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The Evaluation of Smart City Construction Readiness in China Using CRITIC-G1 Method and the Bonferroni Operator

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ABSTRACT With the development of information science and technology such as big data and cloud computing, the proposal of smart city realizes the transformation of urban governance from growth mode to refine operation mode. Smart city is an advanced stage of urban informatization development and urban governance, which must have a certain development foundation and corresponding environmental protection, that is, the preparation for smart city construction. First of all, through literature research and expert interviews, the critical success factors influencing the construction of smart city are selected, and the evaluation index system of smart city construction readiness is established; Secondly, the objective and subjective weights of indicators are determined and combined by using CRITIC and G1 methods to design. Thirdly, the Bonferroni operator is used to build the evaluation model of smart city construction readiness, calculate and sort the final evaluation value of the scheme; Finally, taking 30 cities in the list of national smart cities as the object of empirical research, the results show that the evaluation model constructed by the text can fully consider the contrast strength and conflict between indicators, eliminate the interaction between indicators, make the evaluation more objective and reasonable, and provide decision-making reference for measuring the construction readiness of smart cities.

INDEX TERMS smart city; readiness; CRITIC; the Bonferroni operator; G1

I. INTRODUCTION

With the rapid development and maturity of important supporting technologies such as the Internet of things, cloud computing and big data analysis [1], [2], urban governance and development usher in a new period of opportunity [3],[4]. In 2008, IBM first formally put forward the concept of "smart city". As a new mode and concept of urbanization development which can improve the accuracy and scientificity of urban governance, [5], smart city can effectively promote the transformation of urban economy and the change of residents' lifestyle, and improve the efficiency of environmental protection and social management, which has attracted more and more attention from countries and all walks of life in the world [6]-[8]. Especially in China, the 13th Five-year Plan for Economic and Social Development of the People's Republic of China in 2016 put the "new type exemplary smart city" as a new direction of city construction. Then general secretary Xi Jinping stressed the importance of building the national integration of national data center once again in the 36th collective study of the Political Bureau of the CPC Central Committee, smart city has received an enthusiastic response in the field of urban governance and urban planning in China. However, due to the different economic and social development situation [9], some cities ignore their own weak foundation, failing to evaluate the overall development status of the city, promoting the construction of smart city blindly, leads to the problems such as limited design, fragmented information, hollow construction, weak security and information island [10],[11], which is difficult to achieve the expected effect.

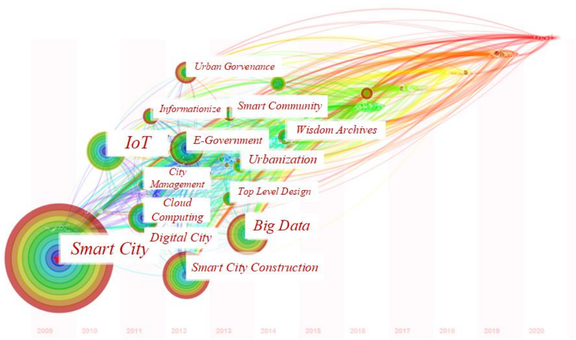

FIGURE 1. **Research on Smart City in China in Recent 10 Years**

At present, the research on smart city has made some achievements. In the field of smart city evaluation, most scholars conduct empirical research on smart city construction with cases, mainly including information security risk assessment, development level and so on[12]-[14], AHP, entropy TOPSIS, gray relation analysis (GRA), back propagation (BP) neural network, entropy weight-cloud model [15]-[19] have been used in smart city evaluation. Looking at the existing achievements in the evaluation of smart city, the following shortcomings are mainly found,

1) The existing evaluation index system is a general measurement index, cannot amply combined with the smart city. There is no scientific and reliable model framework and fixed path selection in the index selection process, which unable to reflect the key points and defects of the smart city in the actual construction process completely. 2) The determination of the index weight has a direct impact on the results of the alternatives. However, the existing research on the determination of the weight of each evaluation index is mainly based on the expert scoring method and the analytic hierarchy process, which tends to focus on the subjective experience, while only using the objective weighting method will ignore the important role of subjective experience in decision-making. 3) Smart city evaluation is a multi-index information aggregation problem. The existing methods of smart city evaluation model have the problems of mutual influence and interdependence among indicators. 4) There are few researches on the evaluation of smart city construction readiness from the perspective of the overall development level of the city, which cannot measure whether the smart city construction and implementation process has achieved the expected goal and the gap between it and the goal with a dynamic perspective.

Therefore, it is of great significance for the development and maturity of smart city to select scientific mathematical model for index weighting. The present study can fill this research gap.

Smart city evaluation is an important way to guide theory and test practice and a research topic with great application value. This paper uses CRITIC-G1 and the Bonferroni operator to evaluate the construction readiness of smart city in China, makes the following practical and academic contributions. First of all, through literature review and expert interviews, the evaluation index system of smart city construction readiness is constructed based on critical success factors, which makes the evaluation index not only scientific and reasonable, but also consistent with the actual situation of smart city construction. Secondly, the objective and subjective weights of the evaluation indexes are obtained by CRITIC method and G1 method respectively, and the combined weights of the indexes are calculated by multiplication normalization method. CRITIC(Criteria Importance Though Intercrieria Correlation) is an objective weighting method based on the concepts of contrast intensity and index conflict. It takes the variability of the indicators and the correlation of the indicators into account, comprehensively measures the weight of the indicators, and fully considers the amount of information and coordination of the smart city readiness evaluation indicators. G1 method is a subjective weighting method based on analytic hierarchy process (AHP). It solves the problem of heavy workload and difficult consistency test of AHP when the amount of indicators is too large. At the same time, it retains the rich knowledge and practical experience of experts to support the index weight. It is a simple and scientific subjective weighting method.In addition, the Bonferroni operator is introduced, which can eliminate the mutual influence and dependence between indexes, and make the aggregation of multi-index information more objective. Finally, this paper is engaged in the pre perspective of smart city construction readiness evaluation, which can analyze whether the current situation of urban development has reached the expected goal and the gap with the goal, and provide a certain decision-making reference for resource allocation and policy-making in smart city.

II. LITERATURE REVIEW

A. SMART CITY

In 2008, IBM put forward the concept of "smart city", which aims to integrate various subsystems of the city by using advanced information technology to operate the city in a more intelligent way [20] In terms of technology, smart city lies in the application and integration of the latest information and communication technologies such as Internet of things and cloud computing; in terms of urban governance, smart city emphasizes participatory governance; as for target, smart city aims to realize the intellectualization of urban governance, public services and people's life [21],[22]. Andrea Caragliu's view is that smart city has the ability to coordinate and manage urban natural resources. Based on the concept of participatory governance, it can ensure the quality of life of urban residents and make urbanization construction and development sustainable. He believes that smart city is a kind of urban governance model with participatory governance as the core, which includes human resources, social capital and communication infrastructure construction, and can promote social and economic sustainability. This view is considered to be highly operable. He emphasizes the role of information technology and believed that smart city realized the prosperity of city through the change of productivity [23]. Margaret Angelidou holds a similar view [24]. Nesrine Ben Yahia insist that smart governance is a collaborative network that can be realized by joint participation of all parties. It needs the cooperation of government, citizens, social technology and other participants to realize [25]. R. G. Hollands emphasizes that smart city use information technology to realize the purpose of urbanization, and explains the connotation of smart city from six aspects [26]. J. R. Gil Garcia, T. A. Pardo and T. Nam put forward that smart city is a complex system with multiple visions [27]. R. Khatoun, S. Zeadally [28] and A. Meijer, M. P. R. Bolivar [29] are consistent with him.

For the risk of smart city construction, information security risk [30]-[32] and construction risk [33]-[35]are two main directions discussed by the academic circle. Some researchers compare the smart city construction project to a large-scale experiment closely related to urban development and residents' quality of life, which shows that the project inevitably has certain risk factors [36]. The construction process of smart city integrates technology, governance, human resources, external economy, society, ecological environment and other factors, which will produce some complex problems [37]. Therefore, scholars conclude that public security awareness, infrastructure and equipment operation and maintenance management, information technology vulnerability and information security management system are the key elements of information security network [38]. At the same time, security management system, data leakage and damage threat, weak security awareness and equipment security vulnerability are the most significant risk factors of the gap between smart cities [11].The project development and construction of smart city must go through the evaluation standards of technology, safety, convenience and rating, and can really achieve the goal before acceptance. The project construction should be based on the planning, development and maintenance of the land system, so as to ensure the balanced use of land in urban construction [39],[40].

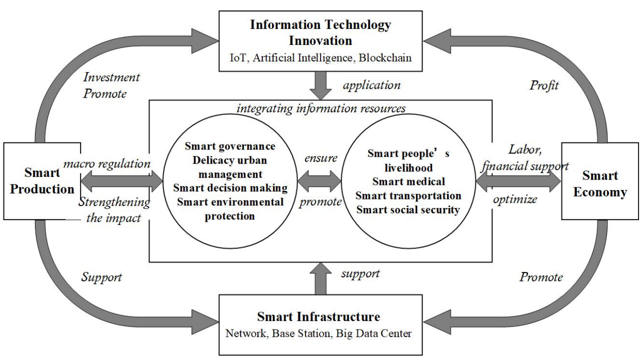

FIGURE 2. The framework of smart city

In China, many cities have included smart city construction in the government's strategic development plan. According to the latest announcement issued by the Ministry of housing and urban rural development, there are nearly 300 smart city pilot units in China at present. Smart city is a new urban development model based on the development and changes of the times. The construction of smart city is not only to meet the needs of the times, but also to maximize the interests of the choice. First of all, the construction of a small and medium-sized smart city can increase the dividend of urban development by 2.5 to 3 times, which is beneficial to the sustainable development of the city. Secondly, smart city can greatly improve the administrative efficiency and management level of government departments compared with the traditional city management mode. Thirdly, smart city can promote the coordinated and efficient operation of all aspects of urban services by using of fully integrated information technology, making our urban operation safe, efficient, green and convenient.

B. SMART CITY READINESS

The concept of readiness first appeared in the field of marketing. When new technology is applied to consumer service, it will cause positive or negative emotional reaction of customers, and also affect the technology development and marketing strategy of enterprises [41]. Based on this, American Marketing scholar Parasuraman proposed technology readiness (TR), which can comprehensively measure whether people are willing to use new technologies to improve their current life from four dimensions [42]. As a kind of psychological construction [43], technology readiness conceptualizes people's general beliefs about technology, which is a kind of overall psychological state, rather than a measure of technical ability [44]. Similar to technical readiness, meuter et al. proposed customer readiness to express a certain condition or state of service [45]. According to the 2009 e-readiness ranking released by the Economist Intelligence Unit, e-readiness reflects the utilization level of electronic information and communication technology in all walks of life, and can measure the development level and prospect of communication technology in the whole country. In addition, the world economic forum believes that informatization readiness is the readiness of a country or group to participate in and benefit from informatization development.

It can be seen that although there are differences in the concept description of readiness between the academic community and the industry, the core concerns are the same, they both emphasize the importance of the current foundation and ability, mainly the description of the current situation. Therefore, it can be considered that readiness is the status quo of the foundation needed to achieve a certain expected goal, and the degree to which the relevant subjects adjust the required basic elements for taking corresponding actions. Smart city, e-government and open data are all proposed under the background of rapid development of information and communication technology. They have certain similarities in construction and development, and need stable information infrastructure, strong policy support and good economic development as necessary support. To sum up, the readiness for the construction of smart city is the degree of preparation for the promotion and implementation of the construction of smart city by the relevant subjects of urban governance, that is, the maturity of the basic conditions required for the construction of smart city.

C. SMART CITY EVALUATION

Smart city evaluation is an important way to test practice and theoretical guidance [46], which can ensure the rationality, foresight, effectiveness and efficiency of smart city construction. It is also a research topic with great application value in the actual promotion and construction of smart city [47]. In 2006, Intelligent Community Forum (ICF) proposed to evaluate the development level of smart community from five dimensions: broadband connection, workforce with knowledge, community marketing, revolution, digital integration and publicity. The system makes an early exploration on the evaluation of smart city, and is the earliest evaluation system on the development of smart city in the world, which lays the foundation for the improvement and upgrading of the follow-up evaluation index [48]. Based on the seven elements of urban services, citizens, commerce, transportation, communication, water supply and energy, International Business Machines Corporation (IBM) put forward that the development level of smart city should be evaluated from four dimensions: network interconnection, smart industry, smart service and smart humanities. This evaluation index system focuses on technology evaluation and investment [49]. In China, Nanjing Information Center (2010), Shanghai Pudong Institute of smart city development (2011), Chinese Academy of smart engineering, and science and technology advisory group of Taiwan Executive Yuan (2010) put forward the smart city evaluation index system based on the specific development and urban governance of different regions.

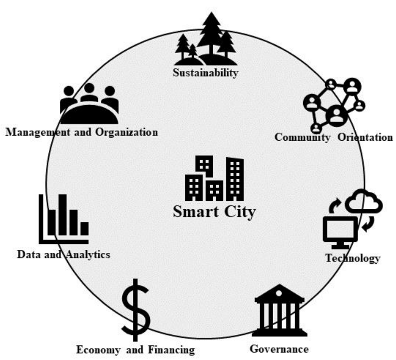

FIGURE 3. Smart City Dimension

In academic circles, scholars have put forward index system based on various evaluation methods, most of the existing achievements are based on system dynamics [50], grey relation theory [51] and "input-output" theory [52], researching on many aspects such as evaluation dimensions and evaluation methods. Using various qualitative and quantitative methods to build the index system, and combining with the actual case to verify the feasibility of the evaluation system [18],[53],[54].Yin yuan (2017) used the improved TOPSIS Model in the smart city evaluation and introduced the obstacle analysis method to make a horizontal comparison on the development of smart city [55]. Yao Yanxia (2017) evaluated the development of Xiangtan smart city by combining Self-Organizing Map (SOM) neural network analysis and time series regression prediction analysis, and concluded that there is a large gap between Xiangtan and developed cities in terms of infrastructure and public services [56]. B. Mattoni, F.Gugliermetti (2015) put forward a new concept of interactive urban development. By defining the sub relationship of urban system, they proposed that all aspects of smart city are integrated as a whole, suggested that economy, energy, environment, community and mobility are the connotation factors of smart city development [22]. This Le, Huang Nguyen et al. (2019) from the perspective of building energy conservation and building energy consumption, summarized that intelligence, modernity, energy conservation, public utilities and sustainable environmental protection are important components of the connotation of smart city [57].

By combing the existing literature, we can draw the following conclusions. First of all, the current research on smart city mainly focuses on the concept and characteristics of smart city, the challenges and development trend, information security risk assessment and construction effect evaluation, and few scholars pay attention to how to evaluate whether a city has the basic conditions of smart city construction, namely the readiness of smart city construction. Secondly, the structure of existing research index system is mostly from the perspective of subjective qualitative, based on the experience of index selection, few scientific and reliable model framework and selection path. Thirdly, experts' scoring method, Analytic Hierarchy Process (AHP) and entropy weight method are often used to determine the weight of indicators, which can't consider the contrast and conflict between indicators, and can't combine the subjective and objective well. Moreover, the methods that have been used in smart city evaluation, such as Grey Relation Analysis, TOPSIS and so on, cannot eliminate the mutual influence and interdependence between the indicators, and then cannot deal with the evaluation problem of multi-index information aggregation.

III. RESEARCH METHODOLOGY

A. SMART CITY READINESS ASSESSMENT RESEARCH FRAMEWORK

The research on smart city in China is still in the primary stage. The theory of smart city construction is lagging behind and practice is ahead of time, which leads to the occurrence of "information island" and repeated construction, cause the waste of resources [62]. The research on smart city construction readiness is of great significance for consolidating the foundation of city construction, reasonable planning and construction scheme, which can effectively solve the problems of lack of planning and weak foundation in the practice of smart city construction. Therefore, starting from the current dilemma of smart city, this paper identifies the critical success factors of smart city construction readiness through literature research and expert interviews, after constructs the index system, the main content of this paper is divided into three steps. The first step is to design the weight of indicators by combining subjective and objective with the CRITIC-G1 method, make the setting of index weight has rich experience of experts and scientific logic at the same time, the second step is to build the evaluation and calculation model of the readiness of smart city construction by using the Bonfreroni operator, considered the contrast and conflict between indicators, the third step is to apply this model to some pilot cities of smart city in China to verify the feasibility of the model. Based on the above logic, the main research framework of this paper is shown in the Figure 4.

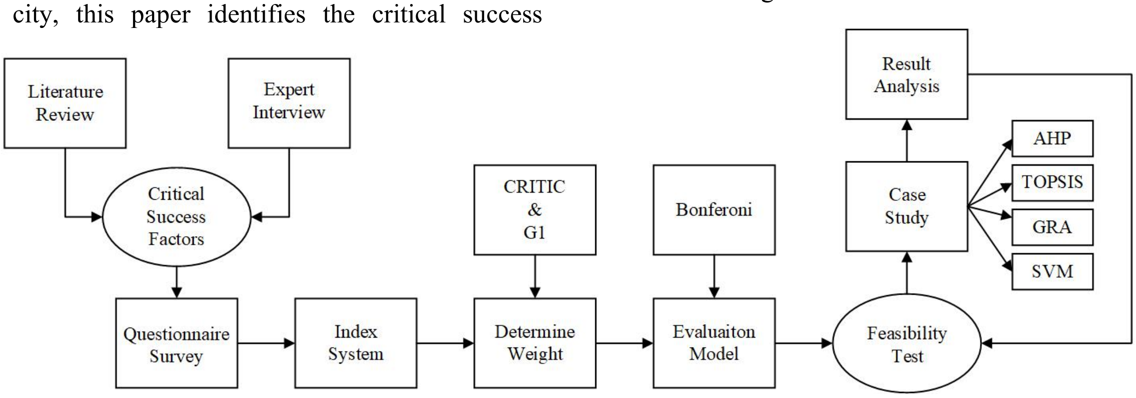

FIGURE 4. Research Framework

B. CONSTRUCT THE EVALUATION INDEX SYSTEM OF SMART CITY CONSTRUCT READINESS

Table 1 summarizes CSFs of smart cities construct readiness generated from a comprehensive literature analysis on smart city, smart cities evaluation and smart city model. First of all, through a large number of literature reading and collation, we have a comprehensive review of the research in the field of smart city. Then, the thesis and research of the target group are screened to determine a set of search criteria which is suitable for the research object of this paper, and the literature including smart city evaluation and modeling is further studied. In addition, we also separately studied the literature contained in the Chinese database to ensure that the identification of key success factors is scientific and comprehensive.

The following retrieval strategy was adopted to explore various types of expression in smart city studies from 2000 to 2020 (Ke et al. 2009; Song et al. 2016): TITLE-ABS-KEY (“smart city” OR “smart cities” OR “smart city assessment” OR “smart city evaluation” OR “smart cities assessment” OR “smart cities evaluation” OR “smart sustainable cities” OR “smart city model” OR “intelligent cities”OR “smarter cities”) AND DOCTYPE (ar OR re) AND SUBJAREA (ener OR engi OR envi OR deci OR econ OR soci) AND PUBYEAR AFT 2000 AND PUBYEAR BEF 2019 AND (LIMIT-TO (LANGUAGE, “English”)) AND (LIMIT -TO(SRCTYPE, “j”)).

Combining literature and opinions of experts, a final list of indexes is provided as FIGURE 5. After identifying critical success factors through the above steps, we get the evaluation indexes of the construction readiness of smart city based on the opinions of experts, and explain them one by one as the table below (TABLE 2).

TABLE I
IDENTIFICATION OF CRITICAL SUCCESS FACTORS FROM LITERATURE

Critical success factor	references
Management and organization	Gil-García, J. R., & Pardo, T. A. (2005). E-government success factors: Mapping practical tools to theoretical foundations. Government Information Quarterly, 22(2), 187–216.
Technology	Gil-García, J. R., & Pardo, T. A. (2005). E-government success factors: Mapping practical tools to theoretical foundations. Government Information Quarterly, 22(2), 187-216.
Governance	Meijer, A., & Bolívar, M. P. R. (2016). Governing the smart city: a review of the literature on smart urban governance. International Review of Administrative Sciences, 82(2), 392 ‑ 408.
Community orientation	Chourabi, H., Nam, T., Walker, S., Gil-Garcia, J. R., Mellouli, S., Nahon, K., Pardo, T. A., & Scholl, H. J. (2012). Understanding smart cities: An integrative framework. 2012 45th Hawaii International Conference on System Science (HICSS). IEEE2289 ‑ 2297.
Data and analytics	Khan, Z., Kiani, S. L., & Soomro, K. (2014). A framework for cloud-based context-aware information services for citizens in smart cities. Journal of Cloud Computing, 3(1), 14.
Institutional context	Lorimer, P. A., Diec, V. M. F., & Kantarci, B. (2018). Covers-up: Collaborative verification of smart user profiles for social sustainability of smart cities. Sustainable Cities and Society, 38, 348-358.
Economy and financing	Lee,J. H., Hancock, M. G., & Hu, M. C. (2014). Towards an effective framework for building smart cities: Lessons from Seoul and San Francisco. Technological Forecasting and Social Change, 89, 80 ‑ 99.
Sustainability	Dall' O' , G., Bruni, E., Panza, A., Sarto, L., & Khayatian, F. (2017). Evaluation of cities' smartness by means of indicators for small and medium cities and communities: A methodology for Northern Italy. Sustainable Cities and Society, 34, 193-202.

TABLE II
DEFINITIONS OF INDEXES

Internet availability rate	The Internet availability rate includes the household popularizing rate of the fixed broadband and the penetration rate of mobile broadband users. The household popularizing rate of the fixed broadband refers to the proportion of users who access the Internet to the national households. The penetration rate of mobile broadband users refers to the proportion of the number of mobile phone users who can access the Internet in the national population.
Video monitoring network coverage rate	Refers to the ratio of effective coverage area of video monitoring to the total area of the whole monitoring area.
Basic database coverage rate	Refers to the ratio of the effective coverage area of the basic database to the total area of the whole region.
Smart grid coverage rate	Refers to the ratio of regional smart grid laying to total grid laying.
Local Administrative Permit Management Online System Coverage Rate	Refers to the proportion of local administrative permit management online system open to mobile payment and service platforms in all administrative permit management organizations.
Digital Urban Municipal Supervision and Management Information System Coverage Rate	Refers to the proportion of digital urban municipal supervision and management information system to all the urban municipal supervision and management information system.
Road Sensor Terminal Installation Rate	Refers to the installation rate of all kinds of traffic information sensor terminals in urban roads above secondary trunk level.
Intelligent Environmental Quality Monitoring Equipment Coverage Rate	Refers to the installation rate of environmental quality intelligent detection device in urban roads above secondary trunk level.

Public electronic health records filling rate	Refers to the ratio of electronic health records to total public health records.
Intelligent bus stop coverage rate	refers to the ratio of the number of urban intelligent bus stops to the total number of bus stops.
Construction rate of the computer center of the education MAN	Refers to the ratio of the area with education MAN computer center to the total number of education MAN areas in a city.
Application rate of RFID Technology	Refers to the proportion of enterprises using RDIF technology in the total number of enterprises in a city.
Proportion of special funds for smart city construction	The proportion of the funds arranged by the municipal budget for promoting the construction and development of smart city in the total annual budget of the city.
R&D investment intensity	Refers to the ratio of R&D expenditure to GDP (regional)
Proportion of science and technology expenditure in the general budget of local finance	Science and technology expenditure refers to the expenditure of the government and its relevant departments to support science and technology activities. Generally speaking, it refers to the scientific research expenditure arranged in the national budget.
Proportion of per capita education expenditure in urban areas	Per capita education expenditure = total education expenditure÷ total urban population.

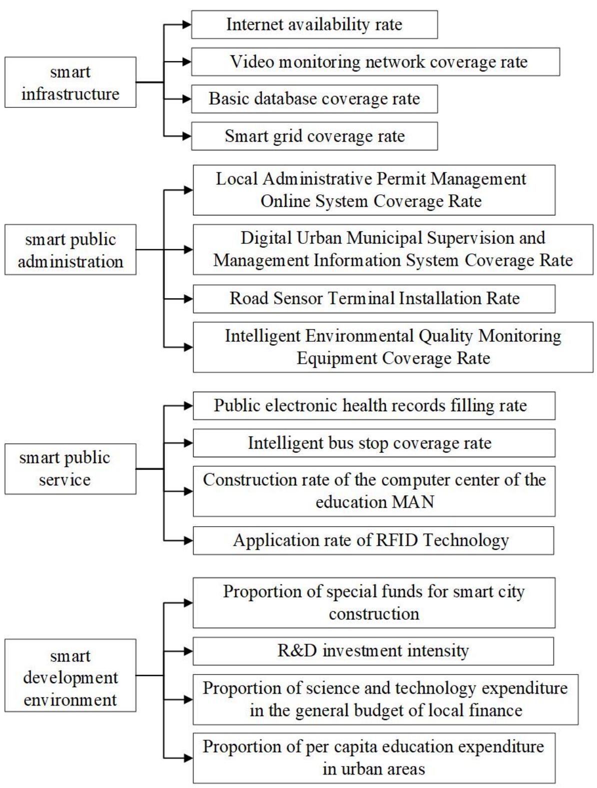

FIGURE 5. **The Evaluation Index System of Smart City Construct Readiness**

C. DETERMINE WEIGHT OF EACH INDEX WITH CRITIC AND G1 METHOD

• ***Objective weights using the Critic method.***

CRITIC (Criteria Importance Though Intercrieria Correlation) is an objective weighting method of index weight proposed by Diakoulaki et al [59]. It can not only measure the difference degree of indicators by standard deviation, but also reflect the correlation between indicators by correlation coefficient. The difference degree is expressed in the form of standard deviation. The larger the standard deviation is, the greater the value difference of each scheme is. Correlation is expressed by correlation coefficient. If there is a strong positive correlation between the two features, the conflict between the two features is low[60]. In recent years, critical method has been applied in many fields such as operations research, economic management, library and information science [61]-[63]. Other objective weight evaluation methods, such as entropy weight method, only consider the degree of variation between the indicators, while in the evaluation of smart city readiness, there is a certain correlation between some indicators. Therefore, this paper applies CRITIC method to the evaluation of smart city construction readiness, so as to determine the objective weight of evaluation index experts. The specific steps of determining weight by CRITIC method are as follows:

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Step1. Calculate the standard deviation of evaluation index σ_j with Eq. (1)

$$\sigma_j = \sqrt{\frac{1}{m}\sum_{i=1}^{m}\left(x_{ij} - \bar{x}_j\right)^2} \tag{1}$$

where $\bar{x}_j$ is the average value of index X_j;

$\bar{\sigma}_j$ is the standard deviation of evaluation index X_j

Step2. Calculate the correlation coefficient matrix of evaluation indexes using Eq. (2), $R = \left(r_{ij}\right)_{n\times n}$

$$r_{ij} = \frac{\sum_{i=1}^{n}\left(x_i - \bar{x}_i\right)\left(x_j - \bar{x}_j\right)}{\sqrt{\sum_{i=1}^{n}\left(x_i - \bar{x}_i\right)^2 \sum_{i=1}^{n}\left(x_j - \bar{x}_j\right)^2}} \tag{2}$$

where $\bar{x}_i$ is the average index value of all schemes of index X_i; $\bar{x}_j$ is the average index value of all schemes of index X_j; r_{ij} is the correlation coefficient between index X_i and index X_j

Step3. Using Eq. (3) to calculate the objective weight w_{Oj} of index X_j

$$w_{Oj} = \frac{C_j}{\sum_{j=1}^{n} C_j}, \quad C_j = \sigma_j \sum_{i=1}^{n}\left(1 - r_{ij}\right) \tag{3}$$

• ***Subjective weights based on G1 method.***

G1 method is also called order relation analysis. This method is an improved Analytic Hierarchy Process (AHP), which can avoid the failure of the test due to too many evaluation indexes when AHP is used to judge the consistency of matrix [64]. The basic principle of G1 method is to sort the importance of evaluation indexes qualitatively, then compare and judge the importance of adjacent indexes according to the sorting results, and get the weight of evaluation indexes finally [65]. Considering that G1 method is a subjective weighting method, which can make full use of the rich knowledge and practical experience of decision-making experts [66], this paper applies G1 method to the evaluation of smart city construction readiness, so as to determine the subjective weight of the evaluation index. The specific steps are as follows：

Step1. Determine the importance of indicators

Arrange the order relation.

$$X_1^* > X_2^* > \cdots > X_{j-1}^* > X_j^* > \cdots > X_n^*$$

between the evaluation index $X_1, X_2, X_3, \cdots, X_n$ and a benchmark layer (target layer) according to the evaluation system.

Step2. Calculate the relative importance of adjacent indicators using Eq. (4).

$$\frac{w_{j-1}^*}{w_j^*} = r_j, j = n, n-1, n-2, \cdots, 3, 2 \tag{4}$$

Step3. Calculate weight coefficient w_j^* with Eq. (5) and (6)

$$w_n^* = \left(1 + \sum_{j=2}^{n}\prod_{k=j}^{n} r_k\right)^{-1} \tag{5}$$

$$w_{j-1}^* = r_j w_j^*, j = n, n-1, n-2, \cdots, 3, 2 \tag{6}$$

• ***Determine the combination weight on the basis of Multiplicative normalization.***

Considering that the objective weight of smart city construction readiness can effectively transfer the difference of index data, and the subjective weight can fully consider the rich knowledge and practical experience of decision-making experts. Therefore, in order to take the above two advantages into account at the same time, reduce the randomness of subjective weight and one sidedness of objective weight, and make the subjective and objective unified, this paper uses the multiplication normalization method to calculate the combined weight of smart city construction readiness. The calculation formula is as follows:

$$w_j = \frac{w_j^* w_{oj}}{\sum_{j=1}^{m} w_j^* w_{oj}} \tag{7}$$

• ***Establish the smart city readiness assessment model using the Bonfreroni (IULWABM) operator***

In the evaluation of smart city construction preparation, the evaluation indexes are not independent of each other, but have certain mutual influence and interdependence. In this context, the Bonfreroni operator can eliminate the mutual influence and interdependence between the indicators, and make the comprehensive evaluation results fair [67]. In recent years, Bonferroni operator has been well developed and applied in practical problems such as multi-attribute comprehensive evaluation and group decision-making [68], [69].

Step 1. Standardize the decision-making information

The evaluation indexes in the evaluation system are not comparable because of their different dimensions, economic significance and expression forms. Therefore, it is necessary to first process the original data and standardize the evaluation index. After transforming the cost index into the profit index, the decision matrix can be expressed as $\widetilde{R}_k = \left(\widetilde{r}_{ij}^{\,k}\right)_{m\times n}$ .Where

$$\widetilde{r}_{ij}^{\,k} = \left\langle \left[s_{a_{ij}}^k, s_{b_{ij}}^k\right], \left(u_{ij}^k, v_{ij}^k\right)\right\rangle = \begin{cases} \left\langle \left[s_{a_{ij}}^k, s_{b_{ij}}^k\right], \left(u_{ij}^k, v_{ij}^k\right)\right\rangle (For Benefit\ Attribute C_j) \\ \left\langle \left[s_{a_{ij}}^k, s_{b_{ij}}^k\right], \left(v_{ij}^k, u_{ij}^k\right)\right\rangle (For Cost Att\ ribute C_j) \end{cases} \tag{8}$$

Step 2. Utilize the BM operator (in general, take p = q = 1) to aggregate all the decision matrices $\widetilde{R}_k$ into a collestive decision matrix $\widetilde{R} = \left[\widetilde{r}_{ij}\right]_{m\times n}$

$$\widetilde{r}_{ij} = \left\langle \left[s_{a_{ij}}, s_{b_{ij}}\right], \left(u_{ij}, v_{ij}\right)\right\rangle = \left(\frac{1}{d(d-1)} \sum_{\substack{k,l=1 \\ k\neq l}}^{n} \left(w_j \widetilde{r}_{ij}^{\,k}\right)^p \otimes \left(w_j \widetilde{r}_{ij}^{\,l}\right)^q\right)^{\frac{1}{p+q}} \tag{9}$$

where $w = (w_1, w_2, \cdots, w_k)^T$ is the weight vector of decision makers.

Step 3. Utilize the BM operator to derive the collective overall preference values $\widetilde{r}_i$ of the alternative A_i ,

$$\widetilde{r}_i = \left\langle \left[s_{ai}, s_{bi}\right], \left(u_i, v_i\right)\right\rangle = \left(\frac{1}{n(n-1)} \sum_{\substack{j,l=1 \\ j\neq l}}^{n} \left(\omega_j r_{ij}\right)^p \otimes \left(\omega_l r_{il}\right)^q\right)^{\frac{1}{p+q}} \tag{10}$$

where $\omega = (\omega_1, \omega_2, \cdots, \omega_n)^T$ is the attribute weight vector, $\sum_{j=1}^{n} \omega_j = 1$

Step 4. Calculate the ecpexted values $E(\widetilde{r}_i)$ of the collective overall values $\widetilde{r}_i$ to rank all the altertives A_i and then to select the best one(s).

Step 5. Rank all the alternatives A_i and select the best one(s).

On the basis of determining the combination weight of smart city readiness evaluation index, this paper uses the Bonferroni operator to aggregate the multi-index information, which can better eliminate the mutual influence and interdependence between the evaluation indexes of smart city construction readiness, thus making the aggregation of multi-index information more objective and fair, and finally making the comprehensive evaluation results more objective and reasonable.

TABLE III
THE WEIGHT OF EACH INDEX

index	C1	C2	C3	C4	C5	C6	C7	C8
Subjective weight	0.0965	0.0642	0.0668	0.0341	0.0520	0.0246	0.0460	0.0704
Objective weight	0.0773	0.0549	0.0862	0.0585	0.0698	0.0455	0.0366	0.0527
Combination weight	0.1160	0.0548	0.0896	0.0310	0.0565	0.0174	0.0262	0.0577
index	C9	C10	C11	C12	C13	C14	C15	C16
Subjective weight	0.0538	0.0667	0.0639	0.0702	0.0840	0.0538	0.0756	0.0775
Objective weight	0.0777	0.0690	0.0637	0.0617	0.0730	0.0519	0.0606	0.0608
Combination weight	0.0650	0.0716	0.0633	0.0674	0.0954	0.0434	0.0713	0.0733

IV. CASE STUDY

A. PROBLEM DESCRIPTION

In the new situation of entering the new normal, smart city will become a new theme of urban development in China during the 13th Five Year Plan period. In general, China's new smart city construction has achieved positive results, but it also faces some problems, such as weak top-level design, insufficient urban data integration and governance linkage, unbalanced urban-rural and regional development, and lack of smart city development ecology. Therefore, it is necessary to carry out targeted improvement to promote the sustainable and healthy development of China's new smart city construction. In addition, COVID-19 has exposed many problems in the construction of smart city in China, so it is necessary to evaluate the readiness of smart city construction in China. The development of smart city construction needs stable information infrastructure, strong policy support and good economic development as the necessary support.

The samples selected in this paper are all from three groups of National Smart City lists (a total of 290). Considering the comparability between cities and the limitation of data, 30 cities from 290 pilot cities are selected as the evaluation objects, including Beijing, Shanghai, Tianjin, Hangzhou, Ningbo, Wuxi, Nanjing, Chengdu, Chongqing, Guangzhou, Shenzhen, Foshan, Xiamen, Fuzhou, Wuhan, Changsha, Zhengzhou, Hefei, Nanchang, Xi'an, Taiyuan, Qingdao, Harbin, Dalian, Changchun, Urumqi, Lanzhou, Nanning, Kunming and Shijiazhuang. According to the evaluation index system, 30

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selected cities are evaluated and ranked in order to provide support for the corresponding basic theory of smart city construction.

B. REALIZE ASSESSMENT OF SMART CITY CONSTRUCTION READINESS USING CRITIC-G1 AND BONFERRONI OPERATOR

Firstly, the sample data is normalized, and then the weight of each index is obtained according to the formula, as shown in the Table III. The comprehensive score is obtained by using the Bonfreroni operator, as shown in the Table IV.

C. RESULTS AND DISCUSSION

In order to verify the effectiveness and effectiveness of this method in the evaluation of smart city construction readiness, this paper compares and analyzes the evaluation results of this method with AHP, Entropy weight-TOPSIS, Grey Relationship Analysis and support vector machine (SVM), as shown in the Table V and FIGURE 6 below.

TABLE IV
THE COMPREHENSIVE SCORE OF 30 CITIES.

city	score	city	core
Beijing	1.0000	Changsha	0.5998
Shanghai	0.8171	Zhengzhou	0.5064
Tianjin	0.6885	Hefei	0.5951
Hangzhou	0.6919	Nanchang	0.5512
Ningbo	0.6852	Xi’an	0.5847
Wuxi	0.6813	Taiyuan	0.5789
Nanjing	0.6973	Qingdao	0.6591
Chengdu	0.6893	Harbin	0.5011
Chongqing	0.6015	Dalian	0.5273
Guangzhou	0.6774	Changchun	0.4829
Shenzhen	0.7086	Urmuqi	0.4075
Foshan	0.6659	Lanzhou	0.3992
Xiamen	0.6499	Nanning	0.4179
Fuzhou	0.6063	Kunming	0.4121
Wuhan	0.6525	Shijiazhuang	0.4284

TABLE V
RESULTS OF SMART CITY CONSTRUCT ASSESSMENT BY DIFFERENT METHOD OR METHODOLOGY

City	Method (methodology)									
	AHP		Entropy weight-TOPSIS		Grey Relationship Analysis		SVM		This paper	
	score	rank	score	rank	score	rank	score	rank	score	rank
Beijing	1.0000	1	0.8700	2	1.000	1	0.8742	1	1.0000	1
Shanghai	0.9137	2	0.9517	1	0.9133	2	0.8096	2	0.8171	2
Shenzhen	0.8842	3	0.8142	3	0.8879	3	0.7728	4	0.7086	3
Nanjing	0.8674	4	0.7640	7	0.8621	4	0.7219	6	0.6973	4
Hangzhou	0.7032	10	0.7763	6	0.8192	6	0.7597	5	0.6919	5
Chengdu	0.7739	6	0.7018	8	0.7930	7	0.6019	12	0.6893	6
Tianjin	0.8529	5	0.6735	9	0.8546	5	0.7765	3	0.6885	7
Ningbo	0.6931	11	0.6269	11	0.7428	9	0.5296	18	0.6852	8
Wuxi	0.6529	15	0.5270	15	0.7207	10	0.6332	10	0.6813	9
Guangzhou	0.7645	7	0.8099	4	0.7599	8	0.6678	9	0.6774	10
Foshan	0.6514	16	0.6592	10	0.6575	15	0.6993	8	0.6659	11
Qingdao	0.6830	13	0.5728	13	0.7066	11	0.7022	7	0.6591	12
Wuhan	0.6906	12	0.6125	12	0.6802	12	0.5281	19	0.6525	13
Xiamen	0.7301	9	0.5283	14	0.6610	14	0.5420	16	0.6499	14
Fuzhou	0.6067	17	0.4522	18	0.6125	16	0.4973	22	0.6063	15
Chongqing	0.7323	8	0.7839	5	0.6700	13	0.6034	11	0.6015	16
Changsha	0.6599	14	0.4085	19	0.5574	17	0.5937	13	0.5998	17
Hefei	0.5982	19	0.3698	20	0.4396	21	0.5825	14	0.5951	18
Xi’an	0.5729	20	0.4827	17	0.5021	18	0.5062	21	0.5847	19
Taiyuan	0.4937	23	0.2865	25	0.4628	19	0.5123	20	0.5789	20
Nanchang	0.5538	22	0.2739	26	0.3705	23	0.4038	26	0.5512	21
Dalian	0.6010	18	0.5118	16	0.4544	20	0.4564	25	0.5273	22
Zhengzhou	0.5716	21	0.3520	21	0.4061	22	0.3827	27	0.5064	23
Harbin	0.4728	24	0.3425	23	0.3550	24	0.4670	24	0.5011	24
Changchun	0.4015	26	0.3516	22	0.2835	27	0.4935	23	0.4829	25
Shijiazhuang	0.3970	27	0.3071	24	0.2940	26	0.5304	17	0.4284	26
Nanning	0.1036	30	0.2394	28	0.1998	29	0.5519	15	0.4179	27
Kunming	0.4599	25	0.2613	27	0.3291	25	0.3286	28	0.4121	28
Urumqi	0.2673	28	0.1536	30	0.2336	28	0.2929	30	0.4075	29
Lanzhou	0.1962	29	0.1960	29	0.1947	30	0.3012	29	0.3992	30

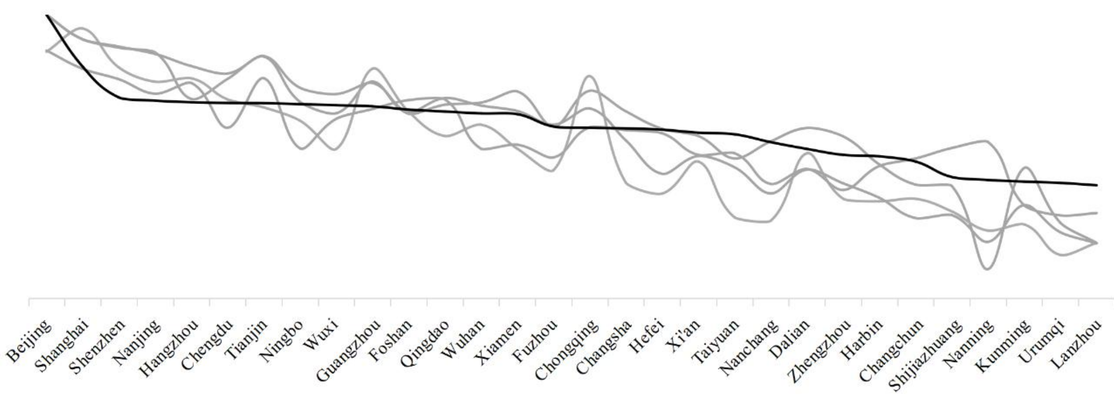

FIGURE 6. **Benchmarking of Different Method (methodology)**

First of all, apply this method and AHP method to this case at the same time (Fig.7), comparative analysis is carried out as follows. From the figure, it can be seen that the overall results are consistent by using two methods to evaluate smart city construction readiness. The cities with a large difference in ranking results are: Chongqing (Ranks 8 places different), Wuxi (ranks 6 places different).

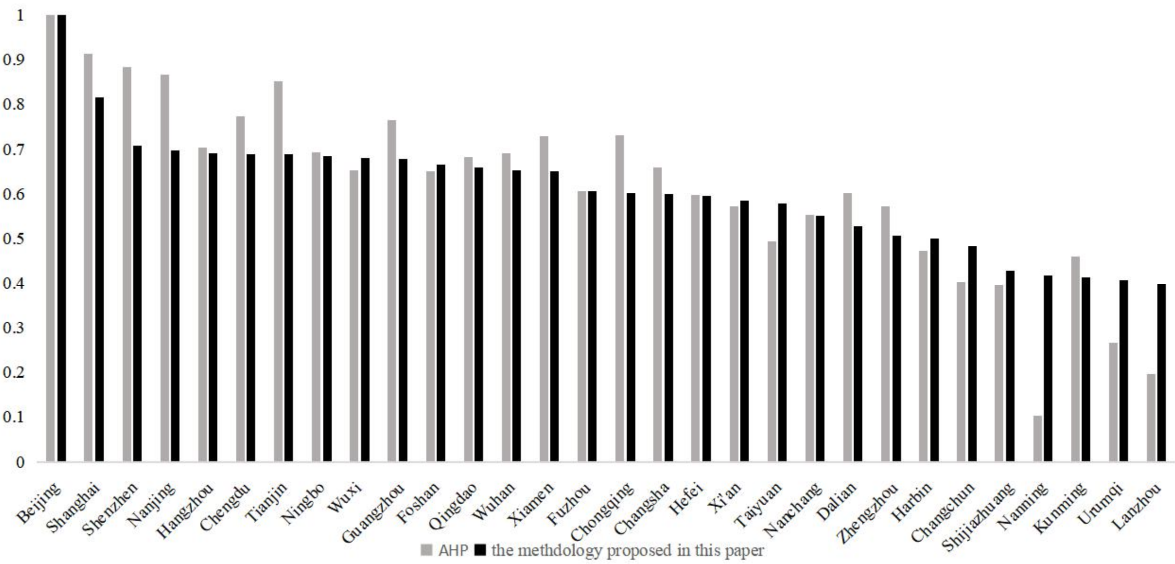

FIGURE 7. **Evaluation Results of AHP and the Method of This Paper**

The difference between the other cities' rankings calculated by these two methods is within 5. The reasons for the different results conducted by the two different methods can be summarized are as follow. On the one hand, the AHP method is completely dependent on subjective evaluation to make order, in the process of the smart city construction readiness evaluation, decision-makers' judgment process prone to too much affected by the subjective preference, resulting in distortion of the objective laws, this paper discussed the smart city construction readiness evaluation involves abundant evaluation index and extensive scale, and some evaluation indexes have contrast strength and conflict, which puts forward high requirements for decision-makers to master the logical relationship between elements. On the other hand, from the perspective of urban development, as the only province-level municipality in the Midwest of China, Chongqing is an important connecting city of the Yangtze River Economic Belt. In 2019, Chongqing proposed to build a famous smart city for the first time at the Smart Expo, and many internet companies like Tencent have already invested in it. It can be seen that Chongqing's smart city development has made some achievements, and the score in the construction of smart medical service is high, but limited to the regional location and other factors, the development power is slightly insufficient. Therefore, in the research results of AHP method, some experts give a high rating based on the current intelligent development trend of Chongqing. However, compared with other central cities and coastal cities, the actual achievements of Chongqing still lag behind.

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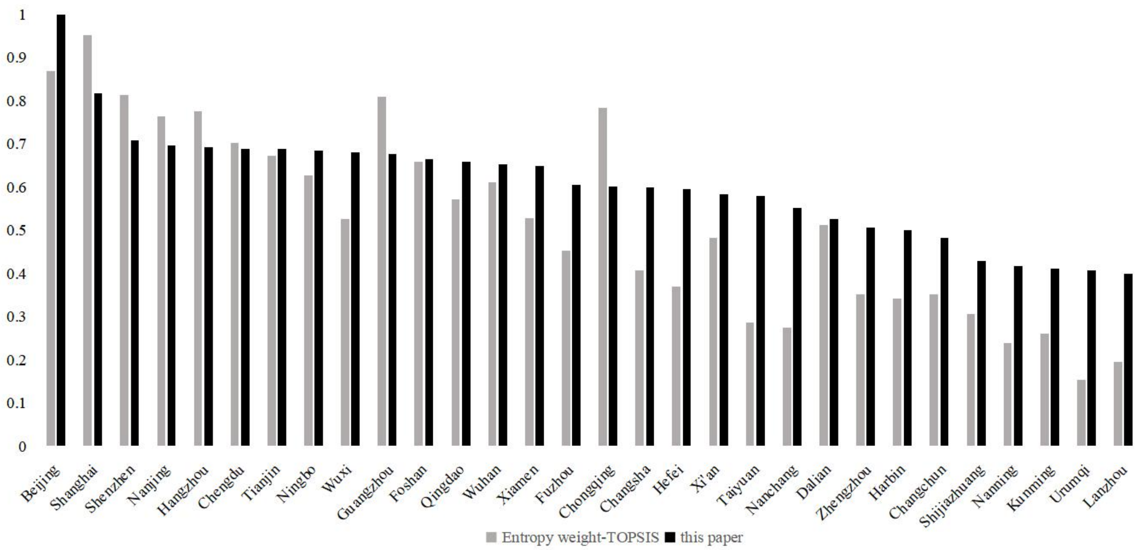

FIGURE 8. Evaluation Results of Entropy Weight-TOPSIS method and the Method of This Paper

Secondly, apply the Entropy weight-TOPSIS method in this case (FIGURE 8).

Compared with the results conduct by the methodology giving in this paper, the rank difference of Chongqing is 11, Guangzhou is 6, and the rank difference of other cities is within 5. The reasons for the different results conducted by the two different methods can be summarized are as follow. On the one hand, entropy weight-TOPSIS method has too strong objectivity in determining the weight, which easily causes the index weight with low importance is great and the index weight with high importance is small. At the same time, the entropy weight-TOPSIS method is based on the Euclidean distance, and the ranking of the target solutions according to the Euclidean distance cannot fully reflect the merits and demerits of the project. On the other hand, from the perspective of urban development, Guangdong, Hong Kong and Macao are regarded as an urban agglomeration for smart city construction in the newly proposed "Outline Development Plan for the Guangdong-Hong Kong-Macao Greater Bay Area" in 2019. This paper only selects mainland cities as the evaluation objects, and does not take the impact of Guangdong-Hong Kong-Macao urban agglomeration's development into account, which may lead to some slight deviation in the evaluation results.

Thirdly, apply the Grey Relationship Analysis in this case (FIGURE 9).

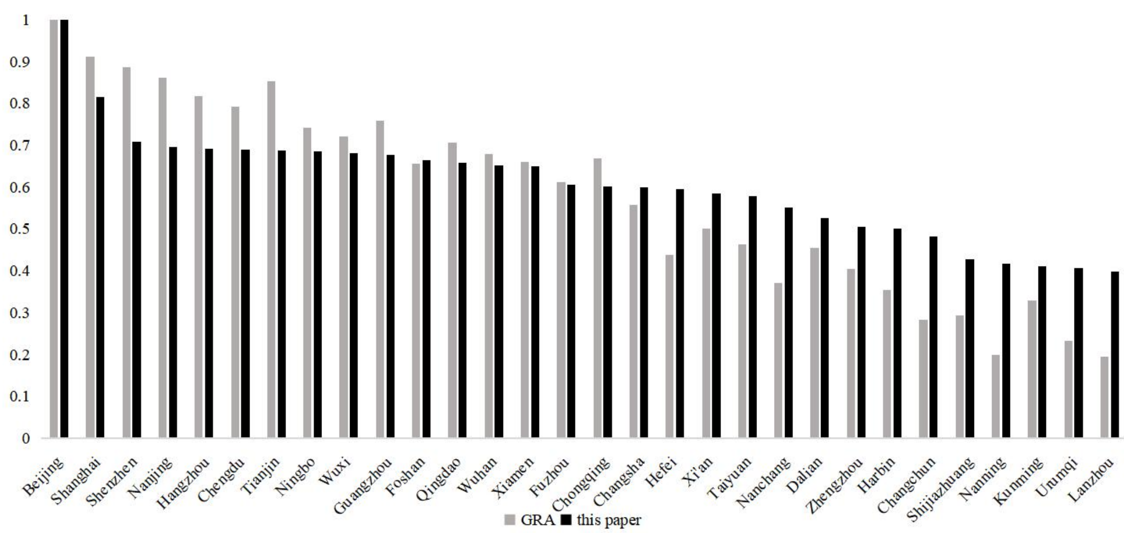

FIGURE 9. Evaluation Results of GRA and the Method of This Paper

Compared with the results conduct by the methodology giving in this paper, the rank difference of Foshan is 4, the rank difference of other cities is within 3. The reasons for the different results conducted by the two different methods can be summarized are as follow. On the one hand, from the perspective of theoretical methods, the calculation method of grey relation analysis has experienced the evolution and development of Deng interrelatedness, improved-relating-degree coefficient, B-mode relation degree, but there are still some defects such as lack of standardization and isotonicity. At present, the contradiction between the four axioms of grey relation and the calculation method of grey relation degree cannot be well solve. On the other hand, from the perspective of urban development, Foshan has been listed as one of the top ten smart cities in China in 2019. As an earlier city selected for smart city construction, Foshan has a little less development potential compared with the city at the peak of development. Coupled with the lack of isotonicity of grey relation analysis, it may lead to different results when using different evaluation methods.

Finally, the support vector machine (SVM) method is applied to the case study (FIGURE 10). Compared with the method in this paper, Nanning differs by 12 places, Ningbo differs by 10 places, Shijiazhuang differs by 9 places, Fuzhou differs by 7 places, Chengdu differs by 6 places, Wuhan differs by 6 places, and the rest of the cities differ within 5 places. The operation of SVM involves some important parameters which have a significant impact on the performance of the algorithm, such as penalty parameter c and the radial basis probabilistic kernel parameter γ . The penalty parameter c determines the penalty degree when the sample is misclassified. The radial basis probabilistic kernel parameter γ , namely the width of Gaussian distribution, determines the radial action range of the function and controls the essence of the nonlinear mapping. Therefore, in the process of practical application, the setting of penalty parameter and kernel parameters is an inevitable problem. Now, most parameter c and γ are obtained by cross validation trial. This method is not only time-consuming but also blind. In this paper, the default cross-validation of software is used to calculate parameter c and γ , so the conclusion obtained by SVM method is not very ideal.

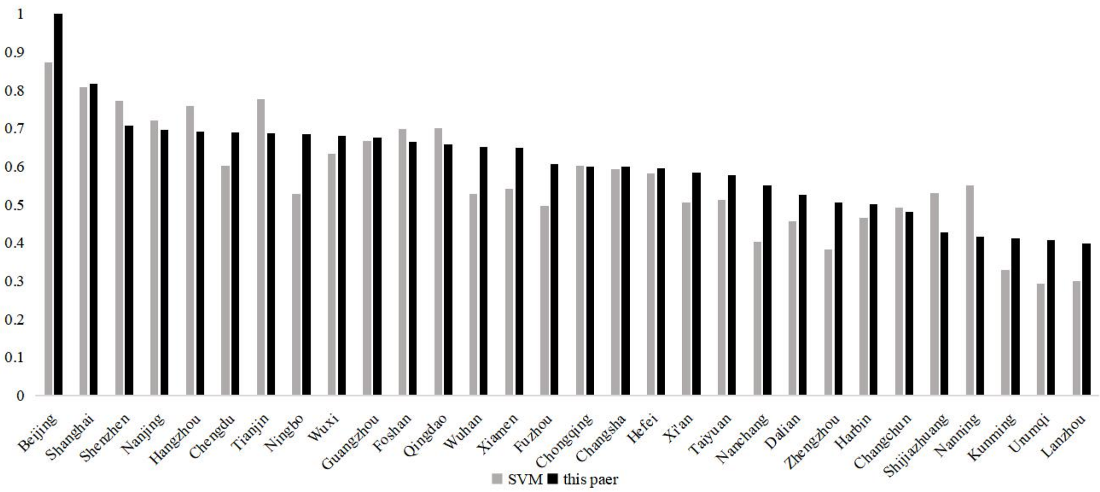

FIGURE 10. Evaluation Results of SVM and the Method of This Paper

D. RELIABILITY TEST

In addition, Spearman's rank correlation coefficients between the proposed method and the above four methods were calculated, which were 0.902, 0.864, 0.934 and 0.849 respectively, $p = 0.000 < 0.1$is significant. It can be seen that the ranking of the proposed method has a good similarity with the above four methods, which further verifies the rationality of the proposed method.

V. CONCLUSION

Aiming at the problem of multi-index information aggregation in smart city construction readiness evaluation, this paper proposes a smart city construction readiness evaluation method based on CRITIC-G1 and the Bonferroni operator. Firstly, the objective weight of the evaluation index of the readiness of smart city construction is obtained by CRITIC method, which can guide the development of smart city construction and its evaluation method and index towards a better direction. Secondly, G1 method is used to integrate the subjective preference of decision-makers, so as to avoid the growth mindset of some cities in the process of intelligent construction to a certain extent. Finally, use the Bonferroni operator to get a more reasonable evaluation result of smart city construction readiness, which can provide decision-making reference for the practical problems of urban governance. An empirical analysis of 30 cities selected from three batches of national smart cities lists is carried out, and the feasibility of the method in this paper for smart city readiness evaluation is demonstrated by comparing with other evaluation methods.

The main conclusions of this paper are as follows.

First of all, smart city construction is synergistic by many factors. In the establishment stage of the index system, sixteen evaluation indexes of smart city construction readiness were selected through literature analysis and expert interview. In the subsequent case study, when the method in this paper is compared with other methods, the phenomenon of large fluctuations in the ranking of individual cities appears. This is due to the different evaluation methods in determining weights and model calculation due to the inherent limitations. The essential reason is that smart city construction readiness is a multi-criteria decision-making problem, which need to fully consider the amount of information and coordination of evaluation index in data processing and building the evaluation index model stage due to the strength and conflicting between each index, as to eliminate the mutual influence between the index and depend on each other, to make the multi-index information gathering to be more objective and fairer.

In addition, through the analysis and comparison of 30 cities that have been shortlisted in the list of smart city construction in China, we can see that China's smart city construction has achieved certain results, and some of them have basically achieved a certain degree of smart. However, there is still a big gap between the development status of different regions and the basic conditions that cities already have. The Bohai Rim urban agglomerations with Beijing, Tianjin and Qingdao as the main cities, the Yangtze River Delta Urban Agglomerations with Shanghai, Nanjing, Hangzhou and Wuxi as the main cities, and the central and western urban agglomerations with Chongqing, Xi'an and Wuhan as the main cities have the necessary foundation and conditions for the construction of new smart cities, and the corresponding smart city construction has achieved certain results. Benchmarking shows that the intelligence capability and level of Beijing, Tianjin and other cities are obviously higher than that of city clusters in the Midwest of China, which is consistent with the actual situation and demonstrates the effectiveness of the evaluation model. In addition, Ningxia, Urumqi, Lanzhou and other cities in Northwest China generally have low scores for smart city construction readiness. On the one hand is due to the smart city development starts late, has not set up perfect supporting infrastructure. On the other hand, the weak location advantage is not conducive to attracting social capital and improving the smart level and development potential of these regions.

It can be seen from the above analysis that, in terms of smart city construction, the government is still lacking in the use and distribution management of social resources, which can also be confirmed by a series of social problems such as labor safety, environmental pollution and so on. In the next step of the construction of smart city, we should focus on the construction of public support system, especially strengthen the capital investment and the introduction of relevant talents, so as to ensure that the construction of smart city always has development vitality and potential.

VI. SUGGESTION

The evaluation index system of smart city constructed in this paper is relatively comprehensive, the indicators selected in this paper are all mandatory quotas with strong accessibility, and many perceptual indexes are not involved. Therefore, adding residents' perception index is one of the directions to improve the smart city index system in the future.

In terms of weighting method, this paper adopts the combination of subjectivity and objectivity to ensure the unity of subjectivity and objectivity in weight calculation. However, the factors of weight change over time are not considered. Therefore, the dynamic factors of index weight change over time can be added in the future research.

Finally, due to time constraints, this paper only takes 30 cities as samples for the horizontal comparison of cities, which lacks dynamic comparison. Therefore, efforts should be made to expand the sample size of the study in future studies.

REFERENCES

[1] He, Yuan, Ivan Stojmenovic, Yunhuai Liu, Yu Gu, "Smart City," *International Journal of Distributed Sensor Networks*, vol.6, no.5, 2014.
[2] Razaghi, M., Finger, M., "Smart Governance for Smart Cities," *Proceedings of IEEE*, vol.106, no.4, pp.680-689, 2018.
[3] Dodgson M., Gann D., "Technological Innovation and Complex Systems in Cities," *Journal of Urban Technology*, vol.18, no.3, pp.101-113, 2011.
[4] XIA Hao-xiang, WANG Zhong-tuo, "Systemic Thinking on Smart Cities," *China Soft Science*, vol.07, pp.66-80, 2017.
[5] Caragliu A., Del Bo C., Nijkamp P., "Smart Cities in Europe," *Journal of Urban Technology*, vol.18, no.2, pp.65-82, 2011.
[6] CHENG Jie, LAI Jian-hua, NIU Wen-yua, "Promoting the construction of smart city with innovation and green," *Information China*, supp.01, pp.32-36, 2013.
[7] Batty M., Axhausen K. W., Giannotti F., "Smart cities of the future," *European Physical Journal-Special Topics*, vol.214, no.1, pp.481-518, 2012.
[8] ZHANG Yong-min, DU Zhong-chao, "The current situation and thinking of smart city construction in China," *Information China*, vol.02, pp.28-32, 2011.
[9] HU Li, CHEN You-fu, "Risk Analysis and Countermeasure for Smart City in China Based on Multi-stage Construction," *China Population, Resources and Environment*, vol.23, no.11, pp.130-136, 2013.
[10] SHAN Zhi-guang, "Challenges to the healthy development of smart cities in China," *Governance*, vol.18, pp.27-32, 2015.
[11] ZOU Kai, XIANG Shang, ZHANGZHONG Qing-yang, MAO Tai-tian, "Model Construction and Empirical Study on Smart City Information Security Risk Assessment," *Library and Information Service,* vol.60, no.07, 19-24, 2016.
[12] GUO Ye, SU Xin-ning, "Study on the Environment, Challenge and Mode of Information Security Management in Smart Cities," *Library and Information Service*, vol.60, no.19, pp.49-58, 2016.
[13] QIN Bin-xuan, "The research of evaluation index system of Smart City base on the System Dynamics Theory," Beijing, China: Beijing Institute of Technology, 2015.
[14] Aborokbah M. M., Al-Mutairi S., Sangaiah A. K., Samuel O. W., "Adaptive context aware decision computing paradigm for intensive health care delivery in smart cities—A case analysis," *Sustainable Cities and Society*, vol.41, pp. 919-924, 2018.
[15] WANG Zhen-yuan, DUAN Yong-jia, "An AHP-based Approach to Evaluation Indicator System of China's Smart City," *Science and Technology Management Research*, vool.34, no.17, pp.165-170, 2014.
[16] LIU Wei-yue, WANG Hai-long, LIU Kai-ge, ZHOU Xiu-xiu, "Construction of Evaluation System for Smart City Based on the Combination Model of Entropy-Weighting and TOPSIS Method: By Taking Beijing, Tianjin and Shanghai as an Example," *Modern Urban Research*, vol.01, pp.31-36, 2015.

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[17] CHEN Wei-qing, LU En-xuan, ZENG Ye-ge, QIN Yun-jiang, “Research on the Evaluation of the Openness Level of Government Data of Smart City Based on Grey Relation Theory and Hierarchical Clustering Analysis,” *Mathematics in Practice and Theory*, vol.50, no.06, pp.43-52, 2020.
[18] MA Qing-tao, SHANG Guo-fei, JIAO Xin-ying, “Evaluation of Smart City Construction Level Based on BP Neural Network,” *Mathematics in Practice and Theory*, vol.48, no.14, pp.64-72, 2018.
[19] CHEN Li, ZHANG Hai-xia, “Evaluation of Green Smart Cities in China Based on Entropy Weight-Cloud Model,” *Journal of System Simulation*, vol.30, no.01, pp.136-144, 2019.
[20] Harrison C., Eckman B., Hamilton R., Hartswick P., Kalagnanam J., Paraszczak J., Williams P., Harrison C., “Foundations for Smarter Cities,” *IBM Journal of Research and Development*, vol. 54, no. 4, pp. 1-16, 2010.
[21] Zhuhadar L., Thrasher E., Marklin S., de Pablos P. O., “The next wave of innovation-Review of smart cities intelligent operation systems,” *Computers in Human Behavior*, vol.66, pp. 273-281, 2017.
[22] Mattoni B., Gugliermetti F., Bisegna F., “ A multilevel method to assess and design the renovation and integration of smart cities, ” Sustainable Cities and Society, vol.15, pp. 105-119, 2015
[23] Caragliu A., Bo C. D., Nijkamp P., “Smart cities in Europe,” *Urban Insight*, vol.18, no.2, pp. 65-82, 2011.
[24] Angelidou M., “Smart city policies: A spatial approach,” *Cities*, Vol.41, Supp.1, pp. S3-S11, 2014.
[25] Yahia N. B., Eljaoued W., Saoud N. B. B., Colomo-Palacios R., “Towards sustainable collaborative networks for smart cities co-governance,” *International Journal of Information Management*, vol.56, 2019.
[26] Hollands R. G., “Will the real smart city please stand up? Intelligent, progressive or entrepreneurial?” *City*, vol.12, no.3, pp. 303-320, 2008.
[27] Gil-Garcia J.R., Pardo T.A., Nam T., “What makes a city smart? Identifying corecomponents and proposing an integrative and comprehensive conceptualization,” *Information Polity*, vol.20, no.1, pp. 61-87, 2015.
[28] Khatoun R., S. Zeadally, “Smart cities: concepts,architectures, research opportunities,” *Communications of the ACM*, vol.59, pp. 46-57, 2016.
[29] Meijer A., Bolivar M. P. R., “Governing the smart city: a review of the literature on smart urban governance,” International Review of Administrative Sciences, vol.82, no.2, pp. 392-408, 2016.
[30] ZHANG Yi, CHEN You-fu, XU Xiao-lin, “Analysis on social risk factors of smart city construction in China,” *Administrative Tribune,* vol.22, no.04, pp.44-47, 2015.
[31] WANG Qing-e, CHAI Xuan-xuan, ZHANG Xuan, “Smart city information security risk and guarantee system construction,” *Science & Technology Progress and Policy*, vol.35, no.24, 20-33, 2018.
[32] Yorgos J., Stephanedes P.E., Mihalis Golias, George Dedes, Christos Douligeris, Sabyasachee Mishra, “Challenges, Risks and Opportunities for Connected Vehicle Services in Smart Cities and Communities,” *IFAC-Papers OnLine*, Vol.51, no.34, pp. 139-144, 2019.
[33] Esposito C., Ficco M., Gupta BB., “Blockchain-based authentication and authorization for smart city applications,” Information Processing & Mnagement, vol.58, no.2, 2021.
[34] FAN Chuang, LIU Yu-ming, “Smart City Construction Risk and Benefit Distribution Method Based on PPP Mode,” *Journal of Harbin Institute of Technology (Social Sciences Edition)*, vol.21, no.02, pp.135-140, 2019.
[35] Masik G., I.Sagan, J.W.Scott, “Smart City strategies and new urban development policies in the Polish context”, *Cities*, vol.108, 2021.
[36] Batty M., “Big data, smart cities and city planning,” *Dialogues in Human Geography*, vol.3, no.3, pp. 274-279, 2013.
[37] SUN Jian-jun, PEI Lei, QIU Peng-fei, SHENG Dong-fang, “The Challenge and Success Experience of Smart City Initiatives——Based on Literature Review and Case Analysis,” *Library & Information*, vol.06, pp.18-24, 2016.
[38] MAO Zi-jun, MEI Hong, XIAO Yi-ming, HUANG Ying-xu, “Risk Assessment of Smart City Information Security Based on Bayesian Network,” *Journal of Modern Information*, vol.40, no.05, pp.19-26+40, 2020.
[39] Yunbo L., Anshen L., “Analysis of the Challenges and Solutions of Building a Smart City,” *International Conference on Construction and Real Estate Management*, pp.1511-1515, 2013.
[40] Ismagilova E, L Hughes, NP Rana, Dwivedi Yogesh K, “Security, Privacy and Risks Within Smart Cities: Literature Review and Development of a Smart City Interaction Framework,” *Information Systems Frontiers*, 2020.
[41] Mick D.G., Fournier S., “Paradoxes of technology: consumer cognizance, emotions, and coping strategies,” *Journal of Consumer Research*, vol.25, no.02, pp.123-143, 1998.
[42] Parasuraman A., “Technology readiness index (Tri): a multiple-item scale to measure readiness to embrace new technologies,” *Journal of Service Research*, vol.2, no.4, pp. 307-320, 2000.
[43] Massey A.P., Khatri V., Montoya-Weiss M.M., “Usability of online services: the role of technology readiness and context,” *Decision Sciences*, vol.38, no.2, pp. 277-308, 2007.
[44] Dupree J., “Techno ready marketing: how and why your customers adopt technology,” *The Free Press*, pp.326-327, 2007.
[45] Meuter M.L., Bitner M.J., Ostrom A.L., “Choosing among alternative service delivery modes: an investigation of customer trial of self-service technologies,” *Journal of Marketing*, vol.69, no.2, pp. 61-83, 2005.
[46] WANG Jing-yuan, LI Chao, XIONG Zhang, SHAN Zhi-guang, “Survey of Data-Centric Smart City,” *Journal of Computer Research and Development*, vol.51, no.02, pp.239-259, 2014.
[47] GUO Yu-hui, TANG Zhi-wei, ZHAI Yuan-fu, “From Smart Cities to New Smart Cities: Smart City Policy Analysis from the Perspective of Policy Tools,” *Journal of Intelligence*, vol.38, no. 06, pp.201-207+200, 2019.
[48] Deakin M., Al Waer H., “ From intelligent to smart cities, ” Intelligent Buildings, International, vol.3, no.3, pp. 140-152, 2011.
[49] Harrison C., Eckman B., Hamilton R., Hartswick P., Kalagnanam J., Paraszczak J., Williams P., “Foundations for Smarter Cities,” *IBM Journal of Research and Development*, vol.54, no.4, pp. 54-59, 2010.
[50] SUN Bin, YAN Bo, SHANG Ya-nan, “Research on Smart City Evaluation System in Baotou Based on System Dynamics,” Urban Development Studies, vol.23, no.08, pp.6-11, 2016.
[51] REN Rui, “The Evaluation about Development of Green and Smart Urban Based on PCA and GRA,” Anhui, China: Anhui Jianzhu University, 2017.
[52] YANG Kai-rui, ZHANG Yi, ZHANG Peng-fei, “Research on Smart City Evaluation Based on Input Output Perspective,” *E-Government*, vol.12, pp.47-54, 2015.
[53] Hamid M., Ismail G., Kemal A., Selcuk U.A., Abdullah K., Adem T., “UAV-Enabled Intelligent Transportation Systems for the Smart City: Applications and Challenges,” *IEEE Communications Magazine*, vol.55, no.3, pp. 22-28, 2017.
[54] ZHAO Meng, WEI Dai-wei, MA Xiao-yu, LI Wen-wen, “The Huimin Evaluation of Smart City Based on Grey Relational Analysis of Interval Type-2 Fuzzy Sets,” *Mathematics in Practice and Theory*, vol.46, no.23, pp.28-37, 2016.
[55] YIN Yuan, “The Research of Smart City Evaluation System Based on Combination Weighting and Improved TOPSIS Model,” Liaoning, China: Dongbei University Of Finance And Economics, 2017.
[56] YAO Yan-xia, “Evaluation on the Construction of Smart City in Xiangtan Based on the SOM Network and Time Series Analysis,” Hunan, China: 2017.
[57] Le L.T., Nguyen H., Dou J., Zhou J., “A Comparative Study of PSO-ANN, GA-ANN, ICA-ANN, and ABC-ANN in Estimating the Heating Load of Buildings' Energy Efficiency for Smart City Planning,” *Applied Sciences-basel*, vol.9, no.13, 2019.
[58] Fernández-Güell J.M., Guzmán-Araña S., Collado-Lara M., Fernández-Añez V., “How to Incorporate Urban Complexity, Diversity and Intelligence into Smart Cities Initiatives,” *Smart Cities*. vol. 9704, pp 85-94, 2016.
[59] Diakoulaki D., Mavrotas G., Papayannakis L., “Determining objective weights in multiple criteria problems: the CRITIC method,” *Computers＆Operations Research*, vol. 22, no.7, pp. 763-770, 1995.
[60] Paulo C. Heredia, Shaoshuai M., “Distributed Multi-Agent Reinforcement Learning by Actor-Critic Method,” *IFAC-Papers OnLine*, vol. 52, no. 20, pp. 363-368, 2019.
[61] ZHANG Yu, WEI Hua-bo, “Combination Weighting Method of

Multiple Attribute Decision Making Based on CRITIC," *Statistics & Decision*, vol.16, pp.75-77, 2012.
[62] ZHAO Shu-qiang, TANG Shan-fa, "Comprehensive Evaluation of Transmission Nnetwork Planning Scheme Based on Improved Analytic Hierarchy Process, CRITC Method and TOPSIS," *Electric Power Automation Equipment*, vol.38, no.03, pp.143-148+162, 2019.
[63] SUN Rui-shan, ZHAN Xin, "Analysis on Influence Factors of Controlled Flight into Terrain of General Aviation Based on ISM-CRITIC Method," *Journal of Safety Science and Technology*, vol.14, no.01, pp.129-135, 2016.
[64] WANG Xue-jun, GUO Ya-jun, "Analyzing the Consistency of Comparison Matrix Based on G1 Method", *Chinese Journal of Management Science*, vol.03, pp.65-70, 2006.
[65] J.X. Xie, Y. Qin, X.L. Meng, et al. "The fuzzy comprehensive evaluation of the highway emergency plan based on G1 method," 2010 3rd International Conference on computer science and information technology, pp. 313-316, 2010.
[66] Jing L., Yao W., "A Safety Assessment of China's Crude Oil Import Based on G1 Method," *Procedia-Social and Behavioral Sciences*, vol. 96, pp. 1738-1744, 2013.
[67] ZHU Bin, XU Zeshui, XIA Meimei, "Hesitant fuzzy geometric Bonferroni means," *Information Science*, vol. 205, pp. 72-85, 2012.
[68] LIU Peide, WANG Yumei, "Multiple attribute decision-making method based on single-valued neutrosophic normalized weighted Bonferroni mean," *Neural Computing&Applications*, vol. 25, no. 7-8, pp. 2001-2010, 2014.
[69] XIA Meimei, XU Zeshui, ZHU Bin, "Geometric Bonferroni means with their application in multi-criteria decision making," *Knowledge-based Systems*, vol. 40, pp. 88-100, 2013.

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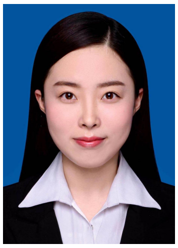

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