Spatial Evolution and Influencing Factors of Urban Innovation Ability using the Improved TOPSIS and Obstacle Degree Model

Bo Tang, Hao Luo
e-mail:tballen196@163.com, e-mail: 747106919@qq.com

Department of Resources and the Urban Planning Guangzhou Xinhua University, Guangzhou, China,

Abstract—Technological innovation and progress is the fundamental driving force to achieve high-quality development. Using the entropy weight method, improved TOPSIS Model, and obstacle degree model, this paper explored the spatial pattern evolution and obstacle factors of Foshan's innovation ability. The results showed that: (1) In the dimension of innovation, Sanshui District had good primary conditions for innovation. The proportion of innovation input rose; Nanhai District and Shunde District had certain advantages in innovation input and output. (2) In terms of spatial distribution, the innovation ability decreased from south to north, and the East was higher than the West; the innovation ability level of Shunde District was the highest, and Gaoming District was the cold zone of innovation activities. (3) The obstacle degree of innovation environment was the biggest, the critical dimension affecting Foshan's innovation ability, but it was generally on the decline; the obstacle degree of innovation output rose.

Keywords—High-quality development; Innovation ability; Improved TOPSIS Model; Obstacle factors; Foshan City

1 INTRODUCTION

During the 14th Five-Year Plan period, China has put forward new development [1]. The core of the new development concept is high-quality development. High-quality products put forward specific requirements for optimizing China's economic structure, the transformation of new and old kinetic energy, the coordinated development of society, people's living standards, and green ecological civilization [2]. However, there are still many dilemmas in regional coordination, urban and rural construction, innovation management [3]. With the increasing demand for industrial upgrading, technological innovation has become a hot topic in research and attention. Innovation-driven and technological breakthroughs are the vital cornerstone of high-quality development. In recent years, the construction of the pilot project of innovative cities has made remarkable achievements, but it is still in the primary stage [4]. At present, most of the research on innovation ability uses the comprehensive index system and spatial analysis tools, focusing on different scale spatial pattern evaluation, such as the national, metropolitan area, city, etc. Ni [5] studied the spatial differentiation law of urban

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innovation ability in the Jinan Metropolitan area through four dimensions: input capacity, output capacity, structure, and environmental support; Deng [6] introduced a degree model to evaluate the differentiation innovation ability of Changchun Metropolitan area. Some scholars also explain the difference between the driving factors of innovation output ability and regional innovation capability from regional innovation capability efficiency [7-8].

Foshan is a member of Guangdong-Hong Kong-Macao Great Bay Area; it is also the only pilot city of comprehensive reform in transforming and upgrading the manufacturing industry in China. Firstly, this paper constructed an evaluation system of Foshan's innovation ability from four dimensions of innovation conditions, innovation input, innovation output, and innovation environment. Then, the TOPSIS model based on entropy information was used for a comprehensive evaluation and spatial evolution. Finally, the obstacle degree model analyzed the influencing factors of innovation capability in Foshan in different years.

2 STUDY AREA AND DATA SOURCES

2.1 Study Area

Foshan City is located in the West Bank of Guangdong- Hong Kong- Macao Greater Bay Area, one of the four development engines of the Bay Area in the East (Fig 1). Relying on the advantageous geographical location of Foshan City, many industrial products are sold to the international market every year, but most of these industries are primary manufacturing industries, which are at the bottom of the industrial chain and have low economic benefits.

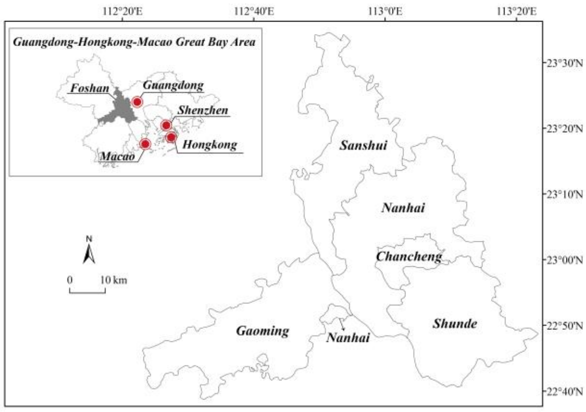

Fig 1. Location of the study area

2.2 Data Sources

The research data are collected through the 2014, 2017, and 2020 Foshan statistical yearbook, statistical yearbook of each district, and national economic and social development bulletin; the road network data is derived from the open street map (OSM). In the innovation environment, the information of Foshan high-tech enterprises is inquired and screened by the official website of enterprise investigation. The scientific research institutions and universities, incubators, and mass creation spaces are obtained through the inquiry of open information platforms of Foshan Science and Technology Bureau and other governments.

3 METHODS

3.1Index System

Under the guidance of "green, coordinated and open" development, it draws on the theories of industrial spatial agglomeration, industrial location, scientific and technological innovation, and competitive advantage; Combined with the current situation of Foshan, the index system is constructed from four dimensions: primary conditions, innovation input, innovation output, and innovation environment. The specific framework is shown in Figure 2.

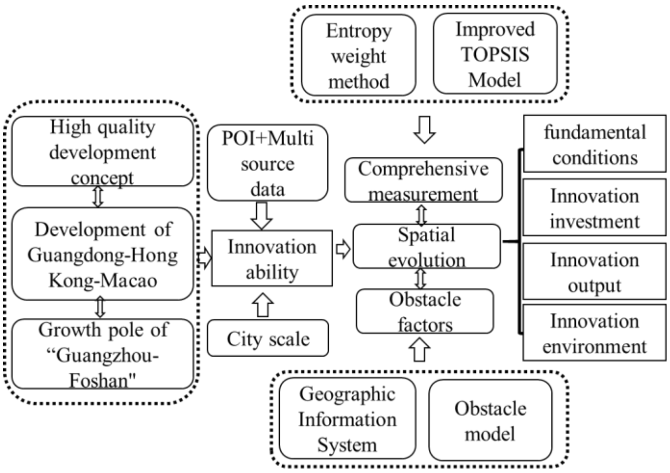

Fig 2 Theoretical Framework

①the four indicators of primary conditions respectively reflect the development level of economic level, investment environment, air environment, and traffic convenience, which are the primary conditions of regional innovation activities. ②in terms of innovation input, the relative indicators of R & D institutions' expenditure and employment personnel and the proportion of financial spending on science and technology are selected to reflect the investment situation and the importance of Foshan to innovation activities. ③in terms of innovation output, Arne considered that holding many patent authorizations and intensive, innovative enterprises are the essential characteristics of creative cities and the active degree of innovation research, so these two will be used as the important indicators of this research evaluation. It considers the proportion of the output value of high-tech products such as precision instruments in the industrial output value and the number of patent applications and the number of effective patents, reflecting the efficiency or effectiveness of innovation output. ④the innovation environment includes high-level researchers, high-tech enterprises, science and education institutions, and universities, and considers the number of innovation places such as incubators and maker space. In addition to the innovation subject, innovation space, and innovation activities, a complete innovation system should also include relevant infrastructure. Therefore, the number of beds owned by 10000 people, the number of primary and secondary school facilities, and the green area coverage of the built-up area are selected to reflect the infrastructure allocation level.

3.2 TOPSIS Model

TOPSIS model is a method of approaching an ideal solution, a standard technology of multi-objective decision-making in system engineering [9]. As the traditional TOPSIS Model equalizes the weight of all indicators, the improved TOPSIS model is adopted. After obtaining the positive and negative ideal solutions, the core idea is to calculate the weighted Euclidean distance between the study area and the positive and negative perfect solutions and calculate, rank, and evaluate the closeness degree. Based on the entropy weight method, the improved TOPSIS model is used to calculate the Euclidean distance between the positive and negative ideal solutions of each administrative region in Foshan. The model is used to test the rationality of the weight of each index and rank the innovation ability of each administrative area. The steps are as follow:

①Weighted matrix R:

$$R = (r_{ij})_{m\times n},\ r_{ij} = \omega_j \cdot r'_{ij}\ (i = 1,2,\cdots,m;\ j = 1,2,\cdots,n) \tag{1}$$

②Positive ideal solution y_j^+ and negative perfect solution y_j^-:

$$y_j^+ = \max(r_{1j}, r_{2j}, \cdots, r_{ij}),\ y_j^- = \min(r_{1j}, r_{2j}, \cdots, r_{ij}) \tag{2}$$

③Euclidean distance between positive and negative perfect solutions:

$$\mathrm{sep_i}^+ = \sqrt{\sum_{j=1}^{n}\left(r_{ij} - y_j^+\right)^2},\ \mathrm{sep_i}^- = \sqrt{\sum_{j=1}^{n}\left(r_{ij} - y_j^-\right)^2} \tag{3}$$

④Relative fit index C_i:

$$C_\mathrm{i} = sep_i^- / \left(sep_i^+ + sep_i^-\right) \tag{4}$$

The closer C_i is to 1, the higher the innovation ability of the object. According to the C_i value from high to low, this paper can get the innovation ability ranking of the five administrative regions of Foshan.

3.3 Obstacle Degree Model

Through the model, the obstacle coefficient of each factor to the improvement of innovation ability is calculated, and the main obstacle factors of each administrative region can be diagnosed, which provides the demonstration basis for the comprehensive analysis of innovation ability in different years. The specific formula is as follows:

$$E_j = R_j \cdot \omega_j, I_j = 1 - X_j \tag{5}$$

Where R_i is the weight of the j index in the criterion layer and X_j is the standardized value of the indicator layer. Then calculate the obstacle degree O_j of the j index to innovation ability:

$$O_j = \frac{I_j \cdot E_j}{\sum_{j=1}^{n} \left(E_j \cdot I_j\right)} \cdot 100\% \tag{6}$$

After the barrier coefficient of each factor in the index layer is obtained, the barrier degree of each classification index in the criterion layer to the innovation ability is calculated:

$$U_i = \sum O_{ij} \tag{7}$$

Where O_{ij} is the obstacle degree of every single index.

4 RESULT ANALYSIS

4.1Innovation Capability Dimension

The results of calculating the relative fit degree of the four criterion layer factors are shown in Table 1.

Tab 1 Ci of four dimensions of innovation ability in Foshan City

Criterion layer	Year	Chancheng district	Nanhai district	Shunde district	Sanshui district	Gaoming district
Fundamental conditions	2013	0.538	0.298	0.379	0.625	0.574
	2016	0.524	0.298	0.380	0.555	0.614
	2019	0.399	0.212	0.261	0.717	0.509
Innovation investment	2013	0.243	0.701	1	0.136	0.072
	2016	0	0.339	0.676	0.604	0.249
	2019	0.276	0.504	0.519	0.542	0.192
Innovation output	2013	0.221	0.450	0.676	0.177	0.089
	2016	0.166	0.332	0.717	0.153	0.100
	2019	0.220	0.227	0.780	0.156	0.075
Innovation environment	2013	0.576	0.450	0.580	0.137	0.014
	2016	0.538	0.416	0.594	0.097	0
	2019	0.466	0.406	0.619	0.120	0

On the whole, the differences of each factor in each area in the same year were noticeable. In terms of primary conditions, the overall fluctuation degree of each district in Foshan City was small. In contrast, the immediate needs of the Nanhai District were at a lower level. The innovation investment of Foshan had changed dramatically in each district; the highland had gradually transferred from Shunde District and Nanhai District to Sanshui District. Chancheng District and Nanhai District were the lowest in 2016; on the contrary, Sanshui District and

Gaoming District reached the highest in 2016. Shunde District showed a declining trend, and Sanshui District had the most noticeable growth in innovation investment. The change range of innovation output was relatively small compared with innovation input, and its C_i value was also relatively low. Shunde District was the stable innovation output center of Foshan, C_i was rising steadily, and the innovation efficiency was high; The output capacity of the Sanshui district was at a low level in the city, C_i was about 0.15, and the innovation efficiency was low. The C_i value of Nanhai District presented a slow downward trend, and Gaoming District was located at the end of the innovation output of Foshan. The change trends in the innovation environment are different in time. Chancheng District, Nanhai District, and Gaoming District showed a downward trend. The level of the innovation environment in Shunde District was constantly improving. In contrast, the story of the innovation environment in Sanshui District showed a fluctuating trend of first declining and then rising.

4.2 Spatiotemporal Evolution Of Innovation Capability

Referring to the relevant literature, according to the C_i value, Foshan City's innovation ability is divided into three grades: general ($0 \le C_i < 0.3$), good ($0.3 \le C_i < 0.5$), and excellent ($0.5 \le C_i \le 1$). As shown in Fig 3, the innovation capacity of Foshan City generally weakened from south to north, and the innovation capacity in the East was higher than that in the West. Shunde District had been an excellent innovation area in Foshan City, Nanhai District and Chancheng District had been good grades, while Sanshui District had changed from "average" to "good," and Gaoming District had always been in the "cold zone" of innovation activities.

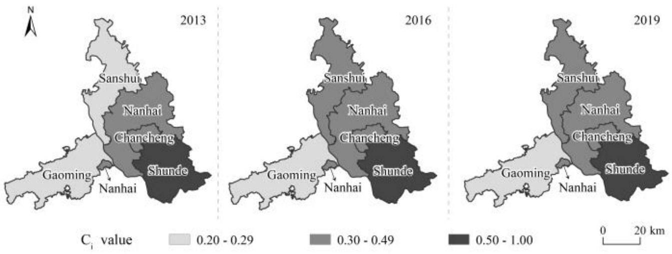

Fig 3 Spatial differentiation of innovation capability in Foshan City

4.3 Obstacle Analysis

Based on the difference in the spatial pattern of innovation ability, the obstacle degree of each dimension and index level factor to innovation ability was calculated. As shown in Table 2, there are differences in the obstacle degree and sizes for each district. The obstacle degree of primary conditions and innovation investment first decreased and then increased. The innovation output at first increased and then fell, while the innovation environment continued to decline. Although the obstacle degree of innovation environment dropped, it was the biggest of the four dimensions, the critical factor affecting Foshan's innovation ability.

Tab 2 Obstacle degree Ui of four innovation ability dimensions (%)

Criterion layer	Year	Chancheng district	Nanhai district	Shunde district	Sanshui district	Gaoming district
Fundamental conditions	2013	9.627	17.078	20.260	3.447	3.931
	2016	7.680	13.322	18.304	5.349	3.340
	2019	13.075	19.749	28.088	3.642	7.422
Innovation investment	2013	15.495	5.999	-0.003	11.249	11.058
	2016	14.742	11.016	6.761	3.359	7.365
	2019	12.046	7.959	9.891	5.984	8.530
Innovation output	2013	20.893	14.652	10.644	15.028	14.196
	2016	34.540	27.844	15.119	25.742	24.319
	2019	26.877	26.886	9.104	23.103	20.889
Innovation environment	2013	53.985	62.271	69.099	70.277	70.816
	2016	43.038	47.818	59.816	65.550	64.976
	2019	48.002	45.406	52.917	67.270	63.159

5 CONCLUSIONS AND DISCUSSION

5.1 Conclusions

(1) From the four dimensions of the innovation ability of each district, Sanshui District and Gaoming District have better primary conditions, and the innovation environment plays an increasingly important role in improving innovation ability. Nanhai District and Shunde District are the highlands of innovation investment. After 2019, Sanshui District becomes the area with the most innovative investment in Foshan. Sanshui District has good primary conditions for innovation, with more input but less innovation output, and its input-output is relatively low. Gaoming District belongs to the area with better primary conditions, insufficient investment in innovation, and a low level of innovation environment. Chancheng District has an advantage in the innovation environment, but its benefit in input and output is not apparent.

(2) The spatial distribution of Foshan's innovation ability decreases from south to north, and the eastern part is higher than the western part. In the later stage, due to the increase of financial investment in innovation, Sanshui District's innovation ability improved significantly faster than other regions of Foshan City, and its relative fitness degree ranked higher than that of Chancheng District. Shunde District has always been the innovation center of Foshan City, occupying a significant advantage in innovation input, output, and innovation environment. At the same time, Gaoming District is the cold spot of innovation activities in Foshan City, and the relative fit degree of relevant input and output is low.

(3) The obstacle degree of innovation environment is patent, which is the critical factor affecting Foshan's innovation ability, but it shows a downward trend. The obstacle degree of innovation output first increases and decreases, and the increase is more significant than the decrease, which becomes the second obstacle dimension of innovation development in Foshan. The barriers of primary conditions and innovation investment are at a low level.

5.2 Discussion

Foshan City is an essential member of Guangdong-Hong Kong-Macao Greater Bay Area. Its development orientation is an advanced manufacturing center, and it is a pilot center for the transformation and upgrading of the manufacturing industry. The innovation environment had been the biggest obstacle to Foshan's innovation ability. Foshan's current innovation environment is still at a low level, lack of innovative talents, imperfect infrastructure allocation level, cannot meet the needs of innovation and development. To achieve the relative balance between supply and demand of high-quality products, it is necessary to increase social infrastructure and capital investment to create an efficient and convenient living and working environment. At the same time, according to the actual demand of each district in Foshan, regional facilities should be built appropriately to share facilities with other cities in Guangdong-Hong Kong-Macao Greater Bay Area to avoid waste of infrastructure resources.

The transformation of Foshan's manufacturing industry and upgrading the high-tech sector are the main breakthrough points affecting its high-quality economic development. At the same time, the talent shortage is the most significant obstacle factor of Foshan's innovation ability. In the future, Foshan can encourage enterprises and researchers to innovate independently, constantly improve the protection policies for intellectual property rights and achievements, create a good innovation environment, and actively establish a talent exchange mechanism, to maximize the spillover effect of knowledge through learning and exchange among high-end talents. Enhance R & D capability, improve the conversion rate of science and technology, realize the integration of scientific research and industry, comprehensively deepen the cooperation between industry, university, and research, form its unique industrial structure, and solve the problem of homogeneity of industrial design.

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REFERENCES

[1] Y J, Shi. (2020) High-quality development: the core of the new development concept—the government responsibility of fostering opportunity and breaking new ground while identifying, responding to, and seeking changes, Frontiers,(22):28-33.

[2] BP.Ren, Y M.Li.(2018) On the construction of Chinese high-quality development evaluation system and the path of its transformation in the new era, Journal of Shaanxi Normal University (Philosophy and Social Sciences Edition), (47):105-113.

[3] W.Wang, BP.Ren. (2015)The stage characteristics of the quantity and quality of economic growth in China: from 1978 to 2014, Reform, (8):48-58.

[4] CL.Fang. (2013)The construction status quo evaluation and bottleneck analysis of Chinese innovative cities， Urban Development Studies, 20（5）90-97.

[5] YT.Ni, YB.C.(2019)Spatial Differentiation of Urban Innovation Capability in Jinan Metropolitan Circle Based on Improved TOPSIS Method, Areal Research and Development, 38(6):63-67.
[6] YW.Deng， T.H, JJ.H, et al.(2020)Research on the Spatial Differentiation of Urban Innovation Capability in Changchun Metropolitan Area, Planners,(36):69-74.
[7] CY.Wang, C.Zhang.(2014)Spatial-temporal Pattern of Prefecture-level Innovation Outputs in China: An Investigation Using the ESDA, Scientia Geographica Sinica,(34): 1438-1444.
[8] JF.He, HO, Zhang, YY.Ye, et al. (2013) Research on Spatial Autocorrelation of Innovation Output in Guangdong Province Economic Geography (2):117-121.
[9] C.Li,FR.Zhang, TF.Zhu, et al. (2013) Evaluation and correlation analysis of land use performance based on entropy-weight TOPSIS method, Transactions of the Chinese Society of Agricultural Engineering,(29): 217-227.