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Evaluation of Smart City Construction and Optimization of City Brand Model under Neural Networks

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Abstract. The study aims to avoid the phenomenon that thousand cities seem the same in the construction of smart cities and the efforts of all walks of life are jointed to implement the construction of smart cities and the creation of city brands. First, the basic theory of smart city construction is introduced. Second, the restricting and promoting factors influencing smart city construction and development are analyzes, and the evaluation system of smart city development is established. Then, the model for smart city construction and development based on the neural network is implemented. Finally, some domestic cities are selected as the dataset to build a training model, and the city brand optimization strategy is proposed. On this basis, an evaluation system for smart city development based on the intelligent neural network and Grey relational analysis Back Propagation Neural Network (GRA-BPNN) is obtained. The entropy weight method (EWM), grey relational analysis (GRA) method and the evaluation method based on Technique for Order Preference by Similarity to an Ideal Solutionv (TOPSIS) are regarded as the members of the control group, and the results of different methods for evaluating the development of smart cities are compared. The results show that the modeling of smart city construction based on neural networks can help to implement an evaluation model for smart city construction and development, and it can help evaluate smart city construction and development accurately. And then the corresponding strategies are proposed to speed up the construction of smart cities with its local characteristics, and then city brands are built. Compared with other evaluation algorithms, the performance of the algorithm proposed is better and more stable and the evaluation results are more reasonable than those of the others, which can prove that the evaluation algorithm is feasible and scientific. This study provides a new idea for the application of deep learning to smart city construction and city brand building.

Keywords: Neural network model; Smart city; Construction and development; City brand.

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1. Introduction

With the progress of urbanization, the demand for economic development, resource allocation, and sustainable development of cities becomes higher. At the end of 2019, urban population reaches 850 million, and the urbanization rate is over 60%. With the increase of the urban population, the need for a higher level of urban management is becoming more and more urgent. Therefore, the concept of constructing a smart city and a new satellite city in large cities is proposed to solve the problem caused by urbanization, and the traditional urban management model needs to be improved [1, 2].

There are following studies on the role of smart cities. The construction of smart cities or digital cities has a positive effect on improving the traffic conditions in big cities, increasing the utilization rate of traffic facilities, speeding up the development mode of green cities, promoting scientific governance, changing the old production mode of the city, improving the living standard of residents and making the residents feel happy [3, 4]. With the accelerating of urbanization, urban development can drive regional development in the brand-led competition in the international market. The Inter-regional competition has become the competition of comprehensive strength with cities as the core, the carrier and the platform. Generally speaking, smart cities can improve the happiness of residents and increase the competitiveness of cities. Research on the theoretical framework and evaluation methods of smart cities: as an important element in urban competition, city brand building gradually becomes a major approach to the development of many cities, and city brand building will inevitably become an important part of urban development. At present, there is no universally acknowledged specific expression of the connotation of urban brand. Different researchers have put forward their own theoretical framework and evaluation systems from different aspects, and have accordingly selected different research methods. Xiang et al. (2019) pointed out that some smart cities have been constructed, but the relevant evaluation system is not established. Therefore, according to the concept of smart city construction, the state of the current smart city construction is obtained by modeling and calculation [5]. And the evaluation index system is constructed. The closest correlation degree of the six indexes is discussed, and the key indexes affecting smart city development are analyzed. Regarding the development status and existing problems of smart cities, Su et al. (2019) argued that smart city construction is an important direction of global urban development and reflects the people's wish for life [6]. The construction of smart city is also a long-term task to promote urbanization and urban development. The new urbanization takes wisdom, and green ecology as the core, and more and more cities plan to construct a city with green ecology, wisdom and wisdom urbanization. Landscape pattern optimization is one of the important ways to realize regional ecological security. But with the rapid development of urbanization, ecological space has been compressed. How to coordinate the contradiction between regional ecological security and socio-economic development has become the main problem of land use. Ming and Wang (2019) also pointed out that with the growth of urban population, the rapid development of smart cities has become the focus of urban regional development [7]. They said that smart healthcare is an indispensable part of smart city construction. However, the security of data and the timeliness of services are the problems faced by the current intelligent medical system. The concept and function of neural network are studied as follows. Back Propagation Neural Network (BPNN) is a multilayer feedforward neural network developed on the basis of the sensor network, and it is widely used in the Internet field. The classification of BPNN is complex, and BPNN has excellent multidimensional function mapping ability. BPNN includes input layers, hidden layers and output layers. In essence, the objective function of the algorithm based on BPNN uses the network error square and the gradient descent method to calculate the minimum function. Nowadays, neural network technology is widely used in all walks of life,attracting wide attention from many experts and scholars. Vekinis and Constantoudis (2020) made predictions by using multi-layer neural networks, including surface roughness and the geometric shape of a given atomic force microscope (AFM) [8]. Dubourg et al. (2019) simulated data by training AFM, and the measurements show a good fitting between the training set and the test set. Machine learning is used to evaluate the samples and fast and efficient selection is realized, reducing the operation cost of AFM measurement [9]. Ostad-Ali-Askari and Shayannejad (2021) used artificial neural networks to calculate the drainage spacing under unstable conditions in areas with different soil properties and drainage spacing. The network designed contains a hidden layer with four neurons, and the drainage spacing calculated by the method is consistent with the actual value, and has higher accuracy than other methods [10] . In addition, machine learning is also widely used in different fields. For example, in the analysis of residential land prices in smart cities, four nonlinear machine learning algorithms are used to build a block residential land price prediction model, which provides a theoretical basis for in-depth understanding of urban residential land prices. In the smart city, the integration of AI and the IoT technology is applied to the smart home to realize the construction of the whole house smart home system. In the smart city fire safety, the improved naive Bayes algorithm is used to improve the sensitivity of fire equipment identification. "Machine learning" can be used in urban drainage design to predict hazards.

It is found that neural network technology is mainly used in the field of natural science, and it is less used to research social life and business activities. In order to solve the problem of "multiple cities look the same" in the construction of smart cities that appeared in many places, people should effectively implement the construction of smart cities and the building of city brands. Therefore, the innovation of this study is that neural network technology is used to study the optimization of smart city construction and city brand building, and a new computer technology is proposed and used in the evaluation of city brand construction. The technology provides a new perspective for the evaluation of smart city construction and development. In the information society, a variety of new computer technologies emerge endlessly, and a technology that can be used to evaluate smart city construction is born. Here, the relevant theories of urban brand optimization are analyzed and studied, and the factors affecting the construction and development of smart cities are analyzed. Then, BPNN is introduced to establish the evaluation model of the construction and development of smart cities, and the urban brand optimization strategy is proposed to evaluate the construction and development of smart cities and optimize the city brand model. The establishment of a BPNN model simplifies the manual calculation, and calculates the correlation among the indicators of the smart city through the grey relational theory to ensure the validity of the assessment of smart city construction. The data output by the BPNN algorithm based on grayscale correlation can be more accurate. This study solves the problem of evaluating the development potential of smart cities, provides a reliable data model for the future development and construction of smart cities, and plays a positive role in improving the development of smart cities and ensuring the ability to build smart cities.

2. Theories of Smart City Construction and Optimization of the City Brand Model

2.1. BPNN

Neural networks. The biological neural network is used to construct the structure of the model based on the artificial neural network (ANN), which is a combination of many artificial neurons. ANN can adjust its internal structure with the change of the external environment. It can also be used as a modeling tool to characterize and model the functional relationship between the input and the output, or to analyze the relations between data. The content of the neural network is an algorithm constructed by the logic of the external environment or human society. The invention of the neural network is inspired by the neural network operation principle of natural biology (human or mammals) [11,12]. ANN is an active learning model, which optimizes the model according to the statistical results. Its cavities are calculated by statistical laws, and many mathematical descriptions in local structural space are obtained. Also, mathematical statistics are mainly used for learning and calculation in the field of machine perception, as well as for simulating the artificial perception system. Finally, ANN obtains the most basic decision and judgment ability. Compared with the traditional logic operation model, this self-learning model is promising. Chen (2020) studied the application of deep learning to smart city construction [13].

ANN does not need to directly reveal the functional relationship between the input, the output, and the mathematical equation. It only needs to use its network independently to learn the laws and the rules between data. When the input value is given, the corresponding output value is obtained.

BPNN. The BPNN system is an artificial neuron model with a multi-layer network. Its basic idea is that the gradient descent method is used to minimize the mean square error between the actual output value given by the model and the expected through gradient search. Figure 1. shows the topological structure of the BPNN model [14, 15].

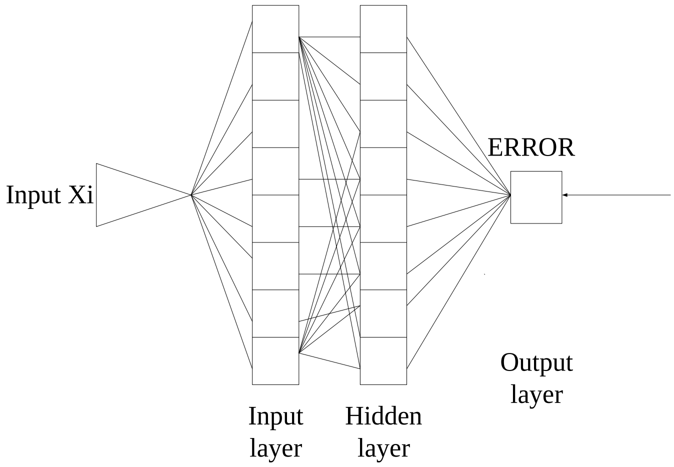

Fig. 1. Topological structure of the BPNN model

The activity of biological neurons is presented by a simple mathematical model. It is used to receive the signals transmitted by other multiple neurons, which are aggregated into total signals. The total signals are compared with the thresholds. If the threshold is greater than the limited, the excitation signal is output. If the threshold is less than the limited, the excitation signal is in the inhibitory state. A plane is divided into two parts by a straight line, and the three-dimensional space is divided into two parts by the delayed plane. A dimension hyperplane n-1 divides the n -dimension space into two parts, which belong to different categories. Such classifiers are called neurons. The equation used in dividing the plane is as follows:

$$ax + by + c = 0\ . \tag{1}$$

The left side of the equation can be greater than zero or less than zero, which respectively represents the point on one side or the other side of the line. This equation is extended into the dimensional space. The high-dimensional form of the line is called a hyperplane. Its equation is as follows:

$$a_1x_1 + a_2x_2 + \cdots + a_nx_n + a_0 = 0\ . \tag{2}$$

The neuron in the model outputs 1 when h is greater than 0 or less than 0. It is used to divide the feature space in half and the two lobes belong to two categories, as shown in Figure 2.

Fig. 2. M-P neuron model

After it is input and learned, the direction of the feature vector is changed. The absolute value of the weight is the influence of the input signal on neurons.

The activation function has six categories:

a. Oblique function: when the absolute value of x is less than c c, f(x)=kx+c. When x is greater than c, it is equal to T. When x is less than -c, it is equal to -T.

b. Threshold function: when x is greater than c, f(x)+1; when x is less than -c, it is equal to 0.

c. The expression of the nonlinear function is shown in equation (3):

$$f(x) = \frac{1}{1+e^{-\alpha x}} (x \in R) . \tag{3}$$

d. The derivative of the Sigmoid function is as follows:

$$f'(x) = \frac{\alpha e^{-\alpha x}}{(1+e^{-\alpha x})^2} = \alpha f(x)[1 - f(x)] . \tag{4}$$

e. The bipolar Sigmoid function is as follows:

$$h(x) = \frac{2}{1+e^{-\alpha x}} - 1 (x \in R) . \tag{5}$$

f. The derivative of the bipolar Sigmoid function is as follows:

$$h'(x) = \frac{2\alpha e^{-\alpha x}}{(1+e^{-\alpha x})^2} = \alpha \frac{1-h(x)^2}{2} . \tag{6}$$

α represents the weight of each node, and the results of the neural network need to be normalized to 0 – 1. When the transmission function is between 0-1, the difference between the results is significant. When the transmission function is more than 1, its variation will be significantly reduced (derivative or slope is relatively small), which has adverse effects on the performance of the BPNN algorithm. The BPNN algorithm uses the gradient information of the transmission function between each node during the process. If the input value is too high, it will lead to a small gradient value, causing the difficulty of adjusting the relationship between the weight and the threshold.

2.2. Grey relational theory

Grey relational analysis (GRA). GRA is a multi-factor analysis method that is often used in the grey system. For the correlation between the two systems, the degree of the correlation varies with time. In the development of the system, the degree of synchronous change is high, that is, the degree of the correlation between the two is high if the changing trends of the two are consistent. Therefore, the grey relational analysis method is based on the similarity or difference of the development trend between the two factors, that is, “grey relational degree”, a method of measuring the relational degree between factors, and it is generally used to analyze the influence and contribution of each factor on the main body under different situations. The grey relational method can calculate the development trend of the curve according to its state and similarity and determine the consistency between districts and counties [16-18].

Grey relational algorithm. The flow chart of the grey relational algorithm is shown in Table 1 [19].

Table 1. Flow chart of the grey relational algorithm

Number	Steps
a	Indexes are set as follows: in $\mu_{ik}(i = 1,2,3,\ldots,n; k = 1,2,3,\ldots m)$, i represents the number of attributes, ω_k is the weight of the table is the weight value of k indicators, C_k is the characteristic proportion of the weight, and f_{ik} is the weight. The relationship of these factors is shown in equations 7–9. $f_{ik} = \frac{\mu_{ik}}{\sum_{i=1}^{n}\mu_{ik}}$ (7) $C_k = -\frac{1}{\ln n}\sum_{i=1}^{n} f_{ik} \ln f_{ik}$ (8) $\omega_k = \frac{1-C_k}{m-\sum_{i=1}^{m} C_k}$ (9)
b	If there are A_i objects, m indexes, and $Ai = (x_1,\ldots x_m), (i = 1,2,3,\ldots,n)$, and the best scheme is marked as $Z^+ = (max\, Z_{i1},\ldots, max\, Z_{im})$, the worst scheme is marked as $Z^- = (min\, Z_{i1},\ldots, min\, Z_{im})$, and the weight of m indexes is $\omega = \omega_1,\ldots,\omega_m$.
c	The grey relational coefficient is calculated as follows: $\xi(k) = \frac{min_i\{min_k\, \Delta_i(k)\} + \rho\, min_i\{min_k\, \Delta_i(k)\}}{\Delta_i(k) + \rho\, min_i\, min_k\, \Delta_i(k)}$ $= \frac{min_i\{min_k\lvert x_0(k)-x_i(k)\rvert\}+\rho\, min_i\{min_k\lvert x_0(k)-x_i(k)\rvert\}}{\lvert x_0(k)-x_i(k)\rvert+\rho\, min_i\{min_k\lvert x_0(k)-x_i(k)\rvert\}}$ (10) ρrepresents the resolution coefficient, and its range is between 0 and 1.
d	The grey relational degree r_i is calculated, and the equation is as follows: $r_i = \frac{1}{n}\sum_{i=1}^{n}\zeta_i(k)$ (11) n represents the number of sequence objects. The larger the value of r_i is, the greater the grey relational degree is. $\zeta_i(k)$ is the grey relational coefficient. When the value is greater than or equal to one-half of the value, the relational effect is obvious.
e	If the optimal sequence r_i is maximum, the maximum relational sequence is obtained.

2.3. Evaluation of smart city construction

Smart cities. A smart city is the advanced form of urban informatization after a digital city and it is constructed by the deep integration of informatization, industrialization, and urbanization. At present, smart city construction promotes the development of connotative urbanization, develops emerging industries, increases new economic growth points, upgrades traditional industries, social energy conservation, and emission reduction, and the transformation of economic development mode, and seizes the opportunity of the industrial revolution in the international competition.

In 2010, smart city construction is first proposed by a company in the United States. The company divides the city and sets up multiple systems with different functions, including the municipal system, the traffic system, and the system to expand its communication capacity, and the systems for water supply and energy supply. These systems do not work alone but cooperate mutually. Under this circumstance, smart city construction and development gradually become the focus of the research. Although the government has not issued specific documents to support the action, researchers in the academic circle have reached a consensus on this issue. Their ideas for smart city construction are that a smart city should have following characteristics: (1) the city management is smarter; (2) living in the city is more convenient; (3) public information is transparent; (4) the utility of resources is reasonable; (5) the ecological environment is livable; (6) the city's culture is inclusive of all kinds of non-mainstream ideas and lifestyles; (7) the interpersonal relationship of the residents is sincere and public services are convenient; (8) the city management is refined; (9) the living environment is livable; (10) the infrastructure is intelligent; (11) the network is safe [20, 21].

The proposal of smart city construction is based on cities' development. Computer technology is one of the emerging technologies, such as blockchain technology [22], cloud computing technology [23], big data technology [24], IoT (Internet of Things) [25], and the mobile wireless network. It can be used to improve the quality of products and services, and its application to the intelligent community, intelligent government affairs, intelligent education, intelligent management, people's livelihood, intelligent medical treatment, and other aspects of city production and life is realized, so that the development of all things is achieved and the harmony between the residents and the city is promoted, making the city more intelligent with the wisdom of the people there.

The digital information lays a good foundation for smart city construction and also entrusts with the new goal and new development vision in the new era. The management of a city is mainly based on computer technology, including IoT, blockchain technology, big data technology, and cloud computing technology. Through monitoring various aspects of the city, real-time data are obtained and provided for the decision-makers and administrative organizations of the city's management, avoiding blind decision-making and making city management more automatic and detailed [26].

Fig. 3. Distribution of pilot smart cities in the provinces of China at the end of November 2018

Smart city construction in China is supported by the central government and local state-owned organizations at all levels. From 2017 to 2018, the state issues a series of policies to encourage the development of smart transportation and healthcare based on cloud computing and artificial intelligence (AI). For example, in July 2017, the State Council issues "Development Planning of New Generation Artificial Intelligence", which points out six key tasks for developing AI in 2030, namely, vigorously developing the economy based on AI, improving the research ability of AI, building a sound research and production system and a new intelligent society based on AI, expanding the application of AI to social life, national defense and military, establishing a widely used application system of AI, and planning scientific research based on AI in the future [27]. Strengthening the application of AI to production, life, military and other aspects of modern society can provide a good starting point for smart city construction. Figure 3 shows the distribution of pilot smart cities in the provinces of China at the end of November 2018 [28].

The above figure shows the current situations of smart cities in China by the end of 2018. The deeper the color is, the fewer pilots there are in the province. The survey shows that the cities along the southeast coast are the first pilots for reform. There are most pilots in Shandong, Jiangsu, and Hunan provinces in China, 30 in Shandong, 28 in Jiangsu, and 22 in Hunan [29].

Nowadays, smart city construction is extensively carried out, but there also appear some problems. First, the understanding of the connotation and development path of smart cities has not yet reached a consensus. Second, the connectivity and sharing of cross-industrial and cross-sectoral information become difficult, leading to the low interoperability between resources and businesses. The reasons may be that some units or departments take the public information as a means to charge the application cost produced by the implementation of the traditional charging policy, each department has its own information system, and the statistical data between the departments are inconsistent. Third, the organizations of each country cannot provide data to other working organs due to different reasons. It has been several years since the Central Committee introduces the concept of the triple play (telephone network, cable television, Internet) to the public. The data connectivity among the various working bodies is weak and overheating appears in smart city construction. Fourth, local governments in some areas are too busy to consider the local financial situation. Fifth, Internet construction is not perfect, and there exist hidden dangers in information security. In this case, many local governments follow the examples of other successful regions, resulting in the phenomenon of "thousands of cities are the same" [30]

Evaluation index system of smart cities. The evaluation index system of smart cities is shown in Table 2 [31, 32].

.**Table 2.** Evaluation index system of smart cities

Categories of indexes	Specific indexes
Economic development and future expectation F	Per capita GDP (Gross Domestic Product) F1 of the surrounding areas Regional real estate investment GDP share F2 Per capita DI (Disposable Income) F3 of the residents in the city City consumer expenditure F4
Social development and future expectations S	The total regional population at the end of year S1 Non-public road freight S2 Non-public highway passenger volume S3
Public Service Quality and Future Development Expectations P	Per capita housing area P1 The average number of beds per thousand patients P2 Average green area P3 Per capita collection of public libraries P4
Technological innovation capability and the expectation I	The proportion of science and technology appropriations to local government expenditure I1 The proportion of research and experimental research development funds to local production output I2 Patent application I3 Number of universities I4 Number of college students I5
Network facility construction E	The proportion of infrastructure expenditure to GDP E1 Thousands of people have network length E2 Fixed number E3 Number of mobile phones E4 Number of network users E5

2.4. City brand building

Basic concept. City brand building is a comprehensive interdisciplinary subject that covers multiple disciplines. It takes brand science, urban economics, urban planning, advertising and marketing, and development as the core, and covers other disciplines, such as aesthetics, manufacturing, and history. Figure 4 shows the disciplines of city brand building [33, 34].

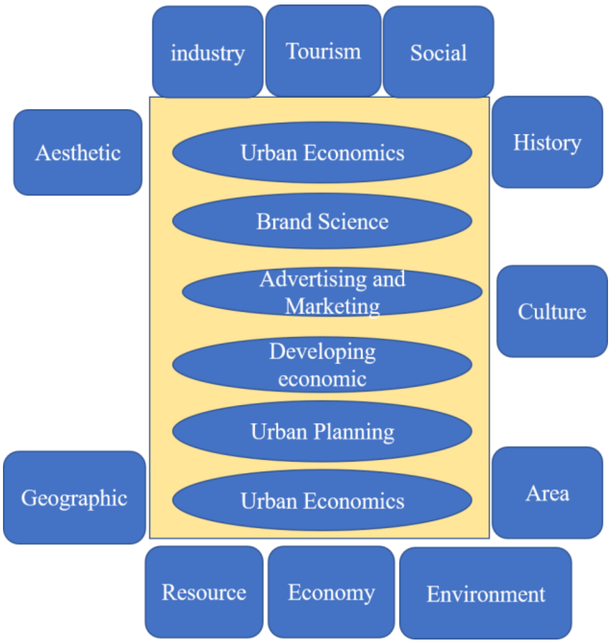

Fig. 4. Disciplines that city brand building covers

Basic theories of city brand building. Basic theories of city brand building include brand marketing theory, sustainable development theory, behavioral geography theory and urban planning theory. The core idea of brand marketing theory is to build a city brand with local characteristics, improve customers' loyalty and increase the added value of the city brand. Sustainable development theory is the principle of urban brand building, that is, it is people-oriented and a harmonious operating framework of "natural-economic-social" should be built. And behavioral geography can be a tool to help promote urban brand building. The urban planning theory is the basis of administrative behavior after urban construction. The city brand building theory is the extension of the urban planning theory and it is proposed to provide new ideas and perspectives for urban construction and development and enhance urban charm and expand the influence of city brands.

Strategies for city brand building. City brand building includes nine strategies, and their relations are shown in Figure 5.

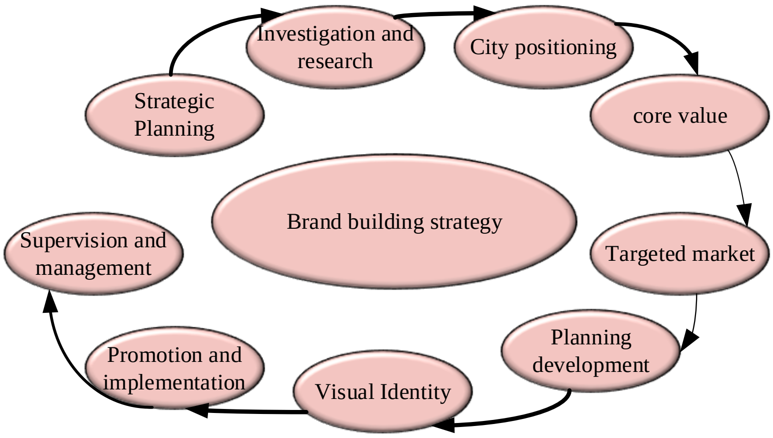

Fig. 5. Strategies for city brand building

Figure 5 shows that strategic planning is the first step in the whole process. The second step is to do some research. The third step is to excavate various resources of the city and find the personality, soul and concept of the city according to the principles of uniqueness, exclusiveness and authority. The fourth step is to build core values. The fifth step is to determine the target market. The sixth step is making plans for city development. The seventh step is determining the identifier. The eighth step is implementing the plan. The ninth step is supervising the promotion of a city brand.

Evaluation methods of city brands. The mainstream evaluation method of a city brand is through principal component analysis, which is a multivariate analysis method. The method can successfully detect the correlation of indexes and does not need to set the weight of the index. Therefore, the method is employed here.

3. Research Model and the Methodology

3.1. Experimental Procedure

In this study, the data of 15 cities including Beijing, Shanghai, Guangzhou, Shenzhen, Hangzhou, Nanjing, Changsha, Guizhou, Ningbo, Chongqing, Chengdu, Xi'an, Kunming, Zhengzhou and Jilin in 2020 are selected as the samples of this experiment. The evaluation model of smart city construction and development is tested experimentally. The Changsha city brand data in 2020 is selected as the sample for this study. Iteration is performed by software MATLAB (MATrix LABoratory), and a total of 20-dimensional vectors are output. The output layer is set to contain 20 nodes, the node is set to 1, and the hidden layer neuron range is controlled between 5-7, a total of 3 neural network structures.

Decision tree algorithm process: Let Q_X=(x=1,2,3,….,\|n|) be the proportion of x-type samples in sample D. When the value of Q_X is smaller, the purity of the D sample will be higher, and the Gini(D) will be smaller. The calculation of the information entropy Ent(D) and its Gini index Gini(D) is as follows:

$$Ent(D) = -\sum_{x=1}^{|n|} Q_X \log_2 Q_X \ . \tag{12}$$

$$Gini(D) = 1 - \sum_{x=1}^{|n|} {Q_X}^2 \ . \tag{13}$$

Data sharing is carried out through the code sharing platform GitLab to improve the repeatability of experiments. The specific steps are given as follows: (1) Enter the GitLab website to register an account. (2) Create a workgroup. (3) Create a GitLab project, and fill in the project name and its type, etc. (4) Import SSH Keys to generate Key file. (5) Upload the project.

3.2. GRA-BPNN model

GRA-BPNN model is realized by combining GRA method with BPNN to evaluate the development of smart cities. The implementation of the model based on the original GRA requires three steps, as shown in Table 3.

Table 3. The model added 3 steps based on the original GRA algorithm

Number	Steps
f	The sample is expressed as $x_{ml} = [x_{m1}, \ldots, x_{mn}]$, the expected output is $y_{ml} = [y_{m1}, \ldots, y_{mn}]$, m is the number of samples, l is the number of input vectors, and the initial value of the threshold is set.
g	If the output value of each layer is $O_{pi} = X_{pi}$, andX_{pi} represent the expected output value of each sample, the error between them is calculated.
h	Modify the weight ω_{ij} and threshold θ_{kj}, and the output layers t and k can be calculated by equations 12-15. $\omega_{ij}(t+1) = \omega_i(t) + \delta_{kj} o_{kj}$ (14) $\theta_{kj}(k+1) = \theta_{kj}(k\ ) \ + \eta\delta_{ij}$ (15) $v_{kj}(t+1) = \theta_{pl}(t\ ) \ + \delta_{pl}\rho_{pl}$ (16) $\theta_{pl}(k+1) = \theta_{pl}(k\ ) \ + \eta\delta_{pl}$ (17) Based on the equations, the weighting coefficients δ, δ, o are improved, and the weighting coefficients of the output layer and the hidden layer are adjusted until the error is less than the preset error. The training is completed or the next cycle starts until the curve converges, and the results are obtained.

The basic structure of the algorithm is shown in Figure 6.

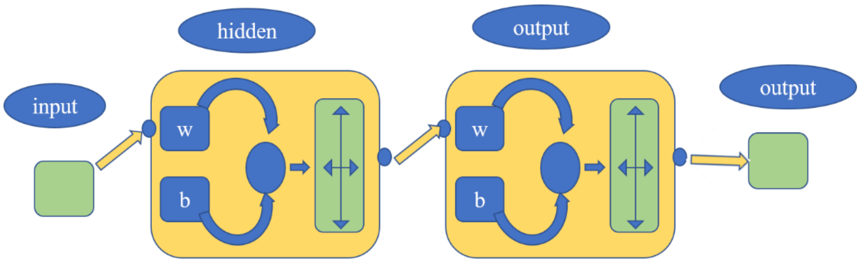

Fig. 6. Structure of the GRA-BPNN algorithm

3.3. GRA-BPNN model

Sample data. Beijing, Shanghai, Guangzhou, Shenzhen, Hangzhou, Nanjing, Changsha, Guizhou, Ningbo, Chongqing, Chengdu, Xi'an, Kunming, Zhengzhou, and Jilin are selected as the samples to test the evaluation model for smart city construction and development because they are the pilots in the national smart city construction. The 15 cities are the first cities that are declared as domestic smart cities, in which the infrastructures are relatively perfect, the level of economic development is high, and the supporting facilities for smart city construction are equipped. The data of the cities mainly come from “2020 national economic and social development statistics bulletin”, “2020 scientific and technological progress statistical monitoring results and scientific and technological statistics bulletin”, “2020 nineteen city financial technology investment comparison” and other statistics on the Internet. These smart cities are represented by English abbreviations to make the calculation process simple. They are represented by City1, City2, City3, City4, City5, City6, City7, City8, City9, City10, City11, City12, City13, City14 and City15. The original data of the construction and development of 15 smart cities in 2020 are shown in Table 4 below.

Experimental software. MATLAB is used to output 20-dimensional vectors. The output layer contains 20 nodes, and the output layer node is set to 1. The neurons in the hidden layer are adjusted from 5 to 7 according to the data, and a total of three structures of neural networks are obtained.

The entropy weight method (EWM), the grey correlation evaluation analysis method mentioned above and the evaluation method based on Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) are introduced to verify the performance of the GRA-BPNN model proposed. The evaluation results of the four different methods of smart city development are compared.

Table 4. Original data of the construction and development of 15 smart cities

	Indexes								
cities	F1	F2	F3	F4	S1	S2	S3	P1	P2
City 1	161409	0.472	4126.88	36947	1408.6	26859	65272	36.27	10.57
City 2	162499	0.372	44.962	29266	1538.0	85416	12802	34.5	9.41
City 3	134001	0.59	42840	25796	591.2	37256	27465	44.4	6.1
City 4	133890	0.280	41853	27839	1165.8	30728	212833	29.1	5.985
City 5	175907	0.36	39164.6	31601	833.4	89400	90380	35.5	8.6
City 6	87439	0.74	34067	23117	661.41	22709	37844	31.18	6.56
City 7	47229	1.050	19106	19106	463.30	22392	61540	23.78	7.3
City 8	62507	1.118	29194	21586	772.2	40242	41218	32.0	5.2
City 9	56372	0.852	21878	168.61	332.54	11642	4948	25.66	7.43
City 10	70476	0.233	31079	21473	1284.5	44439	135170	39.9	7.95
City 11	97197	0.42	39149	29420	740.68	28465	50257	38.2	3.83
City 12	121262	0.774	30932.3	21268	832.82	45640	30730	35.86	6.81
City 13	63952	0.96	29465	21794	554.59	29284	18498	31.73	8.91
City 14	182006	0.609	41110	26703	483.34	19509	27088.9	39.07	7.56
City 15	135693	0.768	40992	267.58	654.20	30110	16727	16727	6.51
	Indicators								
Cities	P3	P4	I1	I2	I3	I4	I5	E1	E2
City 1	16.6	1.12	5.54	0.172	51622	190	61.00	0.185	14.136
City 2	13.12	1.12	5.98	0.172	51622	69	51.588	0.085	2.900
City 3	11.99	3.14	4.02	0.148	49790	17	16	0.24	4.885
City 4	17.7	1.09	5.16	0.202	59517	6	8.35	0.229	2.116
City 5	16.6	0.97	3.99	0.145	59518	81	94.4	0.225	2.116
City 6	16.45	0.73	2.8	0.006	3278	111	17.77	0.287	3.216
City 7	12.3	1.34	1.06	0.328	4064	56	34.52	0.466	1.70
City 8	14.01	1.10	3.21	0.042	3642	61	45.45	0.328	0.942
City 9	11.08	2.99	2.017	0.002	20536	4	4.84	0.537	2.116
City 10	14.37	0.60	2.44	0.039	1123	81	97.75	0.177	4.06
City 11	11.9	0.51	2.19	0.026	3282	61	39.73	0.254	3.406
City 12	11.65	0.53	2.05	0.045	4432	54	71.28	0.591	4.576
City 13	11.9	0.94	50.4	0.038	34367	13	12.25	0.081	4.440
City 14	15.82	2.85	2.80	0.038	56105	55	81.85	0.252	4.441
City 15	16.1	2.40	1.9	0.029	1369	44	47.59	0.2577	1.803
Cities	E3	E4	E5						
City 1	67.98	174.5	42.42						
City 2	64.39	145.7	48.74						
City 3	54.20	140.2	49.96						
City 4	53.39	168.9	33.2						
City 5	71.28	150.1	79.57						
City 6	26.82	236.2	21.16						
City 7	23.64	214.9	21.8						
City 8	24.31	93.5	14.64						
City 9	41.68	194	33.19						
City 10	37.0	241.4	46.02						
City 11	33.18	74.0	24.48						
City 12	33.09	78.9	40.53						
City 13	43.89	131	51.36						
City 14	45.9	198.7	17.9						
City 15	27.95	157	50.42						

4. Results of Smart City Construction and Development and the Optimization of the City Brand Model Based on Neural Networks

4.1. Original Data of Smart City Construction and Development and their grey Correlation Degree

The original data are obtained based on the grey correlation theory, and the grey correlation degree of each index is shown in Table 5.

Table 5. Grey correlation degree of each index

Economic development and expectation F	Social development and expectations S	Public service quality and development expectations P	Technological innovation capability and expectation I	Network facilities construction E
F1=0.830	S1=0.779	P1=0.903	I1=0.784	E1=0.643
F2=0.769	S2=0.673	P2=0.891	I2=0.422	E2=0.519
F3=0.892	S3=0.613	P3=0.916	I3=0.706	E3=0.815
F4=0.856		P4=0.681	I4=0.542	E4=0.843
			I5=0.722	E5=0.706

The order of correlation in Table 5 is: P3 > P1 > F3 > P2 > F4 > E4 > F1 > E3 > I1 > S1 > F2 > I5 > E5 > I3 > P4 > S2 > E1 > I4 > E2 > S3 > I2. After the principle of correlation is simplified and the indexes that are not greater than 0.5 are excluded, 20 qualified indexes are finally obtained. Generally, the grey correlation index is between 0 and 1. The greater the correlation is, the greater the correlation between several indexes is. The above table shows that the correlation between development expectation P and smart city prosperity is the highest, and the other three indexes except P4 are about 0.9. The correlation between social development and expectation S is the lowest, about 0.7. The correlation between economic development and expected F is the second, indicating that public services and development expectations have the greatest impact on smart city development and city brand building. Financial funds also have a great impact on city development, while social development, expectations and network facilities have little impact on city development and brand building

The original data are normalized according to the obtained 20 indexes, and the results are shown in Figure 7.

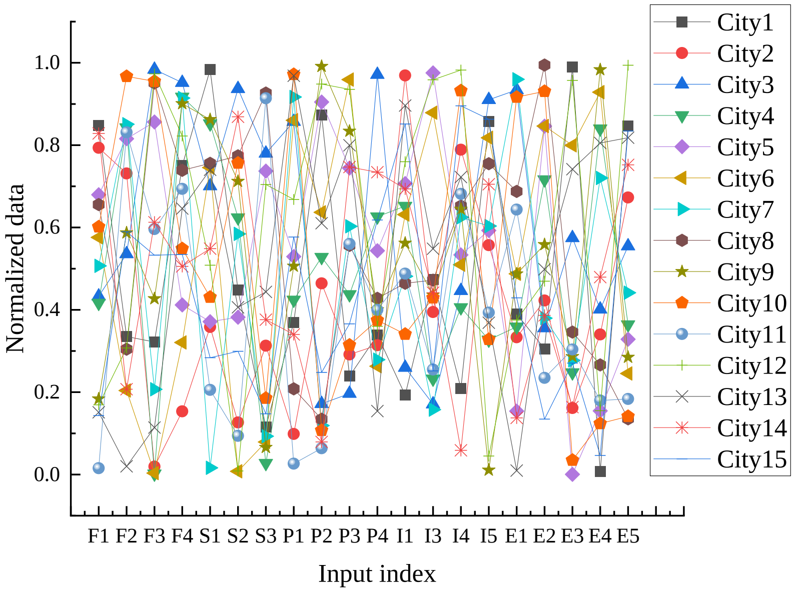

Fig. 7. Normalized results of original data

Figure 7 shows that the original data are normalized. According to the 20 available indexes, the samples are normalized by premnmx function, and the data after normalization are distributed between (-1, 1). The normalized data can make the function converge faster and improve the convergence accuracy.

4.2. Iterative results and the structure of networks

Figure 8 shows different iterative results with different numbers of the nodes in the hidden layer.

The blue line in the Figure represents the training iteration curve, the red line represents the test iteration curve, and the green line represents the verification iteration curve. When the number of hidden layer nodes of the neural network reaches 5, the best performance of the training reaches 1.63 * 10-2 after 20 iterations. And the curve converges and the number of hidden layer nodes of the neural network reaches 8 after13 training iterations. The optimal result of the training reaches 9.74 * 10–2 after 20 iterations. And the curve converges after the iterations are trained 2 times. The number of hidden layer nodes of the neural network reaches 7 after 0.131 * 102 iterations, and the best value during the training reaches 1.63 * 10-2. Since the number of iterations begins to decrease rapidly after the number of hidden layer nodes reaches more than 5, from 20 iterations of 5 nodes to 2, the curve converges, and the value reaches more than 9.74 * 10-2, indicating that the neural network model is good. Alhasoun and Gonzalez

(2019) proposed a method to collect and mark image data, and then train the deep Convolutional Neural Network (CNN) for street classification. A total of 9 nodes in 3 hidden layers is required to achieve the reduction from 30 iterations to 20 [35]. Cutchan et al. (2020) introduced a feature space for geospatial configuration, which contains semantic information. Then, the data in the feature space are used for deep learning. Finally, the high-precision prediction of city development is realized, and the number of iterations is reduced to 20 times by using eight neurons in two layers [36]. In short, the model based on BPNN and GRA has good performance.

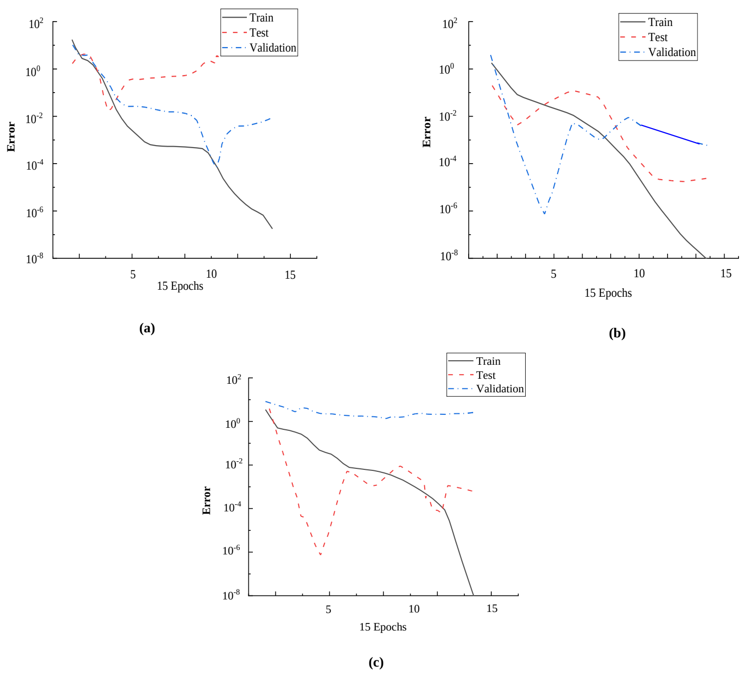

Fig. 8. Iterative results of different nodes in the hidden layer (a) *5 nodes* (b) *6 nodes* (c) *7 nodes*

The evaluation results of the 15 cities by the recommended model, EWM, GRA and the evaluation method based on TOPSIS are shown in Figure 9.

Figure 9 shows that the evaluation results of 15 cities by different algorithms are different. Among them, the EWM algorithm obtains the highest data value, the difference between the highest value and the lowest value is about 1, and the curve fluctuates significantly. The data values obtained by the GRA and TOPSIS algorithms are relatively close and the difference is not large, and the curves of the two algorithms fluctuate greatly. The data value obtained by the GRA-BPNN algorithm is the lowest, the overall evaluation fluctuates between 0.5 and 1, and the fluctuation range is the smallest, which is closer to the actual situation. The difference in the potential of the development level of smart cities is similar. However, the curve of the recommended model is relatively flat and stable than that of the other three methods, and its evaluation results are more reasonable than the other three methods, which proves that the evaluation method proposed is feasible and scientific. It further proves that the evaluation model based on grey relational theory and BPNN is effective and reasonable in evaluating the development potential of smart city and plays a positive role in the future construction of smart city.

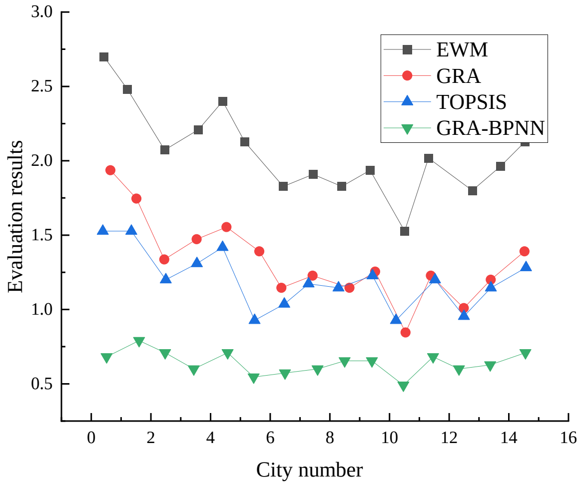

Fig. 9. Comparison of evaluation results of four algorithms

In summary, the proposed evaluation model based on grey correlation theory and BPNN has excellent performance, good stability and scientific test results. First, according to the grey correlation analysis method, the grey correlation degree of each index is calculated, and the original indexes are reduced. The reduced index is used as the input variable for BPNN to obtain an intelligent neural network for the development potential of smart cities based on GRA-BPNN. Finally, 15 smart cities in China are selected for empirical research. According to the designed intelligent neural network for the development potential of 15 cities based on GRA-BPNN, MATLAB 8.0 software is used as the calculation and simulation platform of the model to train and simulate the model. Finally, EWM, TOPSIS and grey correlation analysis method are used to evaluate the development potential of smart cities. The effectiveness and rationality of the evaluation model based on the grey correlation theory and BPNN are proved by comparing its evaluation results with other methods.

5. Conclusion

Based on smart city construction and development, the evaluation model of smart city construction and development based on BPNN is analyzed, and the strategies for smart city construction and city brand building are discussed. Then, the data of smart city construction and city brand building in various regions are analyzed and filtered, and the appropriate data are selected to establish the dataset. Subsequently, the evaluation model for smart city construction and development based on BPNN is implemented and trained. Finally, the performance of the evaluation model is tested by comparing the evaluation results of EWM, GRA and TOPSIS. The experimental results show that the performance of the evaluation model for smart city construction and city brand building based on BPNN is good, and the accuracy and timeliness of evaluation are achieved. Although some achievements are made, there are still some limitations that have to be improved. And they are summarized as follows: (1) in the design of the evaluation index system of smart city development, there are few research results to be referred to, and the designed evaluation index system of smart city development needs to be further improved; (2) in terms of empirical research, only 15 pilot cities are selected as research samples. The size of the samples is small, and the conclusion may not be universal; (3) in-depth analysis of smart city construction is not comprehensive. In future research, the above three points should be improved. In addition, the following two will be the focuses of the follow-up research: (1) improving the compatibility of the model and optimizing the algorithm, and adding more machine learning algorithms to improve the repeatability of model results and increase model reliability. (2) Coordinating all parties to carefully select samples. (3) Getting more training set samples to train the model.

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