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Comprehensive Evaluation of Basic Public Health Service Quality Based on TOPSIS Improved Dynamic Triangle Fuzzy-- A Case Study of Zhengzhou

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Abstract: *To comprehensively evaluate the development of basic public health services in Zhengzhou, and to provide data reference for relevant departments to adjust their future decisions. TOPSIS was adopted dynamic triangulation fuzzy multi-attribute decision-making method to comprehensively evaluate the quality of basic public health service in Zhengzhou. After comprehensive evaluation, the top three places of basic public health service quality were Zhongmou in 2016, Zhongmou in 2015 and Erqi in 2016, and the bottom three places were Zhongyuan in 2011, Gangqu in 2011 and Gangqu in 2012. This method comprehensively considers the growth and difference degree of evaluation indexes in different years and regions, and selects the best schemes according to the comprehensive evaluation value. Compared with other methods, this method objectively considers the difference degree of attribute value, growth and change as well as the different psychological preferences of decision makers, and finally obtains scientific and reasonable ranking results, which can effectively meet the actual decision-making needs.*

Keywords: *Triangular fuzzy number, TOPSIS, National basic public health services*

1. Introduction

In order to ensure the life and health of all citizens, China carried out a new round of medical reform in 2009, introducing the "National Basic Public Health Service Plan" (NBPHSP). On the one hand, efforts are needed to control infectious diseases due to limited national funds, inadequate staffing of primary medical institutions and changing disease spectrum. On the other hand, there are also a large number of patients with non-communicable diseases, including 160-170 million with hypertension, over 100 million with hyperlipidemia, 92.4 million with diabetes, 700-2000 million with overweight or obesity, and 120 million with fatty liver[1]. Therefore, an accurate and timely comprehensive evaluation of basic public health service quality is of great significance.

At present, there are few articles related to the comprehensive evaluation of basic public health service quality. TOPSIS and RSR are common evaluation methods in multi-objective decision analysis, which are widely used in health evaluation and health decision making[2, 3]. However, TOPSIS uses the full distance of indicators to conduct indirect evaluation and is vulnerable to the influence of values with large dispersion degree, while rank-sum ratio method substitutes indicators with rank in non-parametric transformation, which is easy to cause information loss[4].

With the complexity of practical decision-making problems and the difficulty of obtaining accurate data, traditional decision-making methods can’t cope with various practical needs. However, the existing static triangular fuzzy multi-attribute decision making methods are not suitable for dynamic decision-making environment, and most of the dynamic methods only consider the difference of the index value, but ignore its increasing degree. Therefore, in order to solve the these problems, this paper adopts the dynamic triangular fuzzy decision-making method based on TOPSIS[5].

2. Methods

2.1 Weight determination method based on triangle fuzzy number

Where $\tilde{a} = [a^L\ a^M\ a^U]$, $0 < a^L \le a^M \le a^U$, $\tilde{a}$ is called a triangular fuzzy number and the

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membership function is [6, 7]

$$\mu_{\tilde{a}(x)} = \begin{cases} 0, & x \le a^L \\ \dfrac{x - a^L}{a^M - a^L}, & a^L \le x \le a^M \\ \dfrac{x - a^U}{a^M - a^U}, & a^M \le x \le a^U \\ 0, & x \ge a^U \end{cases} \tag{1}$$

Where a^U is the upper bound of $\tilde{a}$, a^L is the lower bound of $\tilde{a}$, and a^M is the median of $\tilde{a}$. When the three are equal, they degenerate to real values.

Let the decision matrix of a dynamic triangular fuzzy multi-attribute decision making problem be

$$\tilde{F}(t_k) = \begin{pmatrix} \widetilde{f_{11}}(t_k) & \widetilde{f_{12}}(t_k) & \cdots & \widetilde{f_{1n}}(t_k) \\ \widetilde{f_{21}}(t_k) & \widetilde{f_{22}}(t_k) & \cdots & \widetilde{f_{2n}}(t_k) \\ \vdots & \vdots & \ddots & \vdots \\ \widetilde{f_{m1}}(t_k) & \widetilde{f_{m2}}(t_k) & \cdots & \widetilde{f_{mn}}(t_k) \end{pmatrix} \tag{2}$$

Where $\widetilde{f_{ij}}(t_k) = [f_{ij}^L(t_k) f_{ij}^M(t_k) f_{ij}^U(t_k)]$ is the evaluation index value of alternatives plan $x_i(i = 1,2,\cdots,m)$ relative to index $s_j(j = 1,2,\cdots,n)$ at the time $t_k(k = 1,2,\cdots,p)$.

$w(t_k) = (w_1(t_k), w_2(t_k),\cdots,w_n(t_k))$ is the weight of each indicator at the moment, $\sum_{j=1}^{n} w_j(t_k) = 1$， $w_j(t_k) > 0$, and w_k is the time weight of the comprehensive evaluation value at the moment of t_k, and satisfies $\sum_{k=1}^{p} w_k = 1, w_k > 0$

The initial decision matrix is normalized and the normalized matrix $\widetilde{F}(t_k)$ is

$$\tilde{Y}(t_k) = \left(\widetilde{y_{ij}}(t_k)\right) = [y_{ij}^L(t_k) y_{ij}^M(t_k) y_{ij}^U(t_k)], \tag{3}$$

For the benefit index

$$\begin{cases} y_{ij}^L(t_k) & = \dfrac{f_{ij}^L(t_k)}{\sum_{i=1}^{m} f_{ij}^U(t_k)} \\ y_{ij}^M(t_k) & = \dfrac{f_{ij}^M(t_k)}{\sum_{i=1}^{m} f_{ij}^M(t_k)} \\ y_{ij}^U(t_k) & = \dfrac{f_{ij}^U(t_k)}{\sum_{i=1}^{m} f_{ij}^L(t_k)} \end{cases}, \tag{4}$$

For the cost indicator

$$\begin{cases} y_{ij}^L(t_k) & = \dfrac{\left(\frac{1}{f_{ij}^U(t_k)}\right)}{\sum_{i=1}^{m} \left(\frac{1}{f_{ij}^L(t_k)}\right)} \\ y_{ij}^M(t_k) & = \dfrac{\left(\frac{1}{f_{ij}^M(t_k)}\right)}{\sum_{i=1}^{m} \left(\frac{1}{f_{ij}^M(t_k)}\right)} \\ y_{ij}^U(t_k) & = \dfrac{\left(\frac{1}{f_{ij}^L(t_k)}\right)}{\sum_{i=1}^{m} \left(\frac{1}{f_{ij}^U(t_k)}\right)} \end{cases}, \tag{5}$$

2.2 National basic health service evaluation method based on TOPSIS

Step 1: According to the normalization matrix $\tilde{Y}(t_k)$, the growth coefficient matrix $\tilde{B}(t_k)$ is calculated

$$\tilde{B}(t_k) = \left(\widetilde{b_{ij}}(t_k)\right) = \widetilde{y_{ij}}(t_k) - \widetilde{y_{ij}}(t_{k-1}), \tag{6}$$

ISSN 2616-5791 Vol.3, Issue 1: 37-44, DOI: 10.25236/AJMHS.2022.030107

Step 2. Calculate the weighted growth matrix

$$\Delta\tilde{R}(t_k) = \left(\Delta\widetilde{r_{ij}}(t_k)\right) = \left(w_j(t_k)\widetilde{b_{ij}}(t_k)\right), \tag{7}$$

Step 3. Calculate positive and negative ideal solutions

The positive ideal solution

$$\Delta\tilde{R}^* = (\widetilde{r_1}^*, \widetilde{r_2}^*, \cdots, \widetilde{r_n}^*) \tag{8}$$

$$\Delta\tilde{r}_j^* = \left[\Delta r_j^{L*}\Delta r_j^{M*}\Delta r_j^{U*}\right] = \left[\max_{1\le i\le m}\max_{1\le k\le p}\Delta r_{ij}^L(t_k)\ \max_{1\le i\le m}\max_{1\le k\le p}\Delta r_{ij}^M(t_k)\ \max_{1\le i\le m}\max_{1\le k\le p}\Delta r_{ij}^U(t_k)\right] \tag{9}$$

The negative ideal solution

$$\Delta\tilde{R}^- = (\widetilde{r_1}^-, \widetilde{r_2}^-, \cdots, \widetilde{r_n}^-) \tag{10}$$

$$\Delta\tilde{r}_j^- = \left[\Delta r_j^{L-}\Delta r_j^{M-}\Delta r_j^{U-}\right] = \left[\min_{1\le i\le m}\min_{1\le k\le p}\Delta r_{ij}^L(t_k)\ \min_{1\le i\le m}\min_{1\le k\le p}\Delta r_{ij}^M(t_k)\ \min_{1\le i\le m}\min_{1\le k\le p}\Delta r_{ij}^U(t_k)\right] \tag{11}$$

Step 4. Calculate the distance from positive and negative ideal solutions

$$\Delta d_j^*(t_k) = d\left(\Delta\tilde{r}_i(t_k), \Delta\tilde{R}^*\right) = \sqrt{\left(\Delta d_{i1}^*(t_k)\right)^2 + \left(\Delta d_{i2}^*(t_k)\right)^2 + \cdots + \left(\Delta d_{in}^*(t_k)\right)^2} \tag{12}$$

$$\begin{aligned}\Delta d_{ij}^*(t_k) &= d\left(\Delta\widetilde{r_{ij}}(t_k), \Delta\widetilde{r_j^*}\right)\\ &= \sqrt{\frac{\left(\Delta r_{ij}^L(t_k) - \Delta r_j^{L*}\right)^2 + \left(\Delta r_{ij}^M(t_k) - \Delta r_j^{M*}\right)^2 + \left(\Delta r_{ij}^U(t_k) - \Delta r_j^{U*}\right)^2}{3}}\end{aligned} \tag{13}$$

$$\Delta d_i^-(t_k) = d\left(\Delta\widetilde{r_i}(t_k), \Delta\tilde{R}^-\right) = \sqrt{\left(\Delta d_{i1}^-(t_k)\right)^2 + \left(\Delta d_{i2}^-(t_k)\right)^2 + \cdots + \left(\Delta d_{in}^-(t_k)\right)^2}$$

$$\begin{aligned}\Delta d_{ij}^-(t_k) &= d\left(\Delta\widetilde{r_{ij}}\widetilde{(t_k)}, \Delta\widetilde{r_j}^-\right)\\ &= \sqrt{\frac{\left(\Delta r_{ij}^L(t_k) - \Delta r_j^{L-}\right)^2 + \left(\Delta r_{ij}^M(t_k) - \Delta r_j^{M-}\right)^2 + \left(\Delta r_{ij}^U(t_k) - \Delta r_j^{U-}\right)^2}{3}}\end{aligned} \tag{14}$$

Step 5. Calculate the relative closeness $\Delta C_i^*(t_k)$

$$\Delta C_i^*(t_k) = \frac{\Delta d_i^-(t_k)}{\Delta d_i^-(t_k) + \Delta d_i^*(t_k)} \tag{15}$$

Step 6. Sort

Rank the change degree of alternative schemes according to the size of $\Delta C_i^*(t_k)$, and the larger $\Delta C_i^*(t_k)$ is, the better is.

Step 7. Calculate the comprehensive evaluation value of each alternative plan at the time t_k

The differences and growth degree of all alternatives are considered simultaneously

$$g_i(t_k) = \alpha C_i^*(t_k) + \beta\Delta C_i^*(t_k),\ 0 \le \alpha, \beta \le 1,\ \alpha + \beta = 1, \tag{16}$$

The alternative schemes are sorted according to the size of comprehensive evaluation value $g_i(t_k)$. The bigger $g_i(t_k)$ is, the better the scheme is.

Where, α and β are of relative importance. When $\alpha = 0$, $\beta = 1$, that is, only pay attention to the growth of alternative schemes, then $g_i(t_k) = \Delta C_i^*(t_k)$. When $\alpha = 1$, $\beta = 0$, that is, only pay attention to the difference degree of alternative schemes, then $g_i(t_k) = C_i^*(t_k)$.

This paper assumes that the data of each year are equally important. Considering the different meanings of each year, time weight can be used to make a secondary weighting of the comprehensive evaluation value obtained in Step 7, that is, step 8 can be carried out.

Step 8. Determine the final comprehensive evaluation value by secondary weighting

ISSN 2616-5791 Vol.3, Issue 1: 37-44, DOI: 10.25236/AJMHS.2022.030107

$$G_i = \sum_{k=1}^{p} w_k g_i(t_k), \tag{17}$$

Where, $w_k = (w_1, w_2, \cdots, w_p)$ is the time weight of the t_k moment, and satisfies $\sum_{k=1}^{p} w_k = 1, w_k > 0$. At this point, it can be sorted according to the second weighted G_i, and the larger G_i is, the better scheme x_i is.

3. Result

3.1 Research data sources

In this study, Zhengzhou, Henan Province, China was taken as the object of investigation, and Zhengzhou Health and Family Planning Commission organized a unified investigation. Each lower health and Family Planning Commission reported the statistical data of national basic public health service items within its jurisdiction by itself, and referred to Zhengzhou Statistical Yearbook of 2016[8].

3.2 Index system construction

According to the content of the national basic public health service project, the implementation of the national basic public health service project in each district of Zhengzhou from 2011 to 2016 was comprehensively evaluated.

Table 1: Evaluation index system of implementation of national basic public health service projects

Level 1 indicators	Level 1 number	Level 2 indicators	Level 2 number
1). Health records	A	Rate of filing of electronic health records	A1
		Health record usage	A2
		JE vaccine coverage rate	A3
		Vaccination coverage rate of meningitis vaccine	A4
		Hepatitis A vaccine coverage rate	A5
		Measles vaccination coverage rate	A6
		Child health management rate	A7
2). Health management of pregnant women	B	Early pregnancy rate	B1
		Postpartum visit rate	B2
3). Health management of the elderly	C	Health management rate of the elderly	C
4). Health management of hypertension patients	D	Health management rate of patients with hypertension	D1
		Standard management rate of hypertension patients	D2
5). Health management of patients with type ii diabetes	E	Health management rate of diabetic patients	E1
		Standardized management rate of patients with diabetes	E2
6). Standardized management of severe mental patients	F	Standardized management rate of patients with severe mental illness	F
7). TCM health management	G	TCM health management rate for the elderly	G1
		TCM health management rate for children	G2

3.3 Weight determination process based on fuzzy trigonometry

First-level index matrix and the calculated fuzzy synthesis degree are

$$\begin{bmatrix} 4.3 & 2.5 & 2.2 \\ 1.9 & 3.4 & 3.4 \\ 2.1 & 2.8 & 1.9 \\ 2.5 & 2.8 & 2.7 \\ 2.7 & 2 & 3.2 \\ 3.5 & 1.8 & 3.5 \\ 3.7 & 2.8 & 2.6 \end{bmatrix} \qquad \begin{bmatrix} 0.22 & 0.14 & 0.11 \\ 0.10 & 0.19 & 0.16 \\ 0.11 & 0.15 & 0.09 \\ 0.13 & 0.15 & 0.13 \\ 0.14 & 0.11 & 0.15 \\ 0.18 & 0.10 & 0.17 \\ 0.19 & 0.15 & 0.13 \end{bmatrix}$$

ISSN 2616-5791 Vol.3, Issue 1: 37-44, DOI: 10.25236/AJMHS.2022.030107

Table 2: Reachability matrix of each evaluation index

	A	B	C	D	E	F	G
A	1.00	1.00	1.00	1.00	1.00	1.00	1.00
B	0.53	1.00	1.00	1.00	1.00	1.00	1.00
C	0.89	3.44	1.00	1.00	1.00	1.00	1.00
D	0.84	2.07	1.00	1.00	1.00	1.00	1.00
E	1.72	1.25	0.51	0.37	1.00	1.00	1.00
F	4.03	1.15	0.53	0.43	0.73	1.00	1.00
G	0.85	2.15	1.00	1.00	0.23	0.49	1.00

Table 3: Relative weights of each evaluation index determined based on triangular fuzzy number

Level indicators	Level 1 weight	The secondary indicators	Level 2 weight	Level 1 weight x Level 2 weight	Sample size	The average	The standard deviation
A	23.33%	A1	27.27%	6.36%	90	88.193	11.321
		A2	23.68%	5.53%	90	44.238	19.245
		A3	18.45%	4.30%	90	95.973	5.636
		A4	12.98%	3.03%	90	97.202	2.579
		A5	11.69%	2.73%	90	96.092	5.858
		A6	4.40%	1.03%	90	96.752	6.354
		A7	1.55%	0.36%	90	87.090	8.395
B	20.67%	B1	41.46%	8.57%	90	75.820	20.822
		B2	58.54%	12.10%	90	81.041	21.728
C	19.71%	C	100.00%	19.71%	90	72.272	15.934
D	9.92%	D1	55.86%	5.54%	90	50.283	27.934
		D2	44.14%	4.38%	90	85.326	14.916
E	12.39%	E1	68.46%	8.48%	90	51.796	26.705
		E2	31.54%	3.91%	90	77.467	22.760
F	8.72%	F	100.00%	8.72%	90	79.049	22.611
G	5.26%	G1	61.41%	3.23%	90	60.566	17.566
		G2	38.59%	2.03%	90	70.173	17.533

3.4 Comprehensive evaluation calculation based on TOPSIS

Table 4: Standardized processing results of each evaluation index

The evaluation index	Positive ideal solution A+	Negative ideal solution A-
A1	100.000	44.700
A2	100.000	19.000
A3	100.000	62.340
A4	100.000	84.300
A5	100.520	50.160
A6	100.000	65.420
A7	100.000	64.990
B1	100.000	14.000
B2	100.000	10.000
C	100.000	36.000
D1	100.000	1.560
D2	102.000	2.620
E1	100.000	8.220
E2	100.000	18.200
F	100.000	4.850
G1	100.000	26.060
G2	108.000	25.000

ISSN 2616-5791 Vol.3, Issue 1: 37-44, DOI: 10.25236/AJMHS.2022.030107

Table 5: Calculation results of TOPSIS evaluation of basic public health service quality in each district of Zhengzhou in 2011

Time	City	Positive ideal solution on distance D+	Negative ideal solution on distance D-	Relative proximity Ci	Sorting result
2011	Dengfeng	32.89	52.235	0.614	45
	Erqi	40.957	51.938	0.559	66
	Gangqu	52.428	40.482	0.436	89
	Gaoxin	38.316	55.258	0.591	55
	Guancheng	45.215	42.931	0.487	84
	Huiji	29.033	58.383	0.668	24
	Jinshui	46.918	45.913	0.495	82
	Jingkai	46.219	49.1	0.515	77
	Shangjie	39.865	54.644	0.578	58
	Xinmi	24.366	61.935	0.718	18
	Xinzheng	42.332	48.761	0.535	73
	Xingyang	33.333	58.207	0.636	37
	Zhengdong	41.237	52.103	0.558	67
	Zhongmou	20.246	63.667	0.759	10
	Zhongyuan	57.107	43.752	0.434	90

Table 6: Calculation results of TOPSIS evaluation of basic public health service quality in each district of Zhengzhou in 2012

Time	City	Positive ideal solution on distance D+	Negative ideal solution on distance D-	Relative proximity Ci	Sorting result
2012	Dengfeng	31.593	53.223	0.628	40
	Erqi	28.214	59.508	0.678	22
	Gangqu	48.869	43.283	0.47	88
	Gaoxin	47.231	49.507	0.512	78
	Guancheng	40.687	45.868	0.53	75
	Huiji	29.082	58.304	0.667	25
	Jinshui	46.609	44.796	0.49	83
	Jingkai	45.14	50.335	0.527	76
	Shangjie	36.132	55.694	0.607	48
	Xinmi	22.689	63.34	0.736	14
	Xinzheng	43.224	49.93	0.536	72
	Xingyang	33.305	58.97	0.639	35
	Zhengdong	40.853	52.248	0.561	65
	Zhongmou	20.006	64	0.762	9
	Zhongyuan	49.112	44.147	0.473	87

Table 7: Calculation results of TOPSIS evaluation of basic public health service quality in each district of Zhengzhou in 2013

Time	City	Positive ideal solution on distance D+	Negative ideal solution on distance D-	Relative proximity Ci	Sorting result
2013	Dengfeng	25.322	58.435	0.698	21
	Erqi	23.074	62.042	0.729	15
	Gangqu	47.683	44.571	0.483	86
	Gaoxin	34.029	56.661	0.625	42
	Guancheng	38.09	47.204	0.553	68
	Huiji	27.952	58.734	0.678	23
	Jinshui	42.353	52.117	0.552	69
	Jingkai	46.467	48.363	0.51	79
	Shangjie	34.139	57.123	0.626	41
	Xinmi	21.99	65.808	0.75	12
	Xinzheng	31.709	58.645	0.649	30
	Xingyang	33.054	59.07	0.641	34
	Zhengdong	40.103	52.078	0.565	63
	Zhongmou	18.419	65.395	0.78	7
	Zhongyuan	38.688	57.756	0.599	50

ISSN 2616-5791 Vol.3, Issue 1: 37-44, DOI: 10.25236/AJMHS.2022.030107

Table 8: Calculation results of TOPSIS evaluation of basic public health service quality in each district of Zhengzhou in 2014

Time	City	Positive ideal solution on distance D+	Negative ideal solution on distance D-	Relative proximity Ci	Sorting result
2014	Dengfeng	22.741	60.003	0.725	16
	Erqi	18.835	67.77	0.783	6
	Gangqu	45.864	42.994	0.484	85
	Gaoxin	29.034	57.504	0.664	26
	Guancheng	36.575	48.696	0.571	61
	Huiji	38.361	54.136	0.585	57
	Jinshui	44.254	51.744	0.539	71
	Jingkai	44.295	50.589	0.533	74
	Shangjie	33.078	58.205	0.638	36
	Xinmi	22.069	63.569	0.742	13
	Xinzheng	31.391	58.556	0.651	29
	Xingyang	35.045	60.753	0.634	39
	Zhengdong	39.177	52.223	0.571	60
	Zhongmou	18.149	65.775	0.784	4
	Zhongyuan	37.72	59.008	0.61	47

Table 9: Calculation results of TOPSIS evaluation of basic public health service quality in each district of Zhengzhou in 2015

Time	City	Positive ideal solution on distance D+	Negative ideal solution on distance D-	Relative proximity Ci	Sorting result
2015	Dengfeng	24.651	58.803	0.705	20
	Erqi	18.975	68.702	0.784	5
	Gangqu	44.883	44.4	0.497	81
	Gaoxin	42.512	55.394	0.566	62
	Guancheng	32.535	51.162	0.611	46
	Huiji	37.294	54.363	0.593	54
	Jinshui	43.151	51.762	0.545	70
	Jingkai	47.639	48.956	0.507	80
	Shangjie	30.536	60.395	0.664	27
	Xinmi	20.468	64.323	0.759	11
	Xinzheng	35.62	53.087	0.598	51
	Xingyang	37.498	55.461	0.597	53
	Zhengdong	33.516	58.257	0.635	38
	Zhongmou	14.967	67.472	0.818	2
	Zhongyuan	33.331	60.208	0.644	33

Table 10: Calculation results of TOPSIS evaluation of basic public health service quality in each district of Zhengzhou in 2016

Time	City	Positive ideal solution on distance D+	Negative ideal solution on distance D-	Relative proximity Ci	Sorting result
2016	Dengfeng	23.182	60.864	0.724	17
	Erqi	17.641	69.219	0.797	3
	Gangqu	38.078	49.3	0.564	64
	Gaoxin	39.469	56.002	0.587	56
	Guancheng	31.991	51.706	0.618	44
	Huiji	36	53.414	0.597	52
	Jinshui	40.184	53.729	0.572	59
	Jingkai	37.617	56.165	0.599	49
	Shangjie	30.172	59.515	0.664	28
	Xinmi	19.337	65.434	0.772	8
	Xinzheng	30.938	56.326	0.645	32
	Xingyang	34.466	57.101	0.624	43
	Zhengdong	32.081	58.632	0.646	31
	Zhongmou	14.504	68.342	0.825	1
	Zhongyuan	24.964	63.096	0.717	19

ISSN 2616-5791 Vol.3, Issue 1: 37-44, DOI: 10.25236/AJMHS.2022.030107

4. Conclusion

It can be seen from the above data that the overall Ci value of Zhengzhou is not high. Observation data in 2016 (Table 10) found that the basic public health services quality sorting first of Zhongmou, Ci value of 0.825, the area of basic public health service quality at the end, the Ci value of 0.564, there is still a large gap between them, how to allocate the basic public health service resources, and balance the service quality is also related departments need to consider the problem. By observing the data from 2011 to 2016 (Table 4-10), it was found that the quality of basic public health service in most regions, such as Dengfeng, Erqi and Gangqu, showed an upward trend year by year, but there were also a small number of regions, such as Huiji and Xingyang, which showed a downward trend. After comprehensive evaluation, the top three places of basic public health service quality were Zhongmou in 2016 (Table 10), Zhongmou in 2015 (Table 9) and Erqi in 2016 (Table 10), and the bottom three places were Zhongyuan in 2011 (Table 4), Gangqu in 2011 (Table 4) and Gangqu in 2012 (Table 5).

The comprehensive evaluation method of basic public health service quality based on TOPSIS improved dynamic triangle fuzzy can comprehensively consider the growth and difference degree of evaluation indexes in different years and regions, and rank the programs according to the comprehensive evaluation value. Compared with other methods, this method objectively considers the difference degree of attribute values, growth and change, and the different psychological preferences of decision makers, and finally obtains scientific and reasonable ranking results to effectively meet the actual decision-making needs.

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