Study on evaluation system of collaborative governance degree of universities in the GBA based on AHP and FCE

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Abstract—Under the background of national strategy and policy, the key to support Guangdong-Hong Kong-Macao Greater Bay Area (GBA)'s construction is the main role of active governance of colleges and universities. How to play the main role and promote the governance of colleges and universities in GBA has gained extensive attention. For catching up on the missing of the evaluation system of university collaborative governance degree in GBA and promote the improvement of university collaborative governance in GBA, this paper puts forward a new university collaborative governance path model in GBA, and establishes a relatively perfect evaluation system framework of university collaborative governance degree in GBA. By collecting a large number of 2754 questionnaires in GBA, Then the Analytic Hierarchy Process (AHP) is used to determine the weight of each level index of the collaborative governance degree of colleges and universities in GBA. According to the data, the Fuzzy Comprehensive Evaluation method (FCE) is used to evaluate the current collaborative governance degree of colleges and universities in GBA. Finally, detailed improvement suggestions are given on the weak links. Based on the evaluation results, this paper concludes that the improvement order of the current collaborative governance degree of universities in GBA is the collaboration between the government and universities, the market and universities, the internal collaboration between universities, and the society and universities, We should focus on optimizing the power of the Development Advisory Committee of colleges and universities and promoting the innovation of higher education system and mechanism in an all-round way. Using this method, we can accurately evaluate the current situation of university collaborative governance in GBA from both qualitative and quantitative aspects, and provide a scientific basis for improving the degree of university collaborative governance in GBA.

Index Terms—analytic hierarchy Process, Collaborative governance of colleges and Universities, evaluation system, fuzzy comprehensive evaluation method, Guangdong-Hong Kong-Macao Greater Bay Area

I. INTRODUCTION

ACCORDING to the World Declaration on Higher Education, the partnership based on common interest, mutual respect and credibility should be a prime matrix for renewal in higher education, the concept of involving multiple subjects in governance is widely promoted, and the collaborative governance of higher education institutions (hereinafter referred to as universities or colleges or colleges and universities for less redundancy) is a new trend in the modernization of university governance (Li Man, 2015)[1]. The Plan for Promoting Higher Education Cooperation and Development in the Guangdong-Hong Kong-Macao Greater Bay Area (GBA), jointly released by the Ministry of Education of the People's Republic of China and People's Government of Guangdong Province in December of 2020, proposes to highlight the five major key tasks of institutional reform, connectivity, innovation, attracting and cultivating talents as well as boosting interactions and mutual learning, on the purpose of building the GBA into a world model for higher education cooperation and innovation in 2035 (Yu Manyue, 2020)[2]. Both of these five major tasks and this goal ask for consultation and win-win cooperation among subjects include universities, government, society and market, which indicates that collaborative governance of higher education institutions is not only an effective way of university governance in the building of the GBA, but also the key to allow colleges fully play universities' active and dominant role in collaborative governance and achieve the goal of the GBA.

The objectives of building the Guangdong-Hong Kong-Macao Greater Bay Area is to integrate society, economy, education and culture among Guangdong, Hong Kong and Macao (Xu Changqing, 2019)[3] and to build a hub for developing high-end technology and talent cultivation. To achieve these, government, universities and society have to participate and play universities' roles, among which the active governance of colleges acts a leading role in building the GBA. In order to encourage colleges to participate in governance and realize constructive interactions among colleges and multiple subjects such as government, society and market as well as the effective inner governance within universities, it is necessary to find out the weaknesses in efficient and collaborative governance and offer the best solution. Before this paper, Pan Chunsheng analyzed the current situation of university governance in China, proposed a collaborative and win-win approach to university governance, and analyzed its connotation, characteristics and role in details (Pan Chunsheng, 2014)[4]. Jiang Dayong proposed that the collaborative governance among government, universities and society poses a theoretical and practical challenge for the reform of higher education in China, but it also offers guidance for this reform (Jiang Dayong, 2019)[5]. The study from Li Weitao sheds light on the barriers and approaches to collaborative governance of education in the process of modernization, and put up important approaches such as improving the collaborative cultivation mechanism in community and promoting the innovation of collaborative governance of regional education (Li Weitao, 2021)[6]. Based on the characteristics of Complex Adaptive System (CAS), Zeng Zhenxiang and her team established an operational mechanism fitting for the structure of subjects in collaborative governance of higher education institutions, which provides a new implementation scheme for the theory of collaborative governance of higher education institutions (Zeng Zhenxiang et al., 2019)[7]. Ding Chen pointed out that the vision of collaborative governance in higher education is to integrate "divided forces" into a "combined force", and analyzed the specific path of forming combined force and realizing collaborative governance of higher education (Ding Chen, 2021)[8]. Combining theoretical research method and qualitative research method, Xu

Changqing and his team proposed a relatively complete role of universities in the building of the Greater Bay Area for the first time, and built a governance path model on the role of universities, which, to a certain extent, provides a theoretical support for the current collaborative governance of higher education institutions in the Greater Bay Area (Xu Changqing, Huang Yumei, 2020)[9]. There are a great deal of studies on collaborative governance of higher education institutions that involves the nature, meaning and the realization methods of collaborative governance. However, two shortcomings are easy to be found in these studies: first, an evaluation system for measuring the degree of collaborative governance in colleges has not been put up, leading to the lack of qualitative and quantitative study to evaluate and the current situation of university collaborative governance; second, the paths to solve problems on university collaborative governance and realize university collaborative governance are not comprehensive and specific, which fails to distribute resources in the best way to solve these problems. Therefore, in order to make up for the lack of evaluation system of collaborative governance degree of higher education institutions in the Greater Bay Area and improve the this collaborative governance level, this paper proposes a new path model of collaborative governance of higher education institutions in the Greater Bay Area and creatively puts up a scientific and reasonable evaluation system of collaborative governance degree of higher education institutions in the GBA. This paper also ranks the improvement order of weaknesses by calculating the weighted values of evaluation indexes and focuses on the priority of problem solving to realize the efficient allocation of resources and reduce waste. The core part of this paper can be divided into three parts. The first part illustrates the mechanism of collaborative governance of higher education institutions and the role of universities in the GBA, explains the characteristics of collaborative governance of higher education institutions in the GBA, and applies Analytic Hierarchy Process (AHP) and Fuzzy Comprehensive Evaluation (FCE) to evaluate on the basis of the characteristics. The second part puts forward a detailed path model of collaborative governance of higher education institutions in the Greater Bay Area based on the existing path model of collaborative governance of higher education institutions, the principles of building the Greater Bay Area and the vision of fully playing the role of universities in the Greater Bay Area. And then this part decomposes the overall path model into evaluation indexes at the sub-criteria level of the evaluation system, enabling the building of the system for evaluating the degree of collaborative governance among higher education institutions in the Greater Bay Area. In the following steps, the current degree of collaborative governance of higher education institutions in the Greater Bay Area is evaluated by Analytic Hierarchy Process (AHP) and Fuzzy Comprehensive Evaluation (FCE) with data collected from 2754 questionnaires. The third part points out the weaknesses in the collaborative governance of higher education institutions in the Greater Bay Area and solutions based on the quantitative assessment value of the degree of such collaborative governance and the weighted deduction value of indicators in each level of to the previous level of indicators.

II. Analysis on the Mechanism of Collaborative Governance in Higher Education Institutions and the Role of Higher Education Institutions

A. Mechanism of collaborative governance in higher education institutions

The mechanism of collaborative governance of higher education institutions is needed to build a system for evaluating the degree of collaborative governance of higher education institutions. Also known as collaborative governance of multiple interest subjects, collaborative governance of higher education

institutions includes government, society, market and other subjects. Taking the common goals of each subject in governance into account, collaborative governance of higher education refers to a effective operation mechanism that benefits all subjects could be formed with each of these subject interacts and decides in a formal or informal way. Collaborative governance of higher education institutions is effective and requires universities to balance external governance and internal governance: to properly handle the relationship with government, market and society externally, and to accurately define the power of political parties, administration, academia and democracy internally (Li Fuhua et al., 2015)[10]. Collective governance takes independent interests as prerequisite. It is not simply the sum of the interests of all subjects, but an organic unity of the interests of all subjects and a cooperation on the full respect of the interests of all subjects (Li Chaoling, Zhong Hong, 2008)[11].

Generally speaking, collaborative governance among higher education institutions has the characteristics of cross-industry, collaboration, check and balance and win-win cooperation[12]. While in the GBA, the administration of mainland areas and Special Administrative Regions (SAR), education management systems and governance levels are different. Therefore, the collaborative governance of universities in the GBA has unique characteristics. The first characteristics is nonlinearity. The multiple subjects in the collaborative governance of higher education institutions include the government, market and society, who all have their own purposes and active adaptability. In the process of interaction of each subject, uncertainty arises due to these differences in the GBA, and the relationship of these subjects will show multiple differences and levels with complex non-linear characteristics. The first characteristics is diversity. Guangdong, Hong Kong and Macao have different governance environment and they have diverse forms, such assigning contracts or forming associations, to cooperate. In summary, these characteristics have to be taken into consideration in the establishment of the evaluation system of the degree of collaborative governance of higher education institutions in the Guangdong-Hong Kong-Macao Greater Bay Area, and this paper adopts the Analytic Hierarchy Process (AHP), which is systematic and practical, and Fuzzy Comprehensive Evaluation (FCE), which can be used to handle fuzzy data, to build the evaluation system.

B. Analysis on the role of higher education institutions in the Greater Bay Area

The role of higher education institutions refers to their corresponding complete rights and interests, responsibilities and obligations, and norms of behavior. Universities in the Greater Bay Area have two roles: general role and special role. In order to further play the supporting role of universities in the building of the Greater Bay Area, this paper will analyze the roles of universities in the Greater Bay Area and takes the roles as the basis of the evaluation system.

Talent nurturing is the most fundamental role of universities and talent is the driving force in the building of the Greater Bay Area (Sui Yifan, 2011)[13]. On the one hand, universities in the Greater Bay Area provide education opportunities for students. On the other hand, graduated students will come back to the GBA to participate in the development of this area, thus forming a beneficial cycle for the economic development of the Greater Bay Area (Lan Shasha, 2019)[14]. Knowledge creation is another general role of universities, where knowledge not only be passed down, but also constantly updated and sees breakthroughs. Secondly, the transformation of academic achievements is an indispensable role of universities. Moreover, the last general role is institutional entrepreneurship, which refers to the act of changing or innovating the existing system to meet self-interest goals (Xu Xianming, 2010)[15]. In traditional higher education governance, government is the dominant player and conduct macro-

regulation on higher education institutions and influence the behavior of universities directly or indirectly at all times. Due to these special characteristics above mention in the Greater Bay Area, the laws and regulations on colleges in the region to develop exchanges and cooperation and enrollment autonomy is obscure and lack practicality. Therefore, universities here should promote the comprehensive deepening of institutional innovation in higher education and the formulation of specific policies on cooperation and exchange.

Universities need to play a more extensive role when interacting with social organizations, taking into account the characteristics and needs of reality in a region (Trippl et al., 2015)[16]. The key to achieve cultural integration in the Greater Bay Area for universities in the region is to play a leading role in developing culture and values. Cultural integration requires residents in Guangdong, Hong Kong and Macao to identify themselves as "Chinese" and "the GBA dwellers", and respect and learn the traditional Chinese culture. Universities have an important role to play in cultural leadership. They should strengthen education on history and culture, so that students can pay attention to China's national conditions, history and social reality (Li Qin, 2019)[17]. In terms of value leadership, universities should teach students China's core values and teach them to recognize core socialist values, the sense of social responsibility and the sense of mission to accomplish the tasks of the country.

III. THE EVALUATION SYSTEM FOR THE DEGREE OF COLLABORATIVE GOVERNANCE AMONG HIGHER EDUCATION INSTITUTIONS IN THE GBA

A system for evaluating the degree of collaborative governance among higher education institutions in the GBA refers to the criteria of the assessment of the degree of collaborative governance among higher education institutions in the Greater Bay Area during a certain period of time, which can be used to measure the degree of collaborative governance among higher education institutions in the Greater Bay Area.

A. The building of the system for evaluating the degree of collaborative governance among higher education institutions in the Greater Bay Area

Under the principles of scientificity, adaptability and practicality, the building of such system is put up as follows (Fig.1). First, the whole practice of collaborative governance scheme among higher education institutions in the GBA lies in four dimensions: the collaboration between society and higher education institutions, government and higher education institutions, market and higher education institutions as well as inner collaboration in higher education institutions themselves. Meanwhile, the last collaboration includes collaboration among higher education institutions in the GBA and inner governance in each higher institution itself.

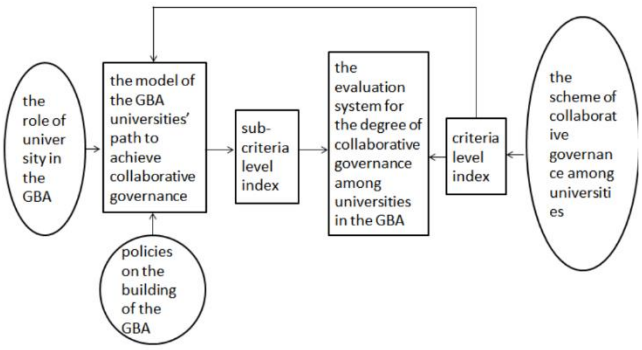

Fig.1. The building process of the evaluation system for the degree of collaborative governance among higher education institutions in the GBA.

Secondly, given the fact that model of the GBA higher education institutions' path to achieve collaborative governance neither fit for the reality of GBA in details and wholeness, nor allow higher education institutions in the GBA to play a leading role in realizing collaborative governance. The following text will take the playing of GBA higher education institutions' special and general role in promoting the development of culture and values. Based on the existing path model of achieving collaborative governance in higher education institutions in the GBA, this paper will uphold the general principles of "to be driven by innovation and led by reform; to coordinate development and plan holistically; to open up and cooperate and achieve a win-win outcome; to share the benefits of development and improve people's livelihood" and the development objectives of "deepening and broadening the cooperation among Guangdong, Hong Kong and Macao; further enhancing the internal driving forces for development; building the framework for an international first-class bay area and world-class city cluster that is vibrant and highly innovative with an optimized industrial structure, promoting a smooth flow of various factors, reaching new heights on the level of social civility, and essentially forming a demonstrably strengthened cultural soft power." (PRC, State Council, 2019)[18] and build a model of the governance path to play the role of higher education institutions in the GBA (more details see Fig. 2) with essential examples of policies and laws from The Development Plan for Enhancing the Cooperation of Higher Education in the GBA. This governance path illustrates the process of reaching collaboration among three entities: higher education institutions in the GBA and market as well as government and society, depicts the collaborative process inside higher education institutions and among universities, and clearly identifies the responsibilities of these entities.

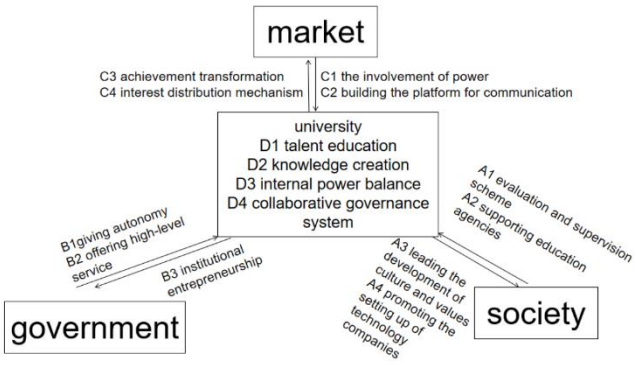

Fig.2. The model of the governance path to achieve collaborative governance of higher education institutions in the GBA.

This model put up here can not only offer guidance for the healthy interaction among society, government and market, and effective inner governance in universities, but provide evaluation factors for qualitative measurement for the situation of collaborative governance among higher education institutions in the GBA. The current model only gives a general path for achieving collaborative governance among higher education institutions and it is not rigorous enough to evaluate it directly as an evaluation standard, so the path needs to be elaborated to make the evaluation system more scientific and the result is shown in Figure 3.

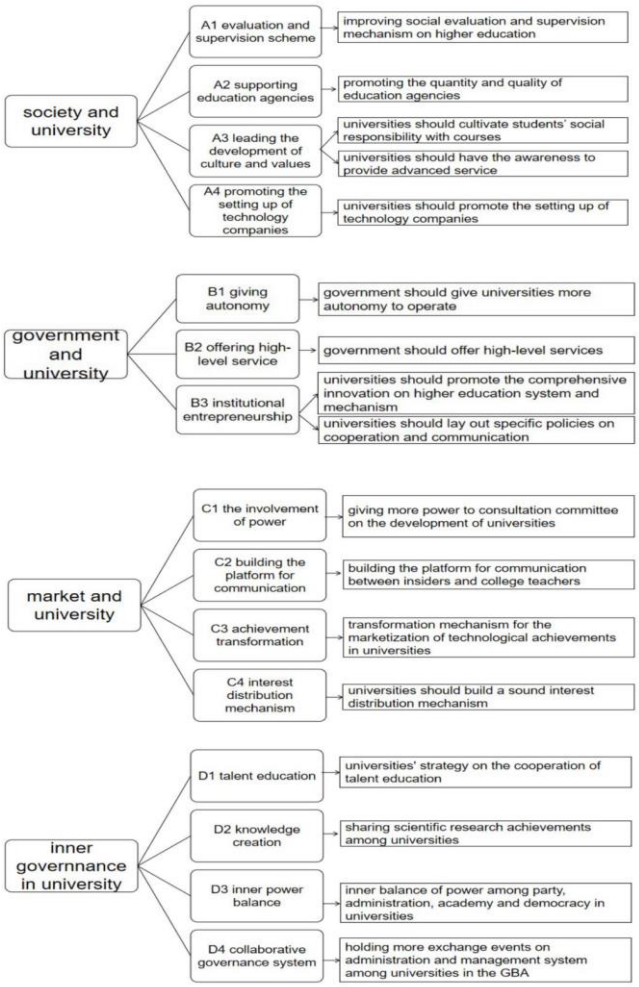

Fig.3. The detailed index on the path of collaborative governance among universities in the GBA.

Based on the detailed model above, a comprehensive evaluating index system on the degree of collaborative governance among higher education institutions in the GBA is formed (see Tab. 1) after transferring those indexes into sub-criteria level.

TABLE 1

THE STRUCTURE OF THE EVALUATION SYSTEM ON THE DEGREE OF COLLABORATIVE GOVERNANCE AMONG HIGHER EDUCATION INSTITUTIONS IN THE GBA

Target level	Criteria level	Sub-criteria level
The evaluation system on the degree of collaborative governance among higher education	Society-university collaboration	social evaluation and supervision mechanism on higher education
		the quantity and quality of education agencies
		universities should cultivate students' social responsibility with courses
		universities should have the awareness to provide advanced service

institutions in the GBA		universities should promote the establishment of technology companies
	Government-university collaboration	government should give universities more autonomy to operate
		government should offer high-level services
		universities should promote the comprehensive innovation on higher education system and mechanism
		universities should lay out specific policies on cooperation and communication
	Market-university collaboration	the power of consultation committee on the development of higher education institutions
		the platform for communication between insiders and college teachers
		transformation mechanism for the marketization of technological achievements in universities
		a sound interest distribution mechanism in universities
	Inner collaboration in universities	universities' strategy on the cooperation of talent education
		sharing scientific research achievements among universities
		inner balance of power among party, administration, academy and democracy in universities
		exchange events on administration and management system among universities in the GBA

B. Confirming the weight of index in the evaluation of the degree of collaborative governance among higher education institutions in the GBA by AHP (Analytic Hierarchy Process)

AHP builds a hierarchy of decision items combining qualitative and quantitative analysis without missing systematic structure and rankings. And it decomposes decision-related factors into three levels: target level, criteria level and sub-criteria level. These levels would be taken account into decision-making analysis to evaluate the relative importance of each index. The importance of each index in the evaluating indicator system on the degree of collaborative governance among higher education institutions in the GBA is reordered and weighed according to the data from 2754 questionnaires covering students, parents, teachers and individuals from all walks of life in the GBA, with a corresponding ratio of 87:10:1:2.

Confirming the weight of index in the evaluation of the degree of collaborative governance among

higher education institutions in the GBA is the basic of building the evaluation system on the degree of collaborative governance among higher education institutions in the GBA, and the steps are as follows.

1) Building a structure for these levels. With the evaluation system on the degree of collaborative governance among higher education institutions in the GBA being the target layer, the mechanism of collaborative governance among higher education institutions in the GBA was set up as the criteria level and the newly-built model on the path to achieve collaborative governance among higher education institutions in the GBA as the sub-criteria level (see Table 1).
2) Building the judgement matrix. A judgement matrix is designed to compare the relative importance of each factor in its level with each factor in its upper level (criteria level or target level). A judgement matrix is needed when AHP is applied to calculate indexes in different levels in evaluation system. And AHP is often used to describe the relative importance with nine scales and its inverse (more details in Tab. 2).

TABLE 2

JUDGEMENT MATRIX SCALES

Numerical rating	Judgement of preferences between two factors
1	two factors are equally important
3	one factor is slightly more important than the other
5	5-one factor is clearly more important than the other
7	one factor is strongly important than the other
9	one factor is extremely important than the other
2、4、6、8	intermediate value
multiplicative inverse	the importance of one factor over the other is between the above when compared

A_{ij} refers to the importance ratio between A_i and A_j, that is to say $A_{ij}=A_i/A_j$ and $A_{ji}=1/A_{ij}$. Following this rule, the judgement matrix between indexes in criteria level and its sub-criteria level can be built with collected data from 2754 questionnaires. Table 3 shows the judgement matrix of indexes in criteria level.

TABLE 3

JUDGEMENT MATRIX OF INDEXES IN CRITERIA LEVEL

	Society-university collaboration	Government-university collaboration	Market-university collaboration	Inner collaboration in university
Society-university collaboration	1	2/3	3	3
Government-university collaboration	3/2	1	9/2	9/2

Market-university collaboration	1/3	2/9	1	1
Inner collaboration in university	1/3	2/9	1	1

First, calculating the result of scale in each row by the formula:

$$M_i = \prod_{i=1}^{n} A_{ij} (i = 1,2 \cdots n) \quad (1)$$

In this formula, A_{ij} means the index in row i, column j, and n means matrix order. Then calculate the geometric mean of the result of scale in each row:

$$a_i = \sqrt[n]{M_i} (i = 1,2 \cdots n) \quad (2)$$

At last, the weight of indexes in the criteria level can be fixed as $[\ 0.3158\ \ 0.4737\ \ 0.1053\ \ 0.1053]$ by calculating the relative weight:

$$W_i = \frac{a_i}{\sum_i^n a_i} \quad (3)$$

Through this process, it is clear that the index of the collaboration between government and university accounts for the highest weight while the index of the collaboration between society and university ranks second, implying that the collaboration among government, society and university should be highlighted in advancing the collaborative governance among universities in the GBA.

In order to ensure the consistency of each subject, the consistency of the judgement matrix should be further tested. In this process,

$$CI = \frac{\lambda_{\max} - n}{n-1} \quad (4)$$

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{B_{wi}}{nW_i} \quad (5)$$

needed to be calculated, among which, CI represents the consistency index of the judgement matrix, $\lambda_{\max}$ refers to the largest eigenvalue, B_{wi} refers to element i of the vector B_w, and N means the scale of the judgement matrix. CR refers to the consistency ratio and

$$CR = \frac{CI}{RI} \quad (6)$$

where RI (Random Index) refers to the mean random consistency index result (see Tab.4) (Lu, Song, 2017) (Bi, 2016)[19][20]. It is generally believed that when $CR \leq 0.1$, the judgement matrix meets the consistency test, and the result is consistent and not contradictory. If the matrix fails to meet the condition of consistency test, the data shall be collected again to generate a new judgement matrix until the consistency test is met. In this paper, the consistency test is conducted on the judgement matrix of the indexes in criteria level, and the $CR = 0.084 < 0.1$, which meets the consistency test. Through the weight

calculation method above and collected data, the weight of the remaining indexes in sub-criteria level could be calculated and the result of final weight is illustrated in Table 5.

TABLE 4

AVERAGE RANDOM CONSISTENCY INDEX

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

TABLE 5

THE WEIGHT OF INDEXES IN EACH LEVEL

Criteria level	Index weight in Criteria level	Sub-criteria level	Index weight in Sub-criteria level	Aggregate index weight in Sub-criteria level
Society-university collaboration	0.3185	social evaluation and supervision mechanism on higher education	0.3279	0.1044
		the quantity and quality of education agencies	0.1639	0.0522
		universities should cultivate students' social responsibility with courses	0.1639	0.0522
		universities should have the awareness to provide advanced service	0.0820	0.0261
		universities should promote the establishment of technology companies	0.2623	0.0835
Government-university collaboration	0.4737	government should give colleges more autonomy to operate	0.2750	0.1303
		government should offer high-level services	0.2250	0.1066
		universities should lay out specific policies on cooperation and communication	0.3000	0.1421
		universities should lay out specific policies on cooperation and communication	0.2000	0.0947
Market-universit	0.1053	the power of consultation committee on the development of universities	0.3500	0.0369

y collaboration		the platform for communication between insiders and college teachers	0.2750	0.0290
		transformation mechanism for the marketization of technological achievements in universities	0.2750	0.0290
		interest distribution mechanism in universities	0.1000	0.0105
Inner collaboration in university	0.1053	universities' strategy on the cooperation of talent education	0.2764	0.0291
		sharing scientific research achievements among universities	0.2513	0.0265
		inner balance of power among party, administration, academy and democracy in universities	0.2513	0.0265
		exchange events on administration and management system among universities in the GBA	0.2210	0.0204

The aggregate weight of indexes in each sub-criteria level of government-university collaboration is near 0.1, which occupies a large amount of proportion. Therefore, the interactive behavior between government and universities deserves attention in the practice of the model of the GBA universities' path to achieve collaborative governance proposed in this paper. When it comes to the rank of weight, the indexes of criteria level on society-university collaboration is in the second place. While the weight of indexes in its sub-criteria level differs more from each other, and every refined governance path has different priorities, so more attention should be paid to the establishment of evaluation and supervision scheme of higher education and technology companies opened by universities. Only by truly understanding the importance of each refined pathway on achieving an ideal collaborative governance among universities in the Greater Bay Area, can such governance be realized with the least resources and energy

C. Applying Fuzzy Comprehensive Evaluation (FCE) method to assess the degree of collaborative governance among universities in the GBA

FCE is a synthetic evaluation method based on fuzzy mathematics that can deal with problems where conditions and factors are too fuzzy and difficult to quantify directly. When applying FCE, quantitative evaluation can be converted to qualitative evaluation by the membership degree theory. In this paper, the fuzzy concept is classified into excellent, good, medium, poor and very poor in the evaluation system for the degree of collaborative governance among higher education institutions in the GBA. The evaluation process is as follows.

1) Establishing factor sets for comprehensive evaluation. The four factors in the formula

$$\lambda = [\lambda_1, \lambda_2, \lambda_3, \lambda_4] \tag{7}$$

respectively refer to university-society collaboration, university-government collaboration,

university-market collaboration, and inner collaboration in universities. The subsets of each influencing factor are also built.

2) Establishing comment sets for comprehensive evaluation. In this paper, five categorical appraisal grades are established, which are V = {excellent, good, medium, poor, very poor}.

3) The evaluation matrix can be built by single factor fuzzy evaluation. The membership degree of index in the evaluation system for the degree of collaborative governance among universities in the GBA refers to different degrees of membership to five levels of comment sets in the evaluation system of the degree of collaborative governance among universities in the GBA. The membership degree of index = the number of people who choose a certain comment set / the total number of people in the five appraisal grades. In this paper, a large number of questionnaires involving 2754 people are collected to study the membership degree of index and a fuzzy mapping matrix

$$P = \left(p_{ij}\right)_{mn} \tag{8}$$

is provided based on the collected data, in which p_{ij} represents the fuzzy membership degree of index i to j levels of appraisal grades (see Table 6). According to Table 6, the status quo of collaborative governance among universities in the Greater Bay Area is in a good condition. Besides, the maximum of the membership degree in each indicator is in the "good" grade, but the value of the membership degree among "general, poor, very poor" levels are so high with many problems to be tackled. Therefore, more strength should be taken to match the ideal situation.

TABLE 6

MEMBERSHIP DEGREE OF INDEX ON THE EVALUATION SYSTEM FOR THE DEGREE OF COLLABORATIVE GOVERNANCE AMONG HIGHER EDUCATION INSTITUTIONS IN THE GBA

Criteria level	Sub-criteria level	Rating of comments				
		Excellent	Good	Medium	Poor	Very poor
Society-university collaboration	Social evaluation and supervision mechanism on higher education	0.31	0.46	0.21	0.02	0
	Quantity and quality of education agencies	0.29	0.46	0.22	0.02	0.01
	Universities should cultivate students' social responsibility with courses	0.30	0.46	0.21	0.02	0.01
	Universities should have the awareness to provide advanced service	0.27	0.40	0.28	0.05	0
	Universities should set up technology companies	0.26	0.40	0.30	0.04	0
	Government should give universities more autonomy to	0.23	0.51	0.23	0.01	0.02

Government-university collaboration	operate					
	Government should offer high-level services	0.22	0.51	0.19	0.03	0.05
	Universities should promote the comprehensive innovation on higher education system and mechanism	0.22	0.49	0.27	0.01	0.01
	Universities should lay out specific policies on cooperation and communication	0.22	0.47	0.27	0.02	0.02
	Give more power to consultation committee on the development of universities	0.25	0.45	0.27	0.02	0.01
Market-university collaboration	Platform for communication between insiders and university teachers	0.26	0.47	0.24	0.02	0.01
	Transformation mechanism for the marketization of technological achievements in university	0.26	0.44	0.27	0.03	0
	Universities should build a sound interest distribution mechanism	0.24	0.42	0.30	0.03	0.01
	Universities' strategy on the cooperation of talent education	0.28	0.48	0.21	0.02	0.01
	Sharing scientific research achievements in university	0.27	0.46	0.24	0.02	0.01
Inner collaboration in universities	Inner balance of power among party, administration, academy and democracy in universities	0.26	0.44	0.25	0.03	0.02
	Holding more exchange events on administration and management system among universities in the GBA	0.27	0.45	0.25	0.03	0

4) A comprehensive evaluation model is set up to calculate the comprehensive evaluation vector. After determining the membership degree matrix and weight vector of each factor, this paper uses the weighted average type fuzzy operator to calculate the comprehensive evaluation vector. The formula is

$$H = W \times P = [w_1 \ \ w_2 \ \ \cdots \ \ w_n \ ] \times \begin{bmatrix} p_{11} & \cdots & p_{1m} \\ \vdots & \ddots & \vdots \\ p_{n1} & \cdots & p_{nm} \end{bmatrix} \quad (9)$$

(W is the weight vector and P is the membership degree matrix).

Based on the index membership degree in Table 6, the weight of index in each level in Table 5 and the formula (9), the evaluation vector of the index of criteria level of society-university collaboration can be represented as:

$$H_1 = W_1 \times P_1 = [0.2887 \ \ 0.43993 \ \ 0.2410 \ \ 0.0049 \ \ 0.0227]$$

$$W_1 = [0.3279 \ \ 0.1639 \ \ 0.1639 \ \ 0.0820 \ \ 0.2623]$$

$$P_1 = \begin{bmatrix} 0.31 & 0.46 & 0.21 & 0.02 & 0 \\ 0.29 & 0.46 & 0.22 & 0.02 & 0.01 \\ 0.30 & 0.46 & 0.21 & 0.02 & 0.01 \\ 0.27 & 0.40 & 0.28 & 0.05 & 0 \\ 0.26 & 0.40 & 0.30 & 0.04 & 0 \end{bmatrix}$$

By the same formula, H2, H3, H4 can be calculated:

$$H_2 = [0.2228 \ \ 0.4960 \ \ 0.2410 \ \ 0.0165 \ \ 0.0238]$$

$$H_3 = [0.2545 \ \ 0.4497 \ \ 0.2648 \ \ 0.0238 \ \ 0.0073]$$

$$H_4 = [0.2703 \ \ 0.4583 \ \ 0.2364 \ \ 0.0247 \ \ 0.0103]$$

and thus the membership degree matrix is

$$\mathrm{P} = \begin{bmatrix} H_1 \\ H_2 \\ H_3 \\ H_4 \end{bmatrix} = \begin{bmatrix} 0.2887 & 0.4393 & 0.2410 & 0.0277 & 0.0049 \\ 0.2228 & 0.4497 & 0.2648 & 0.0238 & 0.0073 \\ 0.2545 & 0.4497 & 0.2648 & 0.0238 & 0.0073 \\ 0.2703 & 0.4583 & 0.2364 & 0.0247 & 0.0103 \end{bmatrix}$$

And the comprehensive evaluation vector is

$$\mathrm{H} = \mathrm{W} \times \mathrm{P} = [0.2520 \ \ 0.4693 \ \ 0.2430 \ \ 0.0217 \ \ 0.0147]$$

The membership degree of the current state of collaborative governance among universities in the GBA in five appraisal grades is 0.2520, 0.4693, 0.2430, 0.0217 and 0.0147, which is same as the macro observation results in Table 6.

5) Conducting quantitative assessment on the degree of collaborative governance among universities in the Greater Bay Area. In this paper, a 10-point scale is applied to assign values to the five levels of the comment set and assignment matrix

$$\mathrm{A} = \begin{bmatrix} 10 \\ 8 \\ 6 \\ 4 \\ 2 \end{bmatrix} \quad (10)$$

can be built. Table 7 classifies the five scores into its corresponding level. Then by multiplying the comprehensive evaluation vector H with the assignment matrix A, L (the quantitative assessment value of the degree of collaborative governance among universities in the GBA) can be calculated:

$$\mathrm{L} = \mathrm{H} \times \mathrm{A} = 7.8486 \quad (11)$$

(H is the comprehensive evaluation matrix and A is the assignment matrix). From Table 7, it can be found that the level of collaborative governance in the Greater Bay Area is in “good” grade, but still not reach the “excellent” grade.

TABLE 7

COMPREHENSIVE EVALUATION CRITERIA FOR THE DEGREE OF COLLABORATIVE GOVERNANCE AMONG UNIVERSITIES IN THE GBA

Points	0~2	2~4	4~6	6~8	8~10
Evaluation level	very poor	poor	medium	good	excellent

By calculating the weighted average and weighted deduction values of sub-criteria level index to criteria index, and the relative weighted average and relative weighted deduction values of criteria to the total score of the degree of collaborative governance among universities in the Greater Bay Area, the negative impact of the key problems and weaknesses in collaborative governance among universities in the Greater Bay Area on reaching an ideal governance among universities in the Greater Bay Area can be calculated (see Tab. 8). Two indicators in sub-criteria level: give more power to consultation committee on the development of universities and universities should promote comprehensive innovation on higher education system and mechanism, respectively rank the first and the second in terms of weighted deduction values, which are the two weakest aspects in the current collaborative governance among universities in the Greater Bay Area and need to be largely improved.

TABLE 8

DEGREE OF COLLABORATIVE GOVERNANCE SCORES AMONG UNIVERSITIES IN THE GREATER BAY AREA

Criteria level	Sub-criteria level	Weighted average	Weighted deduction values	Relative weighted scores	Relative weighted deduction values
Society-university collaboration	Social evaluation and supervision mechanism on higher education	2.6625	0.6165	2.5164	0.6416
	Quantity and quality of education agencies	1.3145	0.3245		
	Universities should cultivate students' social responsibility with courses	1.3178	0.3212		
	Universities should have the awareness to provide advanced service	0.6380	0.1820		
	Universities should set up technology companies	2.0354	0.5876		
Government-university	Government should give universities more autonomy to operate	2.1560	0.5940	2.4490	0.7090
	Government should offer high-level	1.7190	0.5310		

collaboration	services				
	Universities should promote comprehensive innovation on higher education system and mechanism	2.3400	0.6600		
	Universities should lay out specific policies on cooperation and communication	1.5400	0.4600		
Market-university collaboration	The power of consultation committee on the development of universities	2.7370	0.7630	2.4762	0.6818
	Platform for communication between insiders and university teachers	2.1725	0.5775		
	Transformation mechanism for the marketization of technological achievements in universities	2.1615	0.5885		
	Universities should build a sound interest distribution mechanism	0.7700	0.2300		
Inner collaboration in universities	Universities' strategy on the cooperation of talent education	2.2112	0.5528	2.4970	0.6610
	Sharing scientific research achievements in universities	1.9903	0.5227		
	Inner balance of power among party, administration, academy and democracy in universities	1.9551	0.5579		
	Holding more exchange events on administration and management system among universities in the GBA	1.7503	0.4597		

IV. CURRENT STATUS OF THE DEGREE OF COLLABORATIVE GOVERNANCE AMONG UNIVERSITIES IN THE GBA AND SUGGESTIONS FOR IMPROVEMENT

The calculated quantitative assessment value (7.8486) of the degree of collaborative governance of universities in the GBA points out the fact that the degree of collaborative governance of universities in the GBA is in a good condition at present. Meanwhile, the weaknesses and the improvement order of the current collaborative governance among universities in the GBA can be set by the weighted deduction value of each level of index to its previous level of index in Table 8. From the calculated results, the improvement priority is ranked as government-university collaboration, market-university collaboration,

inner collaboration in universities and society-university collaboration. And the focus should be put on optimizing power to consultation committee on the development of universities and promoting the comprehensive innovation on higher education system and mechanism. Recommendations for improving indicators in each sub-criteria level are as follows.

1) Government-university collaboration. The ranking of weighted deduction value in the sub-criteria level is: universities should promote the comprehensive innovation on higher education system and mechanism > government should give colleges more autonomy to operate > government should offer high-level services > universities should lay out specific policies on cooperation and communication. In order to achieve collaborative governance between universities and government, strengthening the awareness and responsibility of universities to comprehensively promote the comprehensive innovation on higher education system and mechanism is the top priority, which allows universities in the GBA fully aware that they are the leading role in promoting the integration and development of education in the Greater Bay Area. As a result, they can actively participate in the process to promote the comprehensive innovation on higher education system and mechanism. Secondly, from the results in Table 8, it can be found that there is still much room for improvement as for government's power to give colleges and universities the autonomy to run schools. To be more specific, government should continue to relax restrictions on the autonomy of colleges and universities to run schools. The government should provide sufficient services for running schools, instead of meddling with the decision-making and behavioral activities of schools. The government should regulate the operation of colleges and universities, instead of restricting the power of colleges and universities to run schools. Given to the quality of services provided by government is not good enough, more energy should be taken advantage to escalate this area. Based on uneven competitiveness and different competitive environment among colleges and universities in the Greater Bay Area, government should also plays their leading role in enhancing the quality of services, offering assistance or advice to colleges and universities who are weak in operation or academy and providing sound development environment for colleges and universities who are excellent in competition. Finally, the formulation of specific policies on cooperation and exchange promoted by universities is generally good, but not good enough to reach an ideal government-universities collaborative governance. The policies on cooperation and exchange such as free electives, mutual recognition of academic qualifications and credits among Guangdong, Hong Kong and Macao is not specific and need to be improved by the active participation of universities in the GBA.
2) Market-university collaboration. The ranking of the weighted deduction value in the sub-criteria level is: give more power to consultation committee on the development of universities > transformation mechanism for the marketization of technological achievements in universities > platform for communication between insiders and college teachers > universities should build a sound interest distribution mechanism. Firstly, as a way for market to involve in universities governance, consultation committee on the development of universities can have larger influences in collaborative governance among universities by gaining more power. Apart from inviting experts to join in the committee, universities also need them to actually provide support to the classification of discipline, talent education, academic research and actively join in decision making and practice. Secondly, market-based mechanism for the transformation of scientific and technological achievements in universities still needs to be improved to make up for the failures

that scientific and technological achievements of universities can't be used due to they don't accord with market rules. Thirdly, platforms for the exchange and communication between insiders and college teachers are not enough. Companies should build more such platforms and hold regular meetings on the integration of education and industry to increase the importance of market. Fourthly, the interest distribution mechanism in universities is not perfect. Universities ought to clarify the interest distribution relationship of different interest subjects to promote each subject to actively join in marketization of scientific and technological achievements.

3) Inner collaboration in universities. The ranking of the weighted deduction value in the sub-criteria level is: inner balance of power among party, administration, academy and democracy in universities > universities' strategy on the cooperation of talent education > sharing scientific research achievements in universities > holding more exchange events on administration and management system among universities in the GBA. At present, in order to improve the degree of collaborative governance among universities, universities are required to improve the governance structure of "party committee takes leadership, president shoulders responsibility, professors focus on academy, conducting democratic management and involving public engagement" and realize the internal power balance among democratic, academic and political parties (Li Liguo, 2019)[21]. Secondly, it is necessary for universities in the Greater Bay Area to better cooperate with each other, formulate joint talent cultivation programs, effectively realize the complementary advantages and sharing of university resources, and cooperate more in recognizing the standard of talent cultivation quality, credits and degrees and jointly-running schools. Then, universities need to uphold the principle of win-win cooperation and share the updates on scientific research. Finally, compared to universities in Hong Kong and Macao, mainland universities are facing more trivial administrative procedures in management. The management systems in universities of these three places differs a lot, so universities in the GBA should hold more activities of administrative management systems to deepen communication and coordination.

4) Society-university collaboration. The ranking of weighted deduction value in the sub-criteria level is: supervision mechanisms for social assessment in higher education > universities should establish technology companies > quantity and quality of education agencies > university should cultivate students' social responsibility with courses > university should have the awareness to provide advanced service. In order to achieve better collaborative governance between society and universities, universities firstly need to help education agencies more actively with guidance on operating, supervision and management. And then universities need to improve supervision scheme for social assessment of higher education. Secondly, universities should actively promote the opening of science and technology companies to offer more benefits for society. Then, education agencies are still a weak aspect to hinder the collaboration between universities and society. Besides, the awareness and ability of insiders to participate in the governance of universities are still inadequate. Each subject should continue to improve the quantity and quality of education agencies, learning from developed countries' experiences on this. Besides, universities should set more courses to cultivate students' sense of social responsibility to better serve and make contributions to the society. At last, universities need to enhance the awareness of offering advanced service and prepare for the development of society in the future.

V. CONCLUSION

The evaluation system for the degree of collaborative governance among universities in the GBA is

an important means to measure the current status of collaborative governance among universities in the Greater Bay Area and also a vital initiative to promote the degree of collaborative governance among universities in the Greater Bay Area. In this paper, the evaluation system framework of the degree of collaborative governance among universities in the Greater Bay Area is built based on four criteria levels: society-university collaboration, government-university collaboration, market-university collaboration, and inner collaboration in universities. Adopting Analytic Hierarchy Process (AHP) method and Fuzzy Comprehensive Evaluation (FCE) method, the conclusion that the current degree of collaborative governance among universities in the Greater Bay Area is good and the priority order of weaknesses is made on the basis of data collected from questionnaires. More details of the conclusion are as follows.

1) This paper firstly analyzes the scheme of collaborative governance among universities and the role of universities in the Greater Bay Area and criteria level index of the evaluation system for the degree of collaborative governance among universities in the GBA on the basis of the scheme of collaborative governance among universities. With the purpose of realizing the collaborative governance role of universities in the Greater Bay Area and the role to play as the universities in the GBA , the model of the GBA universities' path to achieve collaborative governance is established by combining its former existing model in line with the principles and purposes of the development of the Greater Bay Area. The detailed explanation for dismantling the result of the model into sub-criteria level index of this evaluation system offers a more rigorous sub-index system for the evaluation of the degree of collaborative governance among universities in the Greater Bay Area and a theoretical basis for scientifically and rationally understand as well as improve the current situation of collaborative governance among universities in the Greater Bay Area
2) Since the characteristics of collaborative governance among universities in the Greater Bay Area are non-linear and diverse and the characteristics of evaluation index system is multi-level and fuzzy in result, this paper adopts Analytic Hierarchy Process (AHP) and Fuzzy Comprehensive Evaluation (FCE) to evaluate the degree of collaborative governance among universities in the Greater Bay Area, in which AHP is applied to calculate the weight of each index and FCE is used to conduct quantitative analysis on the degree of collaborative governance among universities in the Greater Bay Area. This paper also further classify four criteria levels of university-government collaboration, university-market collaboration, university-society collaboration and inner collaboration in universities into sub-criteria levels to provide a new method for measuring the degree of collaborative governance among universities in the Greater Bay Area.
3) This paper has collected data from 2754 valid questionnaires for respondents in the GBA and calculated the current quantitative assessment value of the degree of collaborative governance among universities in the Greater Bay Area as 7.8684 based on the data, which belongs to the good level of the comprehensive evaluation. Weighted deduction value between sub-criteria level and criteria level index and the relative weighted deduction value between the index of the criteria level and the total score of the degree of collaborative governance among universities in the Greater Bay Area can be calculated according to Table 8. This paper also proposes the improvement order of government-university collaboration, market-university collaboration, inner collaboration in universities and society-university collaboration, advocates to properly endow power to consultation committee in universities and universities should promote the comprehensive

innovation on higher education system and mechanism and provides practical and efficient improvement order and suggestions for each sub-criteria level, offering valuable guidance for the collaborative governance among universities in the Greater Bay Area to reach a higher level .

STATEMENTS & DECLARATIONS

The authors declare that they have no conflict of interest. And it is original, no plagiarism, multiple submissions, etc. This article does not contain any studies with animals performed by any of the authors. Informed consent was obtained from all individual participants included in the study.

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The authors have no relevant financial or non-financial interests to disclose.

C. Author Contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Shiqian Gu, Shuxian Hao and Hongfei Guo. The first draft of the manuscript was written by Shuxian Hao and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

D. Data Availability

The datasets generated during the current study are not publicly available due to individual privacy could be compromised but are available from the corresponding author on reasonable request.

E. Code Availability

The code in this article is written by MATLAB. The code generated during the current study are available from the corresponding author on reasonable request.

REFERENCES

[1] Li Man, *"On the Knowledge Logic of the Transformation of University Governance Mode,"* *Educational Research,* no.3, pp.56-63, 2015.

[2] Yu Manyue, "The Development Plan for Enhancing the Cooperation of Higher Education in the Guangdong-Hong Kong-Macao Greater Bay Area." *Zhongguo Jiaoyu Bao*, Dec.2020.

[3] Xu Changqing, Huang Yumei., "Research on the Integrated Development of Higher Education in Guangdong-Hong Kong-Macao Greater Bay Area under the View of Institutional Change," *China Higher Education Research*, no.7, pp.25- 32 ,2019.

[4] Pan Chunsheng, "Collaborative Win: New Trend of Modern University Governance," *Research in Educational Development*, no.21, pp.44-49, 2014.

[5] Jiang Dayong, "Step ahead: Guangdong Model for Construction of High-level University," *Higher Education Exploration*, no.4, pp. 41-45, 2019.

[6] Li Weitao, "Coordinated Education Governance in the Process of Modernization: Barriers and Approaches," *Research in Educational Development*, no.3, pp. 12-19, 2021.

[7] Zeng Zhenxiang,Yang Qingxiu, Zhang Lin., “The Structure and Operational Mechanism of Collaborative University Governance Based on the CAS Theory,” *Journal of Hebei University of Technology (Social Sciences Edition)*, np.1, pp. 70-77, 2019.

[8] Ding Chen, “From ‘divided force’ to ‘combined force’: Analysis on the Realization Path of Collaborative Governance in Higher Education,” *Industrial & Science Tribune*, no.8, pp. 285-286, 2021.

[9] Xu, Changqing,Huang, Yumei., “Research on Universities’ Roles and Collaborative Governance in the Development of Guangdong-HongKong-Macao Greater Bay Area,” *Journal of Public Administration*, no.2, pp. 109-124, 2020.

[10] Li Fuhua,, Wang Ying., “On the Collaborative Promotion of University Governance and Management,” *Journal of Higher Education*, no.4, pp. 27-32, 2015.

[11]Li Chaoling,Zhong Hong, “A Study on Collaborative Governance of Modern Universities,” *Jiangsu Higher Education*, no.2, pp. 32-35, 2008.

[12] Hongfei Guo, Linsheng Zhang, Yu Zhang, Yaping Ren, Xin Lian, Rui Zhang, Na Ding, “A Differential Game-Based Approach for School-Enterprise Collaborative R&D Strategy on Digital Twin Technology,” *IEEE Access,* Vol. 8, 2020, 188688-188698.

[13]Sui Yifan, “On the Mission and Safeguard of University,” *Educational Research*, no.2, pp. 69-72, 2011.

[14]Lan Shasha, “An Analysis on Driving Force of universities Among the GBA Area for Economic Development.,” *Corporate Finance*, no.10, pp. 98-99, 2019.

[15]Xu Xianming., “A Research on University Philosophy,” *Social Sciences in China*, no.6, pp.37-43, 2010.

[16]Trippl, M., Sinozic，T.＆Lawton，S.H, “The Role of Universities in Regional Development: Conceptual Models and Policy Institutions in the Uk, Sweden and Austria,” *European Planning Studies*, no.9, pp. 1722-1741, 2015.

[17]Li Qin., “An Analysis on the Development,Implications and Governance of ‘Hong Kong Independence in Schools’,” *Hongkong and Macao Journal*, no.2, pp. 52-61, 2019.

[18]PRC, State Council, “Outline Development Plan for the Guangdong-Hong Kong-Macao Greater Bay Area,” Feb.2019.

[19]Lu Wanquan, Song Xinqiang, “ Research on performance assessment evaluation of university managers based on AHP--Take a university in Guangdong as an example,” *Higher Education Exploration*, no.10, pp. 40-46, 2017.

[20]Bi Hexia., “Identification Model Construction for Poor Students Based on Methods ‘Fuzzy Comprehensive Judgement’ and ‘Fuzzy Hierarchical Analysis’ with Big Data Technology,” *Higher Education Exploration*, no.6, pp. 105-114, 2016.

[21]Li Liguo, “From De jure to De facto: An Analysis of Effective University Governance,” *Journal of East China Normal University (Educational Science)*, no.5, pp. 1-16, 2019.