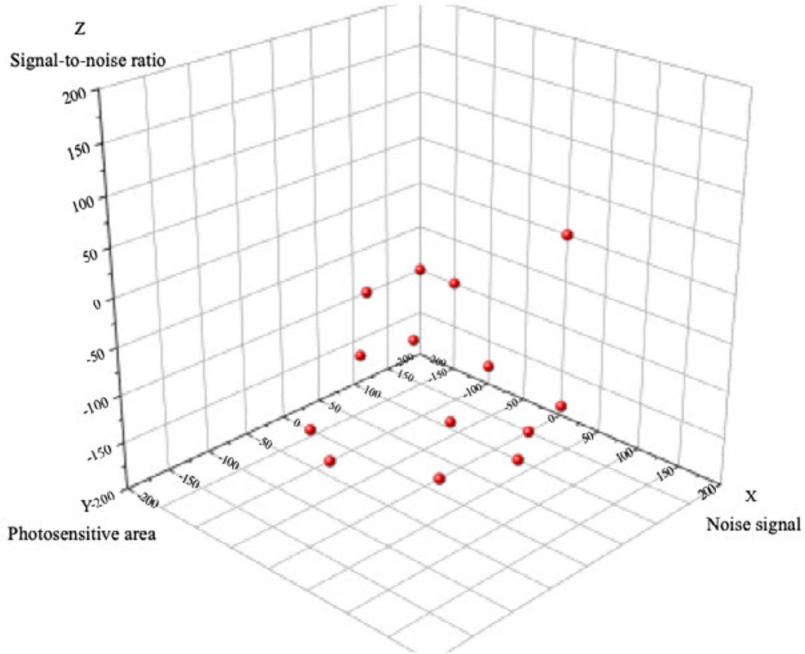


(a) Mobile terminal-oriented model



(b) Based on VR realistic technology

Figure 2. Experimental distribution of strong noise points

As can be seen from Figure 2(a), the number of strong noise points of the 3D game industry model for mobile terminals is high. It is mainly concentrated in the -200 to 100 interval on the sensing area axis and in the 0-100 interval on the noise signal axis, with an average signal-to-noise ratio of -150% and poor noise immunity and perceptual interaction ability, which cannot adapt to the future development direction of the social class industry.

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As can be seen from Figure 2(b), the number of strong noise points of the functional game industry expansion path based on VR real-world technology is small and the distribution is more dispersed. The distribution is mainly concentrated in the -100 to 0 interval on the sensing area axis, which improves the distribution efficiency by 50% compared with the 3D game industry transformation model for mobile terminals. On the noise signal axis mainly concentrated in the 100 to 200 interval, the distribution interval of the noise signal was adjusted upward by 100 points, the signal-to-noise ratio was -100% on average, which improved by 50%, the noise resistance was better, and the reconstruction effect was significantly better than that of the 3D game industry transformation model for mobile terminals. It indicates that the functional game industry based on VR realistic technology has better adaptability in terms of computational game image display and complex game operation, etc., and has better performance capability in both immersion and interactivity, which can be combined with social industry for the operation of functional game industry transformation and upgrading.

4.2. SCENE FRAME RATE COMPARISON RESULTS

Scene frame rate is the number of frames per second to refresh the picture during the game, and the increase in scene frame rate can make the game picture more smooth. In order to make the measurement results have an accurate operation, this paper uses the timing function in the control system of the computer to calculate the frame rate of an interactive 3D scene. According to the standard variation value of the frame rate, the theoretical contrast value of the 3D scene frame rate is shown in Figure 3.

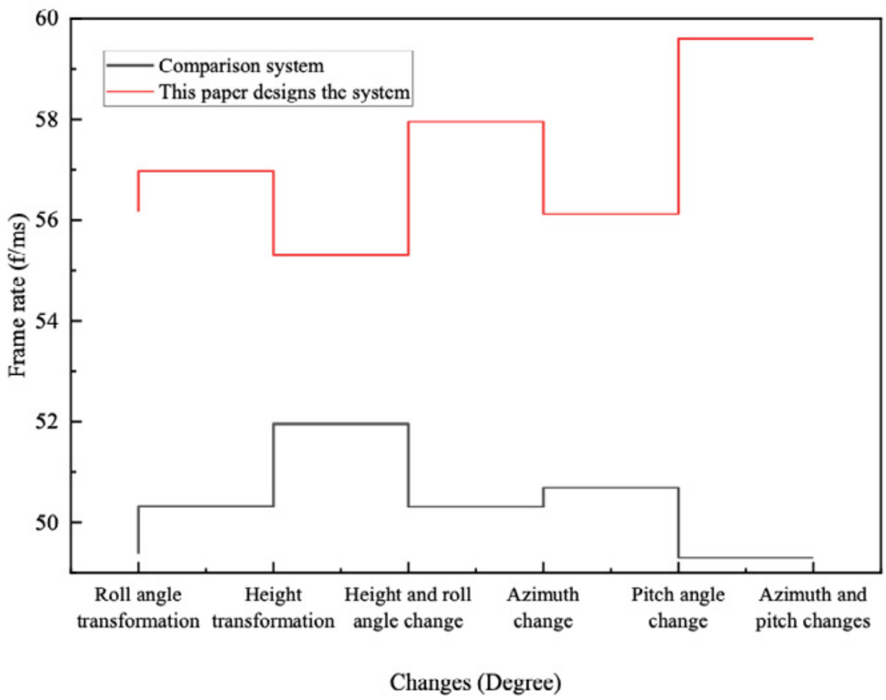

Figure 3. Comparison results of frame rate of scenes

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As can be seen from Figure 3, compared with the 3D game industry transformation model for mobile terminals, the functional game industry expansion path based on VR real-world technology has selected entities with better performance in the process of industry integration, which can be configured for screen playback by the animation industry. The height angle change is improved by 6.65f/ms and the cross-roll angle change is improved by 6.79f/ms. This change reduces the complexity of dynamic and static feature parameters, making the restored interactive 3D images clearer and more intuitive. Azimuth and pitch angle relative to the 3D game industry transformation model for mobile terminals improved by 15.18% and 10.83% respectively, making the picture quality obtained after behavior control better and the animated character behavior connection more smooth, improving the real-time game scene change. It can be seen that the functional game industry based on VR real-world technology can upgrade the physical combination experience of the game, with a new operating feel and three-dimensional audio-visual cooperation, to the sports competition industry for integration development.

4.3. NUMBER OF MODEL TEXTURES

In the process of establishing the 3D model of the game animation character, the behavioral realism of VR natural interaction method plays an important role in the preliminary judgment of the society, and the number of model textures can intuitively reflect the picture quality and connection smoothness after the behavioral control. The comparison results of the number of model textures between the 3D game industry transformation model for mobile terminal and the functional game industry expansion path based on VR realistic technology are shown in Figure 4.

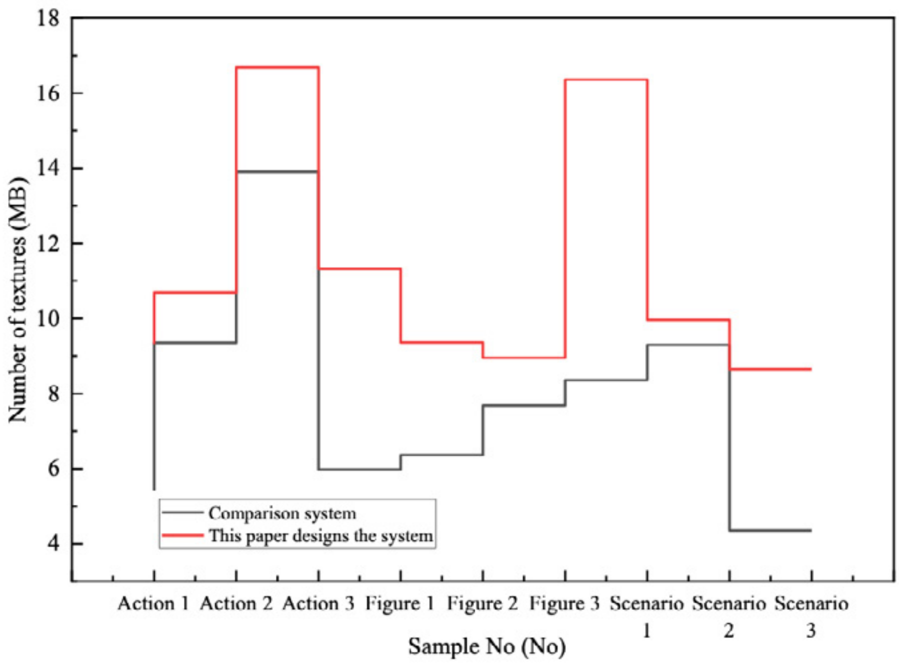

Figure 4. Model texture number comparison results

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As can be seen from Figure 4, the functional game industry expansion path based on VR real-world technology can reach a maximum texture number of 16.68 MB in the three elements of action, character, and scene. compared to the 3D game industry transformation model for mobile terminals, the texture enhancement of the action sample is between 3 MB and 4 MB, the texture enhancement of the character sample is between 2 MB and 7 MB, the texture of the scene sample The texture of the scene sample has the largest enhancement, from 0.69MB to 9MB, and the overall enhancement of the model texture number is between 0.69 and 9MB. This indicates that the functional game industry based on VR real-world technology is highly motivated and engaged in specific knowledge areas and is conducive to expansion in the direction of the education industry, with the ability to provide scaled scenes, visualize complex abstract information or operational mechanisms, and create a highly immersive game-based learning experience for learners at relatively low cost.

5. CONCLUSION

This paper explores the expandable direction of the functional game industry based on VR realistic technology and designs the expansion path of the functional game industry from the perspective of game realistic interactive experience, and the conclusions obtained are as follows:

1. The distribution of the number of strong noise points in the design path of this paper is more dispersed, the distribution interval of the sensing area is adjusted downward by [-100,100], the distribution interval of the noise signal is adjusted upward by 100 points, and the signal-to-noise ratio is improved by 50% on average. It indicates that the functional game industry can use VR realistic technology to transform and upgrade the operation of the game to the social class industry.

2. Based on VR real sensory technology relative to the 3D game industry transformation model for mobile terminals, the height, and cross-roll angle changes are improved by 6.65f/ms and 6.79f/ms, respectively, and the azimuth and pitch angles are relatively improved by 15.18% and 10.83%. It shows that with the support of VR real-world technology, the functional game industry can develop into the sports competition industry by upgrading the physical combination experience of the game.

3. On the three elements of action, character, and scene, the number of textures of VR real-world technology can reach up to 16.68 MB, with an improvement range of 0.69 to 9 MB. It indicates that the functional game industry based on VR realistic technology has the ability to provide scaled scenes that can create a highly immersive game learning experience for learners and can be expanded in the direction of the education industry.

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APPLICATION OF HYBRID TEACHING MODE IN TRANSLATION TEACHING FROM THE PERSPECTIVE OF ECOLOGICAL CONCEPT TEACHING

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ABSTRACT

Blended teaching is a model of teaching that combines traditional classroom teaching with online teaching. The integration of blended teaching is not only the integration of carrier means but also the breakthrough of teaching mode and the expansion of teaching time and space. Based on the theory of education ecology, this paper first analyzes the mixture of college English translation teaching modes and indicates that the college English translation teaching system from the dimension of the language training system, cultivation system, and communication dimensions cultural dimensions of three parts, and communicative dimension culture contains three platforms, four interaction, five links. Then, the hardware and software of the hybrid teaching ecosystem are designed to realize translation teaching. In the test to verify the system performance in this paper, it was found that the overall iteration value of the system presented a rising trend with the increasing number of tests, and in 6 tests, the maximum iteration value of the system in this paper was always 3-12 higher than the maximum iteration value of the teaching system in the traditional protocol data test group. Therefore, the hybrid teaching ecosystem designed in this paper has obvious advantages in reliability and practicality.

KEYWORDS

Ecological concept; Hybrid; Teaching mode; Translation Teaching

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1. INTRODUCTION

With the development of science and technology and the arrival of the Internet era [1-3], modern teaching methods based on new media and Internet technology bring opportunities for classroom teaching reform [4], which brings great challenges to traditional translation teaching for English majors in colleges and universities [5-6].

Restricted by the nature of the curriculum [7], traditional translation classes are often teacher-led and passively accepted by students [8], without getting rid of the basic characteristics of traditional teaching such as unilateralism, indoctrination, and compulsion [9-10]. The lack of vividness and interactivity in listening, speaking, and other courses results in mechanical, dull, boring, and stylized classes. Students lack enthusiasm for knowledge and subjective initiative in learning, resulting in low classroom teaching efficiency and an easy-to-produce classroom "ecological crisis" [11-13].

Hybrid teaching is an organic combination of traditional classroom teaching and online teaching [14]. The integration in hybrid teaching is not only the integration of carrier means but also the breakthrough of teaching mode and the expansion of teaching time and space [15]. According to the characteristics, applicability, and superiority of the hybrid teaching mode [16-18].

In the past two years, with the continuous development of the Belt and Road Initiative, translation talents have played an increasingly important role in Sino-foreign exchanges. However, as a college English course for cultivating compound foreign language talents, the emphasis on translation teaching is seriously inadequate [19-21]. Most domestic studies focus on translation teaching for foreign language majors, but the research results on college English translation teaching are relatively few [22]. According to the literature [23] and [24], a small number of scholars have put forward their views on the main problems existing in College English translation teaching in China, including teaching design, teachers' quality and construction of teachers, textbook compilation, and evaluation methods of translation ability. Literature [25]- [26] has proposed a new translation theory called "ecological translatology", which has attracted widespread attention from scholars at home and abroad. According to the literature [27], eco-translatology refers to "an ecological approach to translation studies, Or translation studies from an ecological Perspective." This theory combines the concepts of ecology and translatology and is interdisciplinary. It not only has important guiding significance in theoretical construction and translation practice guidance at the macro level but also provides a new perspective for college English translation teaching. Literature [28] makes systematic statistics on the number of translation teaching research papers from the perspective of "ecological translation" published on CNKI and points out that ecological translation theory has attracted the attention of college English translation teaching researchers and teachers. Literature [29] proposed the concept of "ecology of education" and the concept of "ecological balance of classroom" based on the ecological research paradigm, expanding the parameters of education research.

Literature [30] shows that the discipline education field in China begins to introduce the concept and paradigm of education ecology and re-examine education and teaching activities from the ecological perspective of system theory and holistic view. A large number of studies have shown that the current study is mostly given the situation of translation teaching in the concept of ecological research, but along with the development of the Internet age, slowly began to combine the traditional approach to learning and online learning, through the environment, content, tasks, and activities to make the two complement each other, to each director, to optimize learning, realize the teaching goal. Therefore, this paper studies the application of mixed teaching mode in translation teaching from the perspective of ecological teaching.

This paper first analyzes the mixed teaching model of college English translation under the guidance of ecological translation studies and finds that the teaching system of college English translation from the perspective of ecological translation studies is composed of three parts, namely, the cultivation system of language dimension, the cultivation system of cultural dimension and the cultivation of communication dimension, which affect each other but are different from each other. Then, based on this, the hardware and software of the hybrid teaching ecosystem are designed to realize translation teaching.

2. A MIXED TEACHING MODE OF COLLEGE ENGLISH TRANSLATION UNDER THE GUIDANCE OF ECOLOGICAL TRANSLATION

The blended teaching model should be learner-centered in translation teaching, integrate online and offline teaching, combine teachers' teaching with students' inquiry, and focus on personalized guidance and deep learning experience in translation teaching. Therefore, the mixed teaching model should take into account the three principles of openness, individuality, and interaction. Openness refers to an open teaching platform, open learning resources, and open interaction and exchange. Students can access the Internet through computers, mobile phones, tablets, and other terminals anytime and anywhere without any restrictions, and learning resources conform to the characteristics of fragmentation [31]. Individuation means that students' personalized learning needs can quickly and accurately feedback questions generated in translation teaching to teachers through the SPOC teaching platform or social software, and teachers can provide one-to-one guidance through various channels. Interactivity refers to the construction of convenient and low-cost communication channels between teachers and students and between students in translation teaching, to promote students to acquire a deep learning experience [32].

The ecological environment of translation includes the language, culture, and communication of the source language and target language, namely, the linguistic dimension, cultural dimension, and communicative dimension. The "three-dimensional" theory here, in which the communicative dimension includes three platforms, four interactions, and five links, is based on the actual characteristics of

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college English translation teaching, this paper constructs a hybrid teaching model of college English translation under the guidance of ecological translation, as shown in Figure 1.

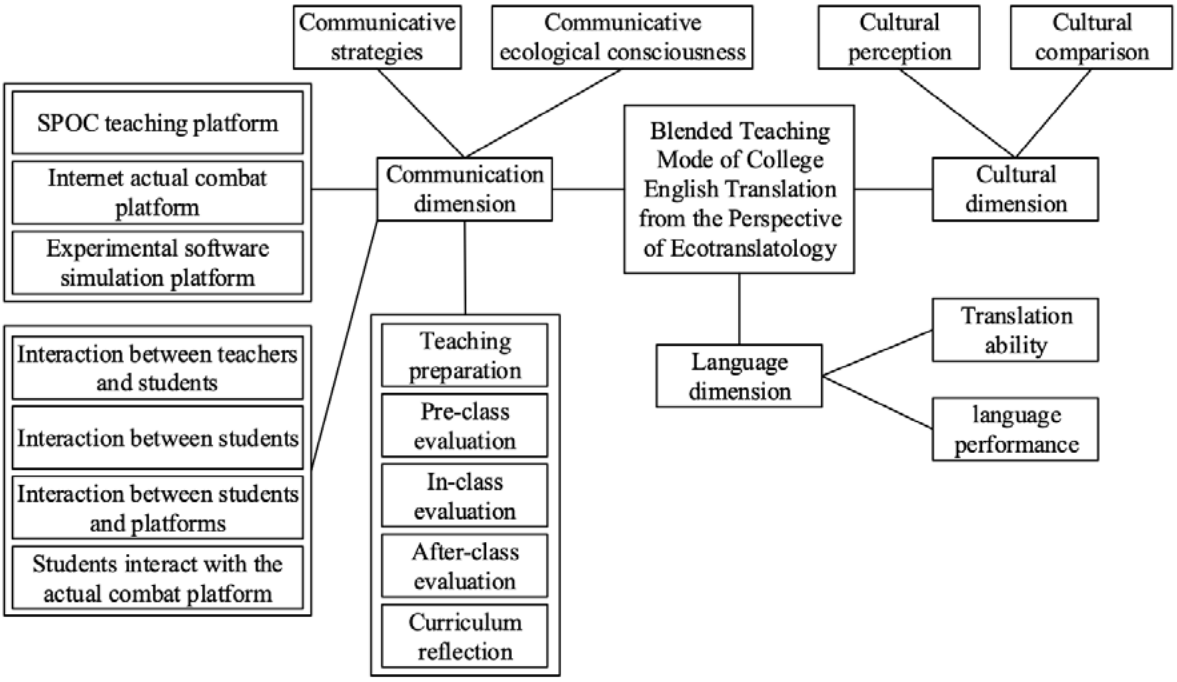

Figure 1. The mixed teaching system of college English translation from the perspective of ecological translation

As can be seen from Figure 1, the college English translation teaching system from the perspective of ecological translation studies is composed of three parts: the language dimension cultivation system, the cultural dimension cultivation system, and the communicative dimension cultivation system. The three aspects interact with each other and have different emphases:

1. Train students' translation ability and language expression abilities from the language dimension

At present, college English teaching mainly targets non-English majors, so their translation ability needs to be further improved, including the improvement of translation theories, translation strategies, translation skills, and other aspects of knowledge [33]. What needs to be noted here is that in classroom teaching, too much attention should be paid to the study of translation knowledge while ignoring the operation of translation practice, and the complementary role of translation theoretical knowledge and translation practice ability should be given full play. Language expression ability is the language expression ability based on translation activities. Language expression ability is the foundation. If students do not have certain language expression abilities, it is difficult to produce high-quality translation works [34]. Because the language expression ability has been involved in other aspects of college English teaching, teachers should also pay attention to the balance between them. Hybrid teaching ecosystem construction.

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2. Cultivate students' cultural perception and cultural comparison ability from the cultural dimension

Some scholars believe that translation is not only a conversion activity between two languages but also a conversion activity of cultural communication and transmission. Cultural perception ability requires students to consciously improve their sensitivity to the original text culture; Cultural comparison ability emphasizes the ability to seek common ground while reserving differences when facing the two cultures of the original text and the target text, and accurately understand the similarities and differences between the two cultures in many aspects, such as thinking mode, value system, customs and language expression [35].

3. Cultivate students' communicative strategies and communicative environment awareness from the communicative dimension

Some scholars believe that the ultimate purpose of translation is communication. Therefore, in the process of college English translation teaching, attention should be paid to cultivating students' communicative strategies and improving their communicative skills to ensure that they can conduct efficient cross-language communication through translation activities [36]. Ecological translation provides a broader perspective, that is, to let students pay attention to the overall ecological environment of communication, rather than simply treating translation as a word processing activity. In translation activities, different translation strategies and communication strategies should be selected according to the ecological environment of the activity. The three platforms refer to the SPOC teaching platform, the Internet actual combat platform, and the experimental software simulation platform; The four interactions refer to the interaction between teachers and students, the interaction between students, the interaction between students and the teaching platform, and the actual platform. The five links refer to teaching preparation, pre-class, in-class, after-class, evaluation, and reflection [37]. The use of information technology by teachers and students in the process of "teaching" and "learning" can create a hybrid teaching ecosystem.

3. HYBRID TEACHING ECOSYSTEM DESIGN

3.1. SYSTEM HARDWARE DESIGN

3.1.1. CONSTRUCT THE CORE PROCESSING CIRCUIT OF THE HYBRID TEACHING SYSTEM

Before the system hardware design, it is necessary to build the core processing circuit of the hybrid teaching ecosystem with a certain comprehensiveness. The ATmega128 chip is selected as the core processor of the processing circuit, and then the chip is placed in the circuit in series with KRY, LED, and LCD. This arrangement has a very important influence on the large-scale information processing of the later online hybrid teaching ecosystem.

The fixed power supply interface and signal receiving interface connected to the end frequency of the development board are also open in general, which can be connected in general and will not affect the related use of the hybrid teaching ecosystem. In the case of no abnormality, the circuit of the development board is in the association state by default, and the jumper in the connection bus of the circuit can be connected with the development board twice, so as to improve the operation stability of the teaching system. At the front end of the ATmega128 chip, the control system running circuit is established, and the installation data information download interface, network communication interface, I/0 inversion interface, and JTAG multi-frequency control interface are added. These interfaces have a great influence on the operation control of the teaching system. The data information can be downloaded to the operation chip and saved by the download interface. Dual engineering communication of teaching is realized through the USART interface. The I/0 inversion interface can monitor and control the corresponding application program, and then transform the program, and finally realize the teaching function of the system. At this point, the core processing circuit of the hybrid teaching system is completed.

3.1.2. DESIGN THE TEACHING SYSTEM INTEGRATED CONTROL CHANNEL

Initialize the serial port of the teaching control system, and modify the user verification program module to set the mode of data frame verification. When the teaching system sends and receives data, the USART interface will automatically generate calculation and verification bits and associate them with the data frame port. The USART interface verification calculation formula is as follows:

$$P = \sum_{i=1}^{n} \frac{1}{(a+b)} - \sqrt{3} \tag{1}$$

Where, P represents the USART interface check value; i represents the check times; n represents the check temperature; a represents the maximum frequency of calculated output; b represents the application frequency of calculated output. Through the above calculation, the specific USART interface check value is obtained. The information register is used to read the control byte data of the teaching system and compare it with the byte-fixing standard.

A loop buffer circuit is constructed in the teaching system circuit to form a controllable data transmission channel. The transmission channel is connected with the ATmega128 chip to expand the RAM rate outside the transmission channel. It is worth noting that the expansion of the RAM rate should be within a certain standard range. Once the RAM rate exceeds the standard, the system will be unable to run, affecting the teaching progress and not conducive to the final completion of the design of an integrated control channel of the teaching system.

3.2. SYSTEM SOFTWARE DESIGN

3.2.1. BUILD A FUNCTIONAL STRUCTURE TREE OF ECOLOGICAL BALANCE IN HYBRID TEACHING

After completing the hardware design of the teaching system, the functional software of the system is designed. Establish a structure tree that can balance the internal functions of the teaching system, and use pseudo code to receive relevant data in the system to avoid data loss. The CommGetChar function calculates the overclocking value of the received code, that is:

$$W = \left(\frac{1}{h} - 1\right) - 3 + k \tag{2}$$

Where, W represents the over frequency value of the receiving code; h represents the receiving stress coefficient; k represents the maximum allowable receiving range. Through the above calculation, get the code over frequency value. Use the if language to associate the overclocking value to add the result to the system. Check the balance of system functions, if the balance is verified, you can continue to operate; If not, recalculate the overclocked value of the receiving code. After verification, close the terminal of the teaching system. Establish the functional structure tree and establish the function

The output layer is mainly divided into the online learning layer, offline communication layer, auxiliary computing layer, data access and collation layer, score query layer, and other functional layers. To find a suitable transfer function, first, build the framework of the structure tree, and add the corresponding programs to the control interface of the system one by one according to the level, so as to achieve balanced teaching. Establish a mixed mechanism, compile intermediate protocol instructions of mixed teaching, add and save them in the basic level of the functional structure tree, and finally realize the construction of a balanced functional structure tree of mixed teaching.

3.2.2. ESTABLISH A REMOTE ONLINE TEACHING DATABASE

After completing the construction of the balanced functional structure tree of hybrid teaching, the remote online teaching database is established. A teaching database is equivalent to a relatively large teaching material warehouse, storing data, information, and audio and video teaching content. Set the system terminal audio and video transmission, processing, and display in adjustable mode. In the remote online

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teaching system, the managed code is compiled and written into the system mechanism in user mode. When done, use the DirectShow API to run the function for a custom numerical calculation of the call, that is:

$$D = \frac{1}{r} + \sqrt{3} - g \tag{3}$$

Where, D represents the value called; r represents the function applied; g represents the exponential applied. Through the above calculation, the call value is obtained. Using the actual call value at this time, the iteration ratio of the teaching system is calculated again, and the specific formula is as follows:

$$A = \int_{V=1}^{W} \left(\frac{1}{6} - m \right) + \frac{1}{(x+y)} - D \tag{4}$$

Where, A represents the time-shift ratio of system operation; w represents operation construction conditions; v represents operation times; m represents system operation delay; x represents the furthest iteration distance; y represents error distance. Through calculation, the specific time shift ratio can be obtained. Add the Filter remote control program in the system, take the Ksproxy Filter platform as the medium, make the teaching system and Ethernet, Internet connection, and realize the remote teaching.

4. RESULTS AND ANALYSIS

4.1. TEST EXPERIMENT

Here, with the help of the SPOC teaching platform, online learning of college students in a city is tested, including attendance, discussion, homework, unit tests, in-class quizzes, and other data statistics. As of May 2021, the number of Chapter learning times of students on the SPOC teaching platform has reached 14,772, and 18 learning task points and 2 non-task points have been released. It includes 12 online self-study video tasks and 8 Chapter quizzes.

In order to verify the effectiveness of the hybrid teaching ecosystem designed in this paper, the statistics of chapter learning times of the SPOC teaching platform reached 14,772 times, 18 learning task points and 2 non-task points were compared between the system designed in this paper and the traditional protocol data teaching system. The traditional protocol data teaching system is set as the traditional protocol data test group, and the system designed in this paper is set as the hybrid teaching test group. Select two computers as the devices for this test, and prepare one computer as the test terminal. Add the initial test parameters to the system, as shown in Table 1.

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Table 1. Parameters of initial test data

index parameter	system terminal	initial server	teaching system certification
running cost factor	450	0.6372	0.73
number of connection weights	6.173	1.6300	2.63
hidden layer running value	1.500	21.7450	5.2

Add the parameters in Table 1 to the system to complete the initialization of the test. Select two groups of the same teaching content as the test object, and ensure that the system is in a stable running state and no external factors affect the test results after the test.

To ensure the accuracy of the test results, the two groups of systems were tested simultaneously. Test terminals and test computers are placed in different rooms, associated with the Internet or Ethernet, to complete the database setting of online teaching. Open the teaching system and start online teaching after counting the number of students. After a certain period of teaching, the relevant test information data is obtained. Then, the sequence communication of online teaching is set up. To calculate the final value of the system teaching order, the formula is:

$$F = A + \sqrt{3} - c \tag{5}$$

Where, F represents the final value of teaching order; A represents the time-shift ratio, and c represents the sequential inertia index. The final value of the actual teaching order is obtained through calculation. The above sequential end values are used to calculate the operation iteration values of the hybrid online teaching system, and the formula is as follows:

$$M = \frac{(\sqrt{2} + 1)}{F} + 4d - 2u \tag{6}$$

Where, M represents the operation iteration value of the teaching system; F represents the sequential final value; d represents the absolute execution instruction factor, and u represents the system certification index.

Test results were obtained through the above tests, and the results were compared and analyzed, as shown in Figure 2.

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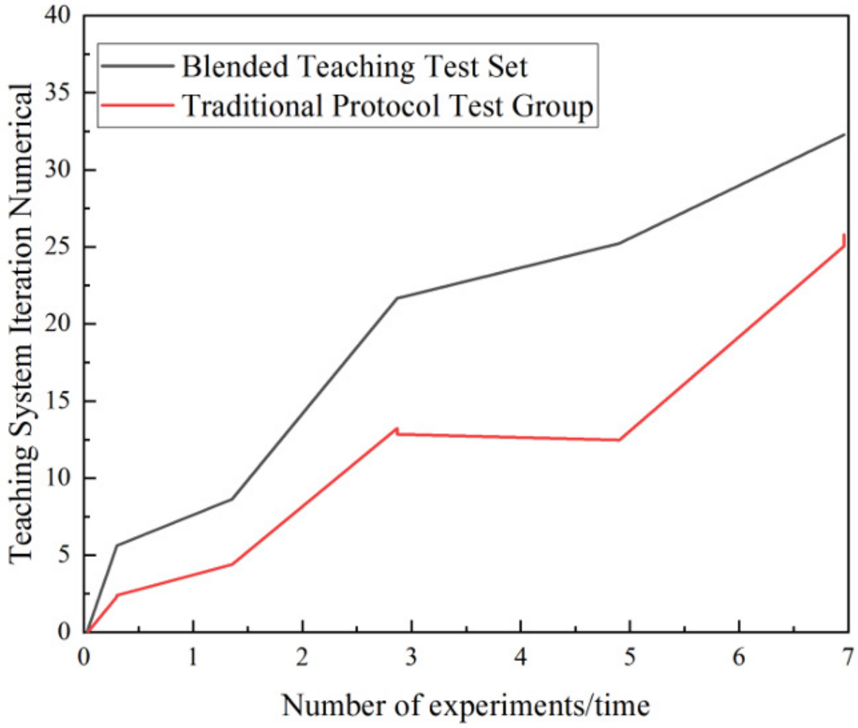

Figure 2. Numerical comparison analysis diagram of running iteration

According to Figure 2, during the first experiment, the maximum iteration value of the teaching system in the traditional protocol data test group was 7, while that in the hybrid teaching test group was 13. In the second experiment, the maximum iteration value of the teaching system in the traditional protocol data test group was 13, while that in the hybrid teaching test group was 17. In the third experiment, the maximum iteration value of the teaching system in the traditional protocol data test group was 17, while that in the hybrid teaching test group was 20. In the fourth experiment, the maximum iteration value of the teaching system in the traditional protocol data test group was 17, while that in the hybrid teaching test group was 25. In the fifth experiment, the maximum iteration value of the teaching system in the traditional protocol data test group was 16, while that in the hybrid teaching test group was 28. In the sixth experiment, the maximum iteration value of the teaching system in the traditional protocol data test group was 28, while that in the hybrid teaching test group was 31. And the overall iteration value of the two test groups showed a rising trend with the increasing number of tests. Thus, with the increasing number of experiments, two iterative numerical test group is also on the rise, but in any one experiment, can be clear that a maximum iterative numerical always higher than the traditional protocol data maximum iterative numerical test group teaching system, this paper designed hybrid teaching ecological system has better performance in terms of reliability and practicability.

In addition, the system designed in this paper and the traditional protocol data teaching system are used to analyze the learning data related to college students, and it is found that there are differences between students in terms of accuracy of the

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translation, interaction between students and teachers in class, and completion of translation homework, as shown in Table 2.

project	translation accuracy %	the proportion of classroom interaction %	percentage of homework completed %
traditional protocol data	65.23%	45.96%	72.17%
this article system	93.77%	90.48%	98.44%

Table 2. Comparison of classroom situation tests between the two systems

Table 2 shows that in the translation teaching test, the accuracy of the system in this paper is 28.54% higher than that of the traditional protocol data teaching system. In terms of the proportion of classroom interaction, this system is 44.52% higher than the traditional protocol data teaching system. In terms of homework completion ratio, this system is 26.27% higher than the traditional protocol data teaching system. As you can see, this article puts forward the ecological concept of teaching from the teaching mode, is online teaching organic to the traditional teaching model, not only improve the learning atmosphere of the class, to change students' passive to accept knowledge and improve the vitality of the classroom listening comprehension, oral English courses and interactive, students are more active in the hybrid teaching mode, which is in line with modern students' love for electronic products and network atmosphere. Therefore, they should be especially active and serious in finishing homework after class. Therefore, the hybrid teaching model proposed in this paper from the perspective of ecological teaching has great advantages in translation teaching.

5. DISCUSSION

In recent years, with the development of education informatization, the mixed teaching mode has been gradually accepted by teachers and students, especially those affected by the epidemic, and this mode shows a trend of popularization. But at present, the blended teaching mode mainly regards online teaching resources as the supplement or extension of the traditional classroom. The mixed teaching mode in many studies is based on an online teaching platform, which has some innovations in teaching methods and achieved good results. But the current blend mode mainly deals with the problem of the "teaching method of the single" focusing on teaching methods of mixing, is less involved in the teaching content reform, does not fully explain how to carry out online teaching evaluation, new teaching content is given priority to with the operating system interface level, did not touch the system core, etc., so in the future hybrid teaching, The teaching content reform, online teaching evaluation and the application of system core technology should be considered, which will not only improve the teaching quality of mixed teaching mode but also greatly improve the enthusiasm of students to learn.

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6. CONCLUSION

The ecological theory under the emergence of hybrid teaching mode of college English translation teaching points out a new road, the theory of translation put forward by the concept of ecological environment for college English translation teaching provides a broader perspective, and will no longer be isolated from the whole teaching contents, translation teaching and online teaching model and hybrid as a new model of education, The content is more abundant and has certain advantages under the current environment. Through this study, it is shown that:

1. The hybrid teaching mode under the theory of ecological translation activity has three dimensions, the dimension of language, culture, and communication dimensions, respectively, it also provides clear thinking, and translation teaching helps to lead to more scholars focusing on the field, and further perfect the system of college English translation teaching, translate for Chinese culture to go out to cultivate more talents;

2. In the communication dimension, there are 3 platforms, 4 interactions, and 5 links. The three platforms refer to the SPOC teaching platform, the Internet actual combat platform, and the experimental software simulation platform; The four interactions refer to the interaction between teachers and students, the interaction between students, the interaction between students and the teaching platform and the actual platform. The five links are teaching preparation, pre-class, in-class, after-class, evaluation, and reflection. The mixed teaching method has practical guiding significance in translation teaching under the ecological concept.

3. Through the analysis of the system performance in this paper, it is found that the overall iteration value of the system in this paper presents a rising trend with the increasing number of tests, and in 6 tests, the maximum iteration value of the system in this paper is always 3-12 higher than the maximum iteration value of the teaching system in the traditional protocol data test group. Therefore, the hybrid teaching ecosystem designed in this paper has obvious advantages in reliability and practicality.

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RESEARCH ON THE TRAINING PATH OF INNOVATIVE AND ENTREPRENEURIAL TALENTS IN COLLEGES AND UNIVERSITIES BASED ON THE THEORY OF INNOVATION ECOLOGY

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ABSTRACT

Under the guidance of the innovation ecology strategy, our country's higher vocational education should strengthen the cultivation of innovative talents, so as to provide a large number of high-quality technical talents with an innovative spirit for our country's macroeconomic transformation and industrial upgrading. This paper proposes research on the cultivation path of innovative and entrepreneurial talents in colleges and universities based on the theory of innovation ecology. Firstly, according to the theory of the social-ecological system, it provides a new perspective for innovation and entrepreneurship education. By exploring various environmental systems of social ecology, this paper explores new paths for the development of innovation and entrepreneurship education from the macro, meso, and micro system levels, constructs a model of innovation and entrepreneurship education for college students that can self-manage, grow and correct themselves, establishes an evaluation index system, and uses the fuzzy analytic hierarchy process to evaluate it, the evaluation value is as high as 93.348, provides theoretical and practical guidance for promoting the development of innovation and entrepreneurship education in colleges and universities in our country.

KEYWORDS

Innovation ecological theory; Talent training; Education model; Evaluation index; Fuzzy analytic hierarchy process

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1. INTRODUCTION

The 18th National Congress of the Communist Party of China proposed the strategy of innovation-driven development and the strategy of promoting entrepreneurship to drive employment. Higher vocational colleges should actively respond to the party's call and run innovation education throughout the entire process of higher vocational talent training. Innovative talents are the engine that promotes the transformation of social science and technology into real productive forces, and the power source to promote the transformation and upgrading of regional economies and industries. Vocational colleges should regard cultivating innovative talents as the lofty responsibility and historical mission of the school, deepen the reform of the higher vocational education system from cultural concepts, management systems, and specific teaching practices, and create a good environment for the healthy growth of innovative talents. ecological environment [1].

The cultivation of innovative talents needs the support of a good ecological environment of higher vocational education. The ecological environment of higher vocational education mainly includes the ecological environment of education and culture, the ecological environment of the education system, and the ecological environment of teaching [2]. The educational and cultural ecological environment is used to regulate the world outlook, values, and methodology of the members of the micro-social environment of higher vocational colleges. The cultural ecological environment of higher vocational education that encourages innovation helps to create a good educational and cultural atmosphere for the cultivation of innovative talents in higher vocational colleges. The ecological environment of the higher vocational education system mainly provides an institutional guarantee for the innovative talent training activities of higher vocational education through its normative institutional documents and promotes the promotion of innovative education to a higher level through the mutual matching of high-level systems and low-level systems. The inner values and way of thinking of vocational education are internalized into the hearts of every teacher and student, and finally promote the formation of a cultural environment advocating innovation in higher vocational colleges [3]. The teaching ecological environment of higher vocational education is the product of its cultural ecological environment and institutional ecological environment acting on specific higher vocational teaching activities. Based on the teaching platform created by the teaching ecological environment, teachers and students in higher vocational colleges can jointly promote students' personalized growth and innovative ability training through interactive teaching activities [4]. Innovative talents usually have the typical courage to explore unknown fields, have the innovative spirit of seeking new and different, have the mind of careful thinking and strong energy, have the ability to be proficient in specific fields of expertise, and have a wide range of disciplines. quality of talents.

Literature [5] believes that innovation and entrepreneurship education should be evaluated from three aspects: comprehensive ability, innovation and entrepreneurship ability, and professional ability of college students. The evaluation mechanism should

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be executable, but a clear index system has not been established. Literature [6] believes that the evaluation system of innovation and entrepreneurship education in colleges and universities is a measure of the level of innovation and entrepreneurship education, and it is also a way to control the quality of innovation and entrepreneurship education development, emphasizing the importance of individual evaluation. Literature [7] believes that the quality evaluation system of innovation and entrepreneurship education in colleges and universities should be evaluated from five parts: system construction, teaching system, cultural atmosphere, management organization, and evaluation feedback. Literature [8] proposes that innovation and entrepreneurship education should be evaluated from the aspects of resource input and the operation mechanism of innovation and entrepreneurship education, without constructing a specific index system. Literature [9] constructs an evaluation system for innovation and entrepreneurship education in colleges and universities from three aspects: environment, educational input, and educational output, including the three levels of society, colleges, and students, but does not specify the weight of each level of indicators. Literature [10] believes that the innovation and entrepreneurship education evaluation system should be constructed from two modules: curriculum system and base construction, in which the curriculum system is the basis for cultivating talents, and the practice system is an important part of cultivating students' innovation and entrepreneurship ability. Evaluation System. Literature [11] believes that the mission of innovation and entrepreneurship education in colleges and universities is to cultivate innovative talents, and the evaluation system should closely focus on six aspects: policy, curriculum, platform, and teachers. Based on the above, it can be seen that the current academic research on the evaluation of innovation and entrepreneurship education mainly focuses on theoretical discussion, and there is less research on the evaluation system.

This paper proposes research on the cultivation path of innovative and entrepreneurial talents in colleges and universities based on the theory of innovation ecology. First, understand the current situation of college students' innovation and entrepreneurship education, and build a model of innovation and entrepreneurship education. Through the investigation and research on the current situation of college students' innovation and entrepreneurship development, the analytic hierarchy process is used to determine the weights of indicators at each level in the evaluation system, and a relatively complete set of evaluation systems of innovation and entrepreneurship education in colleges and universities is obtained to provide reference for promoting the development of innovation and entrepreneurship education in colleges and universities.

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2. INNOVATION ECOLOGICAL THEORY

2.1. BIOLOGICAL METAPHOR

Biological metaphor is the basic assumption of innovation ecosystem theory, which looks at socio-economic organizations and phenomena from the perspective of biology, identifies the producers, consumers, and decomposers of innovation, and the interaction between innovation subjects and between subjects and the environment. role [12]. Because of their special resource endowments, university think tanks will gradually develop into important structural holes in the innovation network, that is, nodes of multi-party relationships and information dissemination. From policy innovation to knowledge innovation, organizational innovation, and institutional innovation, from policy network to knowledge dissemination network, cultural derivative network, and ideological interaction network, an innovation ecology is formed [13].

Similar to natural ecosystems, there are also different types of species, ethnic groups, and communities in the innovation ecology of university think tanks. They interact and interact with environmental elements such as culture, knowledge, technology, policy, and capital to form an innovation ecosystem. It exhibits ecological characteristics of diversity, symbiosis, dynamic stability, and evolution [14]. From an external point of view, university think tanks and various ecological entities compete, cooperate, and collaborate on the basis of innovative environmental elements; from an internal perspective, university think tanks comprehensively utilize funds, policies, systems, and other elements to continuously innovate, providing more microscopic innovation entities. Appropriate micro-ecology promotes the spiral development of knowledge innovation[15].

2.2. INTERNAL (MICRO) INNOVATION ECOLOGY

In the internal innovation ecosystem, university think tanks assume the role of the innovation ecological environment [16]. It is different from traditional university scientific research institutions. Based on its unique talent allocation, research funding, management system, research methods, and evaluation methods, it has formed a special innovation "greenhouse", which promotes, guarantees, and supports the micro-innovation subject - research talents. The training path carries out knowledge innovation, organizational innovation, and institutional innovation [17].

First of all, from the perspective of creation, the essence of think tank products is that researchers integrate and process data, materials, and information, combine their own invisible knowledge, and use appropriate research methods to create a knowledge innovation process of valuable new ideas, new viewpoints, and new suggestions. The reason why university think tanks have a relatively high efficiency of knowledge innovation is that they have the advantages of a complete theoretical

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system, rich experience, and sufficient talents, and have established a data-based research methodology system. The procedure specification is studied, and the conclusion is strong neutrality and less subjective color [18]. Second, university think tanks take the establishment of an open and collaborative think tank brand and organizational culture as the basic principles of institutional setup, so they mostly adopt a flat organizational structure and a goal-driven organizational strategy, weaken the color of administrative management, and focus on projects rather than departments. Axis flexibly combines research teams and promotes the ice-breaking integration of philosophy, social sciences, and natural sciences from personnel to institutions in the process of interdisciplinary and inter-institutional research [19]. Third, university think tanks are innovating in the management system. In terms of talent, a competitive talent introduction system, a dynamic talent utilization system, and a humanized employee management system are adopted, such as the chief researcher responsibility system, the revolving door system, and the specially-appointed researcher system. There are obvious differences in management methods; in terms of finance, the management system of scientific research funds of university think tanks is generally not contrary to the financial management system of parent universities, but in terms of culture and value orientation, it pays more attention to the intellectual contribution of people; the think tank's own database, research report pool, and experimental equipment can be opened to all researchers to explore the sharing of intellectual property rights[20].

2.3. (MACRO) INNOVATION ECOLOGY

In the external innovation ecosystem, university think tanks assume the function of the main body of the innovation ecosystem and compete, cooperate, and collaborate with ecological main bodies such as official think tanks, social think tanks, parent universities, interest groups, media, and data/investigation companies to form policy recommendations and public opinion, trying to influence and guide decision-makers and the general public.

There are three levels of relationships in the macro university innovation ecosystem: the first is the relationship between university think tanks and the government. One of the most fundamental organizational goals of university think tanks is to influence government behavior through professional analysis and advice and to serve the scientific and democratic decision-making of the party and the country. Therefore, university think tanks and the government are a typical supply and demand relationship. The government is the demander for consulting services such as policy alternatives, evaluation opinions, and policy recommendations. University think tanks are the supply side, and both parties are dominated by the demand-side market. This is the emergence of the think tank industry. Economic foundations of development. The second is the relationship between university think tanks and other innovative subjects.

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1. University think tanks often cooperate with interest groups or official think tanks, and use the social networks and data information resources of interest groups (such as regional chambers of commerce and industry associations), as well as the internal reference information and reporting channels of official think tanks, to jointly complete countermeasures and suggestions to influence Government decision-making to form a certain social policy [21].

2. University think tanks and social think tanks will independently choose the mode of competition or cooperation based on their respective research expertise and resource capabilities; at the same time, both parties will also cooperate more with the media to achieve the goal of shaping public influence, discovering social problems, and promoting policy ideas. There is no absolute leader in the three-party relationship, but the game is played according to the best-choice strategy at the time. The relationship model may change at any time, but it is impossible for either party to be expelled from the market, which fully reflects the characteristics of system self-organization and dynamic stability of the innovation ecology [22].

3. There is a deep coexistence relationship between university think tanks and parent universities. The parent university supports the university think tank in terms of intellectual resources, research funds, and relational networks; the university think tank provides feedback to the parent university in terms of social influence, scientific research propositions, research methods, and reputation. The third is the relationship between university think tanks and the general public. There is a two-way supply and demand relationship between university think tanks and the general public, and the two sides exchange value around information dissemination. On the one hand, the general public is both a provider of information and a demander of information; on the other hand, university think tanks form political views and convey them to the general public by collecting the needs and opinions of the general public. The innovative knowledge, innovative methods, and innovative culture upheld are also disseminated [23].

3. INNOVATION AND ENTREPRENEURSHIP EDUCATION MODEL CONSTRUCTION

3.1. ECOSYSTEM THEORETICAL BASIS

The construction of an innovation and entrepreneurship education system for college students should follow the principle of reciprocity, interaction, and mutual adjustment between individual development and social needs, establish a corresponding ecosystem model, and realize the training goals for students based on this. The ecological model was proposed by Jerman and Guiterman in the 1980s. This model emphasizes that the individual cannot be separated from the field of life, and

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must pay attention to the relationship between personal life experience, development period, living space, and the ecological environment. Environmental barriers are individual problems. important factor. Another theoretical ecological system theory proposed at the same time as the ecological model to specify social work, that is, the social-ecological system theory considers that the individual and society are whole, and can be divided into micro-system, mesosystem, and macro-system according to the size and characteristics of the group, individuals can be in any system at the same time, but the relationship between individual behavior and social environment is interdependent and mutually restrictive.

The social environment, which Pinks and Minahan think can be divided into the primitive system, formal system, and social system, should be considered a dynamic system. Therefore, when building an innovation and entrepreneurship education model for art college students, each individual student should be integrated into the social environment, and the solution to individual student problems should be understood and judged in the social environment [24].

3.2. INNOVATION AND ENTREPRENEURSHIP EDUCATION MODEL CONSTRUCTION

The innovation and entrepreneurship education model of college students should be constructed based on the above-mentioned ecological system theoretical basis, in order to achieve the coordinated development of individuals and society and achieve the training goals of higher education for students [25]. Based on the perspective of system ecology theory, the main bodies of the micro-system, meso-system, and macro-system in the construction process of innovation and entrepreneurship education model are students, teachers, and society respectively. Figure 1 reflects the relationship between the three in the innovation and entrepreneurship education model.

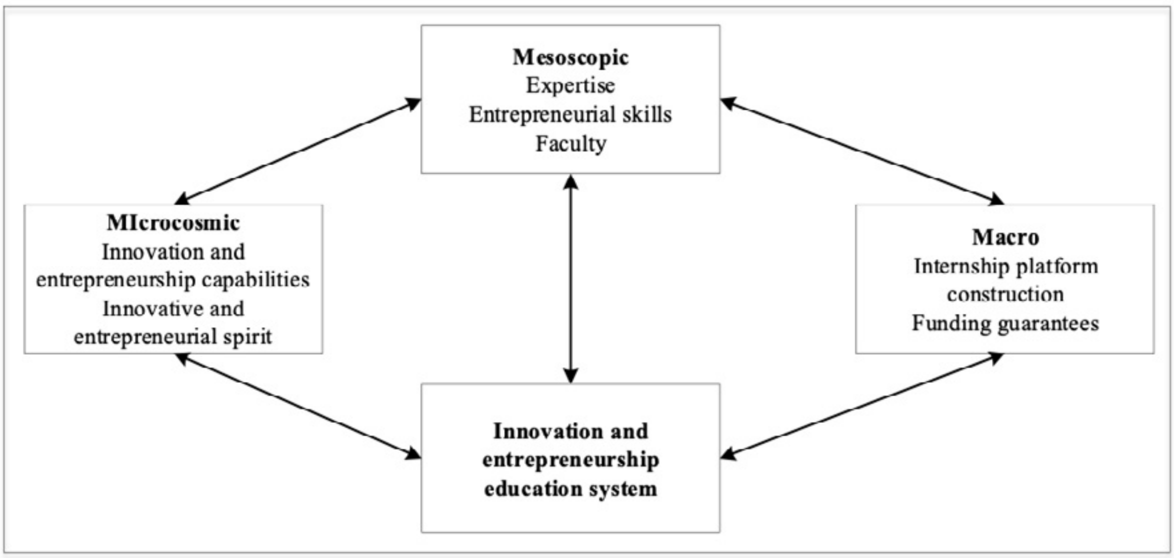

Figure 1. Innovation and entrepreneurship education model

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3.3. STRUCTURAL FACTORS OF THE INNOVATION AND ENTREPRENEURSHIP EDUCATION MODEL

Ecosystem theory is the leading theory of innovation and entrepreneurship education model construction, which divides the construction of the model into three sets of successively stacked environmental systems, and these systems influence each other [26]. For the construction of the innovation and entrepreneurship education model for college students, no organization, institution, or individual can complete it independently. It requires the joint interaction of multi-layer systems, synthesizing the constituent factors of each system, and analyzing the structural factors of the innovation and entrepreneurship education model, as shown in Table 1. The model is more scientific and effective.

Table 1. Structural factors of the innovation and entrepreneurship education model

Microsystem Factors	Mesosystemic factors	Macro system factors
Family	Social education	Cultural traditions
School	Knowledge structure	Values
Peer group	Working group	Social media

The influence of the above-mentioned structural factors on the subjects of each system varies widely. Therefore, in the process of constructing the innovation and entrepreneurship education model for college students, we should pay attention to the improvement of self-education awareness, give full play to the function of family entrepreneurship education, and improve the chain of school entrepreneurship education, so as to integrate college students. Innovation and entrepreneurship education have gradually transformed from the educational function of colleges and universities to a kind of social work, which runs through the growth process of each individual. When innovation and entrepreneurship education are transformed into social work, the subjects of each system in the model become the service objects of social work. The service object comes from the system, and social work's intervention in the individual is the intervention in the system, and it is no longer a purely personal problem. In short, the individual and the system are always in a process of dynamic development and balance and finally tend to be perfect.

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4. THE CULTIVATION PATH OF INNOVATIVE AND ENTREPRENEURIAL TALENTS IN COLLEGES AND UNIVERSITIES

4.1. CONSTRUCTION OF TEACHING ECOLOGICAL ENVIRONMENT FOR CULTIVATING INNOVATIVE TALENTS IN HIGHER VOCATIONAL EDUCATION

The construction of teaching ecological environment is the basic content of ecological environment construction of higher vocational education for the cultivation of innovative talents. Higher vocational colleges can start from the following aspects.

4.1.1. STRENGTHEN THE HARMONIOUS COEXISTENCE OF THE TRADITIONAL TEACHING ECOLOGICAL ENVIRONMENT AND THE TEACHING ECOLOGICAL ENVIRONMENT THAT SUPPORTS THE CULTIVATION OF INNOVATIVE TALENTS

In order to effectively enhance the necessary inclusiveness of the traditional higher vocational teaching ecological environment for innovative thinking and innovative behavior, higher vocational colleges should strengthen the traditional higher vocational education ecological environment and support the cultivation of innovative talents from the level of the convergence of strategic management concepts. Symbiosis of educational ecological environment. In the process of implementing the normative education management system, higher vocational colleges can give higher vocational education managers certain discretion to implement the system. Leave plenty of strategic living space [27].

4.1.2. EMPHASIZE THE INTERACTION BETWEEN THE TRADITIONAL HIGHER VOCATIONAL TEACHING ECOLOGICAL ENVIRONMENT AND THE CONSTRUCTION OF THE HIGHER VOCATIONAL TEACHING ECOLOGICAL ENVIRONMENT THAT SUPPORTS THE CULTIVATION OF INNOVATIVE TALENTS

Vocational teachers should establish a student-centered educational philosophy, restructure course categories, and change course structure by establishing a career-oriented innovative curriculum system, so as to increase students' interest and motivation in acquiring innovative curriculum knowledge. Vocational colleges can

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increase the proportion of credits of general courses to the total credits, use general courses to expand the breadth of knowledge that students have mastered and consolidate the knowledge foundation for their associative innovative thinking. The construction of the professional ability training system for innovative talents should also pay attention to the mutual penetration of practical teaching and theoretical teaching. This is helpful to cultivate the innovative thinking ability and systematic problem-solving ability of vocational students [28].

4.1.3. STRIVE TO BUILD AN OPEN HIGHER VOCATIONAL TEACHING ECOLOGICAL ENVIRONMENT THAT SUPPORTS THE CULTIVATION OF INNOVATIVE TALENTS

The curriculum construction of higher vocational colleges should be systematically planned with the goal of cultivating innovative talents. By strengthening the communication and exchange between various majors and courses in higher vocational colleges, and reconstructing the professional curriculum system with modular curriculum construction, the problem of cross-cutting teaching content of each curriculum can be effectively resolved. Higher vocational colleges should optimize the development of curriculum structure, take the work structure as the clue of curriculum structure development, take the knowledge relationship required in the work process as the basic framework of curriculum structure development, and focus on developing modular curriculum knowledge suitable for project-based teaching methods. The system incorporates students' innovative thinking and innovative activities into the specific project teaching process. By introducing the working methods and work content of enterprises and institutions into the project teaching system, students' innovative behaviors can be effectively incorporated into the practical knowledge system of enterprises and institutions, so as to improve vocational students' practice based on real productivity its innovation activities and enhance the effectiveness of its innovation activities [29].

4.1.4. FOCUS ON BUILDING A SOCIAL HIGHER VOCATIONAL TEACHING ECOLOGICAL ENVIRONMENT THAT SUPPORTS THE CULTIVATION OF INNOVATIVE TALENTS UNDER THE GUIDANCE OF THE CONCEPT OF THE UNITY OF KNOWLEDGE AND ACTION

Higher vocational teachers can based on the market demand for higher vocational talents, take school-enterprise cooperation as a platform, take innovative ability training as the core, and penetrate the teaching content of higher vocational knowledge and higher vocational skills, so as to ensure that what students learn is consistent with the production and practice of enterprises. Consistent. Vocational colleges can develop a path--target-based practice base, which takes the student employment market as a path to establish teaching goals according to students' personalities, and configure practice units according to teaching goals, so as to ensure that students complete their internships on the socialized training platform. The task, and form a comprehensive professional quality with strong practical ability [30].

4.2. EDUCATIONAL EVALUATION METHODS

As an important breakthrough in promoting higher education reform and an important way to cultivate new talents, innovation, and entrepreneurship education has received more and more attention. Therefore, it is of practical significance to establish a scientific and reasonable evaluation system for innovation and entrepreneurship education. The specific steps for evaluating innovation and entrepreneurship education using the fuzzy analytic hierarchy process are as follows:

Establish an evaluation index system for innovation and entrepreneurship education. According to the analysis of the evaluation objects, a scientific and reasonable set of evaluation indicators for innovation and entrepreneurship education is established, the weight of each indicator is determined by the AHP, the judgment matrix is constructed according to the T.L. satty scale theory, and the pairwise comparison method is used to determine the impact of each indicator on the total. The relative importance of the target layer, that is, the judgment matrix is obtained. Determine the weight of each indicator at each level. A certain number of experts were selected to investigate and score the weights of each layer of indicators, and the analytic hierarchy process was used to process the judgment matrix data.

Determine the comment set. According to the quality of the evaluation target, it will be graded, that is, the comment set $V = \left(v_1, v_2, \ldots\ldots, v_5\right)$. For example, the comments can be defined as 5 levels, $V =$ (excellent, good, medium, poor, poor).

Establish a fuzzy evaluation matrix, the formula is:

$$R = \begin{Bmatrix} R_{11} & R_{12} & \cdots & R_{1n} \\ R_{21} & R_{21} & \cdots & R_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ R_{m1} & R_{m2} & \cdots & R_{mn} \end{Bmatrix} \tag{1}$$

Among them, $R_{ij}(i = 1,2,\ldots m, \mathrm{j} = 1,2,\cdots, n)$ describes the membership degree of the jth-level comment made on the ith evaluation index, that is, the membership degree vector.

Build a fuzzy comprehensive evaluation model. It is necessary to comprehensively consider various influencing factors, and combine the orientation of talent training in colleges and universities and the actual laws, select evaluation indicators objectively

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and reasonably to ensure the integrity and rationality of the indicators of the evaluation system, and then obtain the weights of indicators at all levels in the evaluation system based on the AHP algorithm to build a scientific and reasonable evaluation index system for innovation and entrepreneurship education.

According to the synthetic algorithm of the fuzzy matrix, its comprehensive evaluation model A is:

$$A = W' \cdot R = \left(A_1, A_2, \ldots, A_n\right) \tag{2}$$

If $\sum A_i \neq 1$, then $A' = \left(A_1', A_2', \ldots, A_n'\right), A' = A_j / \sum A_j, (j = 1,2,\ldots,n)$.

Determine the score set, set $K = \left(K_1, K_2, \ldots, K_n\right)^T$, n is equal to the level of the comment set, K_i represents the score of the comment at level i, with 100 points out of 100, then the formula is:

$$K_i = i \times 100/n(i = 1,2,\ldots n) \tag{3}$$

Calculation and evaluation of results. Inferred:

$$B = A \times K \tag{4}$$

Or

$$B = A' \times K \tag{5}$$

Formula (4) and formula (5) are used as the scores of the evaluation objects, and the quality of innovation and entrepreneurship education is evaluated according to the value B.

Now, the fuzzy analytic hierarchy process described in this paper is used to evaluate its innovation and entrepreneurship education behavior and the quality of its achievements, and an evaluation index system for innovation and entrepreneurship education is established, as shown in Table 2.

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Table 2. Evaluation index and index measurement table

Main target	First-level indicator	Secondary indicators	Indicator measure
Evaluation of Innovation and Entrepreneurship Education in Colleges and Universities(A)	Government level (B_1)	investmentB_{11}	Proportion of innovation and entrepreneurship education funding to total education funding
		Governing bodies and systemsB_{12}	According to whether the government or school has set up a special innovation and entrepreneurship education management institution and its management system, the innovation and entrepreneurship education shall be specially managed and scored (0~100)
		Policies and Preferential MeasuresB_{13}	Score (0~100) according to whether the government has issued relevant preferential policies and measures related to innovation and entrepreneurship and their implementation effects.
		School philosophy and planningB_{21}	Score (0~100) according to whether you have a good innovation and entrepreneurship education school running concept and teaching plan
	school level (B_2)	Curriculum system settingB_{22}	Scoring according to whether a sound innovation and entrepreneurship education curriculum system is set up and its effect(0~100)
		FacultyB_{23}	Score according to whether it is equipped with high-quality innovation and entrepreneurship education teachers and their teaching ability(0~100)
		Campus cultural environmentB_{24}	Score (0-100) according to whether there is a positive campus cultural environment for cultivating innovation and entrepreneurship, such as rich campus innovation and entrepreneurship activities, etc.
		Educational facilities and practice basesB_{26}	Score (0~100) according to whether the school has built a complete innovation and entrepreneurship education training, practice base and facilities
	Social dimension (B_3)	Social reputationB_{31}	Score (0~100) according to whether the school's innovation and entrepreneurship education is approved and recognized by the society, and whether it cultivates high-quality innovation and entrepreneurship talents for the society.
		Social atmosphereB_{32}	According to whether a good atmosphere and environment for innovation and entrepreneurship has been formed in the society, and whether it actively supports innovation and entrepreneurship education in colleges and universities (0~100)
		Business groupB_{33}	According to whether enterprises and related groups in the society support innovation and entrepreneurship education in colleges and universities, provide necessary positions and practice bases, etc. (0~100)
		Research abilityB_{41}	Scores (0-100) according to students' ability to participate in scientific research, such as enthusiasm for participating in scientific research and ability to complete projects independently

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	Student level （B4）	Innovative achievements B42	The number of articles published by students and the results of participating in various activities, which can be selected for one year
		Entrepreneurship rateB43	The proportion of the total number of graduates who start their own businesses, one year can be selected
		PracticeB44	Number of students participating in extracurricular practical activities

Use AHP to determine the weight of each indicator. Construct the index judgment matrix of the layer B, and determine the weight of each index of the layer B. Through the calculation, the weight of each index of the layer B:

$$W_B' = (0.2634,0.5638,0.550,0.1178)^T \tag{6}$$

In the same way, the indicator weight of the secondary indicator layer is obtained:

$$W_{B_{1j}}' = (0.6370,0.1047,0.2583)^T \tag{7}$$

$$W_{B_{2j}}' = (0.421,0.2606,0.5015,0.0649,0.1309)^T \tag{8}$$

$$W_{B_{4j}}' = (0.1175,0.5650,0.2622,0.1047)^T \tag{9}$$

Determine the comment set. Position the comments into 5 grades {poor <60), poor (60~70), moderate (70~80), good (80~90), excellent (>90)}.

A fuzzy comprehensive evaluation model is established, according to $A = W^T \cdot R$ and normalized to get:

$$A_{B_{1j}}' = W_{B_{1j}}^T \cdot R_{B_{1j}} = (0.2914,0.3967,0.1936,0.1183,0) \tag{10}$$

Similarly:

$$A_{B_2}' = (0.736,0.2556,0.3564,0.2144,0.1000) \tag{11}$$

$$A_{B_{3j}}' = (0.0681,0.1682,0.2291,0.3501,0.1845) \tag{12}$$

$$A_{B_{4j}}' = (0.1105,0.2846,0.3637,0.2412,0) \tag{13}$$

So the layer B membership vector is:

$$R_B = \begin{bmatrix} A_{B_{1j}}' \\ A_{B_{2j}}' \\ A_{B_{3j}}' \\ A_{B_{4j}}' \end{bmatrix} = \begin{bmatrix} 0 & 0.1969 & 0.4000 & 0.4031 & 0 \\ 0 & 0.2039 & 0.4352 & 0.2045 & 0 \\ 0 & 0.0180 & 0.0270 & 0.0266 & 0.0205 \\ 0.1365 & 0.4068 & 0.4111 & 0.0456 & 0 \end{bmatrix} \tag{14}$$

The comprehensive evaluation model:

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$A = W_B^T \times R_B = (0.0161, 0.2157, 0.4006, 0.2283, 0.0893)$, get after normalization:

$$A' = (0.0169, 0.2271, 0.4217, 0.2403, 0.0940) \quad (15)$$

Determine the score set. $K_1 = 20$, $K_2 = 40$, $K_3 = 60$, $K_4 = 80$, $K_5 = 100$ so $K = (20, 40, 60, 80, 100)^T$.

Then, the evaluation values of the method in Literature 6, the method in Literature 7, and the method in this paper are compared and analyzed, and the specific content is shown in Figure 2.

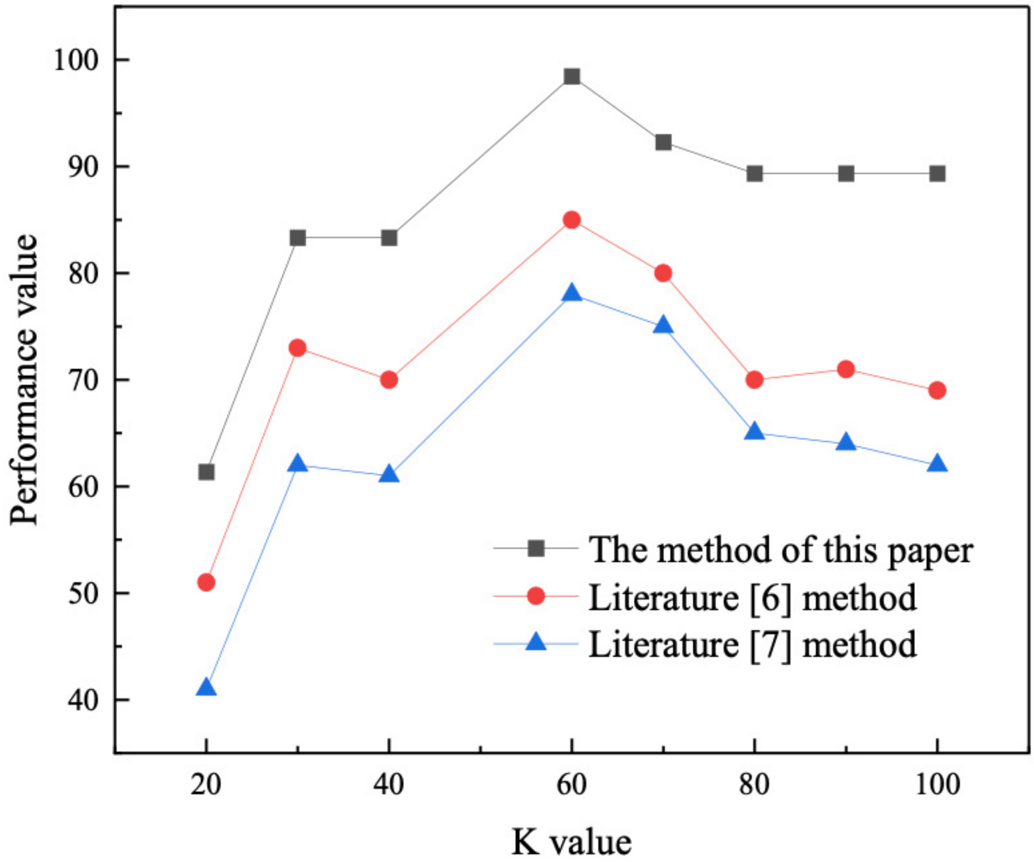

Figure 2. Different methods to evaluate performance

It can be clearly seen from Figure 2 that when the score set is $K_3 = 60$, the evaluation value of the method in Literature 6 is the highest of 85, the evaluation value of the method in Literature 7 is 76, and the evaluation value of the method in this paper is 100. In contrast, the evaluation performance of this paper is highest, thereby greatly improving the level of education. The innovation and entrepreneurship education evaluation system proposed in this paper, as an important tool to measure the development level of innovation and entrepreneurship education in colleges and universities, can provide an important guarantee for the development and improvement of the quality of innovation and entrepreneurship education in colleges and universities and has wide applicability and high advantages.

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Analysis of results and suggestions for improvement. In the evaluation index system of innovation and entrepreneurship education in colleges and universities, the weights of the first-level indicators are, from large to small, educational investment, educational process, educational achievement, and educational background, among which educational investment and educational process account for a large proportion in the innovation and entrepreneurship education system. , education investment greatly affects the development level of innovation and entrepreneurship education in colleges and universities. Although the educational background has a low weight, it is still indispensable for the development of innovation and entrepreneurship education in colleges and universities. In the ranking of secondary index weights, the school environment plays a key role in the evaluation of educational background. Therefore, colleges and universities should focus on creating an environment for innovation and entrepreneurship in schools. Among the elements of education investment evaluation, funding investment occupies a more important position, and the intensity of funding investment is an important supporting condition affecting the development of innovation and entrepreneurship education in colleges and universities. In the evaluation elements of the educational process, because the teaching plan can directly affect the quality of personnel training in colleges and universities, it occupies a greater weight. Among the elements of educational achievement evaluation, the social benefits of innovation and entrepreneurship education in colleges and universities play an important role. According to $B = A' \times K$, this evaluation value is calculated as $B = 93.348$. The above results show that the quality level of innovation and entrepreneurship education in this university is relatively high, and the improvement of the quality level of innovation and entrepreneurship education can provide a better environment for talent training.

5. CONCLUSION

The innovation and entrepreneurship education of college students is a systematic, three-dimensional, and long-term project. The ecosystem theory is applied to the field of college students' innovation and entrepreneurship education, and the problem of college students' innovation and entrepreneurship is viewed more scientifically and comprehensively from a systematic perspective. Based on the innovation ecology theory, this paper constructs an innovation and entrepreneurship education model, and conducts a comprehensive evaluation and empirical analysis of the innovation and entrepreneurship education evaluation index system created by the government, schools, society, and students at four levels, and uses the fuzzy analytic hierarchy process. The result is as follows:

1. In the evaluation index system of innovation and entrepreneurship education in colleges and universities, the weights of the first-level indicators are, from large to small, educational investment, educational process, educational achievement, and educational background, among which educational investment and educational process occupy a large part in the innovation and entrepreneurship education system. A large proportion, of education

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investment greatly affects the development level of innovation and entrepreneurship education in colleges and universities. Although the educational background has a low weight, it is still indispensable for the development of innovation and entrepreneurship education in colleges and universities.

2. In the ranking of secondary index weights, among the elements of educational background evaluation, the school environment plays a key role. Therefore, colleges and universities should focus on creating an environment for innovation and entrepreneurship in schools. Among the elements of education investment evaluation, funding investment occupies a more important position, and the intensity of funding investment is an important supporting condition affecting the development of innovation and entrepreneurship education in colleges and universities. In the evaluation elements of the educational process, because the teaching plan can directly affect the quality of personnel training in colleges and universities, it occupies a greater weight. Among the elements of educational achievement evaluation, the social benefits of innovation and entrepreneurship education in colleges and universities play an important role.

3. The comments are positioned in 5 grades {poor <60), poor (60~70), moderate (70~80), good (80~90), excellent (>90)}, and the evaluation value is obtained by calculation It is 93.348, indicating that the education system of this article is very efficient, and the talent training is better. However, in the actual evaluation work, it is still necessary to continuously modify and improve the index system, so as to provide a certain evaluation basis for promoting the healthy and orderly development of innovation and entrepreneurship education in my country.

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THE COMPREHENSIVE APPLICATION OF THE LAWN ECOLOGY OF THE FOOTBALL FIELD IN ENHANCING THE INTENTION OF SPORTS CONSUMPTION

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ABSTRACT

With the continuous progress and development of society and the outstanding achievements of football in the field of competitive sports in recent years, the enthusiasm of citizens to participate in sports and fitness has become higher and higher. The course turf ecology is a multi-layered organic whole composed of many natural and social factors, which is an important symbol of football competitiveness. It can be predicted that the relationship between sports and the environment and the impact of environmental changes on consumer intentions are global and long-term. Therefore, according to the annual change status and formation factors of ecological benefits such as carbon sequestration and oxygen release, transpiration water release, and heat absorption in the turf of a football field in a city, the time series stability test method and the multiple regression analysis method are used to discuss the comprehensive application of the lawn ecology of the football field in enhancing the intention of sports consumption. The experimental results verify that the ecological benefits of lawns have a significant positive effect on sports consumption intentions, which can not only optimize the unreasonable sports consumption structure, improve the level of sports consumption, and increase the proportion of consumption amount of more than 5,000 yuan from 5.06% to 23.34%, but also make the leading sports consumption motivation from a more symbolic display of personality, status symbols, and social entertainment to a sportsmanlike physique, entertainment, spiritual enjoyment, and positive guidance of sports consumption motivation.

KEYWORDS

Football field; Lawn ecology; Sports consumption intentions; Time series stationarity test; Multiple regression analysis

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1. INTRODUCTION

China's economy and society continue to lead through new consumption, emphasizing the in-depth excavation of sports consumption potential, promoting the development of the fitness and leisure industry, accelerating the transformation and upgrading of residents' consumption structure and industrial structure, and laying a good policy foundation for the transformation and upgrading of the sports industry [1-3]. With the continuous strengthening of residents' awareness of sports consumption, the vitality of the sports consumption market has been stimulated, sports fitness and leisure activities, sports venues and facilities management, physical education and training and other sports service industries have rapidly developed into the core links of the sports industry, the development and growth of the sports service industry, continuously meet the needs of residents for sports and fitness, and accelerate the transformation and upgrading of the sports consumption structure [4-8].

The report of the Nineteenth National Congress pointed out that it is necessary to continuously promote green development, strengthen environmental governance, increase the protection of ecosystems, seek a dynamic balance between environmental benefits, economic benefits, and social benefits, promote high-quality economic development with a high level of ecological environment, accelerate the formation of new formats, and promote consumption transformation [9-11]. As an important part of economic consumption, sports consumption is an important booster for promoting the optimization of consumption structure [12]. Therefore, it is of great significance to clarify the impact of the ecological environment on the upgrading of sports consumption [13].

The awareness of sports consumption among urban and rural residents has been continuously strengthened, sports consumption behavior has gradually developed, and the sports consumption structure has begun to be optimized and upgraded, continuously promoting the development and growth of the sports industry [14-15]. Sports consumption belongs to a higher level of demand, and only after meeting physiological, safety, and other needs will people consume sports to meet the needs of self-realization [16]. In essence, the upgrading of the sports consumption structure is mainly reflected in the transformation from physical consumption to participatory and ornamental consumption, and through the pursuit of high-quality sports products and services, driving the rise of high-end sports consumption brands [17-23]. From the perspective of macro, mesoscopic, and microscopic, the upgrading of sports consumption structure includes the optimization of the sports market structure, the adaptation of the supply structure and demand structure of the sports industry, and the improvement of the supply level of enterprise services and products [24].

There are few studies at home and abroad on the influencing factors of improving sports consumption intentions, and most of the studies are analyzed from the perspective of sports consumption behavior. For example, the literature [25] aims to analyze the characteristics of consumer behavior, as well as the relationship between purchase motivation, perceived risk, and behavioral intention, and after statistical

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analysis, it is found that sneakers are the main products purchased by consumers online. There are no differences between genders in purchase motivation, perceived risk, and behavioral intent. Consumers of different ages have different motivations to buy and perceive risks. Consumers' purchase motivation and perceived risk have a predictive effect on behavioral intentions. The literature [26] in the study directly verified that the income level of residents has a significant impact on residents' sports consumption decisions. Literature [27] uses the literature survey method, descriptive statistics method, spatial Darwinian model Moran discrete graph, and Lisa cluster graph to summarize the correlation and influence mechanism between real estate price and the improvement of residents' sports consumption, and studies the influence of real estate price on the growth of residents' sports consumption from a macro perspective. Literature [28] analyzing the current situation of mass fitness sports consumption in Jiangxi province, introducing the extended linear expenditure system, from the perspective of consumer demand, the new growth point of sports consumption in Jiangxi province, and puts forward proposals for the development of sports consumption of, increase public choice of sports consumption, provide reference for promoting diversified sports consumption in Jiangxi province. Literature [29], using an independent sample t-test and variance, the sports consumption motivation of college students was analyzed, and the score of the sports consumption motivation scale showed that the consumption demand caused by the phenomenon of motivation and motivation played a positive role in the sports consumption motivation behavior that met the requirements of individual socialization, self-proof and self-acceptance. From the existing research, it can be found that the improvement of sports consumption intentions mainly depends on the transformation of residents' sports consumption behavior, that is, from frequent purchase of sports clothing and supplies to frequent viewing of sports competitions, participation in sports skills training and other service-oriented consumption, while the influencing factors of the change in consumer behavior mainly include the level of economic development, the level of development of urban sports facilities and events, and the awareness of sports participation [30], and the existing research is less involved in the study of the impact of the level of ecological environment development on sports consumption behavior.

People call the football field "green field", the lawn is the key to the design of the entire sports field, the basis of operation, but also the core of the football project. The ecological situation of natural turf is not only related to the performance of athletes and the display of competition level but also related to the consumption intention of the entire sports field. Therefore, based on the improvement and upgrading of sports consumption intentions, adhere to the concept of green development, from the perspective of football fields, explore the impact of lawn ecological level on the improvement and transformation of sports consumption intentions, and pass. The time series stability test method and the multiple regression analysis method are verified, to actively implement the concept of ecological civilization construction, continue to deepen the construction of the ecological environment system, pay attention to the coordinated development of ecology and sports consumption, and truly realize the transformation and upgrading of sports consumption intentions.

2. THE CURRENT SITUATION OF THE ECOLOGICAL BENEFITS OF THE LAWN OF THE FOOTBALL FIELD

A soccer field covering an area of about 7,500 square meters was selected as the research object, and the green grass species of the course was grassland early maturing grass [31], the soil was mainly brown soil and brown soil, the thickness is unknown, and the sprinkler irrigation conditions are good. According to the terrain and vegetation growth status, the sample collection area was in the area with a rich vegetation community, the lawn grass grew well, and the sunshine was sufficient. The current status of lawn ecological benefits is shown in Figure 1. According to Figure 1 (a), the daily carbon sequestration, transpiration release, and heat absorption per unit area of grassland precocious grass are multiplied by the total leaf area and the number of days of the grassland early maturing grass in the same month, and the cumulative value of 9 months is obtained: the annual carbon dioxide absorption is 3516.13t, the annual oxygen release is 2646.84t, the annual transpiration discharge is 902434.63t, and the annual transpiration heat absorption is 1975642.16GJ. This is shown in Figure 1(b). According to the statistical analysis of the annual oxygen sequestration capacity and transpiration heat absorption capacity of the football field's turf in Figure 1(b), the quantitative data on the ecological benefits of improving the surrounding environment can be calculated, to make the following quantitative evaluation of its ecological benefits.

According to the statistics, it is estimated that each person consumes about 1506.43g of oxygen per day, and according to the oxygen release carbon sequestration of the grass of the target football field of precocious grass 13.43g/m2, it can be calculated that the turf in the stadium is about 100 square meters, which can meet the oxygen consumption of an adult for a day, including gas and breathing. The heat absorption and cooling benefit of the lawn, such as compared with the air conditioner with a power of 1 kilowatt (calculated by 100% of the refrigeration efficiency), the daily heat absorption of the 1m2 grass precocious grass is 12.16MJ, which is equivalent to the air conditioner working for nearly 3 hours, it shows that the grass of the football field has a very obvious heat absorption and cooling benefit to the surrounding environment.

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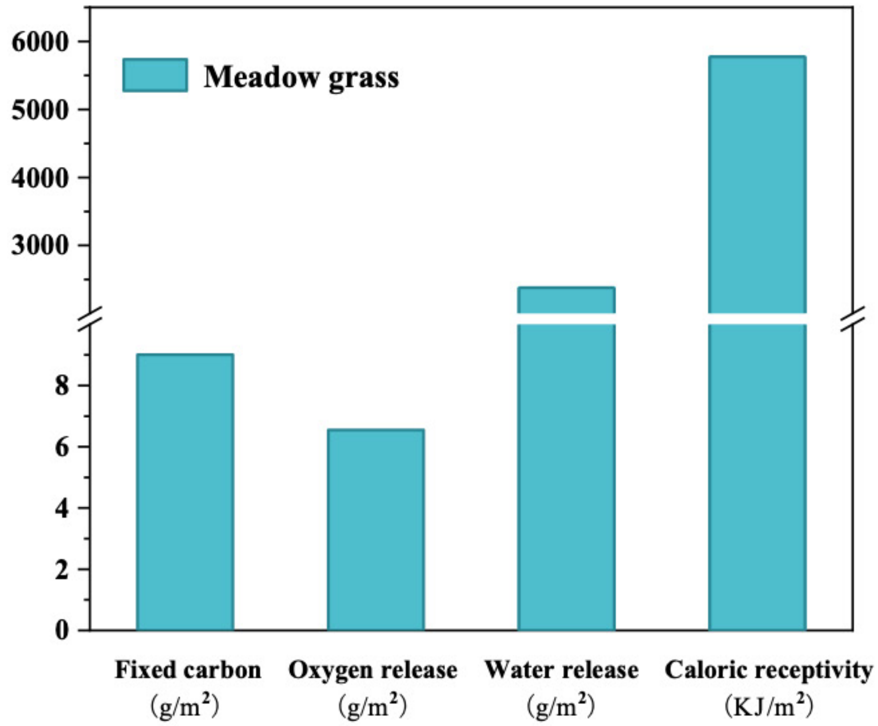
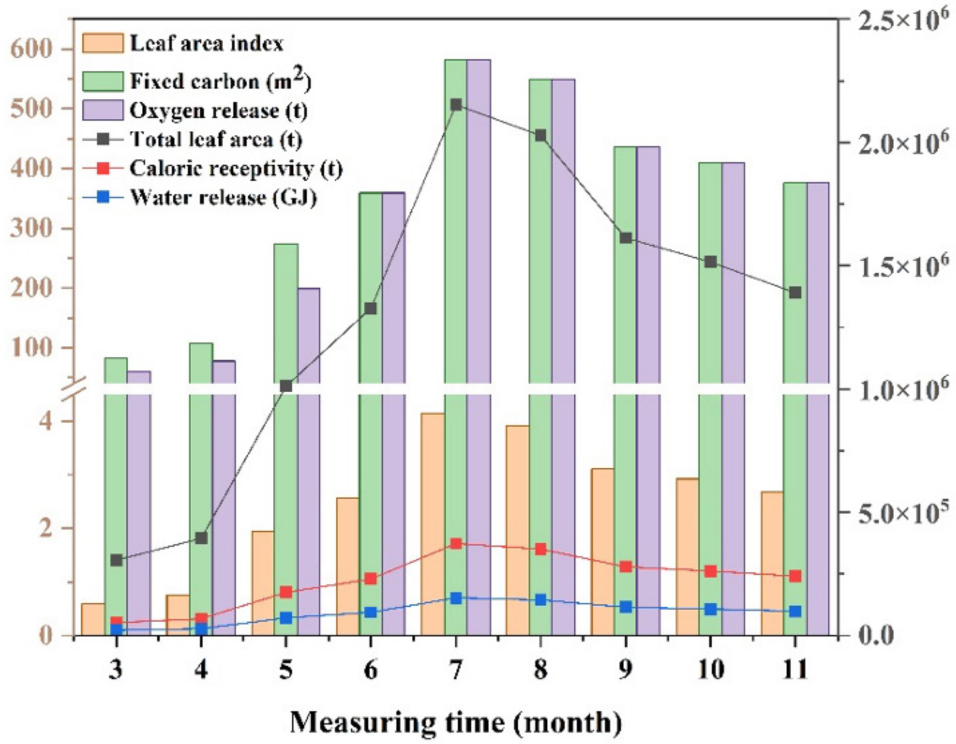


(a) daily ecological benefits per unit area



(b) annual ecological benefits

Figure 1. schematic diagram of the ecological benefits of the turf in the study area

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In summary, the evaluation of the ecological benefits of the turf green space of the studied football field is mainly divided into the following aspects:

1. Lawn green space dust retention benefits: plant leaves themselves have a strong ability to hold dust, which is due to their surface characteristics and their wetness. When the airflow containing sand dust passes through the lawn, some of the dust with larger particles will fall on the surface or surface of the plant due to leaf obstruction. Since trees can adsorb and filter dust, the dust in the air is greatly reduced, which also reduces the bacterial content in the air that comes with it. Lawn can be used as a natural "vacuum cleaner", which can continuously filter the dust in the air through acceptance, adsorption, and other effects. The pitch's turf has a daily dust stagnant of 8.11g per square meter. The stadium lawn is also one of the best tools to reduce dust and dust in the air. Large areas of turf grass can absorb dust around itself through the fluff on its leaf surface, or the secretion of grease, etc., to prevent it from flying into the air again. These green plants have been baptized by nature and their recuperation, which can circulate and purify the air and block dust. The dust content over the football field is about 73% lower than that of the lime football field without a paved lawn.

2. Bactericidal effect of lawn and green space: lawn can absorb gases harmful to the human body, and has different degrees of killing and inhibiting of pathogenic microorganisms such as bacteria that live in the air. The green turf environment in the stadium is large, this turf grass can purify the air, can absorb harmful gases in the atmosphere, such as carbon dioxide, sulfur dioxide, ammonia chloride, ammonia, chlorine, and so on. Lawn grass can combine ammonia and ammonia sulfide into proteins. It can oxidize toxic nitrites into useful salts, and the bacteria levels above lawns were only a third of those in public spaces.

3. Lawn green space to reduce noise: the stem and leaf surface of lawn grass are rough and uneven, with a large number of micropores and dense fluff, just like the uneven sound absorber, which can weaken the sound wave transmission or make the sound wave deflect and refract during the transmission process, reducing the energy of the noise. The leaves and upright stems of turf grass have a relatively good effect of absorbing noise and can absorb and weaken by an average of 150~950Hz.

4. The role of lawn green space in purifying soil and conserving water and soil: the lawn grows rapidly on the football field, and the stems and leaves are also very luxuriant, which can cover the rain and prevent the rain from directly hitting the ground during the landing process. The vegetation plants grow densely, slow down runoff, and at the same time can intercept sediment, etc., forming a relatively tight root network, which can loosen the soil, improve the permeability and penetration rate of the soil, and increase the ability to permeability and water storage. At the same time, the residual roots left under

the lawn and the dead branches and leaves on the ground can bring a very rich organic matter to the soil. These substances are decomposed in nature to form a large amount of humus, which significantly increases the soil particle structure, improves the physical and chemical properties of the soil, and also increases the erosion resistance of the soil itself. The leaves of the grass precocious grass can absorb harmful gases, in addition, they can absorb a large number of harmful substances and their root system, which also gives the lawn the ability to purify the soil. At the same time, they also play a positive role in increasing soil fertility. The large green lawn on the course can not only improve the surface environment but also improve the soil conditions underground.

5. Lawn green space regulation microclimate: the main performance of the stadium lawn to regulate the microclimate is: first, it can intercept precipitation, and the penetration rate is much higher than that of the open ground, which has a very positive effect on the water in the conserving soil. Second, due to the transpiration of lawn grass, the lawn can regulate air temperature and humidity in the air. Compared with bare ground, the humidity on the lawn is generally about 18.12% higher than that on the bare ground. Third, because the lawn can absorb the heat of the radiation field surface, the surface temperature in summer is about 5 ° lower than that of the bare ground, while in winter, the lawn is about 6 ° higher than the bare ground, which makes the green lawn play a very positive role in regulating the microclimate. Through the transpiration of moisture in the air, the lawn reduces the temperature in the air and increases the humidity, creating a cooler, comfortable, and pollution-free climate environment.

6. Lawn green space beautification environment: football field as part of urban greening, applied to urban planning and construction, its purpose is to make the city look more beautiful, and people live more comfortably. Such a green environment can play a positive role in everyone's physical health. To improve the quality of human settlements, it is necessary to increase the construction of green spaces. The construction of the football field lawn and the quality of the living environment are directly proportional, and the better the ecological benefits of the lawn, the better the quality of the living environment. Conversely, the worse the benefits, the correspondingly reduced the quality of the human settlement environment.

3. TIME SERIES STATIONARITY TEST MODEL

Based on calculating the ecological benefit index and the sports consumption intention index, the cointegration model and error correction model between the natural environment index of the stadium lawn, the sports consumption structure index, the sports consumption level index, and the sports consumption motivation index are constructed, and the long-term equilibrium relationship and short-term

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fluctuation relationship between the ecological benefits of the lawn and the sports consumption intention are analyzed.

1. Data stability analysis: in real life, because most of the time series data are unstable, to avoid the occurrence of pseudo-regression, before taking the correlation test, a stability test is required to examine whether the lawn ecological benefit index, sports consumption structure index, sports consumption level index, and sports consumption motivation index are stable. The results of the stationarity test of the unit root time series of the turf ecological benefit index sequence and the sports consumption intention index sequence are obtained, which are shown in the following Table 1.

Table 1. unit root test results

Variable	Unit root statistic	Conclusion
Lawn natural environment index	1.651355	smooth
Sports consumption structure index	0.509842	smooth
Sports consumption level index	0.854573	smooth
Sports consumption motivation index	0.438995	smooth

The unit root test [32] was carried out by the time series stationarity test method, and the test results showed that the index of the four dimensions of sports consumption intention and the lawn ecological benefit index sequence were all first-order single-integer sequences, so the sports consumption intention index and the lawn ecological benefit index could be cointegration tested.

(2) Cointegration test: first, the residual sequence is extracted, and then the unit root test is performed on the extracted residual sequence to obtain the unit root test results. The value of the unit root test statistic is -3.038522, below the critical value of 1% of the significance level of -2.541505, indicating that the significance level is 1%, the residual sequence can be considered to be a stable time series, and there is a long-term equilibrium cointegration relationship between the ecological benefits of the lawn and the intention of sports consumption, the equation is as follows:

$$Y = 0.17X_{1t} + 1.288X_{2t} + 0.121X_{3t} + 1.011 + ecm_t \qquad (1)$$

Where Y represents the lawn ecological benefit index; X_{1t}, X_{2t}, X_{3t} indicate the sports consumption structure index, sports consumption level index, sports consumption motivation index; ecm_t indicates the error correction factor.

(3) Error correction: according to the above analysis results, it can be learned that there is a long-term equilibrium relationship between the ecological benefits of lawns and the structure of sports consumption, the level of sports consumption, and the motivation of sports consumption, but it is impossible to know the short-term fluctuation link between lawn ecological benefits and sports consumption intentions.

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Therefore, based on constructing a cointegration model, the short-term fluctuation relationship between the indicator variables is analyzed by creating an error correction model, and the error correction model is constructed as follows:

$$\Delta Y_t = 0.113\Delta X_{1t} + 0.586\Delta X_{2t} + 0.114\Delta X_{3t} + 0.452ecm_{t-1} \quad (2)$$

Where, ΔY_t indicates the revised lawn ecological efficiency index; ΔX_{1t}, ΔX_{2t}, ΔX_{3t} indicates the revised sports consumption structure index, sports consumption level index, sports consumption motivation index; ecm_{t-1} represents the historical error correction factor.

The results showed that the change in the sports consumption intention index not only depended on the change of the turf ecological benefit index but also depended on the deviation of the previous turf ecological benefit index to the sports consumption intention index. The fitting coefficient of the error correction item ecm_t was -0.385, indicating the improvement of the deviation. As the coefficient of the error correction term is less than 0, when there is a deviation between the float of the sports consumption intention index in a short time and its equilibrium point in a long time, the error correction term will make a negative adjustment to it, and the adjustment strength is the absolute value of the coefficient. From the size of the fitting coefficient, it can be seen that the turf ecological construction of a football field has the greatest influence on the sports consumption level index and the least influence on the sports consumption structure index.

4. MULTIPLE REGRESSION ANALYSIS MODELS

Multiple linear regression methods are also commonly used to analyze problems where one variable affects multiple variables at the same time [33]. For different problems, a variety of specific analysis methods have been derived, such as: the entry method, deletion method, forward method, backward method, stepwise regression analysis method, etc. [34-38]. If the linear regression analysis equation is optimal, all the independent variables in the range will be considered, and the regression equation will be introduced into the regression equation from largest to smallest according to the degree of significant influence on the dependent variable, so that the regression equation will be optimal. The method is divided into the following steps:

1. Establish an equation between the independent and dependent variables based on assumptions.

2. Solve the parameters of the regression equation.

3. The significance of the regression effect is tested, and the linear effect of each variable on the dependent variable is analyzed significantly.

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4. Eliminate the variables with less significant secondary effects, and re-establish the variables containing the significant influences for the regression equation solution test.

5. Through multiple rejections and equation reconstruction, the independent variable factors of significant regression are selected.

Define a univariate linear regression model using the following expressions:

$$Y_i = a + b_1 X_{1i} \tag{3}$$

The basic calculation process of multiple linear regression is the same as that of univariate linear regression, so the formula for constructing a multiple linear regression model is as follows:

$$Y_i = a + b_1 X_{1i} + b_2 X_{2i} + \ldots + b_{i\pi} X_{\pi i} \tag{4}$$

Where, Y_i represents the estimated value of the dependent variable; a, b_i are regression coefficients; X_i are the independent variable.

5. RESULTS AND ANALYSIS

5.1. EFFECT VERIFICATION OF THE COMPREHENSIVE APPLICATION OF THE TIME SERIES STATIONARITY TEST MODEL

Through the calculation of the time series stationarity test model, the variation trend of sports consumption intention with the ecological benefits of football turf was obtained, as shown in Figure 2. To better fit the actual situation, consumption structure, and consumption motivation are not unique, there will be a phenomenon of coexistence of multiple consumption patterns and consumption motives, so the total proportion of the two indicators will be greater than 100%.

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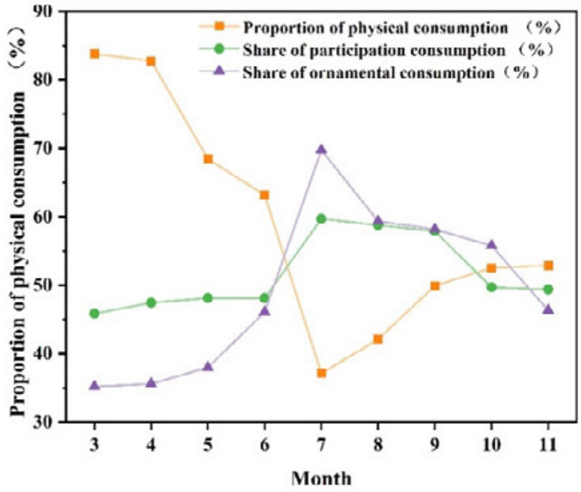
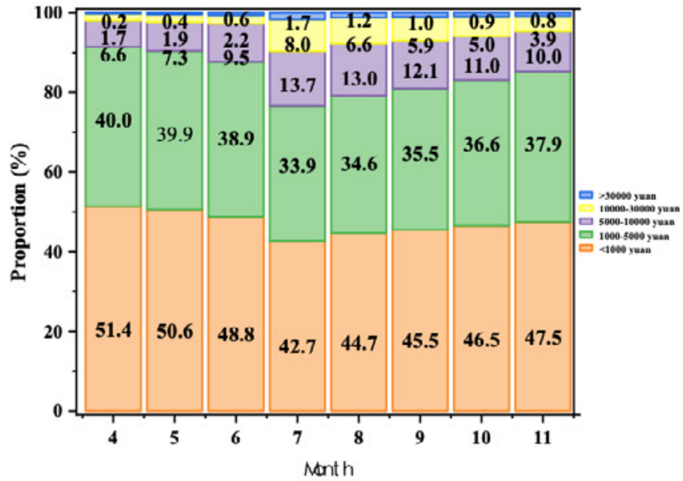
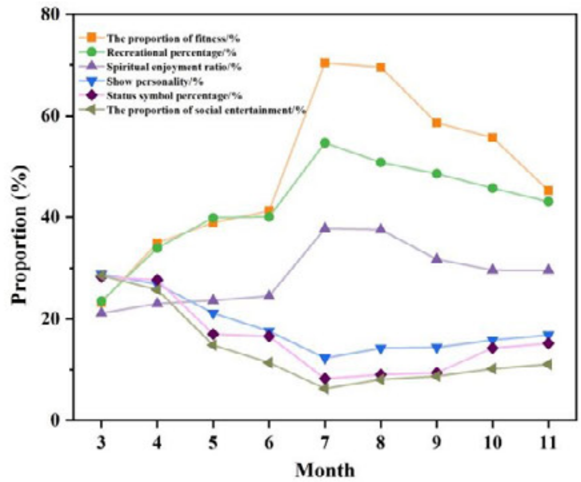


(a) consumption structure



(b) level of consumption



(c) consumption incentives

Figure 2. Effect diagram of turf ecology improving sports consumption intention

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Figure 2 (a) shows that when the ecological benefits of the football field turf are at the lowest, the sports consumption structure is unbalanced, and the physical sports consumption mode in the sports consumption structure accounts for a relatively large proportion, accounting for 83.82%. The proportion of participatory sports consumption was 45.86%. The proportion of watching physical activity was 35.2%. Overall, in the sports consumption structure, the proportion of physical consumption is the highest, and the proportion of participatory sports consumption and ornamental sports consumption is the lowest, which also shows that sports consumption is mainly based on physical consumption, while participatory consumption and ornamental consumption still have broad room for development. When the ecological benefits of the stadium lawn continue to improve, and reach the peak in July, by weakening the sound wave transmission or making the sound wave deflection and refraction in the transmission process, reducing the energy of the noise, through the transpiration of the moisture in the air, so that the temperature in the air is reduced, the humidity increases, creating a cooler, comfortable, no pollution climate environment, so that people are more willing to participate in sports activities, so that the sports consumption structure gradually tends to balance, and develop in a positive direction. The proportion of physical sports consumption patterns in the sports consumption structure is relatively small, accounting for 37.12%. The proportion of participatory sports consumption was 59.71%. The proportion of watching sports activities was 69.74%. On the whole, the consumption structure has been greatly optimized and upgraded, so that the proportion of physical consumption in the sports consumption structure is the lowest, while the proportion of participatory sports consumption and ornamental sports consumption is the highest, which has vigorously promoted participatory consumption and ornamental consumption.

Figure 2 (b) shows that the ecological benefit of the football field lawn in March is the worst, the sports consumption capacity is insufficient, although there is still a certain degree of sports consumption expenditure, the amount of sports consumption expenditure below 1000 yuan is 53.45%, the amount of consumption expenditure between 1,000 and 5,000 yuan is 41.49%, the amount of sports consumption expenditure between 50,001 and 10,000 yuan is 3.65%, and another 1.21% is 3.21%. The amount of sports consumption expenditure is between 10,001 and 30,000 yuan, and only 0.2% of the amount is spent on sports more than 30,000 yuan. This shows that most of the funds spent on sports are below 5,000 yuan, which shows that when the ecological benefits of the football field lawn are not good, the overall level of sports consumption is not high. When the ecological benefits of the course lawn are in the best state, the lawn can achieve loose soil, improve the permeability and penetration rate of the soil, increase the ability of water permeability and water storage and soil retention, improve the surface environment and underground soil conditions, make the city look more beautiful, people live more comfortably, therefore, as far as possible to balance the two consumption levels based on 5,000 yuan, reduce the amount of sports consumption below 5000 yuan. Significantly increased the amount of consumption of more than 5,000 yuan in sports, increasing the proportion of sports consumption expenditure below 1,000 yuan to 42.73%, the proportion of consumption

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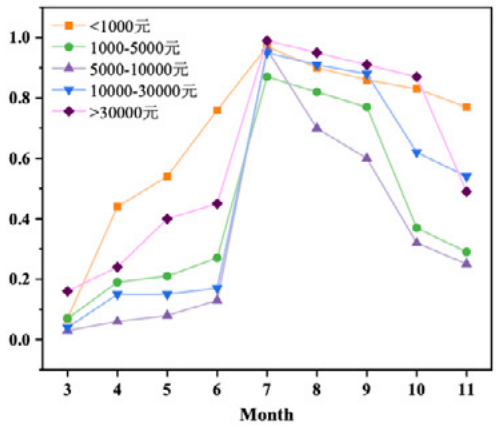
expenditure between 1,000 and 5,000 yuan to 33.93%, the proportion of sports consumption expenditure between 50,001 and 10,000 yuan to 13.7%, and the proportion of sports consumption expenditure between 10,001 and 30,000 yuan to 7.98%. The proportion of spending more than $30,000 on sports increased to 1.66%. Although the five sections of consumption level have not been completely improved, most of the capital expenditure on sports is still below 5,000 yuan, but it has actively promoted consumption and significantly improved the overall level of sports consumption.

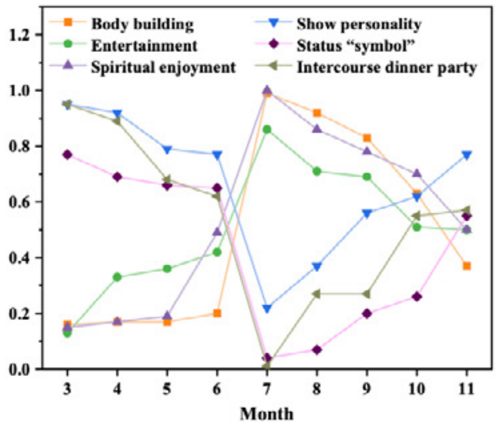
According to Figure 2(c), it can be found that when the ecological benefits of the football field lawn are getting lower and lower, the motivation for sports consumption is becoming increasingly alienated, showing a symbolic consumption trend from rational consumption to emotional consumption. At this time, the top three sports consumption motivations are "highlighting personality" (accounting for 28.79%), "status symbols" (accounting for 28.28%), and "social entertainment" (accounting for 28.54%). On the one hand, the results of the obtained data show that residents have different motivations for sports consumption, on the other hand, it shows that sports consumption has been given more special significance, reflecting that sports consumption is not only physical activities and spirits, but also in social and personality. In a sense, it shows the trend of sports consumption to symbol consumption. On the side, it also directly shows that the ecological benefits of the lawn of the football field affect the changing trend of sports consumption motivation, and there is a certain guiding effect on sports consumption motivation. In July, the ecological benefits of the lawn of the football stadium were the best, and the motivation for sports consumption showed a healthy consumption trend from emotional consumption to rational consumption. This is because the lawn has a strong ability to hold dust so that the dust in the air is greatly reduced, and thus also reduces the bacterial content in the air, through the transpiration of the moisture in the air, so that the temperature in the air decreases, the humidity increases, creating a cooler, comfortable, no pollution climate environment, the external consumption symbol evolves into inner sportsmanship, therefore, the improvement of ecological benefits will be the top three of the sports consumption motivation from "highlighting personality", "status symbol", "social interaction" to "physical fitness", "recreation" and "spiritual enjoyment" increased the proportion of the three active consumption motivations from 23.22%, 23.48%, and 21.15% to 70.42%, 54.68%, and 37.79%. It can be seen from this that the ecological benefits of the lawn of the football field have an effective role in promoting and promoting the motivation of sports consumption in addition to guiding.

5.2. MULTIVARIATE REGRESSION ANALYSIS MODEL COMPREHENSIVE APPLICATION EFFECT VERIFICATION

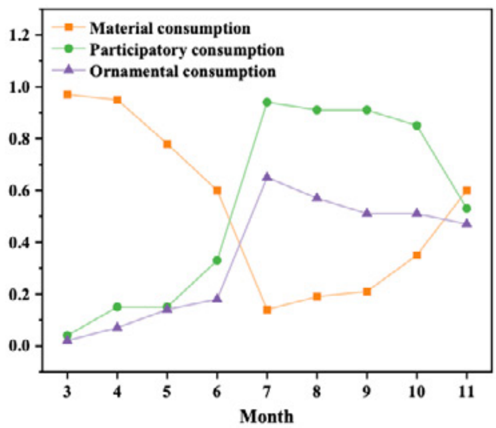
Using the univariate and multiple linear regression models, the intentional improvement effect of the turf ecology of the football field on the sports consumption structure, sports consumption motivation, and sports consumption level is discussed, and the regression factor number analyzed by the linear regression model is shown in Figure 3.



(a) the impact of lawn ecology on the level of sports consumption



(b) the influence of lawn ecology on the motivation of sports consumption



(c) the influence of lawn ecology on the structure of sports consumption

Figure 3. Schematic diagram of the effect of lawn ecology to enhance sports consumption intention based on multiple regression analysis methods

The regression coefficient shown in Figure 3(a) is the result of the regression analysis method used to explore the influence of the ecological benefits of football field turf on the level of sports consumption, and the regression model can be expressed as:

$$Y = 1.488 + 0.632X_1 + 0.354X_2 + 0.428X_3 + 0.249X_4 + 0.513X_5 \quad (5)$$

Where, Y indicates the ecological benefits of the pitch turf; X_1, X_2, X_3, X_4 and X_5 represents different consumption intervals in the sports consumption level, respectively.

According to the regression model, the lawn ecology of the football field has a positive effect on the level of sports consumption. Because the regression coefficient with a consumption level below 1,000 yuan is the largest, and the regression coefficient of 10,000 yuan to 30,000 yuan is the smallest, it is further explained that the ecological benefits of the football field lawn have the greatest impact on the sports consumer groups below 1,000 yuan, and the sports consumer groups of 10,000 yuan to 30,000 yuan have the least impact.

Because the lawn through its foliage fluff, or secretion of grease, etc., can adsorb dust around itself, to prevent it from flying into the air again, for those living in the air bacteria and other pathogenic microorganisms, with different degrees of killing and inhibition, football field as part of the urban greening, applied to urban planning and construction, can make the city look more beautiful, people live more comfortably, and the quality of the living environment to improve the construction of green space. Therefore, the higher the ecological benefit of the football field lawn, the more people are willing to spend more money on the construction of projects in the field of sports.

Therefore, the number of regression factors corresponding to each level of sports consumption level is increasing with the improvement of ecological benefits, which is greatly improved from 0.07, 0.07, 0.07, 0.03, 0.04, and 0.16 at low lawn ecological benefits to 0.97, 0.87, 0.96, 0.95 and 0.99 at high lawn ecological benefits, respectively, which greatly improves the sports consumption level at each stage, and the experimental conclusions obtained are consistent with the comprehensive application verification effect of the time series stability test method.

Figure 3(b) Using sports consumption motivation as an independent variable and stadium turf ecology as the dependent variable, multiple linear regression analysis was carried out to explore the influence mechanism of football field turf ecology on sports consumption motivation. The regression equation can be expressed as:

$$Y = 1.923 + 0.515X_1 + 0.602X_2 + 0.654X_3 + 0.448X_4 + 0.396X_5 + 0.751X_6 \quad (6)$$

Among them, Y represent the ecological benefits of the stadium turf; X_1, X_2, X_3, X_4, X_5 and X_6 respectively represent different consumption purposes in the sports consumption motivation.

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From the regression equation, it can be seen that the regression coefficients of the independent variables are all positive, and the ecological benefits of the stadium turf have a positive impact on the motivation of sports consumption. The regression coefficient of social entertainment (i.e., 0.751) is greater than that of mental enjoyment (i.e., 0.654), entertainment (i.e., 0.602), physical fitness (i.e., 0.515), personality (i.e., 0.448), and status symbols (i.e., 0.396), further indicating that the ecological benefits of football field turf on the sports consumption motivation of social entertainment are more influential than other consumption motivations. Because the lawn is a natural "vacuum cleaner", through acceptance, adsorption, and other effects, continuously filters the dust in the air, by absorbing harmful gases in the atmosphere, reducing the bacterial content in the air, ammonia, sulfide ammonia into protein. It can oxidize toxic nitrite into useful salts, so that the stadium environment becomes a healthy place in the true sense of the body, so the higher the ecological benefits of the football field lawn, the easier it is to strengthen the body, recreation, spiritual enjoyment and other positive and positive motivations for consumption, therefore, the leading sports consumption motivation from the more symbolic display of personality, status symbols, social entertainment into sportsmanlike physical fitness, recreational entertainment, spiritual enjoyment, effectively positive physical fitness, recreational entertainment. The number of regression factors for mental enjoyment of the three sports consumption motivations increased from 0.16, 0.13, and 0.15 when the ecological benefit was poor to 0.99, 0.86, and 1. The experimental results verified the analysis conclusion of the comprehensive application effect of the time series stationarity test method again, which is enough to show that the turf ecology of the football field has a strong promotion effect on sports consumption intention.

Figure 3(c) takes the sports consumption structure as the independent variable and the ecological benefit of the football field lawn as the dependent variable, and further uses the one-factor analysis of variance to explore the relationship between the ecological benefit of the football field lawn and the sports consumption structure, which is of statistical significance. In this study, a univariate linear regression analysis of the ecological benefits of football field turf and the structure of sports consumption was carried out, and the regression coefficient was greater than 0, indicating significance. Therefore, further research on physical consumption patterns of the consumption structure of sports consumption patterns, the participated consumption patterns, ornamental type correlation test, the correlation coefficient is 0.711, multicollinearity relationship between independent variables are, therefore, the research to a yuan linear regression model to explore the ecological benefits of football field grass affect sports consumption structure. The regression coefficient equation of turf ecological benefit on sports consumption structure is as follows:

$$Y = 1.272 + 0.503X_1 + 0.537X_2 + 0.418X_3 \tag{7}$$

Among them, Y represents the ecology of the stadium lawn, X_1, X_2 and X_3 different types of the sports consumption structure.

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According to the regression coefficient of the regression equation, it can be seen that the ecological benefits of the turf of the football field have a positive impact on the structure of sports consumption. The regression coefficient (i.e., 0.537) for participatory consumption is the largest, while the regression coefficient for ornamental consumption (i.e., 0.418) is the smallest. Therefore, it is further explained that the ecological benefits of the football field lawn have the greatest impact on the participatory consumption model and the least impact on the ornamental consumption model. Because the lawn can intercept precipitation, and the penetration rate is much higher than the empty ground, its transpiration effect and the absorption of radiation surface heat can regulate the temperature and humidity in the air, so that the temperature in the air is reduced, the humidity increases, compared with the bare ground, the summer surface temperature is about 5 ° lower than the bare ground, on the contrary, in winter, the lawn is about 6 ° higher than the bare ground, and the humidity on the lawn is generally about 18.12% higher than the bare ground, creating a cooler, comfortable, no pollution sports environment, so the higher the ecological benefit of the football field lawn. Easier it is to promote participatory and ornamental consumption patterns, therefore, the sports consumption structure is effectively upgraded and optimized. When the ecological benefits are not good, the regression factors of the physical consumption mode, the participatory consumption mode, and the ornamental consumption mode are 0.97, 0.04, and 0.02, respectively. When the ecological benefits of the lawn are getting better and better over time, the regression factors of the participatory consumption mode and the ornamental consumption mode reach a peak state in July, and the value is as high as 0.94 and 0.65, while the regression factor of the physical consumption mode is 0.14. The ecological benefits of lawns have a good balancing effect on the structure of sports consumption.

6. DISCUSSION

Under the concept of "green water and green mountains are golden mountains and silver mountains" and the development concepts of innovation, coordination, green, openness, and sharing, China's ecological civilization construction has entered a period of victory. To deepen reform and achieve progress in the construction of ecological civilization, it is necessary to vigorously improve the ecological environment. At present, the development of China's sports industry is in a critical period of structural transformation, to promote the high-quality development of the sports industry, starting from the ecological benefits of the stadium lawn, the following development suggestions are proposed:

1. Continue to deepen the construction of the lawn ecological benefit system, vigorously advocate the concept of healthy sports consumption, and promote the positive growth of the economy in the sports field to enhance the level of ecological benefits in China and enhance its positive role in promoting the transformation and upgrading of residents' sports consumption.

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2. Actively implement the concept of ecological civilization construction, give play to its coordinated role in promoting the upgrading of sports consumption, scientifically formulate ecological environment planning policies in the context of the new development stage, new development concept, and new development pattern, adhere to the concept of green development in the process of sports industry development, promote the high-quality development of the sports industry by strengthening ecological benefits, and realize the transformation and upgrading of the sports consumption structure.

7. CONCLUSION

As a way of socializing in people's daily lives, sports are inevitably affected by environmental changes, and existing research has not yet introduced ecological and environmental factors into the field of sports consumption and sports industry research. Therefore, this paper studies the influence of the turf ecology of the football field on the consumption level, consumption structure, and consumption motivation of the residents, and uses the time series stationarity test method and the multiple regression analysis method to verify the comprehensive application of the lawn ecology of the football field in enhancing the intention of sports consumption, and finally, the following research conclusions are obtained:

1. With its strong dust retention capacity and adsorption capacity, the stadium lawn can encourage more people to effectively participate in football sports activities, improve the sports consumption structure, change the proportion of physical consumption, participatory sports consumption, and ornamental sports consumption, and change the three proportions from 83.82%, 45.86%, and 35.2% to 37.12%, 59.71%, and 69.74% respectively.

2. Football stadiums as part of urban greening, applied to urban planning and construction are of great significance, lawn ecology can improve the quality of human settlements, to pursue a more comfortable quality of life, and the construction of football stadium funds will have more investment, to a certain extent to increase the consumption level of more than 5,000 yuan.

3. After the purification and absorption of the lawn, part of the harmful gases in the atmosphere are dissipated, and some are beneficially transformed, which strengthens the ecological level and health of the stadium environment, and guides the motivation of sports consumption from a more symbolic display of personality, status symbols, and social entertainment to a sportsmanlike physique, pastime, and spiritual enjoyment.

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/16/

SUSTAINABLE DEVELOPMENT OF VOCAL MUSIC ECOLOGY IN A DIGITAL ECOLOGICAL ENVIRONMENT

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ABSTRACT

The phenomenon of noise interference during vocal transmission can lead to the problem of poor vocal transmission quality. This paper proposes a study on the sustainability of vocal ecology in a digital ecological environment. First, the matching tracking algorithm can extract the time-frequency characteristics of the effective signal, attenuate the interference of noise, and improve the propagation quality. A sustainable development GA-BP network model is established, and the adjustment amount of each weighting coefficient is obtained according to the gradient algorithm and using the inertia adjustment strategy. The coordination is regulated through feedback control strategies to ultimately achieve ecological sustainability of vocal music. The analysis results show that the average relative error of the simulation prediction of the sustainable development GA-BP network model is 3.54%, the maximum relative error is 8.11%, and the average relative error is within 5% of 70%. It has significant superiority and high efficiency in comparison with the prediction degree of the traditional model.

KEYWORDS

Digital ecology; Vocal ecology; Sustainability; Time-frequency characteristics; GA-BP model

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ABSTRACT

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1. INTRODUCTION

At this stage, traditional vocal music has faced an increasing crisis of survival, and many of these varieties have reached a situation where there is no one to succeed them and they are on the verge of being lost [1]. Therefore, the question of how to develop the economy while preserving this cultural heritage from its impact is becoming more and more of a challenge for the vocal community. Whether the traditional vocal music is preserved in a "museum style" or in a dynamic process of "moving without changing shape", there are various ways to preserve it [2-4]. However, the fundamental reason for the current crisis of traditional vocal music lies in the changing ecological environment and the "imbalance" in the development of Chinese vocal music culture [5-7]. Therefore, the conservation and development of traditional vocal music must not deviate from traditional vocal music and its related ecosystem, and must not deviate from the direction of development recognized by contemporary human society, which is the path of "sustainable development" [8-11].

Ecosystem was originally a natural science concept for studying the relationship between organisms and their living environment, which was later used by other humanities and social science scholars [12-15]. The so-called ecosystem of traditional vocal music is the state of existence of traditional vocal music and its relationship with the surrounding cultural vein [16-19]. According to this definition, the author not only focuses on traditional vocal music in this paper, but also places it in a broader context to examine the mechanism of interaction, interdependence, and interconstraint between it and the natural, economic, and cultural environments at different stages of human civilization's development [20-22].

The concept of sustainable development means that not only can the needs of modern people be met, but more importantly its ability to allow future generations to take a more reasonable interest in it and give full play to its utility [23]. It is an inevitable trend for vocal ecology to take the path of sustainable development [24]. Many people have different views on it, regardless of any viewpoint, its final purpose is that vocal music can take a sustainable path. So that vocal music can endure in the world of music and not be replaced or disappear [25].

The literature [26] found that the Birmingham School transformed popular vocal music, film, television, advertising, and other forms of popular culture from a condemned "other" to an "I" worthy of understanding and study. As a form of text, vocal music conceals different ideological positions behind its text. To achieve a "common and beneficial" vocal cultural ecology, it is necessary to construct a vocal cultural ecology model by taking people's intervention and two-way dialogue as the basic path. In the literature [27], it is argued that the demand for education has greatly increased with the popularization of Internet informatization, and so has the teaching of vocal music in universities. Nowadays, digitalization has gradually become a main trend on university campuses, and it is a big trend not only in China but even in the international arena. Thus, university vocal teaching should make full use of the digital campus environment and take advantage of this condition of exogenous factors, and university vocal teaching can also enter a new mode and make continuous progress. Therefore, teachers in university vocal music teaching should first change their teaching concepts and develop their information literacy skills, so that they can make university vocal music education compatible with the digital campus environment. The article mainly analyzes how university vocal teachers should change their concepts and correctly use digital thinking to reform university vocal music. Then the teaching concept is updated, information literacy is cultivated, and the reform of the university vocal music teaching mode is actively carried out. The teacher's successful change of teaching concept is the full use of the digital campus environment, which is conducive to the reform of the university vocal music teaching mode. The literature [28] argues that folk vocal music is a very important type of vocal music at present, and it is developing rapidly all over the world. Folk vocal music is a kind of embodiment of national culture, and its good development and dissemination is the development and dissemination of national culture. The new media environment provides a better platform for propaganda and development, and through the corresponding technology to achieve better results, so that the national culture can also be well reflected. According to literature [29], the emergence of Massive Open Online Course (MOOC), a large-scale online course, has injected new vitality and vigor into global education reform. Universities in various countries have started a boom in building MOOC platforms, and vocal music teaching in universities has also joined the tide of reform. The literature [30] shows that the emergence of new media has had a profound impact on people, and vocal performance skills development is also deeply affected by the new media environment. Vocal performance also needs to adapt to the characteristics of the new media environment and meet the requirements of the new media environment. Compared with the traditional training method, the way to cultivate vocal performance skills in the new media environment has undergone a big change. The focus should be on innovation from stage design, new musical instruments, and the performers themselves, giving full play to the role of media communication to enhance the vocal performance skills of the performers. To help performers better express their vocal works and more fully embody the thoughts and emotions contained in the works.

To sum up, this paper further develops this issue based on the previous research. This paper proposes a study on the sustainable development of vocal ecology in the digital ecological environment. Unlike the above studies, this paper explores the sustainable development of vocal ecology from the perspective of a digital ecological environment. Through MP time-frequency feature extraction, the interference of noise is reduced to improve the quality of vocal music when it is transmitted. Then a sustainable GA-BP network model is constructed, and the coordination degree is adjusted by using a feedback control strategy. Finally, the sustainable development of vocal music ecology is realized.

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2. DIGITAL ECOSYSTEM

At this stage, cloud storage, cloud computing technology, mobile intelligent terminals, and other concepts are slowly blowing a new wave [31]. Social development operation timeout takes mobile data network as the key information period, and all kinds of Internet media are diverse. The integration and combination of a lot of information promote the rapid development of all walks of life. Therefore, it is particularly critical to the ability of data collection and sorting. From the perspective of communication, the original instrumental music is easier to spread than the simple method of "oral and heart-to-heart teaching" or the initial Internet media such as turntables, tapes, and short videos of television and radio. Today, the communication methods and regions of Internet media are more common, and the coordination ability of communication methods is more diversified. It has added a new opportunity to the spread and development trend of music art, thus adding new challenges.

The deep integration of digital technology and digital means with ecological environmental protection will help build a wise and efficient information system for ecological environmental management and provide strong support for improving the modernization of environmental governance. The party group meeting of the Ministry of Ecology and Environment also pointed out that the ecological and environmental system should effectively improve the ability to think and professional quality of the digital economy, and digitally help promote the modernization of the ecological and environmental governance system and governance capacity [32].

Vocal music communication under the protection of data and information ecological environment shows many new characteristics and realizes the change of communication methods from simplification to diversification. Traditionally, the production and transmission of vocal music is unilateral, and the transmission process is a simple, top-down linear process. Under the protection of data information ecological environment, vocal music communication methods will have great changes. No matter the founder of vocal music, the lecturer of management mode, or the audience, they can become part of the vocal music communication process. The whole process is closely connected and overlapped with each other. The communication and connection between these three subjects are immediately fair, which enriches the vocal communication methods [33]. Therefore, to complete the innovative development of vocal communication, we should first create a new core value of communication. Instead of sticking to traditional communication methods, we should think about the key points in the communication process and combine a new communication method. Under the complex network, we attach great importance to the demand of vocal music itself for creative quality. From the perspective of the audience, strive to write vocal classics close to life and full of positive energy, flexibly use Internet technology and network resources to communicate and exchange software development technology, constantly innovate communication concepts, and establish a sense of design and development of scientific and technological innovation.

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3. VOCAL ECOLOGICAL SUSTAINABILITY STRATEGY

3.1. MP TIME-FREQUENCY FEATURE EXTRACTION

Ecological environmental vocal signals are complex signals, consisting of multiple sounds and noises, and it is a difficult task to reduce noise interference and ensure vocal quality when propagating these sounds [34]. The key is how to extract features with better noise immunity. Frequency domain features are commonly used as Mel frequency cepstrum coefficients, while time-frequency domain representations are commonly used as short-time Fourier transform and wavelet transform. When extracting time-frequency features, the signal is decomposed into several waveforms that best match this signal, which are called time-frequency atoms. MP is a decomposition that selects the most suitable signal structure on a redundant dictionary of Gabor atoms to obtain a flexible, intuitive, and judgmental feature set. Therefore, the MP algorithm is proposed to be used to obtain effective time-frequency features.

As shown in Figure 1, the first step of the classification system is the front-end processing, which includes pre-processing and feature extraction. In the feature extraction stage, we extract the MFCC parameters, and MP time-frequency features.

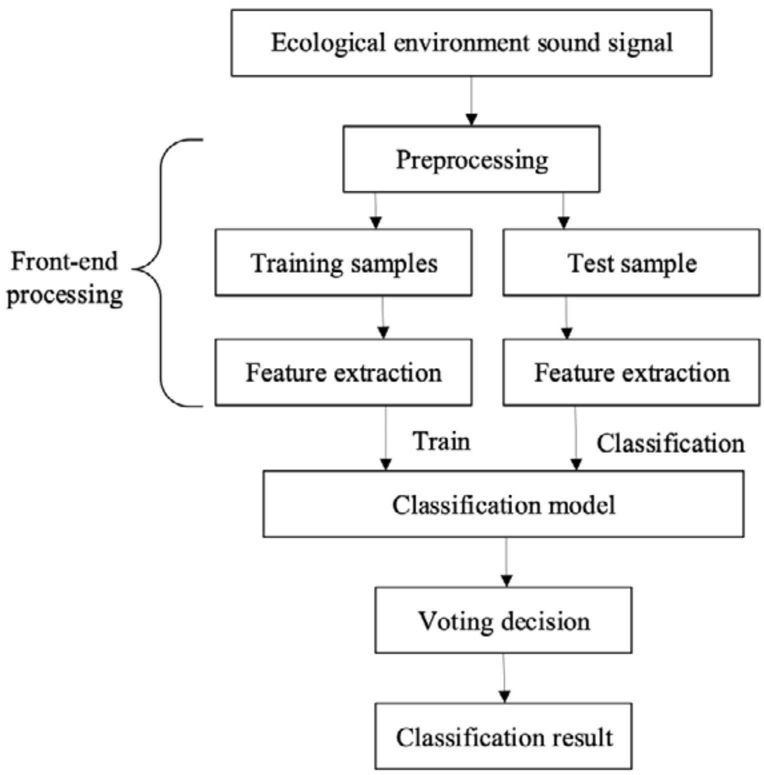

Figure 1. Classification system diagram of vocal ecology

All sound files were sampled using a sampling frequency of 11025Hz, 16 bits per sample, and polyphonic to monophonic conversion. Finally, all sound files were organized into two parts, one for training and the other for testing. The duration of

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each type of sound file used for training was 30 seconds, while each type of sound file used for testing had 20 files, each with a duration of 3 seconds.

The MFCC was analyzed from the perspective of the human ear's nonlinear psychological perception of frequency height, and a nonlinear Mel frequency scale was used to simulate the auditory system of the human ear. The specific steps for calculating MFCC parameters are as follows.

1. (1) Divide the ecological audio signal into a series of consecutive frames, here with Hanning windowed framing, each frame containing $N = 1024$ samples, adjacent frames with 512 samples overlap. The discrete power spectrum $x(n)$ is obtained by taking the square of the mode after the fast Fourier transform of each frame $x(n)$ after windowing.

2. (2) Design a filter set $H_m(n)$, $m = 0,1,\cdots,M-1,n = 0,1,\cdots N/2-1$ consisting of overlapping triangular bands, where $M = 36$, N is the number of samples of a frame, and these bands are nearly uniformly distributed on the Mel axis. Calculate the power value P_m, $m = 0,1,\cdots,M-1$ after passing through M triangular filter $H_m(n)$.

3. (3) Calculate the natural logarithm of P_m, and then further do the discrete cosine transform (DCT) to obtain a set of MFCC parameters $Mfcc_m$, $m = 0,1,\cdots,K-1$. The DC component $Mfcc_0$ is discarded, and the latter $K-1$ coefficients are taken as MFCC parameters. In this study, the K value is taken as 17, i.e., only 16 MFCC coefficients are extracted from each frame.

The basic idea of MP is based on the decomposability and reconstruction of the signal by adaptively searching for time-frequency atoms that can match the local features of the signal in an overcomplete library, and finally representing the signal as a linear combination of time-frequency atoms [35]. This algorithm provides a sparse linear expansion of the waveform to decompose the signal over an overcomplete function dictionary.

The following describes the main steps of the MP algorithm.

Need to make the dictionary D become a waveform with parameters φ_γ, denoted as follows:

$$D = \left\{ \varphi_\gamma : \gamma \in \Gamma \right\} \tag{1}$$

Here Γ as a set of parameters and φ_γ as elements. The information decomposition of a signal s can be expressed as:

$$s = \sum_{i=1}^{m} \alpha_{\gamma_i} \varphi_{\gamma_i} + R^{(m)} \tag{2}$$

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Here $R^{(m)}$ is the remainder. For a given s, m and D, get minimized $\gamma_i(i = 1,2,\cdots,m)$, $\alpha_{\gamma i}(i = 1,2,\cdots,m)$ that minimizes $R^{(m)}$.

The atom φ_{γ_0} As the first element, the details are as follows:

$$\left| < s, \varphi_{\gamma_0} > \right| \ddot{\text{O}} \left| < s, \varphi_{\gamma} > \right| \quad \forall \gamma \in \Gamma \tag{3}$$

The first operation extracts the atoms φ_{γ_0} from s, obtaining the remaining $R^{(0)}$. The formula is obtained as:

$$s^{(k)} = s^{(k-1)} + \alpha_k \varphi_{\gamma_k} \tag{4}$$

Where $\alpha_k = R^{(k-1)}$, $\varphi_{\gamma_k} >$ and $R^{(k)} = s - s^{(k)}$. The relationship between the approximate decomposition and the residual $R = R^{(m)}$ of the actual signal after m iterative operations is shown in Equation (2).

Since the decomposition based on Gabor time-frequency domain atoms is more flexible. Therefore, we construct the dictionary using the Gabor function, which is a sinusoidally modulated Gaussian function, and the discrete Gabor time-frequency atoms are represented as follows:

$$g_{s,u,\omega,\theta}(n) = \frac{K_{s,u,\omega,\theta}}{\sqrt{s}} e^{-\pi(n-u)2/s^2} \cos[2\pi\omega(n-u)+\theta] \tag{5}$$

Where $s \in \in^{+}$, u, $\omega \in$, $\theta \in [0,2\pi]$ and $K_{s,u,\omega,\theta}$ are normalization factors, so $\left\| g_{s,u,\omega,\theta} \right\|^2 = 1$, $\gamma = (s, u, \omega, \theta)$ is used to denote the parameters of the Ga- bor function. The atomic parameters of the Gabor dictionary in the MP algorithm are selected from the binary integer sequence. The proportion s corresponds to the width of the atom (which varies with time) and is obtained from the binary sequence $s = 2^p$, $1\tilde{\text{N}}p\tilde{\text{N}}m$ and the size of the atom is $N = 2^m$.

The framing process for extracting MP time-frequency features is the same as for extracting MF-CCs earlier, with 1024 samples per frame and 50% overlap.

3.2. GA-BP NETWORK MODELING

BP neural network can not only complete the input and output of discrete system projection but also complete self-learning and simple construction. However, the BP neural network training speed is relatively slow, so we must use an optimization algorithm to improve[36].

Genetic algorithm (GA) is an arbitrary global search and optimization method that follows the theory of natural selection and species evolution and develops rapidly [36]. By improving the BP neural network (GA-BP) according to the genetic algorithm, we can better get the initial weight value and threshold value of the neural network, prevent network training from falling into the local minimum value, and strengthen the

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convergence speed. The GA-BP network model of sustainable development is shown in Figure 2 below.

The network has high robustness and fault tolerance and can solve the impact of noise interference. Parameters and the size of the model are the key factors affecting the training speed of the network model. The network stores its learned parameters or weights in the main memory. Generally, the less weight the model has, the faster it will run. Select the feedback Hopfield network structure, as shown in Figure 2, including an input layer, an implicit layer, and an output layer. Of which:

1. Input layer neurons: demand influencing factors and supply influencing factors, a total of N (the same influencing factor is counted as one), neurons are noted as $\{Z_1, Z_2, \cdots, Z_N\}$;
2. Output layer neurons: the actual representation of coordination, only one;
3. Implied layer neurons: the number of neurons is M, neurons are recorded as $\{H_1, H_2, \cdots, H_M\}$.

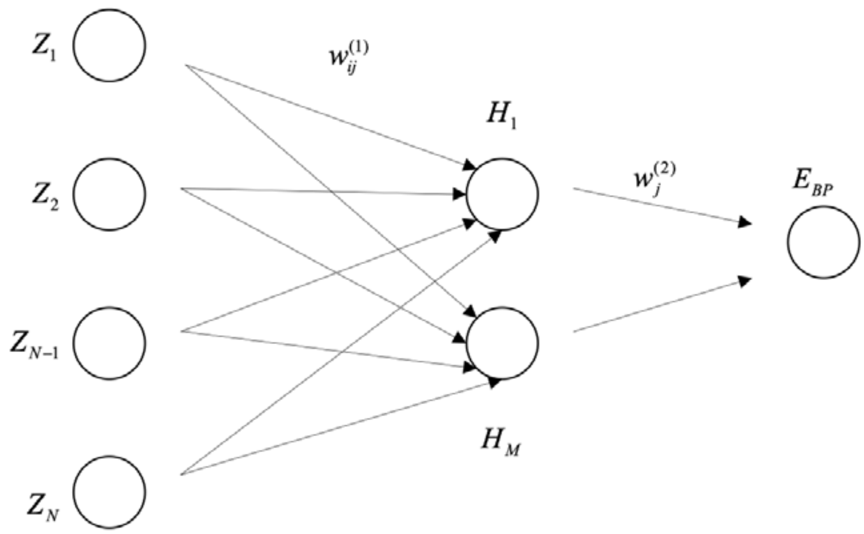

Figure 2. Sustainable development GA-BP network model

Let the connection weight coefficient from the input layer to the hidden layer be $W_{ij}^{(1)}(i = 1,2,\cdots, N; j = 1,2,\cdots, M)$. Let the node outputs of the hidden layer and the output layer of the $1(1 = 1,2,\cdots, n)$ training sample $(z_{11}, z_{12}, \cdots, z_{1n})$ be $h_{ij}(j = 1,2,\cdots, M)$ and v_1 respectively:

$$h_{1j} = f\left(\sum_{i=1}^{N} w_{ij}^{(1)} z_{1i}\right) \tag{6}$$

$$v_1 = f\left(\sum_{j=1}^{M} w_j^{(2)} h_{1i}\right) \tag{7}$$

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Where f is the Sigmoid function $f(x) = \left(1 + e^{-x}\right)^{-1}$.

Let the ideal output of the 1st training sample be θ_1, which is defined as:

$$\theta_1 = \begin{cases} 1, \rho \text{O} \rho^* \\ 0, \text{ Other} \end{cases} \tag{8}$$

Where $\rho *$ describes the coordination threshold. Then the total error of all sample outputs is defined as:

$$E_{BP} = \sum_{i=1}^{n} \left(v_1 - \theta_1\right)^2 \tag{9}$$

For the initial values of the randomly generated weight coefficients, there must be an error between the actual output and the desired output. In this paper, the error back propagation GA-BP algorithm is used to gradually reduce the total error by continuously learning the training samples and adjusting the weight coefficients, and the network learning process ends when the error reaches a specified level.

First, we calculate the output error squared and the partial derivatives concerning the weight coefficients separately:

$$\begin{cases} \dfrac{\partial E_{BP}}{\partial W_j^{(2)}} = \sum_{l=1}^{n} \dfrac{\partial E_{BP}}{\partial v_1} \dfrac{\partial v_1}{\partial W_j^{(2)}} \\ \dfrac{\partial E_{BP}}{\partial W_j^{(1)}} = \sum_{l=1}^{n} \dfrac{\partial E_{BP}}{\partial v_1} \dfrac{\partial v_1}{\partial h_{ij}} \dfrac{\partial h_{ij}}{\partial W_{ij}^{(1)}} \end{cases} \tag{10}$$

Secondly, according to the gradient algorithm and using the inertia adjustment strategy, the adjustment amount of each weight coefficient is obtained:

$$\begin{cases} \Delta W_j^{(2)}(t+1) = \varepsilon \left(-\dfrac{\partial E_{BP}}{\partial W_j^{(2)}}\right) + \delta \Delta W_j^{(2)}(t) \\ \Delta W_{ij}^{(1)}(t+1) = \varepsilon \left(-\dfrac{\partial E_{BP}}{\partial W_{ij}^{(1)}}\right) + \delta \Delta W_{ij}^{(1)}(t) \end{cases} \tag{11}$$

Where ε represents the training pace and δ represents the inertia coefficient. Finally, the equations are updated according to the coefficients entitled by equations (10) and (11), and the expressions are obtained as follows:

$$\begin{cases} W_j^{(2)}(t+1) = W_j^{(2)}(t) + \Delta W_j^{(2)}(t+1) \\ W_{ij}^{(1)}(t+1) = W_{ij}^{(1)}(s) + \Delta W_{ij}^{(1)}(t+1) \end{cases} \tag{12}$$

This paper designs a feedback control algorithm for the demand-supply influence factors. The adjustment quantity is determined as follows.

Let the sample state $\left(z_1, z_1, \cdots, z_N\right)$, whose components are the demand or supply influencing factors, if the coordination degree ρ of the sample does not reach the predetermined threshold $\rho*$, take the control strategy as follows: adjust z_k to $z_k + \Delta z_k$, where Δz_k is the adjustment amount of the response, specifically determined according to the following formula:

$$\begin{cases} f\left(\sum_{j=1}^{M} W_j^{(2)} h_j \right) \ddot{O} \rho^* \\ h_j = f\left(W_{kj}^{(1)} \Delta z_k + \sum_{i=1}^{N} W_{ij}^{(1)} z_i \right), j = 1, 2, \cdots, M \end{cases} \tag{13}$$

The value of the adjustment Δz_k of the state component z_k can be obtained by solving equation (13) backward according to Newton's iterative method.

4. ANALYSIS AND RESULTS

The contradiction between man and nature, development, and limitation is gradually recognized and has now become a hot spot for research. The concept of sustainable development is proposed in such a context. China's vocal ecology is gradually developing into one of the pillar industries of the national economy, so it is of great strategic importance to study the sustainable development of vocal ecology.

This paper takes SPSS software as the platform and uses a data-reduction module and neural networks module to simulate pca2rbfnn. The data from 324 months from January 1995 to December 2021 of the input layer index are used as the sample set, the data from 300 months from 1995 to 2021 are used as the training set, and the data from 24 months from 2020 to 2021 are used as the test samples for the test of the results. GA-BP neural network and BP neural network are used to predict respectively, and the root mean square error (MSE) and average relative error (MAPE) are compared and analyzed. To verify the efficiency of the vocal ecology sustainable development model established in this paper.

$$MAPE = \sum_{n=1}^{N} \frac{\left| \frac{y_n - \overline{y_n}}{y_n} \right|}{N} \tag{14}$$

$$MSE = \sqrt{\frac{1}{N} \sum_{n=1}^{N} \left(y_n - \overline{y_n}\right)^2} \tag{15}$$

Where y_n is the true value, $\overline{y_n}$ is the simulation prediction value, and $n = 1,2,\cdots,N$ is the number of test samples, which is 24.

In neural network training, the overall goal of Internet training is 0.001%, and the learning rate is 0.1. When the original weight value of a neural network is optimized,

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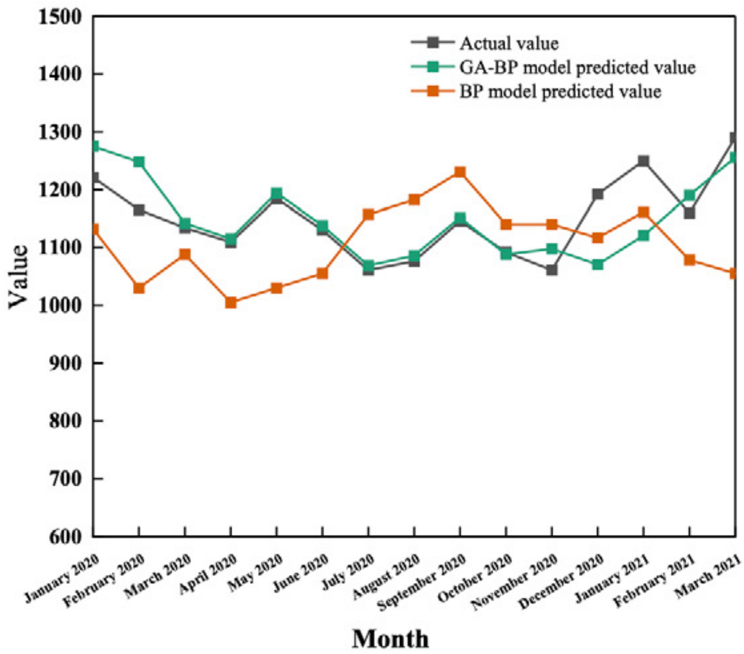
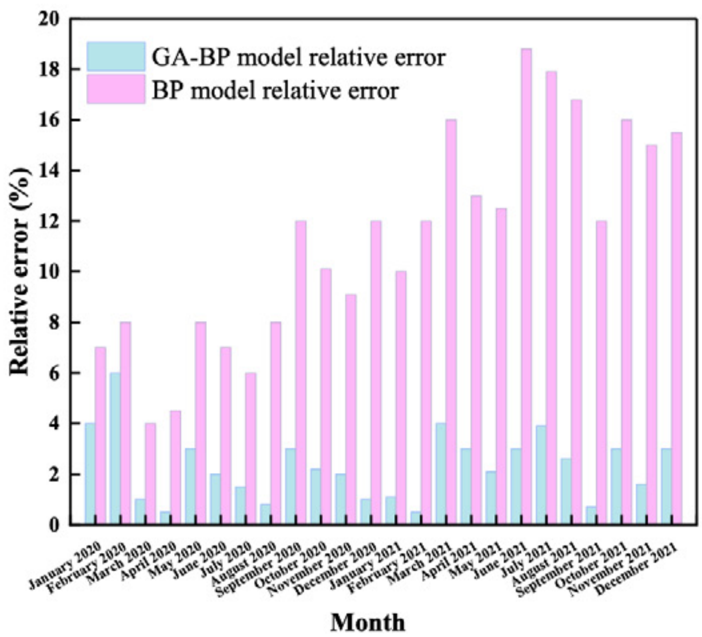
the population value is 100, the number of genetic iterations is 300, the value of crossover probability is 0.7, and the probability of gene variation is 0.005. The simulation training is carried out according to the neural network. The estimated conclusions from 2020 to 2021 are shown in Figure 3 below. The simulation error of the two modes is calculated according to table (14) and style (15), and the conclusion is shown in Table 1.



(a) Actual and simulated predicted values



(b) Forecast error percentage

Figure 3. Comparison of prediction values of different models from 2020-2021

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It can be seen that the built model compared to the traditional model from 2020 to 2021 can describe the general development trend of vocal music development trend.

The average relative error of simulation prediction of the GA-BP neural network model is 3.54%, the larger relative error is 8.11%, and the average relative error is 70% within 5%. The simulation and prediction effect of the GA-BP neural network is very good, and it can better grasp the transformation of vocal music development trends. The average relative error of the BP neural network is 10.16%, and the larger relative error is 14.50%. The MSE of the two neural network models is very large.

Table 1. Simulation performance comparison of neural network models

Method	GA-BP	
Mean square error	2591.98	19150.28
Average relative error (%)	3.54	10.16
Maximum relative error (%)	8.22	14.50
Convergence accuracy	5.96E+04	3.73E+03
Iterations	195	285

According to the construction performance of neural networks, and then the prediction and analysis accuracy of the Internet can be improved. By further improving the simulation performance, it can be found that the convergence accuracy and iteration times of the GA-BP neural network entity model are significantly better than those of the BP neural network entity model. In other words, the GA-BP neural network has a faster convergence rate and convergence accuracy than the traditional BP neural network, which shows that using an evolutionary algorithm to improve the BP neural network is effective. The deviation, convergence rate, and accuracy of prediction and analysis are better than the BP neural network, which is normative for vocal music dissemination, and can be used as the basis for distinguishing the development trend of vocal music green ecology.

As a key form of expression in the construction of spiritual civilization, music art has been increasingly emphasized by everyone. Under the protection of data ecological environment, collect and sort out different vocal music network resources according to data statistical analysis. Reasonable and effective dissemination of vocal plastic arts, the audience can get a variety of relatively satisfactory information content through simple retrieval, and provide convenient service items for everyone more purposefully and effectively. The dissemination theme is clear and perfect, giving the audience a multi-directional and integrated visual experience. At the same time, vocal music transmission saves a lot of time and network resources. Vocal music network resources can be continuously reused many times, further improving the dissemination efficiency.

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5. DISCUSSION

The vocal plastic arts of some groups are shared by others through the publication of social software, which promotes the transmission of such vocal music network resources for more people to appreciate. We should attach great importance to the interactive communication of all parts of the whole process of communication, identify problems as soon as possible, and understand the audience's feedback. In the indoor space of the Internet, strict supervision is also needed to maintain the Internet discipline of physical and mental health and harmony. Give warning and corresponding punishment for plagiarism. At the same time, we should focus on purifying the network environment, sort out unhealthy and depressed vocal music works, and give us active vocal music network resources.

6. CONCLUSION

In this paper, the sustainable development of vocal music ecology is studied from the perspective of a digital ecological environment. The vocal music sustainability model of the GA-BP network is constructed for prediction and comparative analysis, and the results show that.

1. A total of 324 months of data from 1995-2021 was used as the sample. The network training target is 0.001% and the learning rate is 0.1; in the process of optimizing the initial weights of the neural network by genetic algorithm, the number of populations is 100, the number of genetic iterations is 300, the value of crossover probability is 0.7 and the probability of variation is 0.005.

2. The vocal music sustainability development model of the GA-BP network was constructed and analyzed using monthly data, and the average relative error of simulation prediction was 3.54%. It indicates that the multi-input GA-BP neural network model based on monthly data can accurately predict the changing trend of vocal music ecological development, which has a certain guiding significance for the future development path of vocal music.

3. The maximum relative error of GA-BP neural network model simulation prediction is 8.22%, and the average relative error within 5% accounts for 70%, which indicates that the simulation prediction of GA-BP neural network is better and can reveal the trend change of vocal music development better.

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ASSESSMENT OF ENVIRONMENTAL CARRYING CAPACITY OF ECOTOURISM IN THE YELLOW RIVER ESTUARY

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ABSTRACT

Tourism environmental carrying capacity, a term born out of the booming development of the tourist industry and a basis for determining whether tourism activities negatively impact the environment, comes under the spotlight in the field of tourism research To preserve the exploitation of tourism resources in the Yellow River estuary, re-frame tourism structure and protect the environment, this paper dissected the current development and utilization of wetland tourism resources in the region and the corresponding resource advantages in virtue of SWOT and assessed the local ecotourism environmental carrying capacity by applying the evaluation model of ecotourism environmental carrying capacity. Years between 2017 and 2021 reported overweighted human social and economic activities in the Yellow River Estuary, proving the assessment outcomes. From 2017 to 2019, it dropped from 0.83 to 0.61, and then slowly and stabilized at this level. Fluctuations were found in the ecological and environmental assimilative capacity. The pollution-accepting capacity, between 2017 and 2018, increased from 1.3 to 1.8, dropped to some 0.61 from 2018 to 2019, and then rose to 1.35 by 2021. Judging from the economic growth in the area, these indicators were constantly rising. It follows that given ensuring ecological security, efforts should be doubled in studying the development of ecotourism in the Yellow River Estuary under the guidance of sustainable development theory, thereby carrying out tourism activities in phases and planned manner.

KEYWORDS

Yellow River estuary; Wetland; Ecological environment; Ecotourism; Tourism environmental carrying capacity

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ABSTRACT

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1. INTRODUCTION

Wetlands, along with forests and oceans, are among the three major ecosystem types in the world and are unique and most productive ecosystems on the Earth's surface due to the interaction of land and water [1-2]. It is one of the most biodiverse ecosystems in nature and one of the most important environments for human survival [3-5]. It is known as the "cradle of life", "birthplace of civilization" and "gene pool of species" [6-10], with ecological and social service functions such as water conservation, climate regulation, environmental purification, provision of resources, and leisure and tourism sites.

With the northward shift of China's economic development center of gravity, the Bohai Rim region, with Binhai New Area and Caofeidian Industrial Zone as its core, has rapidly emerged as a new "growth pole" for China's economy [11-13]. This initiative has promoted the process of economic and tourism integration in the Bohai Rim region, which has brought the Yellow River Estuary closer to other cities and tourism areas in the Bohai Rim [14-15]. In the integrated development of tourism around the Bohai Sea, the Yellow River estuary and the Beijing-Tianjin region form a good complementary urban tourism, with good external conditions for rapid development and its foundation, which can be built into an important segment of tourism development in the Bohai Sea region [16-19].

In many places, tourism is no longer a "smoke-free industry". Destructive construction and tourism development activities destroy the landscape environment and biological habitats of tourism sites, making the conflict between humans and nature more intense, endangering the survival of biological species and even the safety of humans themselves [20-23]. In this situation, the protection of the natural ecological environment got more attention to realize the harmony between humans and nature, and ecotourism developed to protect the ecological environment is naturally favored by more and more travelers [24-25]. With the increasing awareness of environmental protection, wetland ecotourism has emerged as a "green tourism" that "returns to nature" [26].

Foreign experts have conducted systematic studies on wetland tourism resources, and experts focus on the development, utilization, and protection of wetland tourism resources. In the literature [27], the hyperspectral data of Zhuhai-1 was used as the research data. The wetland classification method for hyperspectral data was explored using these experiments. The literature [28] identified the spatial-geographic scope analyzed the cultural, sports, and tourism points of interest, and explored the spatial distribution characteristics and changing trends of mixed resources in the Yellow River Basin based on data analysis. This study also makes suggestions for the development of cultural, sports, and tourism resources in the basin from different perspectives based on the theoretical model of development, aiming to promote the high-quality development of the region. The literature [29] addresses the strong interest in these resources that have been generated over the past few years. Visitors interested in them were found to gain knowledge, opportunities, experiences, and

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entertainment, while economic facilities (and the towns and regions in which they are located) can shape the image and brand and enhance their reputation. These benefits are important and are prerequisites to stimulate the development of these resources and link them to the destination's strategic plan for sustainable development. The literature [30] mainly studied the resources of the Yellow River estuary and Buzeen wetlands and proposed effective ways of managing the sustainable development of the resources. Through the management of tourist' activities and ecotourism awareness, the protection of wetland resources is enhanced, and the satisfaction of tourists and residents is effectively improved. From the research content, most of the studies focus on the development of wetland ecotourism resources and the planning of wetland ecotourism products. In particular, the research focuses on the coastal type and other lake and river-type wetland ecotourism sites, accounting for about 90% of the total number of studies. In terms of research methods, most of them adopt qualitative methods, lacking the support and depth of quantitative data, thus increasing the probability of the influence of human judgment factors. The study area is also mainly for different types of wetland ecotourism sites and mostly for wetland nature reserves. The Yellow River Delta is the last large river delta to be developed among the three major deltas in China, with obvious resource and location advantages and promising development prospects. Based on the study of the natural landscape pattern, the characteristics of the ecological resources and their tourism development potential should be analyzed to find out the effective ways and means suitable for the development of ecological tourism. The literature [31] takes the conservation and utilization of ecotourism as the development prospect. For the unstable structure and fragile ecological function, ecological restoration should be carried out according to local conditions to ensure water recharge and protect the native vegetation. It also carries out artificially assisted breeding and renewal, introduces and selects salt-tolerant plants, increases vegetation species, and improves vegetation coverage. The above literature shows that in accelerating the ecological tourism development of the Yellow River estuary, tourism resources are of great strategic importance in promoting economic and cultural construction and the coordinated development of the regional economy. The above research results fully recognize the special characteristics of ecological tourism development and focus on the goal of building an efficient ecological economic demonstration zone, developing protection and protection in development, and promoting the coordinated development of the regional economy and society.

The Yellow River estuary is the main body to promote regional economic development, location conditions, rich natural resources, and broad development prospects, the development of the Yellow River estuary ecotourism has important and far-reaching significance to the development of the entire province and city. To achieve good social and environmental benefits while better promoting the economic development of tourism, this paper conducts a SWOT analysis of ecotourism in the Yellow River estuary by assessing the environmental carrying capacity of the estuary. The advantages and disadvantages of ecotourism resources in the Yellow River estuary were obtained. The evaluation model of ecotourism environmental carrying

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capacity is established based on the self-purification capacity of the ecological environment system.

2. SWOT ANALYSIS OF ECOTOURISM IN THE YELLOW RIVER ESTUARY

Huanghekou eco-tourism has many advantages and opportunities. The unique wetland ecotourism resources, convenient location, high-quality ecological environment, strong government support, the strategic opportunity of "Shandong on land and Shandong on the sea" and ecotourism gradually become the main direction of tourism consumption. SWOT analysis can make a study of the scenario in which the research object is located. Therefore, it has certain applicability to the ecotourism of the Yellow River Estuary. The SWOT matrix analyzes the situation of ecotourism from four aspects: strengths, weaknesses, opportunities, and threats, as shown in Figure 1. The analysis shows that the Yellow River estuary wetland ecotourism development has both advantages and disadvantages, and opportunities and challenges coexist. To make full use of these advantages and opportunities, to overcome the shortcomings and disadvantages, to meet the challenges, to create tourism products with characteristics, to establish their brand, and to improve the core competitiveness of the scenic area.

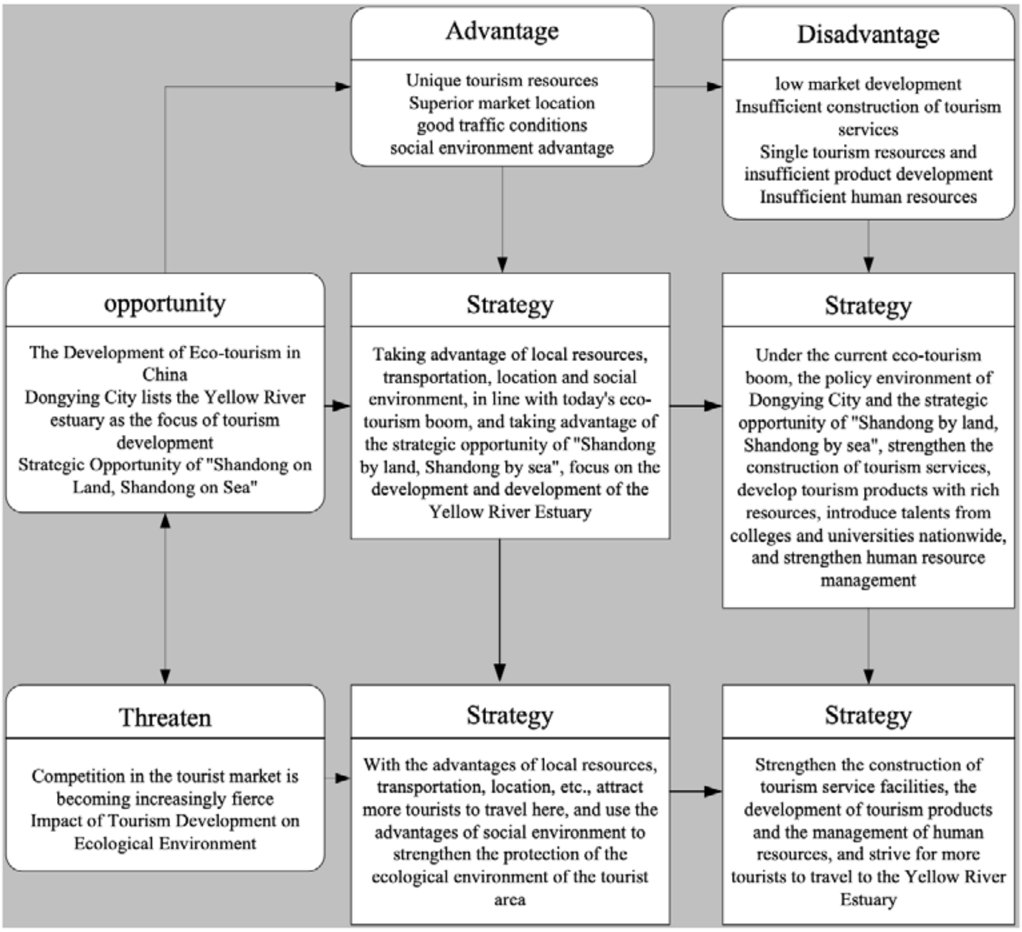

Figure 1. SWOT matrix analysis

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2.1. ADVANTAGES

Unique tourism resources. Located at the mouth, the Yellow River Estuary Ecotourism Area is the most typical coastal estuarine wetland and the most important migratory bird habitat in China, with well-preserved natural resources, providing a good resource base for developing true ecotourism. The Yellow River estuary is also the second largest oil industry base in China, with the estuary's pristine landscape forming a strong contrast to the modern oil fields, giving a visual impact. Such tourism resource characteristics and resource combination forms can be considered national or even world-class for scientific examination, science education, tourism, and leisure vacation [32-34].

Superior market location. Huanghekou is in the center of China's Bohai Sea economic belt and the Yellow River economic belt, and the Liaodong Peninsula across the sea is the Jiaodong Peninsula north to Beijing, Tianjin, and Tang, the development of the hinterland including North China, Northeast China, the lower and middle Yangtze River provinces, the Pearl River Delta and the central and western regions.

Good transportation conditions. Based on the Shengli oilfield, the transportation infrastructure is good, and there are convenient transportation conditions between Huanghekou and domestic and foreign countries. At present, Huanghekou has convenient highway and railroad traffic access to all major cities in China, which is greatly improved. Small and medium-sized aircraft can land on the airport runway, so the Yellow River estuary has a multifunctional transportation network of roads, railroads, waterways, and airways [35-37].

Social environment advantage. The development of tourism as a breakthrough to promote local economic development, increased tourism development, and the formulation of relevant preferential policies, the development of tourism has become a social consensus.

2.2. DISADVANTAGES

Low degree of market development. The degree of development of the source market is low, the attractiveness to tourists is not enough, and the market-oriented operation method is not very mature.

Insufficient construction of tourism services. Modern tourism competition includes the promotion service to the source of tourists, tourism in the food, accommodation, travel, and other services to product after-sales service and other tourism service competition. Good tourism services need modern tourism service reception facilities but also need a high level and high quality of professional service management personnel, the Yellow River mouth is currently facing a shortage of talent problem.

Tourism resources single, and product development is insufficient. Huanghekou tourism resources, although unique, the current lack of boutiques and highlights, and

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landscape quality seasonal differences are great, tourism off-peak season contradiction is prominent. Tourism product development is less and lack of boutique and personalized tourism products.

Insufficient human resources. The competition of the modern tourism industry with business training and human resources with higher education in tourism is an important element of competition and an important factor in the soft environment of tourism development, and Huanghekou is insufficient in this regard.

2.3. OPPORTUNITIES

The development of eco-tourism in China. The booming tourism industry provides a good opportunity for the development of the Yellow River Estuary. With modernization and economic and social development, tourism is gradually shifting to "green" ecotourism. The Yellow River Estuary is a real and original ecotourism area, which will be favored by domestic and foreign tourists.

The Yellow River estuary is the focus of tourism development. The Yellow River estuary occupies tourism resources including the natural landscape with the ecology of the Yellow River estuary wetlands, the modern industrial landscape with oil as the main theme, and the ancient Qi culture as the theme of historical and humanistic tourism resources in two of the three pieces, and want to make the Yellow River estuary to become the city's tourism development to drive the "frontrunner".

The development strategy of "Shandong on Land and Shandong on Sea" provides an opportunity for the development of tourism. To revitalize the development of tourism, the strategy of "Shandong on Land and Shandong on Sea" is proposed, and the Yellow River estuary is the center of gravity of "Shandong on Land" and Bohai Bay is the center of gravity of "Shandong on Sea". The Yellow River estuary is a combination of "Shandong on land and Shandong on the sea". This development strategy provides a good opportunity for the development of eco-tourism in Huanghekou.

2.4. THREATS

Increasing competition in the tourism source market. According to statistics, 24 out of 31 Chinese provinces and cities have made tourism a key development industry. The proximity of Huanghekou to the Dalian seaside and Qingdao seaside, and the many famous domestic attractions around, have affected the number of tourists visiting Huanghekou to some extent. However, if Huanghekou can be successful in tourism image planning, tourism product development, and tourism product promotion, borrowing the surrounding area tourist attractions will play a role in the formation and development of the Huanghekou source market.

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Yellow River estuary's ecological environment is more sensitive and fragile, in the development of the slightest carelessness, it will cause the reverse environmental succession, directly affecting the quality and benefits of ecotourism. The breakage of the Yellow River, ice ribs, and storm surge hazards are all due to ecotourism and wetland ecosystem threats.

3. EVALUATION MODEL OF ECOTOURISM ENVIRONMENTAL CARRYING CAPACITY BASED ON THE SELF-PURIFICATION OF ECOSYSTEM

The ecotourism environment carrying capacity refers to the tourism intensity that the natural ecological environment of the tourism area can withstand without degradation within a certain period. Research shows that the ecological environment system itself has a certain regeneration capacity. The purpose of determining the environmental carrying capacity of ecotourism is to control the impact of tourism on the environment within the range of environmental regeneration capacity, that is, the environmental impact caused by tourism activities (such as the adverse impact of tourism activities on vegetation) shall not break through the regeneration capacity. At the same time, the self-cleaning capacity of the natural environment can completely absorb and purify the pollutants produced by tourists (e.g., pollution of the water bodies of tourist sites by tourism activities); around these two requirements, a series of assessment models for the carrying capacity of the tourism environment are established.

This type of model assumes that the environmental impacts caused by tourism activities can be controlled to a reasonable extent through strict management, and thus the ecological carrying capacity of the tourism environment depends on the ability of the natural ecosystem to purify and absorb tourism pollutants and the amount of pollutants produced by tourists per unit of time. Based on this assumption, some researchers have established the formula for measuring the carrying capacity of the tourism environment:

$$EEBC = \mathrm{win}(WEC, AEC, SEC) \tag{1}$$

Where: $EEBC$ is the ecological environment carrying capacity, take the minimum value of the three components WEC, AEC, SEC. WEC is the water environment carrying capacity (with the water surface as the main tourist resource, take = sewage port treatment capacity / per capita sewage generation, not with the water surface as a tourist attraction or does not constitute the main environmental factors, then take infinity). AEC is the atmospheric carrying capacity (for tourism activities that do not generate atmospheric pollution, infinity is desirable. (When atmospheric pollution is generated, AEC A = regional atmospheric environmental capacity / per capita exhaust gas generation). SEC is the carrying capacity of solid waste generation (SEC = daily solid waste capacity / average daily solid waste generation per person).

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Based on this concept, a more intuitive measurement model was developed as shown in Equation 2.

$$F_0 = \sum_{i=1}^{n} S_i T_i / \sum_{i=1}^{n} P_i \tag{2}$$

Where: F_0 is the ecological carrying capacity (daily carrying capacity), expressed as the maximum allowable amount of tourists received per day, P_i is the amount of pollutant i produced by each tourist per day, S_i is the amount of the ith pollutant purified and absorbed by the natural ecological environment, T_i is the self-purification time of various pollutants, n is the number of tourism pollutant types. Considering that tourist attractions generally treat pollutants artificially, thus expanding the pollution absorption capacity of the natural environment. The above formula is amended to formula 3:

$$F = \left(\sum_{i=1}^{n} S_i T_i + \sum_{i=1}^{n} Q_i \right) / \sum_{i=1}^{n} P_i \tag{3}$$

Where F is the extended ecological capacity; Q_i is the amount of pollutant i that is treated manually each day.

4. RESULTS AND ANALYSIS

4.1. ECOTOURISM ECONOMIC DEVELOPMENT BEARING STATUS

From 2017 to 2021 human socio-economic development is over-carrying, and its pressure mainly shows a trend of gradual increase and stabilization. The carrying capacity value of human socio-economic development calculated by the evaluation model of ecotourism environment carrying capacity, decreases from 0.83 to 0.61 from 2017 to 2019 and then shows a trend of slow stabilization at this level. It can be seen that the pressure of human socio-economic development on regional resources and ecological environment still exists and is likely to persist for a long time, although the rate is slowing down, the trend has not changed. To further analyze the pressure brought by human socio-economic development to the Yellow River estuary region, this paper analyzes the pollution elements according to the results of the evaluation model assigned to the ecotourism environmental carrying capacity of the ecological system self-cleaning, and the population, socio-economic and ecological environment in the category layer human socio-economic development as shown in Figure 2.

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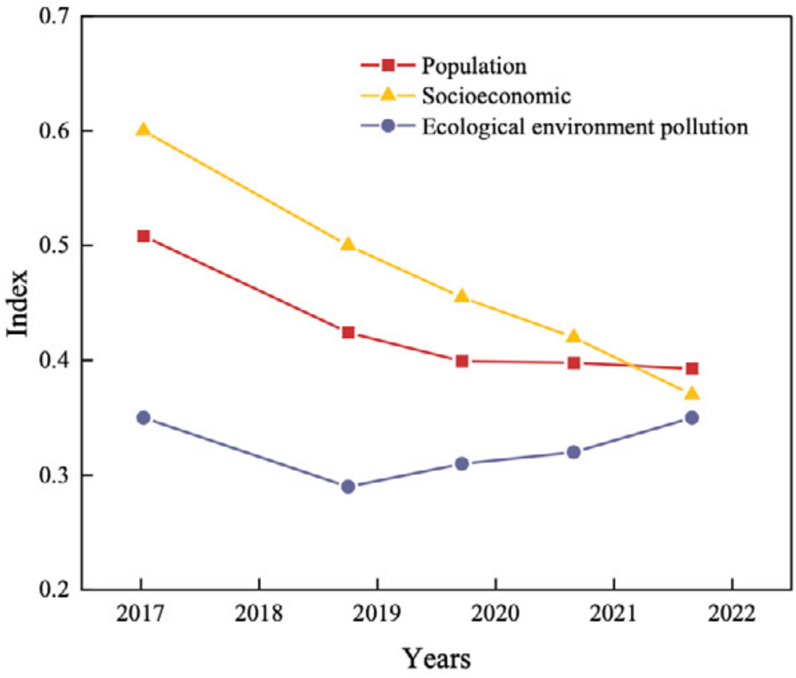

Figure 2. Changes in population, socio-economic, and ecological pollution

As can be seen from Figure 2, the three elements of population, social economy, and ecological environment pollution are in the overload state, and ecological environment pollution has been the dominant element of overload from 2017 to 2021, followed by economic development. The ecological and environmental carrying capacity has been at a low level between 0.25 and 0.35 since 2018, with the lowest value reaching 0.26. The indicators in the factor layer include population size, marine industry output value, wastewater discharge, mariculture area, and red tide occurrence area. With the rapid economic development, the average annual growth rate of the total industrial output value from 2017 to 2021 is 28.7%, which is higher than the national average of 12.1% during the 15th Five-Year Plan. The rapid development of population and rough industries inevitably brings a large increase of pollutants such as wastewater, COD, and ammonia nitrogen, leading to the deterioration of marine ecology and the expansion of the area where red tide occurs, etc. From the current economic development of the Yellow River Estuary region these indicators are expanding, and at the same time, with the Binhai New Area and the Yellow River Delta Efficient Ecological Zone rising as national strategies, this growth trend will be inevitable in a longer period, and at the same time, it will bring great challenges to the ecological and environmental carrying capacity of the Yellow River estuary.

4.2. ANALYSIS OF ECOLOGICAL POLLUTION ABSORPTION CAPACITY

The ecological and environmental pollution carrying capacity of the Yellow River estuary region shows a fluctuating trend, from 2017 to 2018, the ecological and

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environmental pollution carrying capacity value increased from 1.3 to 1.8, decreased to about 0.61 in 2018-2019, and increased to 1.35 in 2021. the overall condition of the ecological and environmental pollution carrying capacity is good, and most of the time is within the bearable range. This is mainly because the carrying capacity of marine resources, ecology, and environment includes two aspects. On the one hand, is the ecological environment, and on the other hand is the human social support. Human social support plays a negative role in the economic development of human society, so it is considered in the overall pollution-carrying capacity. Human social support plays a leading role in the process of resource, ecological, and environmental carrying capacity of the Yellow River estuary. For further analysis, see Figure 3 for changes in ecological and environmental pollution carrying capacity of the Yellow River estuary region. From Figure 3, the carrying capacity of ecology and environmental pollution carrying capacity is mainly considered in three aspects, which are environmental pollution carrying capacity, ecological and environmental quality, and human society's support.

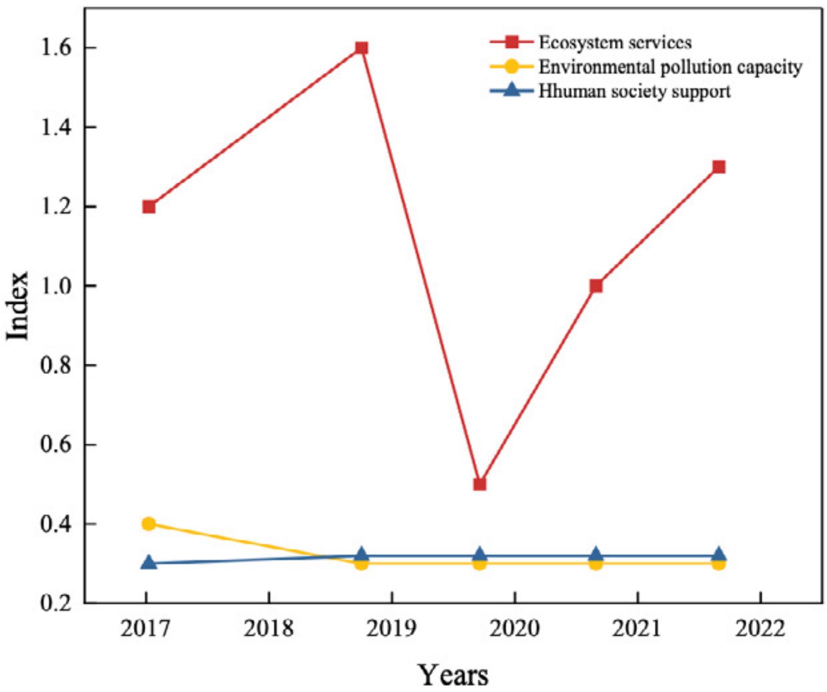

Figure 3. Changes in marine ecology and environmental pollution carrying capacity

The environmental pollution carrying capacity is over-carrying, showing a trend of first weakness and then strength. The main indicators considered for the environmental pollution carrying capacity are the environmental capacity of ammonia nitrogen and active phosphate. The upward trend is mainly due to the increase in wastewater and pollutant discharge compliance rates. In recent years, the investment in environmental protection infrastructure has been increased around the world, which has controlled the amount of wastewater and pollutants entering the sea at source, thus making the environmental pollution capacity of the Yellow River estuary effectively controlled. The ecological environment quality mainly includes two indicators: the ecosystem service function and the density of phytoplankton. From

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Figure 3, we can see that the ecological environment quality is very volatile, and the carrying status fluctuates above and below the carrying capacity critical value, which is in a more dangerous alert state. The ecological environment quality is the only element in the critical and bearable state of carrying capacity, and the ecological environment quality reflects the integrity and health of the ecosystem. The health of the ecosystem is directly related to the strength of marine resources and ecological environment carrying capacity. If we do not pay attention to it, it will easily lead to the overload condition of the region as a whole. Therefore, the health of marine ecosystems should be closely monitored. The carrying status of human support elements is in an overload state. From this, we can see that human support still has great potential. For example, we can increase the investment in environmental protection and improve the rate of sewage treatment. By improving the level of scientific research and innovating science and technology, it will play a useful role in improving the carrying capacity of the resources, ecology, and environment.

The analysis of the results of resource, ecological, and environmental carrying capacity shows that the Yellow River Estuary is generally in a bearable condition for resources and ecological environment from 2017 to 2021. However, the overall carrying level is low and at the edge of a near-critical carrying state, which needs to be paid high attention. The Yellow River estuary region is currently carrying very limited remaining space, the region's population, rapid socio-economic development, and excessive exploitation of the resources, are super-bearing. This has brought tremendous pressure to the resources and ecological environment. At present, if the ecological environment did not have a strong pollution-absorbing capacity, the Yellow River estuary region as a whole would be over-carrying. The quality of the marine ecosystem plays a leading role in the pollution-carrying capacity of the Yellow River estuary ecosystem. Thus, it can be seen that the health of the ecosystem can effectively improve the overall carrying level of resources, ecology, and environment.

5. DISCUSSION

To better develop the ecological tourism environment, can be satisfied by providing tourists with a good tourism environment and ecological knowledge education. At the same time, it constrains the behavior of tourists, requiring them to make their contribution to nature conservation while enjoying nature and receiving nature knowledge education. Ecotourism is inevitably the best way to combine people and nature and thus becomes the highlight of tourism. On the one hand, caring about getting the best level of satisfaction. On the other hand, people have increased their sense of responsibility for the environment of human development, and have begun to pay attention to how to make the best use of existing resources to meet the needs of the present while considering how to keep the resources that will meet their needs for future generations unimpaired and undamaged. As a kind of tourism with a sense of responsibility that has a special feeling for ecology and culture, this sense of responsibility of ecotourism is a strong guarantee for its development.

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6. CONCLUSION

Based on the results of the SWOT analysis of ecotourism, this paper assesses the current situation of the environmental carrying capacity of ecotourism by using the evaluation model of ecotourism environmental carrying capacity of ecological environmental system self-cleaning. Summarizing the whole paper, the following main research conclusions are drawn.

1. From the ecotourism economic development bearing status, human socio-economic development is in over-bearing status in 2017~2021. 2017~2019 decreases from 0.83 to 0.61, and then shows a trend of slow stabilization at this level. According to the ecological environment and socio-economic development, the development of ecotourism should be researched, which must be guided by the theory of sustainable development and carry out tourism activities in a systematic and planned manner under the premise of ensuring ecological safety.

2. The three elements of population, social economy, and ecological and environmental pollution are in the overload state, and ecological and environmental pollution has been the dominant element of overload from 2017 to 2021, followed by economic development. The ecological and environmental carrying capacity has been at a low level between 0.25 and 0.35 since 2018, with the lowest value reaching 0.26.

3. The ecological and environmental pollution-carrying capacity of the Yellow River estuary region shows a fluctuating trend, with the ecological and environmental pollution-carrying capacity value rising from 1.3 to 1.8 from 2017 to 2018, decreasing to about 0.61 from 2018 to 2019, and rising to 1.35 by 2021. Therefore, the management of ecotourism in the Yellow River estuary should be strengthened, mainly to maintain ecological balance, control ecological deterioration, environmental pollution, and artificial destruction of wetland landscape, and protect biodiversity. We establish scientific, perfect, reasonable, and effective management standards and measures in management, restrain and control relevant stakeholders, strengthen communication with local community residents, coordinate the interests between residents and ecotourism development, and promote the promotion of healthy and harmonious development of local tourism.

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EFFECTS OF OUTDOOR VOLLEYBALL EXERCISE ON CARDIORESPIRATORY FUNCTION UNDER A HEAVY HAZE ENVIRONMENT

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ABSTRACT

Haze has been one of the originators of the impact on human health. It is noteworthy that all functions of the human body can decline or even fail in a heavy haze environment. In this paper, the environmental monitoring website was used to count the data of meteorological and other natural factors as well as socio-economic influencing factors in the target cities over the past year. On this basis, the spatial and temporal distribution patterns of heavy haze weather were analyzed and studied. For the 100 volunteers who had been exposed to heavy haze pollution for a long time, the physical activity time of volleyball was classified into four levels using the quadratic method. Apart from that, a mixed linear model with fixed and random effects was constructed to explore the effects on cardiorespiratory fitness after outdoor volleyball exercise under a heavy haze environment. According to the model analysis results, the outdoor volleyball exercise had a significant interaction effect on pulmonary ventilation function in men only. Moreover, volleyball could be beneficial to the target group when the physical activity had not yet reached the level of high-level volleyball physical activity. This resulted in an improvement of 0.2L, 0.04L, 1.19%, and 0.03L in their pulmonary ventilation function indexes, respectively. However, the negative effects of a heavy haze environment were heavier after reaching a high-level degree. In addition, the indicator kept decreasing, from 2.04L, 1.13L, 63.63%, 1.99L to 1.98L, 1.04L, 60.78%, and 1.83L, respectively.

KEYWORDS

Heavy haze; Outdoor environment; Volleyball; Human cardiorespiratory fitness; Physical activity level.

INDEX

ABSTRACT

KEYWORDS

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5. **DISCUSSION**
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1. INTRODUCTION

Haze is one of the weather phenomena of atmospheric pollution. If there is haze in the air, the air at this time contains a large amount of particulate matter, such as dust, soot, and dust. These substances make the air more turbid and the visibility level decreases with it, usually below 10 km [1-3]. There is a clear difference between fog and haze. Since haze particles are generally distributed in the air in a uniform form, the visibility in the air is very uniform when haze weather occurs. There is a clear difference between fog and haze, as haze particles are generally distributed in the air in a uniform form, so when haze weather occurs, the visibility in the air is very uniform. Haze contains many particles that are harmful to the human body, and some of them can enter the interior of the human body directly through the respiratory tract and cause serious damage to the human body [4-5]. Haze contains mainly sulfuric acid-like substances and carbon particles. Since it contains more visible light and the scattering wavelength of these visible lights is longer, the haze seen by the naked eye is generally orange or yellow [6-8]. Most cities in China generally show an orange-gray color when the air appears polluted, because black carbon is one of the main atmospheric pollutants in China [9]. Unlike the effects caused by other severe weather, when haze occurs it is characterized by a wide area and long duration. Many harmful substances are contained in the air, especially absorbable particles that can enter the human body through the respiratory tract and can cause incalculable damage to humans [10-11].

With the rapid development of China's economy and technological reform, the size of China's economy has been expanding over time. At the same time, air pollution in China is increasing, especially in economically and industrially developed cities, and the number of accidents and deteriorations caused by air pollution is increasing [12-13]. In the original lexicon, "haze" was a natural phenomenon, which is a substance that causes an obstacle to visual distance [14-16]. Nowadays, it has evolved to be caused mainly by the pollution of the environment by human economic activities, so the protection of the environment should receive more and more attention [17].

With rapid economic development and rising national living standards, people have begun to pursue a healthy lifestyle, and more and more people are joining the ranks of exercise [18]. Due to the large population in China, indoor exercise places cannot meet the needs of the public, and outdoor exercise has become an important way for people to participate in exercise [19]. However, due to the aggravation of air pollution in recent years, whether outdoor exercise should be adhered to under air pollution conditions has led to extensive discussions [20-22]. The study of air pollution and exercise was first started by developed Western countries, however, with the rapid development of industrialization, air pollution in China has become increasingly serious and the exercise population has gradually increased. Therefore, it is necessary to investigate the relationship between air pollution and the physiological health of the outdoor exercise population in China [23-25].

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The effects of air pollution on the physical and mental health of exercising populations have received international attention. For example: the literature [26] investigated temporal changes in particulate matter exposure along urban waterfront trails. A recreational choice framework was used to examine the impact of visitor perceptions of air quality and health benefits on track usage. The average air quality during the collection period was "good" to "moderate". The results suggest that these empirical factors may influence leisure choice depending on other factors, such as significance. The literature [27] measured exertional spirometry and exertional expiratory volume in 1 second outdoors before and after two trials of 3200 m running. Subjective ratings of respiratory distress were quantified after exercise using a 10 cm visual analog scale. Results validation: PM2.5 differed ≥18 μg/m3 between trials. 3200 m run time did not differ between trials despite feeling more respiratory discomfort during the bad air trial compared to the good air trial. There was no significant difference in post-exercise exertional spirometry between low and high PM2.5 conditions. Ten healthy males were selected in the literature [28] and completed two 90-minute constant load cycling trials under trap or filtered air conditions. Metabolic profiles were evaluated using non-targeted analysis based on nuclear magnetic resonance metabolomics. Results showed that metabolic pathways for glycine and serine metabolism were altered during 30 minutes of exercise under TRAP conditions. Arginine and proline metabolism at 60 minutes of exercise; glycolysis at 90 minutes of exercise. The literature [29] was aimed at 80 non-smoking participants aged 16 to 21 years, using a bicycle ergometer for incremental testing, while measuring heart rate and ventilation per minute. A linear mixed model was constructed using data obtained from the cardiorespiratory exercise test. Ten individuals were randomly selected as an external validation group to assess predictive performance using an eight-fold cross-validation procedure. During the cardiorespiratory exercise test, air pollution concentrations were monitored and inhalation loads were calculated. Results validation: The median difference between ventilation measurements and predictions was 0.3 L/min and the difference between inhalation load based on fit and measurements was 0.0 to 0.3μg in all participants. In the literature [30], 30 healthy young men were invited to perform two separate 15-minute submaximal exercise trials on a cycle ergometer. The trials measured blood pressure, pulse oximetry, spirometry, and exhaled nitric oxide fraction. The results validated that the decrease in 1-second exertional expiratory volume/FVC following exercise at high air pollutant concentrations during the exposure test was significantly and negatively correlated with SO2, PM10, and PM2.5 concentrations. By collating and summarizing the current literature, the effects of air pollution on exercise were mainly studied in two aspects: the effects of air pollution on the physical and mental health of the outdoor exercise population, and the effects of air pollution on outdoor exercise behavior. However, most of the studies were conducted mainly on the hazards of air pollution on the physiological health of the exercise population.

When outdoor exercise is performed under air pollution conditions, it can lead to increased disease prevalence and reduced life expectancy once lung air pollutant deposition increases to a certain level. For this reason, in this paper, 100 volunteers

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were selected from regions with a more severe spatial and temporal distribution of haze, and the level of physical activity generated by outdoor volleyball exercise was grouped according to their cardiorespiratory fitness and total daily metabolic equivalent values using a quadratic approach. Based on a simple linear model, the effects of outdoor volleyball exercise on the heart and lungs in a heavy haze environment are discussed by combining continuous variables such as systolic blood pressure and diastolic blood pressure with categorical variables such as volleyball activity level. The purpose of the study was to increase awareness of cardiorespiratory health and physical activity in volleyball and to increase the importance of physical activity and the benefits of changing exercise patterns in a heavy haze environment.

2. CHARACTERISTICS OF SPATIAL AND TEMPORAL DISTRIBUTION OF HEAVY HAZE IN THE STUDY AREA

On the environmental monitoring website, the data of natural and, socio-economic influencing factors of the target city in the last year were counted to analyze and study the spatial and temporal distribution pattern of heavy haze weather [31-33]. The spatial distribution state of particulate matter concentrations in a year was analyzed based on the PM2.5 and PM10 concentrations counted in the city throughout the year [34-35]. Figure 1 is made based on the quarterly averages of PM2.5 and PM10 concentrations of polluting particulate matter at eight monitoring sites in the city throughout the year related to heavy haze weather, using spatial interpolation with GIS technology. This figure gives the spatial distribution of PM2.5 and PM10 concentration values of particulate matter in the target city for the last year, respectively [36].

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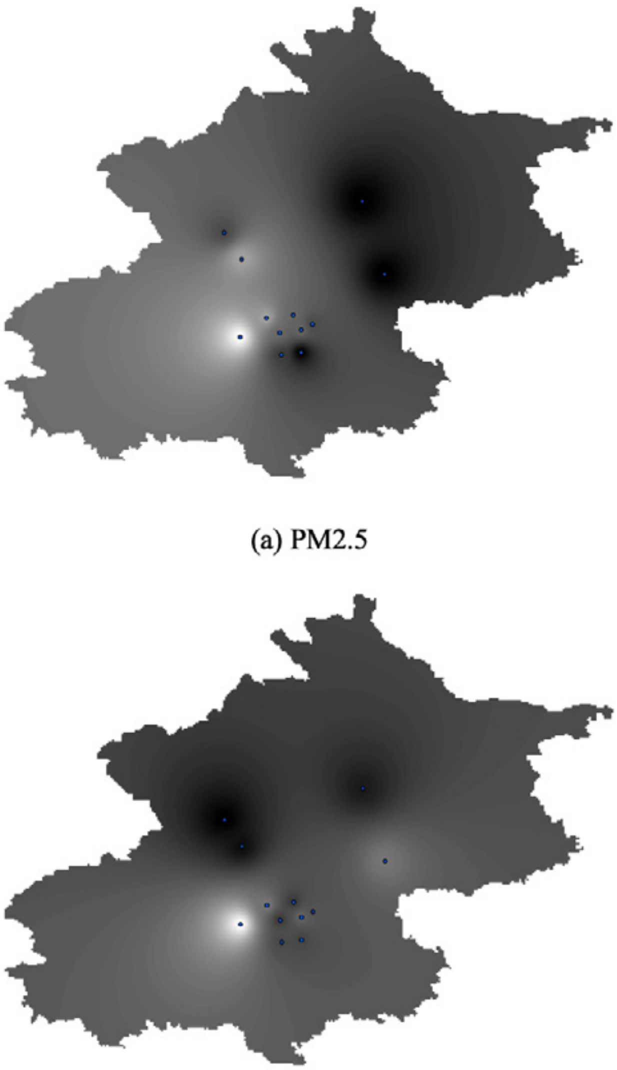

(a) PM2.5

(b) PM10

Figure 1. Spatial interpolation distribution of pollutants in different seasons under heavy haze environment

As can be seen from Figure 1, the concentration values of particulate matter in the same quarter have an uneven regional distribution in terms of spatial distribution. According to the current land use situation of the city, the concentration of polluting particulate matter decreases gradually from the city center to the outskirts of the city in a scattering pattern. The distribution of the same polluting particulate matter varies from season to season, with generally lower overall concentration values in spring and summer, and generally higher overall concentrations in autumn and winter. The generally low concentration values of these spring and summer pollutants are mainly influenced by meteorological conditions. Due to increased precipitation in spring and summer, rain has a purifying effect on pollutants, while high temperatures and high humidity in summer are also conducive to the diffusion of pollutants. And the overall concentration of polluting particulate matter is generally higher in autumn and winter, mainly due to the influence of pollution sources, and factors such as fireworks during

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the Spring Festival and dust storms in the north. Spatially, the overall pollution particulate concentration values are gradually decreasing from the city center to the outskirts of the city in a scattering pattern. The distribution trend of PM2.5 and PM10 concentration values of different pollutants varies with the quarter. However, their distribution states are similar in the same quarter, while remaining similar to the distribution states of haze. In summary, the pollutant particulate matter has uneven distribution in space, the more economically developed the region, the higher the pollutant concentration value, and vice versa, lower. Temporally, influenced by various factors such as pollution sources and meteorological elements, there are significant differences between different months and concentrations, showing cyclical changes, and mainly concentrated in the autumn and winter seasons.

3. RESEARCH ON THE EFFECT OF OUTDOOR VOLLEYBALL ON HUMAN CARDIORESPIRATORY FITNESS

3.1. SELECTION OF RESEARCH OBJECTIVES

To improve the accuracy of the research results, 100 volunteers aged 18 years or older who participated in the survey in the study area were selected as valid samples to explore the effect of outdoor volleyball exercise on human cardiorespiratory fitness in the region with long-term heavy haze pollution. Among them, the data of volunteers with missing data during the survey were excluded. The mean age of all study subjects was 28.94±0.55 years, including 64 males with a mean age of 32.11±0.38 years and 36 females with a mean age of 24.95±0.87 years. Physical activity level subgroups were classified according to the quartiles of the total daily metabolic equivalent values of the 100 study subjects included. The daily metabolic equivalents of the study subjects were solved by the following equation.

$$MET = \sum \left(MET_n \times H_n\right) \tag{1}$$

Where MET_n is the metabolic equivalent of volleyball exercise, and H_n is the average daily volleyball time. Figure 2(a) shows that body mass index, 1-second expiratory volume with force, volume-to-lung capacity ratio, maximum expiratory flow, and maximum oxygen uptake were greater in men than in women in the total study population. Quiet heart rate was greater in females than in males. The group sizes of males and females in different physical activity levels after volleyball exercise outdoors are shown in Figure 2(b). Due to the large range of physical activity time data in volleyball, the quartile method was used to classify the physical activity time in volleyball into four different classes. Those with average daily physical activity time of 0 to 69.4 minutes were classified as low grade, those with average daily physical activity time of 69.4 minutes to 110.5 minutes were classified as medium grade, those with average daily physical activity time of 110.5 minutes to 153.1 minutes were

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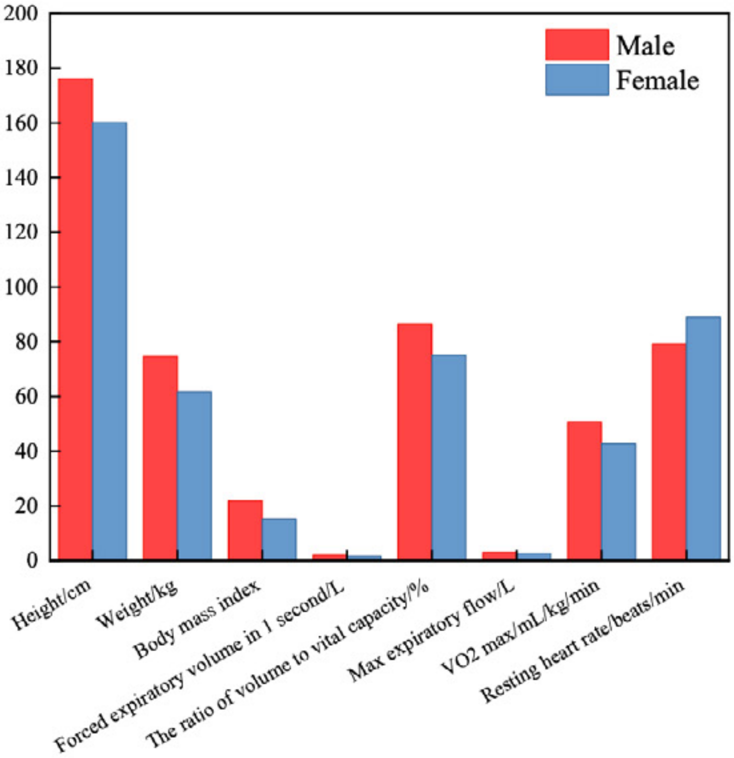
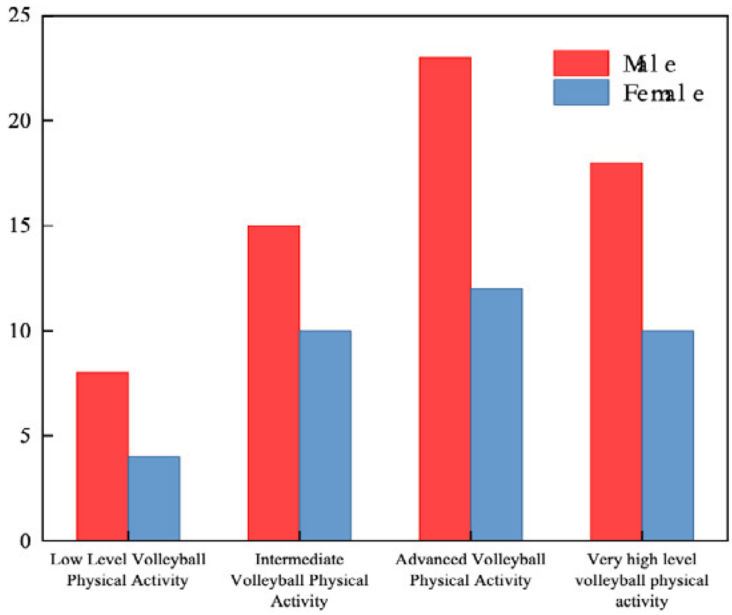
classified as high grade, and those with average daily physical activity time of 153.1 minutes or more were classified as very high grade [37].



(a) Mean value of physical indicators in normal condition



(b) Number of physical activity level groups for outdoor volleyball

Figure 2. Schematic diagram of the study population

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3.2. ANALYTICAL MODEL OF THE EFFECT OF OUTDOOR VOLLEYBALL EXERCISE ON CARDIORESPIRATORY FITNESS

In this study, a mixed linear model with fixed and random effects was used to investigate the relationship between volleyball exercise activity level and cardiorespiratory fitness in a heavy haze environment. The analysis involved continuous variables such as age, body mass index, systolic blood pressure, diastolic blood pressure, and volleyball exercise activity level, as well as categorical variables such as gender, body mass index classification, particulate matter category, and outdoor volleyball exercise activity level. The construction process of the mixed linear model is as follows.

A simple linear model was established with systolic or diastolic blood pressure as the independent variable and other variables as the dependent variables, as follows.

$$Y = XB + U \tag{2}$$

Where Y is the dependent variable; X is the independent variable; B is the estimated parameter matrix; and U is the error matrix.

Record the statistically significant variables in the simple linear model.

Gradually add a random variable to ensure the significant variables in step 2. At the same time, the performance of the model is evaluated using the bare pool informativeness criterion and the Bayesian information criterion auxiliary indicator. Step 3 is repeated until either the deficit pool informativeness criterion or the Bayesian information criterion for the potential candidate model is found [38-39].

Based on the potential model in step 3, two or more random variables are gradually added to determine the significant variables in step 2. At the same time, the bare pool informativeness criterion and the Bayesian information criterion are applied to the performance evaluation of the model. This step is repeated until a potential candidate model is found for either the deficit pool informativeness criterion or the Bayesian information criterion.

Adjust the random intercept in the random structure until the best model with the minimum value of the Bayesian information criterion is found.

Compare the models from steps 2, 3, 4, and 5 with the analysis of variance methods to obtain a significantly improved model. Based on the model structure, the effects of random variables are represented graphically.

Mixed linear model analysis was performed with systolic and diastolic blood pressure as dependent variables and age, height, weight, body mass index, metabolic equivalent, PM2.5-0day, PM2.5-7day, PM2.5-15day, PM2.5-30day, and PM2.5-60day as independent variables, respectively.

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The Pearson model was used to filter and compare multiple variables, and the dependent variable with the highest correlation with the cardiopulmonary dependent variable was selected for modeling to derive the index with the greatest impact on cardiopulmonary, resulting in the optimal model equation in systolic blood pressure.

$$hyper - value \sim 1 + age + height + (1 + weight/met - class) + (1/BMI - class) \tag{3}$$

The same modeling approach was used to select the higher correlation variables for diastolic pressure modeling, and in the diastolic pressure model, the optimal model was:

$$\begin{aligned} hyper - value \sim 1 &+ pmvalue * weight + age + (0 + age/met - class) + (1/gender) \\ &+ (weight/BMI - class) \end{aligned} \tag{4}$$

It was found that volleyball motor activity level classification and body mass index classification were important random terms in both systolic and diastolic models, and gender was an important random term in the diastolic model. Therefore, based on the results of the systolic and diastolic blood pressure models, gender, volleyball sports activity level, and their interactions were emphasized.

4. RESULTS AND ANALYSIS

Using the systolic optimal model and diastolic optimal model, the effects of volleyball exercise on the cardiopulmonary function of the target subjects under a heavy haze environment in the recent year were investigated. The model analysis results of the daily average of each cardiorespiratory function index shown in Figure 3 were obtained.

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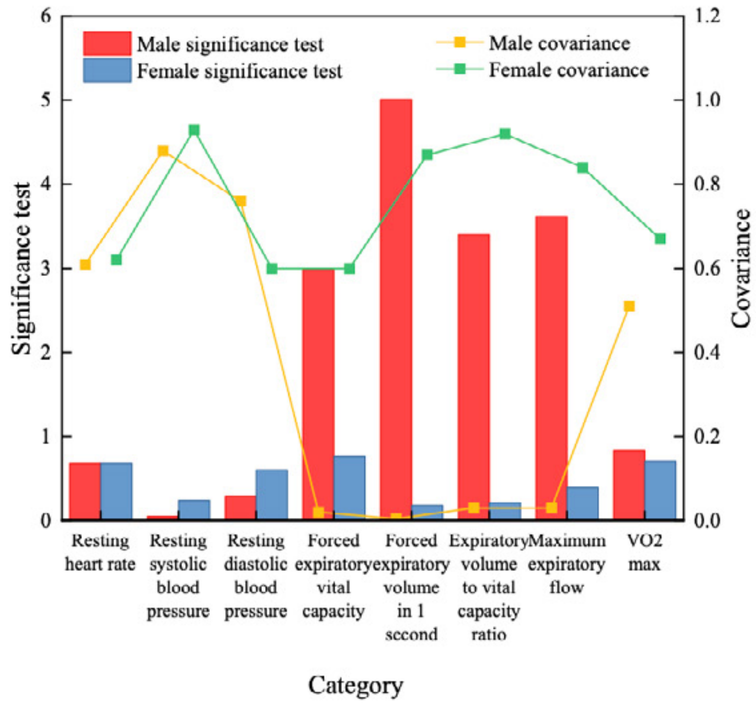
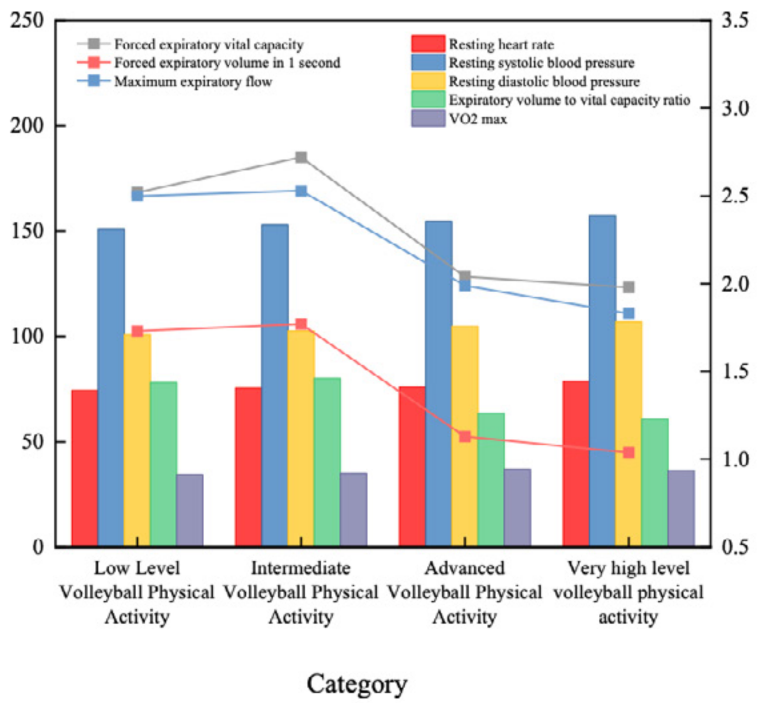


(a) Association test between volleyball and cardiopulmonary function by gender



(b) Cardiorespiratory fitness indices of men in different physical activity groups of volleyball

Figure 3. Effect of volleyball exercise on human cardiopulmonary function under heavy haze environment

The results of the association test analysis between volleyball exercise and cardiopulmonary function by gender (see Figure 3(a)). The significance test for quiet heart rate was 0.68 with a covariance of 0.61. The significance test for quiet systolic blood pressure was 0.05 with a covariance of 0.88. The significance test for quiet diastolic blood pressure was 0.29 with a covariance of 0.76. The significance test for expiratory volume per second was 2.99 with a covariance of 0.02. The significance test for expiratory volume per second was 5.01 with a covariance of 0.004. The significance test value of expiratory volume to spirometry ratio was 3.4 with a covariance of 0.03. The significance test value of maximum expiratory flow was 3.62 with a covariance of 0.03. The significance test value of maximum oxygen uptake was 0.83 with a covariance of 0.51.

Among them, the significance test values of quiet heart rate, quiet systolic blood pressure, quiet diastolic blood pressure indexes, and maximum oxygen uptake related to cardiac function were all less than 1, and the covariance values were all greater than 0.5. The above data indicate that significant interaction effects were found on four indexes of pulmonary ventilation function in men: expiratory lung volume with force, expiratory volume with force in 1 second, expiratory volume to lung volume ratio, and maximum expiratory flow. However, no interaction effect of volleyball exercise in a heavy haze environment was found on cardiac function and maximal oxygen uptake in males. For all cardiopulmonary function indicators in women, the significance test value for quiet heart rate was 0.68. the covariance was 0.62. the significance test value for quiet systolic blood pressure was 0.24 and the covariance was 0.93. The significance test for quiet diastolic blood pressure was 0.69 with a covariance of 0.6. The significance test for expiratory volume per second was 0.76 with a covariance of 0.6. The significance test for expiratory volume per second was 0.18 with a covariance of 0.87. The significance test for expiratory volume to spirometry was 0.21 with a covariance of 0.92. The significance test for maximum expiratory flow was 0.39 with a covariance of 0.84. The significance test for maximum oxygen uptake was 0.7 and the covariance was 0.67. The significance tests for all cardiopulmonary function indicators were less than 1 and the covariance was greater than 0.5, indicating that there was no significant interaction effect of volleyball on cardiac function, pulmonary ventilation, and maximum oxygen uptake in women in heavy haze. This revealed that volleyball physical activity in a heavy haze environment produces different health effects (predominantly on lung function) in study subjects of different genders, but the mechanisms involved are currently unclear. The main reason for this is that it is not clear whether the differences between genders are due to differences in physiological mechanisms or due to different social attributes. This may also contribute to the fact that no significant differences were found in pulmonary ventilation function in girls in this study.

Figure 3(b) presents an analysis of cardiopulmonary function indicators (except quiet heart rate, quiet systolic blood pressure, quiet diastolic blood pressure indicators, and maximum oxygen uptake) in men within different volleyball physical activity groups. The results showed that in the high-grade and very high-grade volleyball physical activity groups, the mean values of 1-second expiratory volume, expiratory volume to spirometry ratio, and maximum expiratory flow were lower than those in the low-grade and medium-grade volleyball physical activity groups. For

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significant cardiorespiratory function in the low-grade volleyball physical activity versus mid-grade volleyball physical activity groups, the longer the volleyball exercise time, the greater the index values (i.e., 2.72 L > 2.52 L, 1.77 L > 1.73 L, 80.1% > 78.91%, 2.53 L > 2.5 L). For cardiorespiratory fitness that was significant in the high-grade volleyball physical activity and very high-grade volleyball physical activity groups, the longer the duration of volleyball exercise, the smaller the index values (i.e., 1.98 L < 2.04 L, 1.04 L < 1.13 L, 60.78% < 63.63%, 1.83 L < 1.99 L). The reason for the results of this study may be that the benefits of volleyball exercise on human cardiorespiratory function outweigh the negative effects of heavy haze when the physical activity has not yet reached the level of high-grade volleyball physical activity. At this point, the higher the level of volleyball physical activity, the better the state of cardiorespiratory function. Volleyball brought greater physical benefits to the target group by lowering blood pressure and improving pulmonary ventilation and maximum oxygen uptake in the study subjects. It also completely suppressed the negative physical effects of fine and respirable particulate matter in a heavy haze environment. causing the target subject's expiratory lung volume with force, expiratory volume with force in 1 second, expiratory volume to lung volume ratio, and maximum expiratory flow rate to increase from 2.52 L, 1.73 L, 78.91%, and 2.5 L to 2.72 L, 1.77 L, 80.1%, and 2.53 L, respectively. but when physical activity reaches high levels of volleyball physical activity and above, not only is the respiratory rate typically faster, but also the probability is that breathing will be done through the mouth. This bypasses the filtration effect of the nasal cavity, leading to more pollutant inhalation, irritating the respiratory system, triggering inflammation, or obstructing the airway. At this point, the positive effects of volleyball on human cardiorespiratory function, such as lowering blood pressure, are far less than the risk of greater exposure of the human body to large amounts of particulate matter that accumulate at low altitudes and do not diffuse easily during breathing at faster respiratory rates. This results in the body's cardiorespiratory function being far more susceptible to the pollution conditions of a heavy haze environment than at low levels of volleyball physical activity versus medium levels of volleyball physical activity. This resulted in a significant decrease in the target subjects' forceful expiratory lung capacity, 1-second forceful expiratory volume, expiratory volume to lung capacity ratio, and maximum expiratory flow rate due to obstructive ventilation dysfunction, obstructive emphysema, respiratory ventilation dysfunction, restrictive ventilation dysfunction, or mixed ventilation dysfunction caused by heavy haze, from 2.04 L, 1.13 L, 63.63%, and 1.99 L, respectively decreased to 1.98 L, 1.04 L, 60.78%, and 1.83 L. In conclusion, excessive physical activity of volleyball in a heavy haze environment can aggravate the inhalation of respirable particulate matter, resulting in the negative effects of a heavy haze environment for the body, overriding the benefits of volleyball for the body.

5. DISCUSSION

For volleyball to achieve its essential role, the hazy environment needs to be effectively improved, but the improvement process takes time to achieve. During this time, volleyball players need to take protective measures to avoid damage to their cardiopulmonary function. The following measures are proposed for the improvement of the haze environment and the protection of volleyball:

1. Volleyball courts are mostly located in the square and other open areas close to the road so sportsmen are directly affected by the hazards of automobile exhaust. There are hundreds of undesirable substances in automobile exhaust. In addition, car exhaust also contains many types of polycyclic aromatic trails, which contain carcinogenic substances. Therefore, it is important to avoid inhaling automobile exhaust fumes as much as possible. The government should take appropriate means to reduce exhaust emissions by formulating reasonable policies to limit the number of vehicles.

2. Wear a professional mask and try to exercise indoors. In hazy weather, masks must be worn outside, and professional medical masks should be chosen. It is recommended to use anti-viral masks, in which the filter layer can filter out some of the bacteria in the haze. More indoor places such as gymnasiums or sports activity centers for volleyball can effectively reduce the amount of haze inhaled.

3. Minimize the consumption of stimulating foods. Since the air pressure is relatively low in hazy weather, groups with poor cardiorespiratory fitness should try not to engage in volleyball or other relatively strenuous exercise. You can eat more items such as pears and lilies. Garlic and shallots both have antiseptic effects, and more of the above-mentioned foods can be eaten in hazy weather to increase immunity.

6. CONCLUSION

Current air pollution levels are becoming increasingly severe, and heavy haze weather environments are strongly associated with increased morbidity and mortality from cardiopulmonary disease. People are increasingly concerned about physical health issues, and more and more people are involved in outdoor physical exercise and sports. Therefore, in this paper, the study population was selected based on the spatial and temporal distribution characteristics of heavy haze in the study area. Based on the quartiles of the daily total metabolic equivalent values of volunteers, the physical activity level groupings for outdoor volleyball were classified. A mixed linear model in which the independent variable was systolic or diastolic blood pressure was used to explore the relationship between the effects of outdoor volleyball exercise on cardiorespiratory fitness in a heavy haze environment, and three concluding points were obtained.

1. Volleyball physical activity in a heavy haze environment produces different health effects on study subjects of different genders. The significance test values for male forceful expiratory spirometry, 1-second forceful expiratory volume, expiratory volume to spirometry ratio, and maximum expiratory flow

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were all greater than 1, and the covariance values were all less than 0.5. Therefore, there was an interaction effect of volleyball exercise on pulmonary ventilation function in males. The significance test values of all cardiopulmonary function indexes in women were less than 1, and the covariance values were all greater than 0.5, so the interaction effect of volleyball exercise on women was not significant.

2. When physical activity has not yet reached the level of high-grade volleyball physical activity, the benefits of volleyball to human cardiorespiratory function outweigh the negative effects of heavy haze. Exercise improved pulmonary ventilation function and maximum oxygen uptake by lowering the blood pressure of the study subjects, resulting in an increase in their pulmonary ventilation function index from 2.52 L, 1.73 L, 78.91%, and 2.5 L to 2.72 L, 1.77 L, 80.1%, and 2.53L, respectively.

3. When physical activity reaches the level of advanced and very high volleyball physical activity, the filtering effect of the nasal cavity is bypassed due to the accelerated breathing rate. This resulted in a decrease in the lung ventilation function index of the target subjects from 2.04 L, 1.13 L, 63.63%, and 1.99 L to 1.98 L, 1.04 L, 60.78%, and 1.83 L, respectively.

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