

# Study on the Regional Innovation Network of Pearl River Delta City Cluster and Its Factor Analysis

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## ABSTRACT

The Pearl River Delta (PRD) city cluster is a national key development area with favorable geographical conditions, and the construction of a regional innovation network will help enhance the economic vitality of the region and the corresponding comprehensive competitiveness, and the PRD city cluster is accelerating the construction of an international science and technology innovation center with global influence. The purpose of this paper is to study the innovation network of the PRD city cluster and to explore the key factors of the regional innovation network using factor analysis. The study proposes the main components of the regional innovation network of the Pearl River Delta city cluster, analyzes them by factor analysis, and finally puts forward suggestions or recommendations.

## KEYWORDS

Pearl River Delta city cluster; Regional innovation network; City cluster; Factor analysis.

## 1. INTRODUCTION

As the trend of economic globalization strengthens in the world, the comprehensive competitiveness of a country often depends on the level of development of urban agglomerations, and innovation is an important source of power to promote the high-quality development of regional economy and enhance the comprehensive strength of the country. The 20th Party Congress proposed that "innovation is the first driving force" and "innovation is the core position in the overall modernization of China". Only by insisting that innovation is the first driving force can China realize high-quality development. Since the 18th CPC National Congress, the investment in science and technology has been unprecedented. The whole society's investment in R & D from 1.03 trillion yuan in 2012 to 2.79 trillion yuan in 2021, based on basic and fundamental research funding increased to 3.4 times that of a decade ago, enterprise science and technology accounted for the proportion of the whole society's investment in R & D reached more than 76%. This is the decade in which China's scientific and technological progress has been the greatest and its scientific and technological strength has been the fastest.

The Pearl River Delta (PRD) city cluster, with its backdrop of the motherland and its proximity to Hong Kong and Macao, is a unique environment for regional innovation and development. In March 2017, in order to give full play to the unique advantages of Hong Kong and Macao, the Party Central Committee and the State Council proposed to study and designate the "Guangdong-Hong Kong-Macao Greater Bay Area City Cluster Development Plan", which is of great strategic significance in promoting China's economic growth and enhancing international competitiveness. In April 2019, the "Outline of the Development Plan for Guangdong-Hong Kong-Macao Greater Bay Area" was In April 2019, the Outline of the Plan for the Development of the Guangdong-Hong Kong-Macao

Greater Bay Area has been launched and implemented, and the cities are gradually forming a trend of fierce competition within the Bay Area. 2022 Guangdong-Hong Kong-Macao Greater Bay Area Collaborative Innovation Development Report focuses on four major patent indexes, namely invention patents, PCT patents, patents of the same family, and the citation frequency of patents, and analyzes the advantageous layouts of innovation institutions and industries, so as to demonstrate the comprehensive innovation capacity, advantages and shortcomings of Guangdong-Hong Kong-Macao Greater Bay Area, and to help the world-class cities to develop their own innovation capabilities and to improve the competitiveness of their economies. This will demonstrate the comprehensive innovation capacity, strengths and weaknesses of the Greater Bay Area and help build a world-class Bay Area. Therefore, we will analyze the regional innovation network of nine cities in the Pearl River Delta city cluster in depth, and use SPSSPRO to conduct factor analysis to find out the innovation advantages of each city's regional development.

## **2. BACKGROUND AND SIGNIFICANCE OF THE RESEARCH**

### **2.1. Research background**

In the context of knowledge economy, global informatization is further developed, regional division of labor is further promoted, and the collaboration between regional cities can become a key move to synergize regional development and transform the growth momentum by integrating the innovation resources within the region and building a regional innovation network. Meanwhile, regional innovation is an important engine of social and economic development, and the construction of regional innovation network will help to enhance the economic vitality of the region and the corresponding comprehensive competitiveness. At this stage, the development of China's regional innovation network has achieved excellent results, such as in the Pearl River Delta (PRD) city cluster, where the region is building an open regional collaborative innovation community, jointly expanding the new space for the development of Hong Kong and Macao, amplifying the leading role of Guangzhou and Shenzhen, "Guangzhou-Shenzhen-Hong Kong" "Guangzhou-Zhuhai-Macao" science and technology innovation corridor has become a key initiative to transform the growth momentum. The "Guangzhou-Shenzhen-HongKong" and "Guangzhou-Zhuhai-Macao" science and technology innovation corridors have become "innovation corridors". The PRD city cluster is accelerating the construction of an international science and technology innovation center with global influence, building the main engine of the development of modern industrial system with science and technology innovation, forming a strategic pivot for the construction of an innovative country and a source of power for high-quality development. During the "13th Five-Year Plan" period, high-tech industries in Shenzhen National Innovation Demonstration Zone have realized leapfrog development, with the value added of the industries increasing from 584.8 billion in 2015 to 974.7 billion in 2020, and the number of Shenzhen's PCT international patent applications in 2020 will be 20,200 pieces. At the same time, the current regional innovation network has also appeared different from the previous new problems, mainly reflected in the following points:

The number of output results and scientific and technological frontiers of the regional innovation network of the Pearl River Delta city cluster are insufficient, in which the suspension of synergistic partnership and the reduction of R&D funding are the two main reasons for the impact on the development of the regional innovation network.

There is a lack of forward-looking top-level institutional design and related planning for the construction of regional innovation systems in the PRD city cluster, and there is a lack of policy support and policy leadership for the construction of cross-regional innovation networks in the region.

The PRD regional innovation infrastructure needs to be further improved. Innovation infrastructure refers to the infrastructure with public welfare attributes that support scientific research, technological development and product development, and can provide convenient conditions for innovation

activities, such as major scientific and technological infrastructure, science and education infrastructure, industrial technology innovation infrastructure, large-scale laboratories, etc., which are generally invested and guided by the government, and the public nature of the innovation infrastructure is its intrinsic attribute, and the results of the construction of the infrastructure belong to the public property, so the innovation infrastructure is a place where relevant innovation activities can be organized. Therefore, innovation infrastructure is an important guarantee and material foundation for related innovation activities.

## **2.2. Research significance**

### **2.2.1. Theoretical significance**

In recent years, domestic and foreign scholars' research on regional collaborative innovation network mainly focuses on the following three aspects: collaborative innovation main body and collaborative innovation elements, the research found that the cooperation of innovation main body in small-scale urban agglomerations makes the inter-city relationship closer, and this close inter-city relationship can replace the original loose economic agglomeration; exploring the model paradigm of collaborative innovation, including the "center" model, "periphery" model, "dual-core" model, etc.; using measurement methods, constructing innovation network evaluation system, measuring the level of network collaborative innovation and innovation performance. - Explore the model paradigm of collaborative innovation, including the "center" model and the "dual-core" model, etc.; use the measurement method to construct the evaluation system of innovation network, and measure and evaluate the level of collaborative innovation and innovation performance of the network.

The theoretical and practical research on regional collaborative innovation network is still in the exploratory period, and a considerable part of it is carried out on the basis of industry-university-research, and there are fewer researches on regional collaborative innovation network as a complex ecosystem under the perspective of flow space. Therefore, revealing the system structure and operation characteristics of the complex, multi-level and dynamic collaborative innovation network can provide powerful theoretical support and decision-making basis for the benign development of collaborative innovation network.

### **2.2.2. Practical significance**

Functionally, as the innovation activities of the PRD city cluster are characterized by high-level and multi-directional cooperation and interaction among government, industry, academia and finance, the regional innovation network has a more reasonable allocation of innovation resources, a concentration of innovation factors, the formation of synergies, a perfect innovation system and innovation infrastructure, and the formation of high-efficiency allocation of innovation resources. In terms of development mode, the construction of the innovation system in the PRD city cluster will show the development direction of multi-level development and regional coordination. At the regional level, promoting the construction of a regional innovation network will lead to the construction of a regional national science and technology center and promote the overall development of the PRD city cluster. In terms of the spatial distribution of innovation resources, emphasis will be placed on regional coordination, the construction of a regional innovation network that matches the positioning of the PRD, and the exploration of an innovation system that meets the characteristics of the PRD region.

## **3. RESEARCH DYNAMICS AND TRENDS IN THE RESEARCH FIELD OF THIS SELECTED TOPIC AT HOME AND ABROAD**

### **3.1. Current situation and trend of research on regional innovation network**

Innovation is the key factor of regional economic growth, and active innovation links are the engine power of social and economic development, while cities are the main spatial carriers of innovation,

and innovation among cities is the important basis for the improvement of urban innovation function. That is to say, the current innovation behavior itself contains the characteristics of network, and the innovation network is the important result of this behavior process (Long Linli, 2022). The concept of "innovation network" was put forward by Friedmann, a British economist, "the networked expression of the systematic innovation process", i.e., the innovation network of urban agglomerations can be regarded as the extension of "organization" in the field of innovation. This means that the innovation network of urban agglomeration can be regarded as the extension of "organization" in the field of innovation. Subsequently, the study of cyberspace based on innovation knowledge flow has become a hot spot of regional research. The formation of regional innovation network space is mainly based on two reasons: one is that innovation, as a factor of economic production, ultimately aims to promote sustainable economic development (Omri, 2020; Sun Wei, 2020); the second is that innovation is an important way to achieve regional high-quality development, and regional cities have formed a more closely integrated network pattern through the sharing of innovation resources (Bi Pengxiang, 2022).

In the era of knowledge economy, innovation has become an important source of power for the high-quality development of a country or region. Countries all over the world take innovation as the propeller of future development, and realize faster development through cooperative innovation, and generally form various forms of cooperation and innovation, such as industry-university-research cooperation, technology alliance, and cooperation in science and technology parks, etc. In the past, most of the innovation cooperation took place within the city, and with the development of transportation, computer science and technology, the traditional "site space" has been changed to "flow space" (Sun Zhongrui, 2022). With the development of transportation and computer science and technology, the traditional "space of site" has changed to "space of flow" (Sun Zhongrui, 2022). The construction of innovation network can help to improve the competitiveness of the region. Cities are not only important agglomerations in space, but also nodes of expanding flow space and complex networks (Zhou Chan, 2017); city clusters, as an important form of regional organization composed of multiple spatially adjacent cities, have the characteristics of integrating regional resources and exerting the advantages of the region as a whole, and therefore, we need to promote the innovation research capacity and innovation cooperation of city clusters (Wei Lihua, 2018; Fang Chuanglin, 2017). 2017).

### **3.2. Research area of regional innovation network**

From the perspective of research area, innovation network research was firstly carried out in enterprises and specific industries, enterprises are the core part of regional innovation system, and the continuous development of industrial clusters provides a favorable environment for enterprise innovation, which forms an interactive relationship with regional innovation, so that the object of innovation network research has gradually transitioned to cities, urban agglomerations, regions and global innovation networks. For enterprise and industry research mostly focuses on high-tech field, Qiliangqun and other scholars (2020) found that in the process of knowledge sharing among the members of innovation network of advanced manufacturing enterprises, there exists an optimal interval for the distribution of benefits among advanced manufacturing enterprises, productive service organizations, and users, which can guarantee the benefits of knowledge sharing and at the same time, maximize the willingness of the main bodies to carry out knowledge sharing. For city clusters, Hu Yue (2020) found that inter-city innovation links have been significantly strengthened. For global innovation networks, the role of clusters as "intermediaries" is more important in mitigating network failures or "systemic failures" among SMEs and between SMEs and non-firm actors, through mechanisms such as R&D alliances and manufacturing expansion programs. It is necessary to include local SMEs, experts and universities from different geographical areas (Mancini, 2021).

### **3.3. Content of research on regional innovation networks**

From the perspective of research content, in recent years, scholars have been expanding the connotation of innovation network. The concept of regional innovation network has not formed an authoritative definition so far, Martin (2016) believes that industrial clusters surrounded by innovation support organizations are regional innovation networks, while Li (2015) scholars have put more emphasis on the role of institutions in the regional innovation network, such as laws, rules, and established practice practices, which regulate different roles in the network through the institutions. Tsai et al. (2016) study supports Li's (2016) study. (2016) support Li's view that the success or failure of new regional innovation networks depends on the regional environment, such as software planning and support, as well as the management of innovation-related policy implementation. In addition, some scholars are devoted to analyzing the composition and mechanism of regional innovation networks. Three scholars, Zhu Hao, Lu Chengzhi and Liu Wang (2016), believe that the regional innovation network is a system of index innovation, industry transfer and knowledge utilization composed of universities, enterprises and government, and the core of regional innovation is enterprise clusters, while universities provide knowledge services and connect external resources for regional innovation. The study of two scholars, Jin Qiaohua and Yan Taihua (2017), found that the government's strengthening of intellectual property rights protection will enhance independent R&D capability and then enhance regional innovation capability.

### **3.4. Research Methods of Regional Innovation Network**

In terms of research methods, the traditional methods of scholars on regional innovation network are mostly based on static yearbook data, constructing regional innovation capacity index system from innovation environment, innovation capital, innovation efficiency, etc., and exploring the spatial pattern of innovation of urban system by combining with the innovation gravity model or system dynamics model (You Daming, 2015). The development of information technology makes the network data convenient and dynamic, and more and more scholars tend to use thesis cooperation data and patent joint application data to measure urban innovation, in order to directly reflect the innovation cooperation of related nodes in the network (Li Jiancheng, 2017). For example, two scholars, Xing Hua and Zhang Changming (2018), used patent cooperation data to study the evolutionary characteristics of the innovation network of the Beijing-Tianjin-Hebei city cluster, and two scholars, Sun Yu and Peng Shuyuan (2021), constructed a multivalued undirected network reflecting the cooperative and innovative relationship of cities based on the invention patent application data of 2018, and used cohesive subgroup analysis and multivalued ERGM to study the characteristics and development mechanism of cohesive subgroups in the innovation network of the Yangtze River Delta city cluster. The characteristics and development mechanism of cohesive subgroups in the innovation network of Yangtze River Delta city cluster are investigated using the cohesive subgroup analysis method and multi-valued ERGM.

### **3.5. Literature Review**

Through summarizing and combing the existing literature, scholars at home and abroad have achieved fruitful results on the spatial structure of urban agglomeration and regional innovation network. The research on regional innovation network of urban agglomerations. Generally, the research is carried out in three aspects: region, content and method. This paper analyzes and locates the regional innovation capacity of each city in the Pearl River Delta city cluster and the surrounding regional innovation environment.

## 4. RESEARCH ON REGIONAL INNOVATION CAPABILITY OF PEARL RIVER DELTA CITY CLUSTER BASED ON FACTOR ANALYSIS

### 4.1. Variable Selection and Data Selection

The Pearl River Delta (PRD) city cluster includes nine cities in Guangdong Province: Shenzhen, Guangzhou, Dongguan, Foshan, Zhaoqing, Zhongshan, Jiangmen, Huizhou and Zhuhai. With a total area of 55,368.7 square kilometers, the nine cities in the PRD gather 53.35% of the population and 79.67% of the total economy of the largest province in China. It is an important economic center of China and has a pivotal strategic position in the overall economic and social development and reform and development of the country.

The Pearl River Delta (PRD) City Cluster aims to become a global scientific and technological innovation highland and an important source of new industries. The PRD is undertaking national science and technology innovation strategies, building major science and innovation platforms, and promoting the deep integration of industrial chains and innovation chains.

In order to study the innovation competitiveness of the PRD cities in depth, it is necessary to construct an appropriate evaluation system. In the process of selecting indicators, the principles of simplicity, science and rationality are strictly adhered to, not only processing the data obtained from the indicators, but also selecting the dominant silver color from the indicators, reflecting the development of innovation in each city from multiple perspectives. For the nine cities using factor analysis, seven indicators were screened and the indicator system was constructed, as shown in Table 1.

The relevant data of 9 cities, including Guangzhou, Shenzhen, Dongguan, Foshan, Zhaoqing, Jiangmen, Zhongshan, Huizhou and Zhuhai, are selected, and the data are obtained from the Guangdong Provincial Statistical Yearbook in 2021.

Table 1 Composition of the indicator system

variables	designation	Indicator units
X1	Gross ProductR&D Activity Personnel	hundred million
X2	R&D Expenditures	people
X3	Expenditures for new product development	billion
X4	Sales revenue from new product development	billion
X5	Private Vehicle Ownership by Municipality	billion
X6	Passenger transportation volume by city	Vehicles
X7	Gross ProductR&D Activity Personnel	million yuan

The analytical method used in this paper is factor analysis, which is a multivariate statistical method that transforms complex variables into comprehensive variables based on the matrix correlation of the original data. Factor analysis focuses on the correlation variables between the original data. Based on the correlation matrix variables of the original data, the variables are categorized according to the degree of correlation. The common factor represents the basic structure of each variable. Problems can be effectively identified and solved based on such importance, providing targeted and effective policy recommendations for the future development of the PRD.

### 4.2. Empirical analysis

Firstly, KMO and Bartlett's test are carried out firstly to determine whether the factor analysis can be carried out. For the KMO value: 0.9 is very suitable for factor analysis, between 0.7-0.9 is suitable, between 0.6-0.7 is OK, between 0.5-0.6 indicates poor, 0.5 should be given up; through the KMO value test can indicate whether it is suitable to use factor analysis. Using KMO and Bartlett's test, the

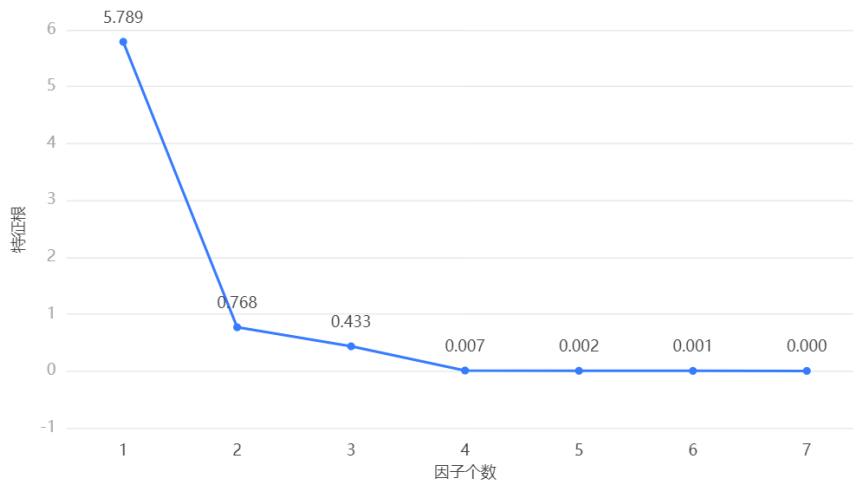
results show that the KMO data is 0.73, greater than 0.6, Bartlett's sphere test P-value is 0.01, less than 0.05, can be carried out factor analysis.

Secondly, the number of factors was determined by analyzing the variance explained table and the gravel plot. The variance explained table is mainly to see the contribution of the factors to the explanation of the variable (can be understood as how many factors are needed to express the variable as 100%), if it is too low (e.g., less than 60%), then the factor data need to be adjusted. The function of the gravel plot is to confirm the number of factors to be selected based on the slope of the eigenvalue decline, and the combination of these two can be used to confirm or adjust the number of factors.

**Table 2.** Explanation of variance table

Total Variance Interpretation						
element	Explanatory rate of variance before rotation			Post-rotation variance explained		
	Eigenroot	Explanation of variance (%)	Cumulative variance explained (%)	Eigenroot	Explanation of variance (%)	Cumulative variance explained (%)
1	5.789	82.701	82.701	435.879	62.268	62.268
2	0.768	10.967	93.668	219.8	31.4	93.668
3	0.433	6.187	99.855			
4	0.007	0.1	99.955			
5	0.002	0.028	99.984			
6	0.001	0.012	99.996			
7		0.004	100			

The above table shows the total variance explained table, mainly to see the contribution of the factor to the explanation of the variable, two factors can express the variable to 93.668 percent



**Fig. 1** Factor analysis gravel plot

The gravel plot is a plot based on the degree to which each principal component explains the variation in the data. Its function is to confirm the number of factor principal components to be selected according to the slope of the eigenvalue decline, combined with the variance interpretation table can be used to confirm or adjust the number of factor principal components, as can be seen from the figure, the fold line becomes flat after two factors.

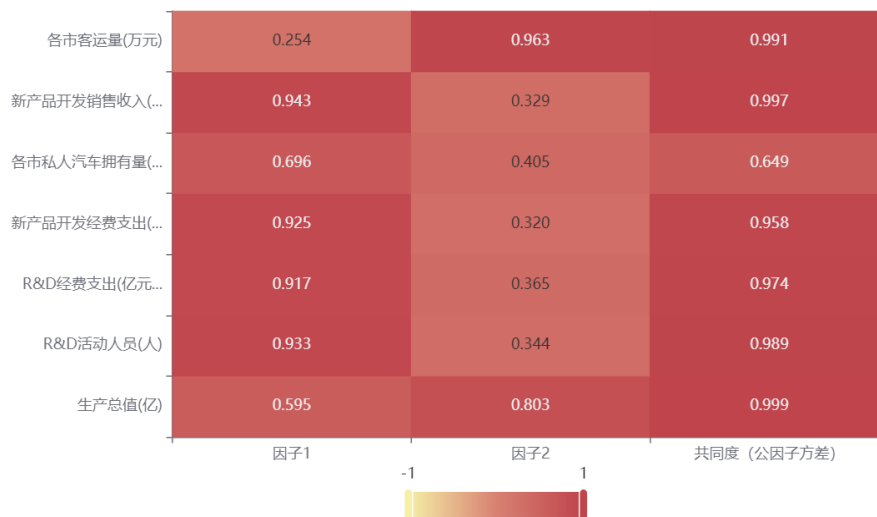
Third, by analyzing the factor loading coefficients and heat map, we can analyze the importance of hidden variables in each factor, such as the study of [polymetallic ore body] in the distribution of 25 kinds of useful elements in the distribution of the law, in which the elements are regarded as indicators,

assuming that the previous section to determine the five factors, factor 1, SO, SO<sub>2</sub>, Na<sub>2</sub>S, HS, H<sub>2</sub>S factor loading coefficients are larger, so we can determine the factor 1 for the sulfide components. By analogy, the hidden variable analysis of each factor can also be combined with the specific business. By analyzing the component matrix, the factor formula is derived.

**Table 3.** Table of factor loading coefficients

Table of factor loading coefficients after rotation			
	Post-rotation factor loading coefficients		Commonality (common factor variance)
	Factor 1	Factor 2	
GDP (billion)	0.595	0.803	0.999
R&D Activity Personnel (person)	0.933	0.344	0.989
Expenditure on R&D (billion yuan)	0.917	0.365	0.974
Expenditure on new product development (billion yuan)	0.925	0.32	0.958
Private Vehicle Ownership by Municipality (Units)	0.696	0.405	0.649
Sales revenue from new product development (billion yuan)	0.943	0.329	0.997
Passenger Transportation Volume by Municipality (million yuan)	0.254	0.963	0.991

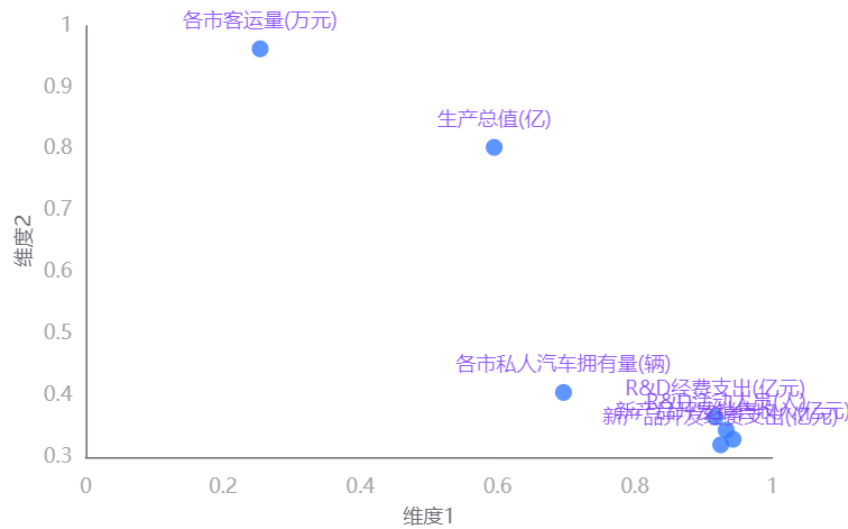
The table shows the factor loading coefficients, which can be analyzed to the importance of the hidden variables in each principal component.



**Fig. 2** Factor load matrix heat map

The above figure shows the heat map of loading matrix, which can be analyzed to the importance of hidden variables in each principal component. At the same time, the hidden variables of each factor can be analyzed with specific business.

Fourthly, based on the factor loading diagram, the spatial distribution of factors can be presented through the quadrant diagram by downscaling multiple factors into two or three factors. If 2 factors are extracted, the 3D loading factor scatter plot cannot be presented, and if 1 factor is extracted, the factor quadrant plot cannot be displayed.



**Fig. 3** Factor load quadrant analysis

Fifth, by analyzing the component matrix, the factor component formulas and weights are derived.

**Table 4.** Component matrix

ingredient matrix		
designation	element	
	Factor1	Factor2
GDP (billion)	-0.115	0.484
R&D Activity Personnel (person)	0.286	-0.138
Expenditure on R&D (billion yuan)	0.267	-0.109
Expenditure on new product development (billion yuan)	0.295	-0.158
Private Vehicle Ownership by Municipality (Units)	0.138	0.042
Sales revenue from new product development (billion yuan)	0.299	-0.158
Passenger Transportation Volume by Municipality (million yuan)	-0.365	0.814

The above table shows the component matrix, which is intended to illustrate the factor score coefficients (principal component loadings) contained in each component, which are used to calculate the component scores and derive the principal component formula. The assessment of regional innovation capacity can be derived from the above linear combination of 2 factors:

$$F1 = -0.115 \times \text{GDP (billion)} + 0.286 \times \text{R\&D activity personnel (person)} + 0.267 \times \text{R\&D expenditure (billion yuan)} + 0.295 \times \text{New product development expenditure (billion yuan)} + 0.138 \times \text{Private automobile ownership in each city (vehicle)} + 0.299 \times \text{Sales revenue from new product development (billion yuan)} - 0.365 \times \text{Passenger transportation in each city (million yuan)}$$

$$F2 = 0.484 \times \text{GDP (billion)} - 0.138 \times \text{R\&D activity (persons)} - 0.109 \times \text{R\&D expenditure (billion)} - 0.158 \times \text{new product development expenditure (billion)} + 0.042 \times \text{private car ownership in each city (units)} - 0.158 \times \text{new product development sales revenue (billion)} + 0.814 \times \text{passenger transportation in each city (million)}$$

It can be obtained from the above:

$$F = (0.623/0.937) \times F1 + (0.314/0.937) \times F2$$

Sixth, the output factor analysis method comprehensive score

**Table 5.** Factor analysis table

designation	Post-rotation variance explained (%)	Cumulative variance explained after rotation (%)	Weight (%)
Factor1	0.623	62.268	66.478
Factor2	0.314	93.668	33.522

The above table shows the principal component weight analysis of factor analysis based on the information of loading coefficients, which is calculated by the formula: variance explained rate/rotated cumulative variance explained rate. The result of weight calculation of factor analysis shows that the weight of factor 1 is 66.478% and the weight of factor 2 is 33.522%, in which the maximum value of indicator weight is factor 1 (66.478%) and the minimum value is factor 2 (33.522%).

**Table 6.** Composite Score Table

rankings		aggregate score	GDP (billions)	R&D activity staff (persons)	Expenditures on R&D (billions of dollars)	Expenditure on new product development (billion yuan)	Private car ownership by municipality (units)	Sales revenue from new product development (billions of dollars)	Passenger traffic by municipality (in millions of dollars)
1	Shenzhen	1.687	30664	420021	1259	2108	2936787	17146	4636
2	Dongguan	0.375	10855	182268	405	637	3205739	9121	899
3	Guangzhou	0.357	28231	138895	377	521	2528163	6100	6731
4	Foshan	0.091	12156	98476	298	421	2843759	5844	2000
5	Huizhou	-0.331	4977	71722	157	217	1370665	3235	889
6	Zhongshan	-0.49	3566	34895	75	136	1273155	1608	624
7	Jiangmen	-0.512	3601	38086	82	121	952961	1495	1360
8	Zhuhai	-0.525	3881	33891	84	167	732824	1726	1003
9	Zhaoqing	-0.652	2649	11296	26	50	631640	601	813

Factor analysis was used to calculate the scores of 9 cities, which were ranked according to their scores: Shenzhen, Dongguan, Guangzhou, Foshan, Huizhou, Zhongshan, Jiangmen, Zhuhai and Zhaoqing.

Shenzhen, as a national single-listed city, a mega city, a special economic zone approved by the State Council, a national economic center and a national innovative city, has a first-class innovation environment and has become an important engine of the international science and technology innovation center in the Guangdong-Hong Kong-Macao Greater Bay Area. Dongguan and Guangzhou, with their high degree of openness, abundant human resources, strong ability to absorb capital, and extensive industrial structure, are important supports for regional innovation capability. Foshan, with its high level of economic development, ranks 27th in the ranking of national innovative cities in terms of innovation capacity. Huizhou, Zhongshan, Jiangmen, Zhuhai, Zhaoqing and other cities are rich in resources and have more space for development. Shenzhen, Dongguan and Huizhou have basically formed a development pattern characterized by IT and high-tech industries, while Guangzhou, Foshan and Zhaoqing focus on the development of equipment manufacturing industry and Internet economy, and Zhuhai, Jiangmen and Zhongshan focus on the development of traditional manufacturing industry and culture and tourism economy.

## 5. RELATED RECOMMENDATIONS

First, the Pearl River Delta (PRD) ranks high in terms of area, population and airport passenger volume among the world's city clusters. The PRD region has a large population, favorable geographic location and strong comprehensive strength, and has a solid foundation for building a regional innovation highland, and it is the most active area in China in terms of regional innovation factors, with Guangzhou being a millennium-old business capital and Shenzhen being an emerging science and technology city that relies on the new economy for its development. Shenzhen and Guangzhou are the main engines of the Pearl River Delta (PRD). Shenzhen and Guangzhou should strengthen their radiation effects on neighboring cities, and the PRD's internal infrastructures should be connected to each other so as to reach the standard of a world-class metropolis. The most basic requirement for a world-class metropolis is convenient commuting between cities, a high commuting rate between cities, and uninterrupted links between cities to ensure the free flow of all kinds of factors, such as the flow of people, logistics, capital and innovation. In promoting the process of infrastructure connectivity, the region should strictly meet the requirements for building a world-class metropolitan cluster, so as to speed up the flow of all kinds of resources. The organic connection of high-speed rail, urban rail and subway transportation should be strengthened to build a commuter metropolitan area with rail transportation as the core. The construction of important highways and corridors in the PRD should be actively promoted and urban transportation links should be strengthened.

Secondly, attention should be paid to deepening industrial division of labor cooperation in the PRD city clusters on the basis of complementary advantages, establishing a number of regional technological innovation cooperation platforms, promoting the in-depth integration of industry, academia and research, and enhancing the efficiency of innovation. Based on the theory of the relationship between specialized production and the development of regional industries, it is necessary to make different industries or the same industry collaborate with each other in research and development, production, management and marketing, and to sum up the experience of the existing cooperation between industry, academia and research. On the basis of summarizing the existing experience of cooperation between industries, universities and research institutes, we should improve the mechanism of industrial division of labor and cooperation in cities to realize the benign cycle within the city cluster. In the stage of industrialization of scientific and technological achievements, we should make use of the advantages of developed manufacturing industries in Guangzhou, Dongguan, Zhuhai and other cities, so as to mass-produce scientific and technological innovations with market prospects, and thus effectively enhance the efficiency of innovations.

Thirdly, give full play to the leading role of large technology enterprises and Internet platform enterprises in regional science and technology innovation, enhance the independent innovation capability of small and medium-sized enterprises, and promote the synergistic innovation of small and medium-sized enterprises in the region. Large enterprises have obvious advantages in talent, capital, technology, brand and market, and are the main force to promote the technological change. Large enterprises have obvious advantages in talent, capital, technology, brand and market, and are the main force to promote technological change. To stimulate the vigor and enthusiasm of independent innovation of large enterprises. Enterprises should encourage employees to innovate independently, allowing employees to use a certain amount of time to put innovative ideas and programs into practice; the contribution of managers and key technical personnel to implement equity incentive mechanism to enhance the responsibility of researchers in research and development.

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