Chapter 20
The Comprehensive Evaluation of "Five Aspects" Based on Coefficient-of-Variation-Modified G1 Combination Weighting

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Abstract In order to test the scientificity of evaluation criteria and evaluation indexes, this paper firstly uses principal component analysis method to analyze the evaluation indexes under the evaluation criteria. Then, this paper uses the ratio of the coefficient of variation of each evaluation index to replace the experts' subjective ratio of the importance degree, building a combination weighting method based on coefficient-of-variation-modified G1. Finally, with this method, this paper makes a comprehensive evaluation of development of "Five Aspects" in Guangdong Province.

20.1 Introduction

As is known, the key to scientific and successful comprehensive evaluation is to scientifically and rationally endow different weight for each evaluation index. At present, important methods for determining the weight of evaluation indicators are subjective weighting method, objective weighting method and combined weighting method. The subjective weighting method can better reflect the subjective intentions or experiences of decision makers or experts, but it cannot accurately reflect the objective real data information of the evaluation indicators. The objective weighting method is opposite. People wanted to find out a scientific evaluation method, which could not only take in the advantages of subjective and objective weighting methods in scientific decision-making but could also solve the problem that single method was incapable of reflecting experts' experience or the objective information of the indexes. In this situation, combination weighting method came into being.

The combination weighting used for comprehensive evaluation absorbs both the advantages of the subjective weighting and the objective weighting. Nevertheless, it overcomes both of their shortcomings. However, the combination weighting method is difficult to allocate the combination coefficient scientifically and reasonably. In order to overcome the shortcomings of combination weighting, many scholars have

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taken different approaches and used the objective weighting method to revise the subjective weighting method. Certainly, the effectiveness of such a revised combination weighting method has been proved. For example, Li [1] used the method of entropy-revised G1 combination weighting to evaluate the development of science and technology. In 2012, he put forward another combination weighting method based on the standard variance-revised group G1 [2]. Zhu and his colleagues [3] used the entropy-revised AHP combination weighting method to evaluate the development of "Five Aspects" in Jilin Province. Nevertheless, Zhu and his colleagues also put forward modified-G2 weighting method based on improved CRITIC [4] and coefficient of variation [5]. Besides, Jia and her colleagues bring about an entropy-modified G2 weighting method [6]. As for improved-G1 method, Xing and her cooperators come up with an improved CRITIC-G1 weighting method [7]. Zhu and his partners put forward a modified G1 method based on information gain ratio [8]. These studies have contributed to the development and application of comprehensive evaluation methods.

The *Opinions on Accelerating the Construction of Ecological Civilization* proposes to coordinate the promotion of new industrialization, informatization, urbanization, agricultural modernization and greening. In order to scientifically evaluate the objective status quo of regional "Five Aspects", based on the comprehensive evaluation index system established by Zhu and his colleague [3], following the principles of scientificity, comparability, operability, comprehensiveness and the availability of data to select the indexes, we firstly construct a comprehensive evaluation index system which can fully reflect the development of the "Five Aspects". Secondly, a coefficient-of-variation-modified G1 combination weighting method is proposed. Finally, our new combination weighting method is used to empirically analyze the development status of the "Five Aspects" in Guangdong Province.

20.2 Construction of the Index System

20.2.1 Basis of the Construction of the Index System and Establishment of the Criterion Layer

The *Opinions on Accelerating the Construction of Ecological Civilization* proposes to coordinate the promotion of new industrialization, informatization, urbanization, agricultural modernization and greening. Therefore, these "Five Aspects" are used as the criterion layer of the index system. Among them, "new industrialization, informatization, agricultural modernization" reflect the principle of innovation-driven, "urbanization" reflects the principle of people-oriented, and "greening" reflects the principle of green and low-carbon.

20.2.2 Construction of the Index System

Drawing on the existing researches, following the principles of scientificity, comparability, operability, comprehensiveness and the availability of data, we establish a comprehensive evaluation index system with five criteria and 25 indexes (Table 20.1). In order to know whether the information of the indexes of each criterion can fully symbolize the criterion, we firstly performed principal component analysis. If all indexes of one criterion could only produce one principal component, it indicated that the principal component could integrate all the information of each index well. In our study, principal component analysis was performed with SPSS 24.0, and selection of the principal component was based on the characteristic root which was more than or equal to 1. All indexes under each criterion layer could only produce one principal component, and each principal component could account for most of the variance variation (close to or beyond 80%), indicating that it is scientific and reasonable to use these indexes to reflect each criterion.

20.3 Coefficient-of-Variation-Modified G1 Combination Weighting Method

20.3.1 Introduction of the Traditional G1 Method

G1 [8–10] is a typical subjective weighting method. The weight of indexes depends on the subjective experience of experts or decision makers. When using the traditional G1 method, the weight of the index layer to the criterion layer is determined first, and then, the weight of the index layer to the goal layer is determined. While using G1 method, the orders of indexes are determined by the experts. Then, the ratio of the importance degree (r_k) of the adjacent index X_{k-1} and X_k is determined according to the determined order, and the weight of each index under the criterion layer is determined according to the value of r_k. The value of r_k is generally referred to Table 20.2.

It can be seen that while using the traditional G1 method, the ratio of the importance degree (r_k) of the adjacent index X_{k-1} and X_k is determined by the experts' experience, and it fails to effectively reflect the information utility contained in the objective data itself. Therefore, the coefficient-of-variation-modified G1 method is used to determine the ratio of the importance degree (r_k) of the adjacent index X_{k-1} and X_k, which can reflect the experts' experience as well as the magnitude of data information through r_k.

Table 20.1 Comprehensive evaluation index system for the development of "Five Aspects"

No.	Criterion layer	Index layer	Direction	Principal component interpretation variance (%)	2013	2014	2015	2016	2017
1	New industrialization X_1	Value-added of industry X_{11}	Pos.	89.51	26 ,894.54	30,079.24	31,290.75	32,650.89	35,291.83
2		Gross industrial output value X_{12}	Pos.		119,139.72	130,081.02	135,308.14	144,926.09	148,173.99
3		Proportion of the gross industrial output value in GDP X_{13}	Pos.		0.43	0.44	0.42	0.40	0.39
4		Value-added of high-tech manufacturing industry X_{14}	Pos.		6654.38	7083.66	7537.34	8475.25	9507.81
5		Proportion of value-added of high-tech manufacturing industry X_{15}	Pos.		0.25	0.24	0.24	0.26	0.27
6	Urbanization X_2	Urbanization rate X_{21}	Pos.	97.02	67.80	68.00	68.71	69.20	69.90
7		Per capita housing construction area X_{22}	Pos.		30.27	31.88	32.25	32.74	33.09

(continued)

Table 20.1 (continued)

No.	Criterion layer	Index layer	Direction	Principal component interpretation variance (%)	2013	2014	2015	2016	2017
8		Proportion of non-agricultural population X_{23}	Pos.		53.69	54.32	54.96	55.60	56.25
9		Per capita disposable income X_{24}	Pos.		29,537.29	32,148.11	34,757.16	37,684.25	40,975.14
10		Per capita consumption expenditure X_{25}	Pos.		21,621.46	23,611.74	25,673.08	28,613.33	30,197.91
11	Greening X_3	Industrial wastewater X_{31}	Neg.	92.04	17.05	17.76	16.15	13.20	12.38
12		Total volume of industrial waste gas emission X_{32}	Neg.		28,434.00	29,793.00	30,923.00	38,846.00	41,997.50
13		Living wastewater X_{33}	Neg.		69.13	72.68	74.93	80.60	83.75
14		Per capita urban public green area X_{34}	Pos.		15.94	16.28	17.40	17.87	18.24
15		Number of public transportation vehicles X_{35}	Pos.		65,844.00	61,685.00	62,947.00	68,965.00	73,888.00

(continued)

Table 20.1 (continued)

No.	Criterion layer	Index layer	Direction	Principal component interpretation variance (%)	2013	2014	2015	2016	2017
16	Informatization X_4	Number of mobile telephones subscribers X_{41}	Pos.	79.95	14,706.06	14,943.37	15,009.75	14,348.96	14,798.85
17		Broadband subscribers of internet X_{42}	Pos.		2154.28	2243.87	2285.19	2850.60	3288.15
18		Popularization rate of mobile telephones X_{43}	Pos.		138.16	139.35	138.35	130.46	132.48
19		Pieces of express mail service X_{44}	Pos.		210,670.00	335,555.90	501,335.00	767,241.56	1013,468.00
20		Annual average number of newspapers and magazines subscribed per 100 persons X_{45}	Neg.		10.58	8.94	8.40	6.25	4.99
21	Agricultural modernization X_5	Total agricultural machinery power X_{51}	Pos.	88.14	2545.30	2611.78	2696.80	2390.50	2410.77

(continued)

Table 20.1 (continued)

No.	Criterion layer	Index layer	Direction	Principal component interpretation variance (%)	2013	2014	2015	2016	2017
22		Total area cultivated using machinery X_{52}	Pos.		3488.03	3612.69	3741.81	3969.17	4014.05
23		Water-saving irrigated area X_{53}	Pos.		268.35	281.77	295.86	301.49	326.19
24		Total area sown using machinery X_{54}	Pos.		204.84	232.88	264.76	315.78	342.21
25		Value-added of agriculture X_{55}	Pos.		3047.51	3118.39	3275.05	3593.64	3712.71

Table 20.2 r_k Value

r_k Value	Notes
1.0	X_{k-1} is as important as X_k
1.2	X_{k-1} is slightly more important than X_k
1.4	X_{k-1} is obviously more important than X_k
1.6	X_{k-1} is especially more important than X_k
1.8	X_{k-1} is extremely more important than X_k

20.3.2 Coefficient-of-Variation-Modified G1 Method

20.3.2.1 Scoring the Evaluation Index

Suppose P_{ij} be the jth index score of the ith evaluation object, V_{ij} the raw data of the jth index of the ith evaluation object, and n means the number of objects to be evaluated. Here comes the scoring formula for positive indexes:

$$P_{ij} = \frac{V_{ij} - \min_{1\le i\le n}\{V_{ij}\}}{\max_{1\le i\le n}\{V_{ij}\} - \min_{1\le i\le n}\{V_{ij}\}}$$

The economic meaning in the formula is the relative distance of the deviation between the jth index value and the minimum value of the ith evaluation object with respect to the maximum–minimum deviation, and higher the score indicates that the index is better. As for the negative indexes, we have another scoring formula:

$$P_{ij} = \frac{\max_{1\le i\le n}\{V_{ij}\} - V_{ij}}{\max_{1\le i\le n}\{V_{ij}\} - \min_{1\le i\le n}\{V_{ij}\}}$$

20.3.2.2 Calculating the Coefficient of Variation

Suppose CV_k be the coefficient of variation of the kth evaluation index, then

$$\mathrm{CV}_k = \frac{\delta_k}{\bar{x}_k}$$

δ_k represents the standard deviation of the kth evaluation index, and $\bar{x}_k$ represents the mean value of the kth evaluation index. The larger the value of CV_k, the more information the evaluation index contains, indicating that the index is more important.

20.3.2.3 Combination Weighting

1. According to the value of CV_k, we determine the ratio of the importance degree (r_k) of the adjacent index X_{k-1} and X_k. The formula is

$$r_k = \begin{cases} \frac{\mathrm{CV}_{k-1}}{\mathrm{CV}_k}, & \text{while } \mathrm{CV}_{k-1} \geq \mathrm{CV}_k; \\ 1, & \text{while } \mathrm{CV}_{k-1} < \mathrm{CV}_k. \end{cases}$$

2. According to the value of r_k, we calculate the coefficient-of-variation-modified G1 combination weight s_m of the mth index under the criterion layer. The formula is

$$s_m = \left(1 + \sum_{k=2}^{m} \prod_{i=k}^{m} r_i\right)^{-1}$$

3. According to the value of s_m, we can calculate the weight of the other index. The formula is

$$s_{k-1} = r_k \cdot s_k, \quad k = m-1, m-2, \ldots, 1, 2, 3$$

4. Suppose α_k be the weight of the kth index under the jth criterion layer to the total goal, s_k be the weight of the kth index to the jth criterion layer under the jth criterion layer, $s^{(j)}$ be the weight of the jth criterion layer to the total goal. Then, we have the weight of the index to the total target α_k:

$$\alpha_k = s_k \cdot s^{(j)}$$

20.3.2.4 Calculating the Score of the Evaluation Object

Suppose P_i be the score of the ith evaluation object. According to the weight and the score of the index, we have

$$P_i = \sum_{j=1}^{n} P_{ij} \cdot a_i$$

20.4 Empirical

20.4.1 Evaluation Objects and Data Sources

We take Guangdong Province as the research object and select the relevant indexes of Guangdong's "Five Aspects" during 2013–2017 as sample. The data needed are from the statistical yearbook of Guangdong Province. Among them, data of industrial wastewater discharge, industrial waste gas discharge and urban domestic sewage discharge are only from 2013 to 2016. According to their development trend, the average growth rate is used to supplement the data of 2017, same as the non-agricultural population. The method predicts the data for three years, from 2015 to 2017. There is data of agricultural machinery, mechanical farming area, water-saving irrigation area and mechanical planting area for 2015–2017, and the average increase is also based on its development trend. The data for 2013 and 2014 will be supplemented (Table 20.1).

20.4.2 Evaluation Index

The data of each index in 2013–2017 are standardized and scored with the evaluation index scoring formula in Sect. 20.3.2.1 (Table 20.3).

20.4.3 Calculating the Coefficient of Variation and the Combination Weight

According to the formula in Sect. 20.3.2.2, we calculate the coefficient of variation of each index. By summing up the coefficient of variation of each index under the same criterion, we calculate the coefficient of variation of each criterion (Table 20.3). According to the coefficient of variation of index and criterion, based on the formula in Sect. 20.3.2.3, we calculate the weight of the index, criterion. Finally, we calculate the comprehensive weight of the index to the total goal (Table 20.3).

20.4.4 Calculating the Score of Evaluation Object

We calculate the scores of each evaluation index according to the formula in Sect. 20.3.2.4. The summation sum is then used to calculate the scores for each evaluation criterion (Table 20.4). For the convenience of analysis, all scores of evaluation indexes time 100.

Table 20.3 Standardized scores and weights of indexes

No.	Index	2013	2014	2015	2016	2017	CV of index	r of index	Weight of index	CV of criterion	r of criterion	Weight of criterion	Comprehensive weight
1	X_{11}	0.00	0.38	0.52	0.69	1.00	0.10	1.153	0.465	0.43	1.321	0.377	0.175
2	X_{12}	0.00	0.38	0.56	0.89	1.00	0.09	1.800	0.403				0.152
3	X_{13}	0.74	1.00	0.60	0.23	0.00	0.05	1.000	0.224				0.085
4	X_{14}	0.00	0.15	0.31	0.64	1.00	0.15	2.642	0.224				0.085
5	X_{15}	0.35	0.00	0.16	0.71	1.00	0.06	–	0.085				0.032
6	X_{21}	0.00	0.10	0.43	0.67	1.00	0.01	1.000	0.245	0.33	1.000	0.285	0.070
7	X_{22}	0.00	0.57	0.70	0.88	1.00	0.03	1.852	0.245				0.070
8	X_{23}	0.00	0.25	0.49	0.75	1.00	0.02	1.000	0.132				0.038
9	X_{24}	0.00	0.23	0.46	0.71	1.00	0.13	1.000	0.132				0.038
10	X_{25}	0.00	0.23	0.47	0.82	1.00	0.14	–	0.132				0.038
11	X_{31}	0.13	0.00	0.30	0.85	1.00	0.16	1.000	0.294	0.54	1.000	0.285	0.084
12	X_{32}	1.00	0.90	0.82	0.23	0.00	0.18	2.283	0.294				0.084
13	X_{33}	1.00	0.76	0.60	0.22	0.00	0.08	1.334	0.129				0.037
14	X_{34}	0.00	0.15	0.63	0.84	1.00	0.06	1.000	0.096				0.028
15	X_{35}	0.34	0.00	0.10	0.60	1.00	0.07	–	0.096				0.028
16	X_{41}	0.54	0.90	1.00	0.00	0.68	0.02	1.000	0.468	1.10	2.275	0.285	0.134
17	X_{42}	0.00	0.08	0.12	0.61	1.00	0.19	6.457	0.468				0.134
18	X_{43}	0.87	1.00	0.89	0.00	0.23	0.03	1.000	0.072				0.021
19	X_{44}	0.00	0.16	0.36	0.69	1.00	0.58	2.033	0.072				0.021
20	X_{45}	0.00	0.29	0.39	0.77	1.00	0.28	–	0.036				0.010
21	X_{51}	0.51	0.72	1.00	0.00	0.07	0.05	1.000	0.375	0.48	–	0.125	0.047

(continued)

Table 20.3 (continued)

No.	Index	2013	2014	2015	2016	2017	CV of index	r of index	Weight of index	CV of criterion	r of criterion	Weight of criterion	Comprehensive weight
22	X_{52}	0.00	0.24	0.48	0.91	1.00	0.06	1.000	0.375				0.047
23	X_{53}	0.00	0.23	0.48	0.57	1.00	0.07	1.000	0.375				0.047
24	X_{54}	0.00	0.20	0.44	0.81	1.00	0.21	2.396	0.375				0.047
25	X_{55}	0.00	0.11	0.34	0.82	1.00	0.09	–	0.156				0.020

Table 20.4 Evaluation scores of the development status of the "Five Aspects" in Guangdong

Year	New industrialization	Urbanization	Greening	Informatization	Agricultural modernization	Comprehensive evaluation
2013	7.37	0.00	14.10	9.02	2.37	32.86
2014	22.11	7.33	10.73	15.77	6.77	62.70
2015	25.86	13.32	13.60	17.89	11.92	82.59
2016	35.12	19.38	13.80	10.43	12.40	91.12
2017	44.41	25.33	13.88	26.02	16.37	126.01

20.4.5 Analysis of the Status Quo of the Development of "Five Aspects" in Guangdong Province

It can be seen from Table 20.4 that the development status of the "Five Aspects" in Guangdong Province is increasing year by year and maintaining a good momentum. The comprehensive score of 2017 "Five Aspects" is nearly four times that of 2013. In order to better present the development trend of the "Five Aspects" in each year, the year is taken as the abscissa, and the "Five Aspects" score is taken as the ordinate to draw the development trend of the "Five Aspects" in Guangdong Province (Fig. 20.1).

It can be seen from Fig. 20.1 that the comprehensive score of "Five Aspects" in Guangdong Province in the five years from 2013 to 2017 has increased year by year, showing the good momentum of the development of "Five Aspects" in Guangdong Province. In concrete terms, new industrialization, urbanization and agricultural modernization have shown a good momentum of development year by year.

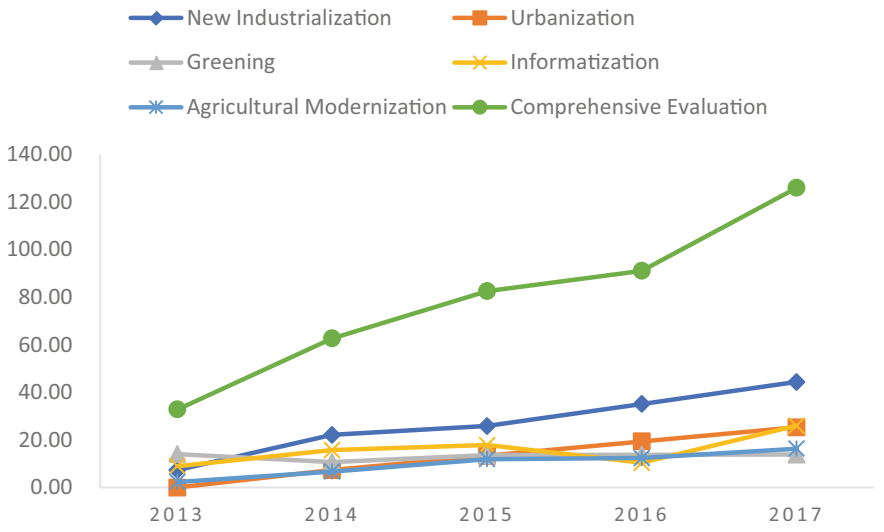

Fig. 20.1 Development trend of "Five Aspects" in Guangdong

The development of new industrialization in 2014–2017 has surpassed other "four aspects", indicating that new industrialization provides a continuous stream of development for the "Five Aspects". This is in line with Guangdong's status of the country's first major economic province.

The development of informatization has experienced ups and downs, but overall, it still shows growth momentum, which can be said that it develops in twists and turns. It should be noted that although the state of the development of greening during the period of 2014–2017 has improved, it still does not reach the level of 2013. During the period of 2013–2017, although the discharge of industrial wastewater in Guangdong Province has been declining year by year, the discharge of industrial waste gas and urban domestic sewage has increased year by year, resulting in a decline in the development of "greening" in Guangdong. Greening dragged the hind legs of the "Five Aspects", indicating that the development of new industrialization, urbanization, informatization and agricultural modernization was at cost of the environment.

20.4.6 Comparison

In previous research, we analyzed the development of the "Five Aspects" based on coefficient of variation weighting method. The results show that during 2013–2017, new industrialization, urbanization and agricultural modernization have shown a good momentum of development year by year. Besides, even though the development of greening during the period of 2014–2017 has improved, it still does not reach the level of 2013 (seen from Fig. 20.2). These findings are consistent with what we found

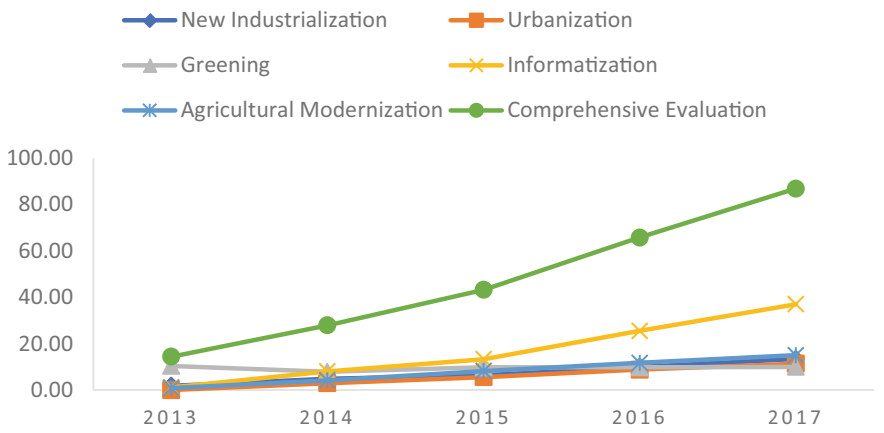

Fig. 20.2 Development trend of "Five Aspects" in Guangdong based on coefficient of variation weighting

based on the coefficient-of-variation-modified G1 weighting method. The difference exists in the informatization.

On the one hand, informatization is the first impetus for the development of the "Five Aspects" based on coefficient of variation weighting, while new industrialization takes the place based on the coefficient-of-variation-modified G1 combination weighting. On the other hand, informatization develops year by year based on the former method, but it develops in twists and turns based on the latter method.

Seen from the historical experience, industrialization promotes the development of urbanization and agricultural modernization, while it influences the development of greening. Nevertheless, new industrialization brings a great need of development of informatization. As a consequence, new industrialization should be the first impetus for the development of the "Five Aspects". Therefore, experts' experience should be taken into consideration while evaluating. Comparatively, the results based on the coefficient-of-variation-modified G1 combination weighting method are more scientific and reasonable.

20.5 Conclusion

In this paper, the coefficient-of-variation-modified G1 combination weighting method is constructed by using the coefficient of variation of the evaluation index. The actual importance degree of the index is determined by the coefficient of variation. Coefficient-of-variation-modified G1 combination weighting method can not only reflect the subjective intention of the experts or the decision makers, but it can also reflect the objective information of the index and solve the problem of reasonable distribution of weights. By using this method, this paper uses the development data of "Five Aspects" of Guangdong Province to conduct an empirical analysis.

Based on our analysis, Guangdong should continue to promote the development of new industrialization and maintain a strong growth momentum in the future development process of the "Five Aspects" while strengthening construction of greening and intensifying efforts to rectify industrial waste emissions on the basis of further reduction of industrial wastewater. Besides, try to raise people's environmental awareness, encourage the recycling of domestic sewage, reduce urban domestic sewage discharge. What is more, increase the intensity of afforestation, promote the use of new energy. In a word, we want gold and silver mountains as well as green water and mountains.

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