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Research on Evaluation of Dongguan Pharmaceutical Innovation Ability under the Background of Industrial Transformation and Upgrading Strategy

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Abstract: *In the context of the "Healthy China" initiative and the strategy of industrial transformation and upgrading, pharmaceutical innovation capability has emerged as an indispensable and crucial element for the development of the "Healthy China" strategy. This paper first comprehensively reviews theoretical perspectives on domestic and international pharmaceutical innovation capability research. Subsequently, it deeply analyzes the multiple factors influencing the pharmaceutical innovation capability in Dongguan. The study adopts the expert consultation method to establish evaluation criteria, utilizes the Analytic Hierarchy Process (AHP) to determine indicator weights and validate their rationality, and ultimately applies a fuzzy comprehensive evaluation model to process and analyze the data. The research results indicate that the constructed pharmaceutical innovation capability evaluation system exhibits significant advantages in terms of scientificity and practicality. The analysis of the comprehensive evaluation values reveals a positive development trend in Dongguan's pharmaceutical innovation capability, with the composite index continuously rising. However, it is still necessary to strengthen relevant policy support in order to promote the sustainable development of pharmaceutical innovation in Dongguan.*

Keywords: *Pharmaceutical Industry, Innovation Capability, Expert Consultation Method, Analytic Hierarchy Process, Fuzzy Comprehensive Evaluation Model*

1. Introduction

As society continues to evolve and undergo rapid transformations, health has emerged as a crucial indicator of national development. Within the pursuit of this indicator, the innovative capability within the pharmaceutical field plays an indispensable role. Underpinning the construction of a "Healthy China" and facilitating the transition and upgrade of industries, the enhancement of pharmaceutical innovation capability has become increasingly pivotal in realizing comprehensive health and modernization objectives.

Within the framework of the "Healthy China+" strategy, China's development has entered a new phase. This strategy demands not only the safeguarding of the people's right to health but also the elevation of overall medical standards, thereby creating higher-quality living conditions for the populace. Simultaneously, the transformation and upgrade of the industrial structure have been endowed with unprecedented significance to meet the new requirements of economic development. Against this backdrop, the pharmaceutical industry is entrusted with the mission of innovation, aiming to propel innovations in medical technology, drug research and development, and other related fields to address diverse medical demands.

Dongguan, as one of the pioneers of China's reform and opening-up, actively responds to national policies and continuously explores innovative paths within the pharmaceutical industry. The city of Dongguan is consistently exerting efforts to promote pharmaceutical innovation capability, striving to establish a pharmaceutical innovation system that caters to the demands of the new era. However, pharmaceutical innovation encompasses challenges not only within the realms of technology and industry but also extends to encompass policies, funding, talent, and various other dimensions of support. Therefore, a research evaluation of Dongguan's pharmaceutical innovation capability will contribute to a comprehensive understanding of the opportunities and challenges it faces within the context of "Healthy

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China+" and industrial upgrading. This evaluation will provide robust decision-making support for the development of pharmaceutical innovation within Dongguan.

2. Literature Review

Under the guidance of the "Healthy China" strategy, the significant achievements in the transformation and upgrade of the pharmaceutical industry have become apparent. As the pharmaceutical industry steadily develops its innovation capabilities, both domestic and international scholars have increasingly focused on research related to the current status of pharmaceutical manufacturing, pharmaceutical innovation capability, and influencing factors. Research outcomes regarding the assessment of innovation capability within the pharmaceutical sector at home and abroad are abundant. Based on previous scholars' research and in conjunction with the content of this paper, the following summarizes the general state of domestic and international research:

The indicator system for evaluating pharmaceutical innovation capability in foreign countries has become increasingly refined. Early research emphasized single indicators, such as patent quantity and research and development investment. With further research, more indicators were introduced, enriching the evaluation system for pharmaceutical innovation capability. Bjerrum et al.(2011) analyzed Europe's pharmaceutical innovation investment and concluded that high-quality education and training enhance innovation capability [1]. Mahajan (2018) explored the structural changes in India's pharmaceutical manufacturing industry under the product patent system, revealing a significant enhancement in innovation capability due to institutional reforms [2]. Prominent foreign pharmaceutical companies and institutions have also constructed unique innovation indicator systems. For instance, Rossi and Cebula (2015) studied research and development investments in 369 listed Italian companies, emphasizing the role of investor participation in promoting innovative development [3].

Research methods have also diversified over time. Foreign evaluation of pharmaceutical innovation capability covers interdisciplinary fields, including data mining, statistical analysis, quantitative and qualitative research, among others. Nybakk, Crespeell, Hansen, (2009)and others utilized indicator models to explore the relationship between pharmaceutical industry competitiveness and innovation [4]. In terms of selecting indicators and assigning weights, methods like multi-factor analysis, Analytic Hierarchy Process (AHP), and regression analysis have been widely applied to determine suitable indicator systems and weights.

While foreign pharmaceutical innovation capability evaluation systems and methods are becoming increasingly mature, their practical application needs to consider the specific circumstances and cultural backgrounds of different countries and regions. Issues related to data quality and completeness also exist, sometimes requiring supplementation with additional data. The unique nature of pharmaceutical innovation makes its evaluation challenging, necessitating more sophisticated research methods and data processing techniques. In the future, there is a need to refine evaluation indicators and methods, enhance data quality and completeness, and promote the healthy development of the global pharmaceutical industry.

Regarding the progress of domestic research on pharmaceutical innovation capability evaluation, both methods and indicator systems have become more diverse. Initial studies primarily focused on single indicators such as patent quantity and economic capability. As research progressed, more indicators were gradually introduced, including research and development investment, research institution innovation capability, patent technology transfer, and more. For instance, Li Bin (2013) used factor analysis and cluster analysis in their paper "Construction of Evaluation Index System for Technological Innovation Capability in China's Pharmaceutical Industry and Its Cluster Analysis," suggesting that industry structure adjustment can promote the upgrading of the pharmaceutical industry [5]. In addition to quantitative indicators, scholars have also introduced qualitative evaluation methods, such as expert assessments and SWOT analysis. Wu Lingxia (2019) and others conducted principal component analysis on data from 2009 to 2016, finding that the synergistic effects of three dimensions collectively contributed to the increasing technological innovation capability of the pharmaceutical manufacturing industry year by year [6]. Similarly, Cao Xin (2020) conducted systematic research using factor analysis on the status of pharmaceutical enterprises, providing guidance for the innovative development of China's pharmaceutical companies [7].

Additionally, the scope of research subjects has gradually expanded from individual enterprises or regions to the national and even international levels. In the initial stages, research primarily focused on assessing pharmaceutical innovation capability within specific companies or regions. For example, Liu

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Peiwei (2015) evaluated the innovation capability of pharmaceutical high-tech enterprises in the three northeastern provinces of China using factor analysis [8]. Guo Xiuqiang (2020) and colleagues employed the Analytic Hierarchy Process with entropy weights to analyze the innovation level of high-tech industries in Guangdong Province, achieving favorable results [9]. As research deepened, an increasing number of scholars began to examine pharmaceutical innovation capability at the national level. Some scholars also compared domestic innovation capability with international standards, using comparative methods to reveal gaps between domestic and foreign innovation capabilities, thus highlighting the innovative status of China's pharmaceutical industry on a global scale. Zhang Mingming and others (2020) employed scientific quantification to evaluate China's pharmaceutical innovation capability. Using dynamic TOPSIS analysis on data from 2008 to 2018 related to clinical trials, drug development quantity, and other aspects for China, the United States, and Japan, they found that China's pharmaceutical innovation potential was gradually surpassing that of Japan. This study identified issues within the innovation process and proposed recommendations for China's rapidly developing pharmaceutical industry [10].

However, research on domestic pharmaceutical innovation capability assessment still faces challenges and issues. First, acquiring data is difficult, and data quality is limited. Second, there is ongoing controversy regarding the setting of indicator weights, necessitating further research and exploration on accurately reflecting pharmaceutical innovation capability. Additionally, some studies exhibit subjectivity, such as expert assessments, indicating a need for more objective evaluation methods.

In summary, research on domestic pharmaceutical innovation capability assessment has gradually gained widespread attention. However, challenges and issues still exist in practical application. Future efforts should systematically consider various factors, refine the indicator system, delve deeper into the intrinsic mechanisms of innovation capability, and better promote the healthy development of the domestic pharmaceutical industry. When compared to both domestic and foreign research on pharmaceutical innovation capability assessment, there is still room for improvement in terms of studying Dongguan's pharmaceutical innovation capability. Therefore, the current study aims to evaluate the pharmaceutical innovation capability of Dongguan with the goal of researching and assessing the region's pharmaceutical innovation capability. Using a comprehensive evaluation model as the assessment method, employing the Delphi method to ensure the rigor and comprehensiveness of indicators, and utilizing on-site investigations to ensure data accuracy, this study also draws on comparative analysis with other cities to identify gaps and propose beneficial strategies to enhance Dongguan's pharmaceutical innovation capability.

3. Construction of the Evaluation Indicator System

3.1 Indicator Selection

This study employs the expert consultation method to confirm the evaluation indicators. The authoritative nature of expert consultation enhances the scientific rigor of the evaluation indicator system and provides reference for assessing Dongguan's pharmaceutical innovation capability. The experts consulted in this study are relevant professionals in the field of this research, including individuals from universities, research institutions, government departments, healthcare institutions, and pharmaceutical enterprises. A total of 22 experts provided feedback. Based on their initial responses, the research team provided feedback on the results of the first round of consultations to the experts and conducted a second round of consultations to seek their opinions. Six experts provided feedback in the second round, resulting in a response rate of 27%.

By reviewing and analyzing indicator data relevant to this study from Dongguan Statistical Yearbooks (2013-2021), a preliminary set of indicators concerning the evaluation of Dongguan's pharmaceutical innovation capability was formulated. Through the expert consultation method, these indicators were modified based on expert opinions. The final set of indicators for evaluating Dongguan's pharmaceutical innovation capability is determined as follows, as outlined in Table 1. To facilitate data modeling, we represent each indicator using a factor set: {Investment in Pharmaceutical Innovation Resources, Policy Support for Pharmaceutical Innovation, output of the Pharmaceutical Innovation Industry}. Within these factors are sub-indicators such as {Human Resource Investment in Pharmaceutical Innovation, Research and Development Funding for Innovation, Number of Pharmaceutical Enterprises}, {Number of Government Policies for Pharmaceutical Innovation, Financial Expenditure on Scientific Endeavors}, and {Number of Innovations in Medical and Health Sector, Added Value of the Pharmaceutical Industry}.

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Table 1: Evaluation index system of pharmaceutical innovation ability in Dongguan

First-class index	Secondary index
Input of medical innovation resources (A1)	Input of human resources in medical innovation (B1)
	Investment in innovative R&D (B2)
	Number of pharmaceutical enterprises (B3)
Medical Innovation Policy Support (A2)	Number of government policies on pharmaceutical innovation (B4)
	Fiscal expenditure on medical innovation (B5)
Output of pharmaceutical innovation industry (A3)	Number of medical and health innovations (B6)
	Added value of pharmaceutical industry (B7)

Notes: B1: statistical number of health technicians; B4: pharmaceutical innovation industry policy; B5: fiscal expenditure on scientific undertakings; B7: added value of pharmaceutical manufacturing industry.

3.2 Determination of Indicator Weights

This study utilizes the Analytic Hierarchy Process (AHP) to assign weights to the evaluation indicators. Firstly, based on the questionnaire responses, indicators relevant to the assessment of pharmaceutical innovation capability are decomposed hierarchically. Using a 1-9 scale for pairwise comparisons, a fuzzy pairwise judgment matrix is constructed for each indicator. Mathematical methods are then applied to calculate the weights and perform consistency tests on these matrices. Finally, the weights for each indicator are determined based on the results of the consistency tests. The outcomes are presented in Tables 2 and 3.

Table 2: Weight table of first-level indicators after normalization

Arithmetic average method	Geometric average method	Eigenvalue method
0.6434	0.6491	0.6491
0.2828	0.2789	0.2790
0.0738	0.0719	0.0719

After obtaining the judgment matrix, it is necessary to conduct a consistency test. If the inconsistency is too significant, the matrix cannot serve as the basis for the evaluation system. Using the consistency test formula, we first calculate the maximum eigenvalue of matrix A.

As matrix A is a 3rd order judgment matrix, referring to the comparison table yields the corresponding average random consistency index. From this, the consistency index and consistency ratio can be determined. Therefore, in this study, the judgment matrix satisfies the consistency test, and the calculated weights possess consistency.

Table 3: Weight Table of Secondary Indicators after Normalization

Indicator	Arithmetic average method	Geometric average method	Eigenvalue method
B_1	0.1735	0.1756	0.1737
B_2	0.1086	0.1080	0.1071
B_3	0.0675	0.0664	0.0660
B_4	0.1735	0.1756	0.1737
B_5	0.3773	0.3769	0.3819
B_6	0.0675	0.0664	0.0660
B_7	0.0321	0.031	0.0316

Similarly, we perform a consistency test for matrix B and calculate the maximum eigenvalue of the matrix as follows.

Given that matrix B is a 7th order judgment matrix, referring to the comparison table yields the corresponding average random consistency index. From this, the consistency index and consistency ratio can be determined. Therefore, in this study, the judgment matrix satisfies the consistency test, and the calculated weights possess consistency.

Through the results of the two consistency tests, it can be concluded that the above indicators can be used to evaluate the pharmaceutical innovation capability of Dongguan.

Based on the two-level indicator judgment matrices established using the Delphi method and the

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Analytic Hierarchy Process, this paper finally selects the judgment matrix weights obtained using the eigenvalue method. These weights from both levels are multiplied to obtain the overall weights for the pharmaceutical innovation capability evaluation indicators. Refer to Table 4 for details.

Table 4: Index weights determined based on analytic hierarchy process

First-class index item	Weight%	Secondary index item	Weight%	Total weight
A_1	0.6491	B_1	0.1737	0.11274867
		B_2	0.1071	0.06951861
		B_3	0.0660	0.0428406
A_2	0.2790	B_4	0.1737	0.0484623
		B_5	0.3819	0.1065501
A_3	0.0719	B_6	0.0660	0.0047454
		B_7	0.0316	0.00227204

4. Evaluation Results

4.1 Data Selection and Processing

By retrieving the annual "Dongguan Statistical Yearbook," relevant statistical data on pharmaceutical innovation capability evaluation indicators for Dongguan from 2013 to 2021 were collected. Subsequently, a screening process was conducted to identify missing and outlier values. After performing descriptive statistical analyses on each variable, the data to be used for the Analytic Hierarchy Process and the fuzzy comprehensive evaluation model were finalized. Refer to Table 5 for details.

Table 5: Values of Relevant Indicators of Pharmaceutical Innovation Ability in Dongguan from 2013 to 2021

YEAR	SNOHT	IIIR&DF	NOPE	PIIP	FEOSU	NMAHIA	IAVPMI
2013	42132	109.93	2046	5	17.3	28	6.4758
2014	43091	127.17	2641	6	14.1	14	9.0028
2015	45226	147.88	2746	5	30.83	20	9.9170
2016	47668	164.83	2465	4	27.94	21	7.8729
2017	50600	188.14	2569	9	33.96	15	13.3409
2018	54317	236.32	2684	7	39.34	16	14.6295
2019	57332	289.96	3165	13	25.36	22	14.7564
2020	58930	342.09	3294	13	34.19	20	24.2916
2021	61046	434.45	3567	6	38.95	26	28.3945

Notes: SNOHT:Statistical number of health technicians (pieces);IIIR&DF:Investment in innovative R&D funds (100 million yuan);NOPE:Number of pharmaceutical enterprises (pieces); PIIP:Pharmaceutical Innovation Industry Policy (Pieces);FEOSU:Financial expenditure on scientific undertakings (100 million yuan);NOMAHIA:Number of medical and health innovation achievements (pieces); IAVPMI:Industrial added value of pharmaceutical manufacturing industry (100 million yuan).

In order to assess the pharmaceutical innovation capability of Dongguan more accurately, the regional comparison method is employed to rank the pharmaceutical innovation capabilities of various prefecture-level cities within Guangdong Province. This approach enables a deeper understanding of Dongguan's position in terms of pharmaceutical innovation capability.

By employing the same evaluation methodology to individually assess the pharmaceutical innovation capabilities of each prefecture-level city within the province, scoring is conducted to rank the capabilities from best to worst, leading to comparative conclusions. Initially, relevant evaluation indicator statistics for each prefecture within Guangdong Province are collected, all of which are sourced from the statistical yearbooks of resp ective cities. Refer to Table 6 for details.

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Table 6: Values of Relevant Indicators of Medical Innovation Ability of Cities in Guangdong Province in 2021

	SNOHT	IIIR&DF	NOPE	IAVPMI	PIIP	FEOSU	NOMAHIA
DG	61046	434.45	3567	28.3945	118	34.19	26
GZ	177835	881.72	3589	499.9815	744	224.13	33
SZ	106271	1682.15	3961	408.25	628	336.63	28
ZH	20673	113.73	675	82.144	303	51.51	10
ST	28252	31.17	1489	20.0877	151	6.51	2
FS	60946	342.36	1128	85.0114	271	101.66	13
SG	23162	19.14	1069	5.6794	37	6.64	3
RH	19991	8.88	1428	3.1542	23	2.59	/
MZ	26524	7.9	1366	2.1898	73	5.29	/
HZ	38771	168.97	3547	8.7446	160	23.62	6
SW	12039	8.07	715	0.1177	49	3.39	/
ZS	26389	81.13	477	33.9147	165	23.93	25
JM	33506	92.72	1844	11.4473	161	16.73	7
YJ	17209	6.08	1051	6.0211	31	3.07	/
ZJ	42353	18.7	2489	10.7681	204	3.14	6
MM	35104	17.17	2638	0.4218	32	3.4	9
ZQ	26441	29.53	1050	10.8905	156	10.16	/
QY	24931	21.76	/	2007.45	43	7.85	/
JY	/	21.56	1493	2265.43	56	3.13	/
CF	/	6.97	/	1138.97	52	3.5	/
CZ	/	8.01	/	1244.85	88	0.97	/

Notes:SNOHT:Statistical number of health technicians (pieces);IIIR&DF:Investment in innovative R&D funds (100 million yuan);NOPE:Number of pharmaceutical enterprises (pieces); IAVPMI:Industrial added value of pharmaceutical manufacturing industry (100 million yuan);PIIP:Pharmaceutical Innovation Industry Policy (Pieces);FEOSU:Financial expenditure on scientific undertakings (100 million yuan);NOMAHIA:Number of medical and health innovation achievements (pieces).
DG:Dongguan; GZ:Guangzhou; SZ:Shenzhen; ZH:Zhuhai; ST:Shantou; FS:Foshan; SG:Shaoguan; RH:River headwaters; MZ:Meizhou; HZ:Huizhou; SW:Shanwei; ZS:Zhongshan; JM:Jiangmen; YJ:Yangjiang; ZJ:Zhanjiang; MM:Maoming; ZQ:Zhaoqing; QY:Qingyuan; JY:Jieyang; CF:Cloud float; CZ:Chaozhou.

Due to the diverse dimensions of various indicators, in order to accurately evaluate Dongguan's pharmaceutical innovation capability, a dimensionless processing of the pharmaceutical innovation capability evaluation indicator data is carried out based on the fuzzy analysis method. This involves determining different degrees of membership corresponding to five evaluation criteria. The formula used to calculate the membership function values in this study is as follows: [The actual formula should be inserted here as it is not provided in the text.]

$$R = \frac{x_{ij} - m_{ij}}{M_{ij} - m_{ij}} = \begin{cases} 1, & x_{ij} \geq M_{ij} \\ \frac{x_{ij} - m_{ij}}{M_{ij} - m_{ij}}, & m_{ij} < x_{ij} < M_{ij} \\ 0, & x_{ij} \leq m_{ij} \end{cases} \quad (1)$$

Among them, i is the year, j is the number of indicators in the year, M_{ij} and m_{ij} represent the maximum and minimum values of each indicator between different regions, and the range of membership R is [0,1].

Table 7: Dimensionless treatment of indicators from 2013 to 2021

Year	B_1	B_2	B_3	B_4	B_5	B_6	B_7
2013	0.0000	0.0000	0.0000	0.1111	0.1268	1.0000	0.0000
2014	0.0507	0.0531	0.3912	0.2222	0.0000	0.0000	0.1153
2015	0.1636	0.1169	0.4602	0.1111	0.6628	0.4286	0.1570
2016	0.2927	0.1692	0.2755	0.0000	0.5483	0.5000	0.0637
2017	0.4477	0.2410	0.3439	0.5556	0.7868	0.0714	0.3132
2018	0.6442	0.3895	0.4195	0.3333	1.0000	0.1429	0.3720
2019	0.8036	0.5548	0.7357	1.0000	0.4461	0.5714	0.3778
2020	0.8881	0.7154	0.8205	1.0000	0.7960	0.4286	0.8128
2021	1.0000	1.0000	1.0000	0.2222	0.9845	0.8571	1.0000

The dimensionless processing results for Dongguan's indicators from 2013 to 2021 are presented in

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Table 7.

4.2 Comprehensive Evaluation Results

By combining the weights assigned to the four indicators with the dimensionless processed indicator data, the comprehensive evaluation scores for Dongguan's pharmaceutical innovation capability for the years 2013 to 2021 are obtained. Please refer to Table 8 for details.

Table 8: Comprehensive Evaluation Scores of Pharmaceutical Innovation Ability in Dongguan from 2013 to 2021

Year	Innovation ability index	Rank
2013	0.0236	9
2014	0.0372	8
2015	0.1247	6
2016	0.1175	7
2017	0.1938	5
2018	0.2419	4
2019	0.2603	3
2020	0.3222	2
2021	0.3471	1

From 2013 to 2021, the comprehensive index of Dongguan's pharmaceutical innovation capability has shown an upward trend, indicating that the overall pharmaceutical innovation capability of Dongguan is at a good level. This trend is in alignment with the real-world situation, demonstrating the feasibility of the pharmaceutical innovation capability evaluation system for Dongguan.

4.3 Comparison of Pharmaceutical Innovation Capability between Dongguan and Other Prefecture-Level Cities in Guangdong Province in 2021

In order to better illustrate Dongguan's pharmaceutical innovation capability level, we will further conduct a comprehensive evaluation of pharmaceutical innovation capability for various prefecture-level cities in Guangdong Province in 2021. Due to severe data gaps in relevant indicators for cities such as Qingyuan, Jieyang, Yunfu, and Chaozhou, we have excluded them from the analysis. Additionally, considering that policies supporting pharmaceutical innovation exhibit time lag and cumulative effects, we have selected policy data from 2013 to 2022 for all cities in Guangdong Province.

Table 9: Comprehensive evaluation of medical innovation ability of prefecture-level cities in Guangdong Province in 2021

Place name	Innovation ability index	Percentage scoring	Rank
Guangzhou	0.3478	100	1
Shenzhen	0.3121	89.73548	2
Dongguan	0.1081	31.08108	3
Foshan	0.1024	29.44221	4
Huizhou	0.0845	24.29557	5
Zhanjiang	0.0741	21.30535	6
Zhuhai	0.0635	18.25762	7
Jiangmen	0.0572	16.44623	8
Shantou	0.0456	13.11098	9
Maoming	0.0447	12.85221	10
Zhongshan	0.0392	11.27085	11
Zhaoqing	0.0386	11.09833	12
Meizhou	0.0285	8.194365	13
Shaoguan	0.0183	5.261645	14
River headwaters	0.0175	5.031627	15
Yangjiang	0.0123	3.536515	16
Shanwei	0.0069	1.983899	17

Based on the total weights obtained through the Analytic Hierarchy Process and the dimensionless processing results of indicator data for various cities in Guangdong Province, we have calculated the pharmaceutical innovation capability comprehensive index for 17 cities in Guangdong Province in 2021. After rescaling the results on a percentage basis and re-ranking, the outcomes are as follows: [Unfortunately, the specific ranking results are not provided in your text.]

From the above table, it can be observed that in 2021, the comprehensive index of pharmaceutical

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innovation capability across the 17 prefecture-level cities in Guangdong Province is significantly led by Guangzhou and Shenzhen. Dongguan ranks third with a score of 31, which is consistent with the actual situation. Therefore, the pharmaceutical innovation capability evaluation system for Dongguan demonstrates feasibility in analyzing the pharmaceutical innovation capabilities of various prefecture-level cities in Guangdong Province.

In summary, based on the research results, the pharmaceutical innovation capability level of Dongguan is notably lower than that of Guangzhou and Shenzhen. Statistical data indicates that Dongguan's innovation achievements are relatively close to the latter two cities, but the industrial added value shows a significant gap. Therefore, Dongguan urgently needs to enhance the efficiency of research and development transformation and strengthen the integration of industry, academia, and research.

5. Analysis of the Results

5.1 Reasons for the Results of Dongguan's Pharmaceutical Innovation Evaluation

Upon analyzing the individual evaluation results of Dongguan's pharmaceutical innovation capability and comparing them with the capabilities of other prefecture-level cities within Guangdong Province, we have identified four main reasons that hinder the development of pharmaceutical innovation in Dongguan.

1) Shortage of Pharmaceutical Innovation Technical Personnel: The pharmaceutical manufacturing industry is capital and technology-intensive, particularly in terms of developing new varieties, which requires significant financial investment and highly skilled technical personnel. When comparing the number of high-tech personnel in the healthcare sector among various cities in Guangdong Province in 2021, Dongguan lags far behind Guangzhou and Shenzhen. The scarcity of pharmaceutical innovation technical personnel, especially those involved in new drug research and development, presents a major bottleneck for the pharmaceutical innovation development in Dongguan.

Insufficient Research and Development Funding: Although the number of healthcare innovation achievements in Dongguan has increased year by year from 2013 to 2021, the overall quantity of achievements still requires improvement.

2) Inadequate Support of Pharmaceutical Innovation Policies: In comparison to cities like Guangzhou and Shenzhen that rank higher, the Dongguan municipal government's support for pharmaceutical innovation policies is insufficient. The government's investment and guidance in the pharmaceutical sector are inadequate, resulting in a lack of enthusiasm for innovation within Dongguan's overall pharmaceutical enterprises and sluggish development of the pharmaceutical innovation industry.

Limited Regional Economic Capability: In contrast to Guangzhou and Shenzhen, which rank ahead, these cities occupy the top three positions in terms of domestic economic capability. Their strong economic foundations, stable economic sources, and substantial GDP provide favorable conditions for pharmaceutical technology development. However, data indicates that Dongguan's GDP lags behind, leading to an absence of favorable conditions and an environment for pharmaceutical innovation research. This hampers the rapid development of the pharmaceutical innovation industry in Dongguan.

5.2 Policy Recommendations for the Development of Pharmaceutical Innovation Capability in Dongguan

1) Strengthen Government Support for Pharmaceutical Innovation Enterprises: The government should enhance its support for pharmaceutical innovation enterprises through favorable policies. Only under the incentive of supportive policies will pharmaceutical enterprises initiate or expedite research and development activities. For enterprises, policy support means access to government-funded resources, services, and policies. Leveraging these conditions effectively can enhance the research and innovation competitiveness and development potential of pharmaceutical enterprises. This will lead to stable growth in pharmaceutical innovation output and sustainable development of the pharmaceutical innovation industry.

2) Enhance and Optimize the Transformation of Innovation Achievements by Pharmaceutical Enterprises: It is recommended that Dongguan accelerate the construction of an integrated pharmaceutical industry park that combines development zones, capital operations, achievement transformation, and enterprise services. Support research institutes, universities, medical institutions, and key enterprises in the biopharmaceutical field to seek national-level major scientific and technological infrastructure and innovation platforms to be established in Dongguan. This will facilitate innovative product development, enhance competitiveness, and promote the transformation of achievements. Encourage universities and research institutes to establish laboratories in hospitals, actively seek input

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and advice from medical professionals at every stage of pharmaceutical product research projects, and improve the possibility of commercializing scientific and technological achievements.

3) Continuously Improve Dongguan's Economic Capability: By increasing the Gross Domestic Product (GDP), more funds can be allocated to the development of pharmaceutical innovation, thus boosting economic strength while supporting the growth of technological innovation. Technological innovation achievements, in turn, contribute to the enhancement of economic capability.

4) Implement Effective Policies to Attract Outstanding Pharmaceutical Innovation Talents: To address the shortage of pharmaceutical innovation technical personnel, Dongguan can implement policies to attract exceptional talent to the city. This can involve offering attractive benefits, providing incentives, and creating a supportive environment for innovative professionals. By bringing in and retaining talented individuals, the local pharmaceutical innovation output and development can be fostered.

By implementing these recommendations, Dongguan can address the challenges identified in the evaluation and promote the growth of its pharmaceutical innovation capability, thereby contributing to the overall advancement of the city's healthcare and pharmaceutical sector.

6. Conclusions

The paper evaluates the pharmaceutical innovation capability of Dongguan City through the use of a fuzzy comprehensive assessment model. The research findings indicate that Dongguan City's pharmaceutical innovation capability is generally at a good level, ranking third within Guangdong Province. However, when compared to Guangzhou and Shenzhen, there still exists a significant gap, primarily due to insufficient contribution from industrial added value. The study suggests that Dongguan City urgently needs to enhance research and development efficiency, strengthen the integration of industry, academia, and research, while the government should increase policy support for pharmaceutical innovation enterprises and implement policies to attract outstanding pharmaceutical innovation talents. Additionally, Dongguan City should continuously improve its economic capacity. However, due to the difficulty in collecting and missing data for relevant evaluation indicators, our assessment of Dongguan City's pharmaceutical innovation capability may not be comprehensive enough, which calls for further in-depth research.

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