Evaluation of Urban Vitality in Shandong Based on Multi-source Data

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ABSTRACT: This paper focuses on the new problem of urban vitality development, and designs 32 link indicators from 6 dimensions, including economy, talent, innovation, industry, people's livelihood and international, to measure urban vitality by using comprehensive evaluation method. The results of the study show that (1) from the overall index, Jinan and Qingdao have been steadily ranked in the top two in the province; (2) from the time dimension of 2018-2022, cities such as Heze and Linyi have made the most obvious progress; Yantai and Weifang have performed more stable over the years. Based on the results of the study, the paper goes on to make a number of recommendations to provide a strategic basis for further improving urban vitality in Shandong.

1 INTRODUCTION

Urban vitality is the guarantee of the vigorous vitality of urban space and the survival and development of urban functions, and has been one of the hot spots of urban research. At present, China is in a stage of rapid urbanization, and the prevalence of blind, sloppy urban expansion that ignores spatial quality has led to traffic congestion, deterioration of urban quality, and imbalance in regional development. The construction of "people-oriented, urban-rural integration, green and economical, livable and harmonious" urban development model, and the in-depth promotion of new urbanization and ecological civilization construction have become the new demands of the current development. Urban vitality studies can evaluate the current state of vitality within cities, effectively examine the spatial quality and distribution characteristics of cities, and provide a new perspective for optimizing town layout and morphology[1].

Urban vitality has a rich connotation, including social, economic, environmental and cultural aspects on the macro level, while on the micro level, it is mainly expressed in the distribution and activities of people in urban space. In 1981, Kevin Lynch, a renowned urban researcher, first identified "vitality" as the primary indicator for evaluating urban spatial form in his book Good City Form. Domestic research on urban dynamics in recent years can be broadly divided into three categories[2]. The first type of research focuses on public space areas such as communities, streets, squares, and commercial complexes within the city, and studies the mechanism of the function, structure, and form of urban public space vitality on vitality, and this type of research is mostly conducted by qualitative analysis and field research[3]. The second category is to take cities as the basic research unit, by constructing single-dimensional vitality indicators such as economic vitality, talent vitality, and consumption vitality that have an important impact on urban development, the most common of which are economic vitality and talent vitality, etc.. Researchers mostly use factor analysis to select the economic vitality and talent vitality that affect each indicator is analyzed for impact effects and weights[4]. The third category is to start from the holistic nature of urban vitality system, consider the comprehensive, diversified and complex characteristics of urban vitality, take the characteristics of social, economic, cultural, environmental and transportation levels as different performance levels of vitality, and conduct a composite evaluation of urban vitality by constructing a comprehensive evaluation index, and the research methods are mostly Delphi expert scoring method, fuzzy comprehensive evaluation, multi-factor comprehensive evaluation method, etc..[5]

2 CONSTRUCTION OF URBAN VITALITY INDEX SYSTEM

2.1 The idea of constructing city vitality index system

As a space with clear geographical boundaries, cities carry a variety of economic and social activities. In the context of the new era, a city with better economic development is inevitably a vibrant city, so the economic development vitality of a city is the most important indicator. As talent and innovation are important factors driving the economic and social development of a region, this paper argues that innovation under the leadership and participation of talent

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is also important for a city. In the new era, industrial upgrading can improve the quality and efficiency of the city's economic development, so this paper also considers industrial upgrading dynamics. In order to have vitality, cities must ensure the livelihood and well-being of city residents, so the livelihood and well-being vitality indicator is selected. A dynamic city has a strong influence and radiation, which will affect the common development of a country or even the world, and in this regard this paper considers the international dynamism of the city. Therefore, in this paper, six types of urban dynamics are considered as first-tier indicators from various aspects of urban economic and social dynamics. Then, according to the connotation of six kinds of vitality and the principle of indicator selection, the corresponding secondary indicators are selected. Since this paper studies urban vitality, the vitality is not only reflected in the development level, but more importantly, it presents a dynamic progress, therefore, in addition to some level indicators, the development speed indicators are also considered to be selected, which is also a major feature in the setting of urban vitality indicators[6-8].

2.2 The basic framework of city vitality index system

Table 1. City Vitality Indicator System and Weights.

Level 1 Indicators	Level 2 Indicators	Level of importance	Synthetic total index weights	Synthesis of index weights for each level of indicators
1.Economic vitality	11 GDP per capita	5	0.054	0.217
	12 GDP growth rate	5	0.054	0.217
	13 Growth rate of general fiscal budget revenue	3	0.033	0.130
	14 Total retail sales of social consumer goods as a percentage of GDP	4	0.043	0.174
	15 Total retail sales of social consumer goods growth rate	3	0.033	0.130
	16 Total Labor Productivity	2	0.022	0.087
	17 Rate of growth of total labor productivity	1	0.011	0.043
2.Innovative vitality	21 R&D investment intensity	5	0.054	0.294
	22 Growth rate of local financial expenditure on science and technology	2	0.022	0.118
	23 Number of invention patent applications per 10,000 population	4	0.043	0.235
	24 Growth rate of invention patent applications per 10,000 population	2	0.022	0.118
	25 Number of high-tech enterprises per 10,000 population	4	0.043	0.235
3.Talent vitality	31 Full-time equivalent of R&D activities per 10,000 employees	5	0.054	0.455
	32 Share of the number of students enrolled in general higher education institutions	3	0.033	0.273
	33 Growth rate of the proportion of students enrolled in general higher education institutions	3	0.033	0.273
4.Industrial vitality	41 Share of tertiary industry	4	0.043	0.250
	42 The proportion of tertiary industry growth rate	2	0.022	0.125
	43 Value added of digital economy as a proportion of value added of tertiary industry	4	0.043	0.250
	44 Growth rate of high-tech enterprises per 10,000 population	2	0.022	0.125
	45 The proportion of the total industrial output value of high and new technology enterprises	4	0.043	0.250
5.Happiness and vitality	51 Per capita disposable income of urban residents	5	0.054	0.333
	52 Growth rate of disposable income per capita of urban residents	3	0.033	0.200

	53 Number of medical beds per 10,000 population	2	0.022	0.133
	54 Growth rate of the number of people participating in urban basic pension insurance	2	0.022	0.133
	55 Living area per urban resident	2	0.022	0.133
	56 Air compliance rate	1	0.011	0.067
6.International Vitality	61 Share of total export value	2	0.022	0.200
	62 Growth rate of total export value	1	0.011	0.100
	63 The proportion of the actual amount of foreign capital utilized	3	0.033	0.300
	64 Growth rate of the actual amount of foreign capital utilized	1	0.011	0.100
	65 Share of total foreign exchange earnings of the tourism industry	2	0.022	0.200
	66 Growth rate of total foreign exchange earnings from tourism	1	0.011	0.100
Total	——		1.000	6.000

2.3 Statistical Measures of Urban Vitality

In this paper, the statistical measurement of urban vitality uses the improved integrated evaluation method of efficacy coefficients, and the synthesis uses the weighted arithmetic average method, where the weights are analyzed by hierarchical analysis.

2.3.1 The choice of single index synthesis method

In this paper, a modified efficacy factor method is used.

$$K_{ij} = \frac{x_{ij} - x_{(s)}}{x_{(h)} - x_{(s)}} \times 40 + 60 \tag{1}$$

Among them, K_{ij} is the score of single indicator of urban vitality, x_{ij} is the observed value of urban vitality, $x_{(s)}$ is the unsatisfied value of urban vitality, $x_{(h)}$ is the satisfied value of urban vitality.

2.3.2 The choice of synthesis method of comprehensive index

This paper uses the weighted arithmetic average method to synthesize the composite urban vitality index.

$$\overline{K}_i = \frac{\sum k_{ij} w_j}{\sum w_j} \tag{2}$$

$\overline{K}_i$ is the overall urban vitality index score of a region, w_j is the weight of each urban vitality index, and k_{ij} is the score of the corresponding urban vitality item.

2.3.3 Determination of weights.

In this paper, the Analytic hierarchy process (AHP) is used. The specific steps are as follows.

1) Rank the indicators in order of importance. In this paper, the 32 assessment indicators are classified into 5 levels of importance: important, relatively important, obviously important, strongly important and extremely important, and are recorded as 1, 2, 3, 4 and 5 levels.

2) Constructs the judgment matrix. The judgment matrix is constructed by comparing the importance of the indicators between two and analyzing the judgment. Let A be the judgment matrix, then we have $A = (a_{ij})_{n\times n}$, where a_{ij} denotes the comparative value of the relative importance of the horizontal row indicators Z_i to the column indicators Z_j.

3) The weights of each indicator are calculated. The calculation formulae are respectively.

$$\overline{a}_i = \sqrt[n]{a_{i1} \times a_{i2} \times \ldots \times a_{in}} = \sqrt[n]{\prod_{j=1}^{n} a_{ij}} \tag{3}$$

$$w_i = \frac{\overline{a}_i}{\sum_{i=1}^{n} \overline{a}_i}, i = 1,2,\ldots,n \tag{4}$$

4) The consistency test is performed on the judgment matrix. The calculation steps are as follows.

(i)Calculate the maximum characteristic roots of the judgment matrix.

$$\lambda_{\max} = \frac{1}{n} \sum_{i=1}^{n} \frac{(AW)_i}{W_i} \tag{5}$$

where AW is the product of the judgment matrix A and the eigenvector W, i.e.

$$AW = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & & & \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \begin{bmatrix} \mathrm{w}_1 \\ \mathrm{w}_2 \\ \cdots \\ \mathrm{w}_n \end{bmatrix} \tag{6}$$

(ii)Calculate the Consistency Index (CI) of the judgment matrix.

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{7}$$

(iii) Calculate the stochastic consistency ratio of the judgment matrix. The Consistency Ratio (CR) for the test can be calculated from the Consistency Index CI by the following formula.

$$CR = \frac{CI}{RI} \le 0.10 \tag{8}$$

Where, RI is the average random consistency index, and the magnitude of its value depends on the number of evaluation indexes in the judgment matrix, which can be obtained by checking Table 2. When CR is less than 0.10, the above judgment matrix is considered to meet the consistency requirements and the weights of the obtained comprehensive evaluation indexes are appropriate.

Table 2. Average random consistency index judgment criteria.

n	2	3	4	5	6	7	8	9	10	11
RI	0	0.5149	0.8931	1.1185	1.2494	1.345	1.42	1.4616	1.4874	1.5156

The weights of the indicators at all levels of the comprehensive evaluation of urban vitality are measured according to the above process, as shown in column 4 of Table 1, in which the random consistency ratio of the judgment matrix of indicators at all levels is less than 0.1, so the judgment matrix is appropriate.

3 COMPREHENSIVE EVALUATION OF VITALITY OF SHANDONG MUNICIPALITIES

3.1 Data source and description

The data in this paper come from the statistical yearbook of Shandong Province and the statistical yearbook of each city in the past years, because in 2018, Laiwu has not been integrated into Jinan as a whole, in the processing of data, this paper chooses to combine Jinan and Laiwu data for calculation; 2022 data are chosen from the data published by the Bureau of Statistics in the first half of the year.

3.2 Comprehensive evaluation results

In this paper, we select 16 cities in Shandong to measure the vitality of cities in six dimensions: economic vitality, talent vitality, innovation vitality, industrial vitality, happiness vitality, and international vitality in terms of GDP growth rate, R&D investment intensity, growth rate of local fiscal expenditure on science and technology, growth rate of invention patent applications per 10,000 population, full-time equivalent of R&D activities per 10,000 employees, value added of digital economy to value added of tertiary industry, growth rate of per capita disposable income of urban residents, growth rate of the number of urban pensioners, growth rate of total export value, and growth rate of total foreign exchange income of tourism. The 32 indicators are used to measure the vitality of cities, including the growth rate of per capita disposable income of urban residents, the growth rate of the number of urban basic pension insurance participants, the growth rate of total export value, and the growth rate of total foreign exchange earnings of tourism. The results of the study are shown in Table 3.

Table 3. Major Cities Vitality Composite Index 2018-2022.

Urban.	2018		2019		2020		2021		2022	
	Index	Rank	Index	Rank	Index	Rank	Index	Rank	Index	Rank
Jinan	72.69	2	76.32	2	74.75	2	77.74	2	78.86	2
Qingdao	76.21	1	79.86	1	77.69	1	79.95	1	80.31	1
Zibo	70.38	6	72.06	7	71.08	6	73.27	6	75.82	6
Zaozhuang	65.18	15	63.29	16	62.18	16	66.08	16	67.31	16
Dongying	69.12	8	70.02	11	69.17	10	71.32	10	72.56	10
Yantai	71.56	3	75.46	3	72.76	3	74.69	4	76.25	5
Weifang	71.08	4	74.93	4	72.02	4	75.08	3	77.56	3
Jining	70.53	5	73.81	5	70.59	7	71.83	9	73.71	9
Taian	68.01	10	69.45	12	67.69	12	69.85	12	70.59	12
Weihai	68.52	9	71.51	8	69.98	8	72.28	8	74.36	8
Sunshine	63.27	16	65.23	15	64.96	15	67.52	15	68.39	15
Binzhou	66.36	14	68.71	13	67.13	13	68.97	13	69.89	13
Dezhou	67.92	11	70.56	10	68.55	11	70.59	11	71.39	11
Liaocheng	67.11	13	67.10	14	66.62	14	68.23	14	68.97	14
Linyi	69.83	7	73.19	6	71.64	5	73.73	5	76.73	4
Heze	67.53	12	70.97	9	69.36	9	72.96	7	75.17	7

From the total city vitality index, Qingdao and Jinan have been steadily ranked in the top two in the province, Heze has continued to improve in recent years, the vitality ranking has been in the middle of the province, Liaocheng, Binzhou, Rizhao, Zaozhuang and other cities compared with other cities, always ranked last in the province.

4 CONCLUSIONS

From the first level of indicators: the top 6 rankings of each classification index of urban vitality in 2018-2022 are shown in Tables 4 to 9.(1) In terms of economic vitality: Qingdao and Jinan have always been in the forefront of the province's "double core" leadership, while Yantai, Weifang, Zibo, Jining and other cities have been performing moderately well.(2)In terms of innovation vitality: the leading role of Jinan and Qingdao twin nuclei is further highlighted, the innovation capacity of Jinan and Qingdao is continuously enhanced, and the level of innovation of cities in the provincial capital metropolitan area and Jiaodong metropolitan area is greatly enhanced by radiation.(3)Thanks to the good educational environment and the concentration of large enterprises, Jinan and Qingdao are the most outstanding performers in terms of talent vitality.(4) In terms of industrial vitality, Jinan and Qingdao have a more reasonable structure of the three industries, and the digital economy is developing at a faster pace, ranking consistently among the top two in the province; (5) In terms of livelihood and happiness vitality, Qingdao performs most consistently and excellently, ranking high in all indicators of livelihood and happiness vitality.(6)The overall internationalization of the eastern coastal region is the highest, Qingdao, Yantai, Weifang exports have been steadily ranked in the top three in the province.

Table 4. City Vitality Economic Index.

Rank	2018		2019		2020		2021		2022	
	Urban	Index	Urban	Index	Urban	Index	Urban	Index	Urban	Index
1	Qingdao	80.32	Qingdao	81.08	Qingdao	79.93	Qingdao	80.16	Qingdao	79.62
2	Jinan	79.61	Jinan	80.25	Jinan	78.62	Jinan	79.37	Jinan	78.58
3	Yantai	78.86	Yantai	78.19	Linyi	76.86	Weifang	78.22	Yantai	77.19
4	Weifang	77.06	Linyi	77.68	Yantai	76.09	Linyi	77.81	Jining	76.39
5	Linyi	75.29	Weifang	77.03	Weifang	75.24	Yantai	77.16	Weifang	75.97
6	Zibo	74.39	Heze	75.46	Jining	74.33	Jining	76.34	Zibo	75.34

Table 5. City Vitality Innovation Index.

Rank	2018		2019		2020		2021		2022	
	Urban	Index	Urban	Index	Urban	Index	Urban	Index	Urban	Index
1	Jinan	81.24	Jinan	81.83	Jinan	82.06	Jinan	80.27	Jinan	81.65
2	Qingdao	80.96	Qingdao	81.36	Qingdao	81.59	Qingdao	79.68	Qingdao	80.82
3	Zibo	76.37	Zibo	78.03	Zibo	78.66	Zibo	77.32	Zibo	78.39
4	Weihai	75.94	Weihai	77.29	Weihai	77.59	Weihai	76.58	Weihai	77.72
5	Yantai	75.35	Dongying	75.86	Yantai	76.37	Yantai	76.09	Yantai	76.68
6	Taian	74.12	Yantai	75.52	Dongying	75.81	Dongying	75.16	Dongying	75.19

Table 6. City Vitality Talent Index.

Rank	2018		2019		2020		2021		2022	
	Urban	Index	Urban	Index	Urban	Index	Urban	Index	Urban	Index
1	Qingdao	80.69	Jinan	80.81	Jinan	81.64	Jinan	82.63	Jinan	80.32
2	Jinan	78.53	Qingdao	80.67	Qingdao	80.38	Qingdao	82.49	Qingdao	79.69
3	Yantai	77.66	Weifang	77.52	Yantai	77.75	Yantai	78.67	Yantai	77.19
4	Zibo	73.26	Yantai	75.35	Weihai	75.39	Dongying	76.82	Weihai	76.07
5	Weihai	73.38	Linyi	73.18	Dongying	72.47	Weihai	76.19	Weifang	74.22
6	Weifang	72.85	Weihai	72.68	Zibo	71.63	Weifang	74.83	Linyi	73.71

Table 7. City Vitality Industry Index.

Rank	2018		2019		2020		2021		2022	
	Urban	Index	Urban	Index	Urban	Index	Urban	Index	Urban	Index
1	Jinan	78.85	Jinan	80.92	Jinan	83.51	Jinan	82.73	Jinan	84.07
2	Qingdao	76.38	Qingdao	80.08	Qingdao	82.84	Qingdao	81.86	Qingdao	82.56
3	Weihai	71.59	Linyi	76.31	Linyi	77.32	Linyi	76.23	Yantai	78.23
4	Linyi	71.02	Weifang	73.55	Yantai	73.59	Yantai	75.42	Linyi	76.78
5	Taian	69.59	Taian	71.67	Weifang	72.76	Weihai	74.08	Weihai	74.79
6	Weifang	68.65	Yantai	71.05	Weihai	72.18	Weifang	73.41	Weifang	71.57

Table 8. City Vitality Happiness Index.

Rank	2018		2019		2020		2021		2022	
	Urban	Index	Urban	Index	Urban	Index	Urban	Index	Urban	Index
1	Qingdao	81.22	Qingdao	80.58	Qingdao	78.53	Qingdao	80.23	Qingdao	83.86
2	Jinan	80.46	Jinan	78.86	Jinan	77.74	Jinan	79.49	Jinan	82.85
3	Weihai	78.59	Yantai	76.19	Weihai	74.59	Weihai	78.07	Weihai	79.37
4	Yantai	78.61	Weihai	75.88	Yantai	73.16	Linyi	75.79	Linyi	77.46
5	Weifang	75.29	Zibo	73.29	Linyi	71.84	Weifang	74.56	Yantai	76.88
6	Zibo	72.89	Weifang	72.46	Weifang	69.87	Yantai	73.79	Weifang	73.29

Table 9. City Vitality International Index

Rank	2018		2019		2020		2021		2022	
	Urban	Index	Urban	Index	Urban	Index	Urban	Index	Urban	Index
1	Qingdao	79.75	Qingdao	80.89	Qingdao	79.67	Qingdao	81.46	Qingdao	80.22
2	Yantai	77.61	Yantai	78.28	Yantai	76.59	Yantai	78.59	Yantai	77.29
3	Weifang	76.39	Weifang	76.67	Weifang	73.47	Weifang	77.63	Weifang	76.34
4	Weihai	76.01	Weihai	75.49	Weihai	72.19	Linyi	74.91	Weihai	74.57
5	Jinan	75.58	Linyi	72.38	Linyi	70.73	Weihai	74.15	Jinan	72.89
6	Linyi	73.72	Jinan	71.09	Jinan	69.59	Jinan	72.28	Linyi	70.49

5 SUGGESTIONS FOR FURTHER IMPROVEMENT OF URBAN VITALITY IN SHANDONG PROVINCE

1.Shandong Province also needs to vigorously promote innovation investment and industrial upgrading. Industrial upgrading inevitably depends on innovation, innovation output has a time lag, but without a certain amount of innovation input, it is difficult to have a qualitative breakthrough in economic and social development. Innovation investment must be precise and reasonable to avoid blindness and monopoly.

2.Shandong also needs to vigorously introduce high-level talents. Most of the talents working in Shandong come from the neighboring provinces of Shandong, which should strengthen the promotion of the city's charm and vigorously attract talents from all over the country and the world.

3.The development of Shandong's three major metropolitan areas still needs to be more coordinated. Qingdao as the core of the Jiaodong metropolitan area is more balanced in all aspects of development, compared with the provincial Jinan metropolitan area, Lunan metropolitan area, the advantages are more prominent.

4.Make full use of the Internet and big data. Big data has the first-mover advantage in information acquisition and distribution, so we should continue to upgrade the city network APP, and use the artificial intelligence "algorithm + recommendation" information distribution mode to understand people's personal preferences, interests and value needs, enhance the effectiveness of information utilization and dissemination, promote the free flow and reasonable allocation of information resources, and enhance the soft power of the city. To enhance the soft power and competitiveness of the city[9].

5.Shandong also needs to vigorously develop transportation. It should be interconnected not only with the city center, but also with other surrounding cities and urban areas, so that it can take full advantage of its own location.

6.High-speed development areas should focus on sustainable development. Heze, Linyi and other regions vitality progress is greater, but we should pay attention to the rapid economic development at the same time focus on sustainable and stable development, to pay attention to industrial upgrading, but also to protect the people's well-being vitality[10].

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