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Quantitative Study on the Dynamic Mechanism of Smart Low-Carbon City Development in China

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Abstract: With the development of new generation technology and the low-carbon economy, the smart low-carbon city has become one of the academic hotspots. Many studies on it have begun; however, the dynamic mechanism is rarely involved. Therefore, this paper uses the Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) method to creatively take a quantitative study on a Chinese smart low-carbon city's dynamic mechanism. The results show that: (1) the three main dynamics of smart low-carbon city development in China are institutional and cultural conditions, facilities and functions conditions and economy and industry conditions, but the overall utility is relatively low; (2) the level of the dynamic operation mechanism of the Chinese smart low-carbon city is distinct between regions, indicating a diminishing spatial law from east to west and differences within regions; (3) the imbalance of the comprehensive dynamic mechanism and the operation status between smart low-carbon cities is prominent, showing a decreasing urban scale law of from big to small and differences within each scale, and a descending administration hierarchy law from high to low and differences within each class; (4) seven basic development patterns can be obtained, and most of the cities belong to the external strong/internal weak mode, which basically matches with its development realities. Finally, general policy recommendations and countermeasures of optimization and improvement are proposed.

Keywords: smart low-carbon city; dynamic mechanism; quantitative study; China

1. Introduction

Cities, as places of capital allocation and resource concentration, places and key areas of wealth generation, the interactive nodes of technology application and knowledge aggregation, the centers of cultural innovation, and the leaders of social, political and economic development, have acquired unprecedented development and prosperity with the impetus of the Industrial Revolution and brought the human world into an urban age. Although urban life on Earth has been greatly improved, over-exploitation of energy and resources, massive destruction of natural ecosystems, worsening pollution of various kinds, great environment and climate changes, and a series of "urban diseases" have appeared [1], which have, in many ways, deteriorated the coordinated development of the human-natural system. In order to keep human society on track for a sustainable and healthy development, many countries have started to embrace the concepts of sustainability and low-carbon economy. Meanwhile, the arrival of a new generation of the information technology, featuring the Internet, cloud computing and big data, promotes the interaction between the concept of low-carbon development (involving low energy consumption, high efficiency and low pollution) and the concept of smart development (involving the integration of big data management network platforms and the spatial information operational monitoring model and visualization systems). This not only provides a creative opportunity and effective way for future sustainable urban development, but also makes the smart low-carbon city increasingly the focus of research attention [2–4]. To this end, researchers have actively expanded relative theoretical and empirical studies, and obtained a lot of achievements in related concepts and connotations, measurement evaluations, development paths [5–9], *etc.* However, on the whole, precise studies of smart low-carbon city development are still in their early infancy, far from forming a complete theoretical system. Furthermore, studies concerning the development factors for its occurrence, the dynamic mechanism, the typical patterns and comprehensive measurement evaluation are very few. Hence, it is necessary to further study and explore relevant contents to make up for this deficiency and fill in research gaps. Therefore, in light of the new development trend around the world, the strategic background of China's harmonious societal construction, as well as the promotion of a new type of urbanization and urban sustainable development, this paper aims to study the development and evolutionary dynamic mechanism of a smart low-carbon city from a quantitative viewpoint to enrich the relevant research field.

According to current research and practice, the development of the smart low-carbon city is propelled both by the pulling force of urbanization and the propulsion force of external elements, as well as the internal changes within its own system. Generally, scholars have studied the dynamics of smart low-carbon city development from three different perspectives:

(1) From a qualitative perspective, researchers have considered population migration and agglomeration [10], transportation technology developments and improving conditions [11], economic structure changes [12,13], policies of institutional change and innovation [14,15], clusters of industrial technology and business [16,17], spillovers of intellectual capital and technology [18,19], and economic and financial globalization [20] as both traditional and new driving forces of smart low-carbon city development. Meanwhile, some specific factors, such as major projects of urban construction and emergent incidents [21], urban planning and development strategies and demolition [14,22], new district construction and regional integration [23], as well as marketing and brand-building of a city [24,25], also influence the process of smart low-carbon city development.

(2) From a quantitative perspective, with the introduction of econometrics and systems engineering methods, time-series data and panel data are used by researchers to quantify the comprehensive analysis of the dynamic mechanism of smart low-carbon city development to expand the knowledge of relevant fields. By using vector autoregression (VAR) models [26], spatial lag panel models [27], linear regression models, logistic regression models [28], innovation-driven models, system dynamics models [29], factor-driven models, urban income-expenditure balance models and other quantitative methods, many scholars have evaluated the impact of different kinds of elements on smart low-carbon city development. For example, with the help of regression analysis, Headey [30] has used exploratory factor analysis to study how distinct factors affect economic growth and to what extent they can influence urban development by exploring nine categories including social and economic capacity, financial and private transactions, geographic features, government control scale, government control quality, trade and government consumption, trade fluctuations, resources and policy rationality, price distortion and urban bias. In China, scholars have investigated the quantitative relationship between various kinds of factors and smart low-carbon city development, including urban land and spatial expansion [31], the industrialization level, transport services and infrastructure development, social fixed investment, technology and innovation, ecological carrying capacity and socio-cultural education [32,33], *etc.*

(3) From an empirical perspective, researchers have tried to further the research on the dynamic evolution process and mechanisms through case studies. For example, a study on the Brazilian Amazon region by Simmons and others [34] showed that long-lasting intense land conflicts and a lack of secondary and tertiary industry supports cannot establish an effective dynamic mechanism for urban development. A study on major countries and regions in East Asia by

McGee [35] found that land reform and technological innovation, utilization of foreign investment, improvement of transportation infrastructure and progressive industrialization can promote urban development. In China, researchers have explored domestic urban development in different regions at distinct scales from different levels and standpoints. For example, some scholars suggested that in the Yangtze River Delta and Pearl River Delta regions, the rapid development of local enterprises, the adequate supply of nonagricultural labor, policies and system innovations, transnational and inter-regional capital investment, industrialization and informatization, and the promotion of modern culture and education were major impetuses for smart low-carbon city development [36,37]. For the city of Beijing, researchers have thought that its dynamic mechanism included not only positive factors of location advantage, natural resource endowment and industrial structure, but also negative ones such as an oversized population, eco-environmental deterioration and policy implementation [38]. For a prefecture-level city such as Yantai, researchers have suggested that a demand system containing economic development and income level, commodity consciousness, education level, geographical environment and macroeconomic policy was the fundamental driving force of urban development [39].

On the whole, the development of smart low-carbon cities is an adaptation process of dynamic evolution, which is propelled by the continuous interaction of internal and external flows of matter and energy. By learning from existing studies, this paper tries to creatively use the merits of the solution from the Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) method to build a quantitative framework of a smart low-carbon city's dynamic mechanism from internal and external systems including science and technology conditions, resources and environmental conditions, economic industrial conditions, infrastructure and functions conditions, key capital conditions, and institutional and cultural conditions to discover the dynamics of smart low-carbon city development in China and fill the blank of the smart low-carbon city area.

2. Materials and Methods

2.1. Materials

2.1.1. Research Objectives

At present, more than 400 cities in China have announced their smart low-carbon city strategies and plans, covering 95% of the sub-provincial and above-level cities and more than 75% of the prefecture-level cities. Taking into account the representativeness of the sample, the availability of statistics, the feasibility of study and the comparability of results, this paper selected four municipalities, 15 sub-provincial cities, 17 other capital cities, 26 prefecture-level cities and six county-level cities as research subjects based on the lists of the national low-carbon pilot cities, the national ecological garden cities, the national smart pilot cities, the national new-type urbanization pilot cities, the Sino-European green smart pilot cities and the Sino-American low-carbon ecology pilot cities. In accordance with the administrative level and urban size, the specific samples of the study can be checked in Tables 1 and 2.

2.1.2. Data Sources

The statistics of this empirical analysis are mainly obtained from the *China Statistical Yearbook* (2014) [40], the *China City Statistical Yearbook* (2014) [41] and the *China Urban Construction Statistics Yearbook* (2014) [42], combined with specific statistical data released in local statistical yearbooks, the local statistical bulletins, local government websites and relevant departments' websites. Meanwhile, other related professional data are acquired from the website of the Ministry of Science and Technology, the website of the Ministry of Environmental Protection, the website of the China Securities Regulatory Commission, the website of the National Tourism Administration, the *China Environmental Yearbook* (2014) [43], the *Almanac of the Chinese Listed Companies* (2014) [44], the *Report on China's Innovative City Development* [45], the *Report on the Performance Evaluation of China's Government Website* (2013) [46], the

Chinese Cultural Relics Statistical Yearbook (2014) [47] and the *Report on China's Green Development Index* (2014) [48] *etc*.

Table 1. Samples of smart low-carbon city research.

Category	Region	City
Municipality	Northeast	-
	East	Beijing, Tianjin, Shanghai
	Middle	-
	West	Chongqing
Sub-provincial city	Northeast	Shenyang, Dalian, Harbin, Changchun
	East	Qingdao, Jinan, Nanjing, Hangzhou, Ningbo, Xiamen, Guangzhou, Shenzhen
	Middle	Wuhan
	West	Chengdu, Xi'an
Other capital city	Northeast	-
	East	Shijiazhuang, Fuzhou, Haikou, Nanning
	Middle	Hohhot, Taiyuan, Zhengzhou, Hefei, Nanchang, Changsha
	West	Guiyang, Kunming, Lanzhou, Xining, Lhasa, Yinchuan, Urumqi
Prefecture-level city	Northeast	Qiqihar, Jilin
	East	Langfang, Qinhuangdao, Yantai, Huaian, Yangzhou, Nantong, Suzhou, Zhenjiang, Wenzhou, Putian, Zhuhai, Guilin, Liuzhou
	Middle	Hulunbuir, Jiyuan, Luoyang, Jincheng, Zhuzhou
	West	Jinchang, Yan'an, Zunyi, Xianyang, Shizuishan, Karamay
County-level city	Northeast	-
	East	Kunshan
	Middle	Xinzheng
	West	Yining, Korla, Dunhuang, Mile

Table 2. Division of smart low-carbon city samples based on urban scale.

Urban Scale Class		City	Sample Size
Super city	-	Shanghai, Beijing, Chongqing, Tianjin, Guangzhou, Shenzhen	6
Megacity	-	Wuhan, Chengdu, Nanjing, Xi'an, Shenyang, Hangzhou, Harbin	7
Big city	Type I	Jinan, Zhengzhou, Changchun, Dalian, Suzhou, Qingdao, Kunming, Xiamen, Ningbo, Nanning, Taiyuan, Hefei, Changsha, Wenzhou, Guiyang, Urumqi	16
	Type II	Fuzhou, Shijiazhuang, Huaian, Lanzhou, Nanchang, Nantong, Yaitai, Haikou, Hohhot, Jilin, Putian, Luoyang, Kunshan, Zhuhai, Qiqihar, Liuzhou, Yanzhou, Yinchuan, Zhenjiang, Xining, Xianyang, Zunyi, Zhuzhou, Qinhuangdao	24
Medium city	–	Guilin, Langfang, Xinzheng, Jiyuan, Korla, Yining	6
Small city	Type I	Jincheng, Yan'an, Shizuishan, Karamay, Hulunbuir, Lhasa, Mile, Jinchang	8
	Type II	Dunhuang	1

In this study, due to the broad professional fields and geographical scope, very few data were difficult to find and collect. Hence, considering the integrity and availability, the paper chose the year 2013 to ensure the actuality of calculation. Concerning missing data, the provincial or urban average score or zero would be used in processing. Then, the above methodology can be applied to measure the dynamic mechanism and development status of Chinese smart low-carbon cities. In the quantitative analysis, because there were some negative indicators in the resource and environmental conditions, it is postulated that the greater the value (*i.e.*, resource and environmental conditions are worse), the stronger the dynamic of the smart low-carbon city development.

2.2. Methods

2.2.1. Index System

Based on relevant research and construction practice, this paper mainly uses theoretical analysis and frequency statistics analysis of existing literature, policy documents, studies and construction standards guidance, as well as expert advice and discussions to construct a quantitative analysis framework of the dynamic mechanism of smart low-carbon city development with 59 major indicators in mainly regards: First, endogenous power, including science and technology conditions which are considered the internal core driving forces, the resource and environmental conditions which are the inherent fundamental driving forces, and the economy and industry conditions which are the foremost internal foundations. Second, the exogenous stimuli, including the facilities and functions conditions which are the prior external preconditions, the critical capital conditions which are the key external driving forces and the institutional and cultural conditions which are the important external supports (Table 3).

Table 3. The index system of the dynamic mechanism of smart low-carbon city development.

Category	No.	Indicator	Unit
Science and Technology	X1	National Key Laboratories	number/one million people
	X2	National Research Centers of Engineering Technology	number/one million people
	X3	Higher Education Institutions	number/one million people
	X4	National High-Tech Industrial Development Zones	number/one million people
	X5	National Technology Business Incubators	number/one million people
	X6	National Innovative Enterprises	number/one million people
	X7	Granted Invention Patents	number/one million people
	X8	Research & Development (R & D) Institutions/Number of the Industrial Enterprises above Designated Size	%
	X9	Contracted Exchange Volume in Technical Market	10,000 yuan
Resource and Environment	X10	Energy Intensity	tons of standard coal/10,000 yuan
	X11	Energy Consumption Elasticity	%
	X12	Water Consumption/Gross Domestic Product (GDP)	m^3/10,000 yuan
	X13	Chemical Oxygen Demand (COD) Emissions	10,000 tons
	X14	Sulphur Dioxide (SO_2) Emissions	10,000 tons
	X15	Number of Days of Good Air Quality	Number of days
	X16	Average Value of Regional Environmental Noise of Urban Area	Decibel (dB)
	X17	Forest Coverage	%
	X18	Direct Economic Losses Caused by Natural Disasters	100 million yuan
	X19	Frequency of Environmental Emergencies	number of times
Economy and Industry	X20	Gross Domestic Product (GDP) of City	100 million yuan
	X21	Economic Density	100 million yuan/km^2
	X22	Local Public Financial Revenue	10,000 yuan
	X23	Ratio of Investment to Output	%
	X24	Industrial Total Asset's Contribution Rate	%
	X25	Proportion of Tertiary Industry	%
	X26	High-tech Industry Output/Total Industrial Output	%
	X27	Exports of High-Tech Products/Total Exports	%
	X28	Total Retail Sales of Consumer Goods	10,000 yuan
	X29	Overall Labor Productivity	yuan/person
Facilities and Functions	X30	Internet Penetration Rate	%
	X31	Mobile Phone Penetration Rate	number/100 people
	X32	Books in Public Library	number/100 people
	X33	Decontamination Rate of Urban Refuse	%
	X34	Density of Drainage Pipeline in Built-up Area	km/km^2
	X35	Green Coverage Rate of Built-up Area	%
	X36	Building of Basic Database of Smart Low-carbon City	score
	X37	Smart Livelihood Service System	score
	X38	Smart Low-carbon Operation and Management	score
	X39	Cloud Computing Platform Construction	score
	X40	Smart Medical System Construction	score

Table 3. *Cont.*

Category	No.	Indicator	Unit
Critical Capital	X41	People Employed	10,000 people
	X42	Research & Development (R & D) Personnel	10,000 people
	X43	Registered Urban Unemployment Rate	%
	X44	Student Enrollment of Higher Education Institutions	number /10,000 people
	X45	Fiscal Expenditure for Science and Technology	10,000 yuan
	X46	Fiscal Expenditure for Education	10,000 yuan
	X47	Density of Research & Development (R & D) Fund Input	%
	X48	Actual Utilization of Foreign Capital	10,000 dollars
	X49	Foreign and Domestic Currency Deposits of Financial Institutions	100 million yuan
Institution and Culture	X50	Innovative Reform of Urban System and Mechanism	score
	X51	Security Level of Smart Low-carbon Development	score
	X52	Degree of Perfection of Related Regulations and Standards	score
	X53	Level of Urban Modern Governace	score
	X54	Urban Credit Environment	score
	X55	Transparency and Incorruption of City Government	score
	X56	Urbanizaiton Level	%
	X57	Opening Degree of City	score
	X58	Activeness of Smart Low-carbon City Construction	score
	X59	Popularization of Smart Low-carbon Lifestyle	score

2.2.2. Methodology

Due to the flexibility and convenience of sample data selection, TOPSIS is considered here to explore the dynamic mechanism of smart low-carbon cities. The TOPSIS method is an effective decision-making technology and scientific method that is often used in the systems engineering field. This method was introduced by Hwang and Yoon in 1981 [49], and has been successfully applied in many areas such as land use planning, material selection evaluation, project investment, health, *etc.* As one of the comprehensive evaluation methods of a multi-objective decision with limited plans, TOPSIS calls for no special sample requirements, which suggests it can be applied to both a small set of data and a large set of statistics. Meanwhile, compared to other similar methods, the algorithm is relatively simple and flexible as it fully uses the information of the original data and is consistent with the facts of objective quantitative results. This method significantly improves the scientific accuracy and operability of multi-objective decision analysis. TOPSIS has been used in many decision problems and is more practical in actual decision-making situations. Hence, we choose it to explore the development dynamics of smart low-carbon cities. In this method, through the normalization of the original data matrix, the optimal outcome (ideal solution) and the worst outcome (negative ideal solution) can be picked out; then, by calculating the distance between each evaluation outcome and the ideal or negative ideal solution, the approach degree and its order can be obtained, which would be the basis for evaluation [49]. The specific steps are as follows:

(1) Establish the feature matrix with the same trend. Generally, the original low-priority indicators are usually converted to high-priority ones through the reciprocal method; *i.e.*, a low-priority indicator X_{ij} (i = 1, 2 . . . , m; j = 1, 2 . . . , n) should be converted to a high-priority one via the formula $X'_{ij} = 1/X_{ij}$. Additionally, the original medium-type indicators can be converted to high-priority ones with the formula $X'_{ij} = |X_{ij} - \textit{standard median value}|$. The same trend feature matrix of original data is:

$$D = \begin{bmatrix} X_{11} \ldots X_{1j} \ldots X_{1n} \\ \ldots\ldots\ldots\ldots\ldots\ldots \\ X_{i1} \ldots X_{ij} \ldots X_{in} \\ \ldots\ldots\ldots\ldots\ldots\ldots \\ X_{m1} \ldots X_{mj} \ldots X_{mn} \end{bmatrix} = \begin{bmatrix} D_1\,(X_1) \\ \ldots\ldots\ldots \\ D_i\,(X_j) \\ \ldots\ldots\ldots \\ D_m\,(X_n) \end{bmatrix} \tag{1}$$

(2) Build the standardized matrix. The same trend feature matrix of original data can be normalized with the following formula:

$$a_{ij} = X_{ij} \Big/ \sqrt{\sum_{i=1}^{m} X_{ij}^2} \quad (2)$$

Then build the standardized matrix related to the normalized vector a_{ij} as follows:

$$A = \begin{bmatrix} a_{11}, a_{12}, a_{13}, \ldots, a_{1n} \\ \ldots\ldots\ldots\ldots\ldots\ldots \\ a_{i1}, a_{i2}, a_{i3}, \ldots, a_{in} \\ \ldots\ldots\ldots\ldots\ldots\ldots \\ a_{m1}, a_{m2}, a_{m3}, \ldots, a_{mn} \end{bmatrix} \quad (3)$$

(3) Construct the standardized weighting matrix. Considering the requirements of TOPSIS and the property of some indicators, the weight (w_{ij}) here is given as the same number to get the standardized weighting matrix:

$$Z = \begin{bmatrix} w_{11} \cdot a_{11}, w_{12} \cdot a_{12}, w_{13} \cdot a_{13}, \ldots, w_{1n} \cdot a_{1n} \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ w_{i1} \cdot a_{i1}, w_{i2} \cdot a_{i2}, w_{i3} \cdot a_{i3}, \ldots, w_{in} \cdot a_{in} \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ w_{m1} \cdot a_{m1}, w_{m2} \cdot a_{m2}, w_{m3} \cdot a_{m3}, \ldots, w_{mn} \cdot a_{mn} \end{bmatrix} \quad (4)$$

(4) Determine the ideal and the negative ideal solutions. According to the above results, the optimal vector Z^+ and the worst vector Z^- can be obtained:

$$Z^+ = \left(Z_{i1}^+, Z_{i2}^+, Z_{i3}^+, Z_{i4}^+, \ldots, Z_{in}^+\right) \quad (5)$$

$$Z^- = \left(Z_{i1}^-, Z_{i2}^-, Z_{i3}^-, Z_{i4}^-, \ldots, Z_{in}^-\right) \quad (6)$$

(5) Calculate the distance. Generally, the n-dimensional Euclidean distance is calculated to acquire the distance between each outcome and the ideal solution D_i^+ and the distance between each outcome and the negative ideal solution D_i^- separately:

$$D_i^+ = \sqrt{\sum_{j=1}^{n} \left(Z_{ij} - Z_j^+\right)^2} \quad (7)$$

$$D_i^- = \sqrt{\sum_{j=1}^{n} \left(Z_{ij} - Z_j^-\right)^2} \quad (8)$$

where Z_{ij} is the standardized weighting value of the *i*-th outcome's *j*-th indicator, and D_i^+ is the closeness degree of each outcome with its ideal solution, which indicates that the smaller it is, the closer is it to the outcome, and the better the plan is.

(6) Calculate the optimal approach degree. Lastly, the approach degree between all the quantitative indicators and the optimal solution can be calculated:

$$C^* = D_i^- / \left(D_i^+ + D_i^-\right) \quad (9)$$

where C^* is in the range [0, 1], within which if the research object is closer to 1, it shows a relatively great level of activity, and if the object is closer to 0, it approaches the worst solution. Generally, there is little possibility for the worst and best outcomes.

(7) Conduct the priority ordering analysis. According to the C^* value, all the research objectives should be arranged in descending order to obtain the optimal solution and analyze the overall situation. If the C^* values are the same, the one with the smaller D_i^+ performs better.

3. Results

3.1. Results of Overall Dynamics

By measuring the optimal approach degree of driving force utility, it can be observed that although the activeness of each driving force diverged in different cities, the difference of the comprehensive optimal approach degree between cities was not particularly large, and the overall optimal approach degree of driving force utility was low. For instance, Beijing, ranking first, had an optimal approach degree of driving force utility which just exceeded 0.478; Shanghai, taking the second place, had an optimal approach degree of driving force utility less than 0.473. The optimal approach degree of driving force utility of the last city, Mile, was just close to 0.09, and most cities' optimal approach degrees of driving force utility were found between 0.12 and 0.26 (Table 4). This suggested that the overall driving force of smart low-carbon city development did not perform very well in promoting and facilitating the sample cities' smart low-carbon development. For the majority of sample cities, the activeness of the institutional and cultural conditions was the highest, then the facilities and functions conditions; the activeness of the economy and industry conditions and the science and technology conditions was moderate, and that of the critical capital conditions was relatively weak, with the resource and environmental conditions being the lowest. Hence, it can be seen that the activeness of the institutional and cultural conditions, the facilities and functions conditions and the economy and industry conditions performed better than other driving forces in the process of Chinese smart low-carbon city development, indicating that these three were the main dynamic types of smart low-carbon city construction and development. In particular:

(1) There were relatively great differences in the optimal approach degree of driving force utility between cities on the science and technology conditions, and the overall optimal approach degree was on the low side which showed a weak influence on smart low-carbon city development. For example, Beijing, ranking first, had an optimal approach degree just near 0.6 (0.566); Lhasa, taking second place, had an optimal approach degree less than 0.4 (0.36776); the optimal approach degree of the last city, Mile, was less than 0.01 (0.0099); and most cities' optimal approach degrees were found between 0.06 and 0.28.

(2) There were relatively small differences in the optimal approach degree of driving force utility between cities on the resource and environment conditions, and the overall optimal approach degree was also on the low side, showing a weak influence on smart low-carbon city development; however, it had a more significant difference in regional characteristics. For example, Shanghai, ranking first, had an optimal approach degree close to 0.4 (0.3996); Ningbo, taking second place, had an optimal approach degree just over 0.36 (0.3658); the optimal approach degree of the last city, Xinzheng, approximated 0.05 (0.045); and most sample cities' optimal approach degrees were found between 0.06 and 0.2.

(3) The difference in the optimal approach degree of driving force utility on the economy and industry conditions was less, and the overall optimal approach degree was at the medium level, suggesting a relatively strong impact on smart low-carbon city development. For example, the optimal approach degree of Shenzhen, ranking first, approximated 0.62 (0.619); Shanghai, taking second place, had an optimal approach degree close to 0.6 (0.598); the optimal approach degree of the last city, Jinchang, was near 0.06 (0.058); and most sample cities' optimal approach degrees were found between 0.1 and 0.28.

(4) The difference in the optimal approach degree of driving force utility on the facilities and functions conditions was relatively great, and the overall optimal approach degree was at the higher level, suggesting a significant impact on smart low-carbon city development. For example, the optimal

approach degree of Shenzhen, ranking first, approximated 0.8 (0.795); Shanghai, taking second place, had an optimal approach degree above 0.65 (0.658); the optimal approach degree of the last city, Qiqihar, was just over 0.11 (0.117); and most sample cities' optimal approach degrees were found between 0.18 and 0.44.

(5) There were great differences in the optimal approach degree of driving force utility between cities on the critical capital conditions, and the overall optimal approach degree was on the low side, which indicated a weak influence on smart low-carbon city development. For example, the optimal approach degree of Beijing, ranking first, approximated 0.8 (0.797); Shanghai, taking second place, had an optimal approach degree above 0.68 (0.68462); the optimal approach degree of the last city, Mile, was just over 0.01 (0.013); and most cities' optimal approach degrees were found between 0.06 and 0.26.

(6) The difference in the optimal approach degree of driving force utility on the institutional and cultural conditions was greater, and the overall optimal approach degree was at a higher level, which was influential for smart low-carbon city development. For example, the optimal approach degree of Beijing, ranking first, exceeded 0.86 (0.862); Shanghai, taking second place, had an optimal approach degree of more than 0.78 (0.78220); the optimal approach degree of the last city, Mile, was less than 0.12 (0.118); and most sample cities' optimal approach degrees were found between 0.2 and 0.6.

According to the value of the comprehensive optimal approach degree of driving force utility, by analyzing the operation s of the dynamic mechanism of smart low-carbon city development, a five-layer dynamic operation matrix on Chinese smart low-carbon city development can be derived (Table 5). From the matrix it can be seen that none of the sample cities has reached the status "Excellent" with regard to its comprehensive dynamics; the top two cities, Beijing and Shanghai, were only just reached the status "Good". The majority of sample cities' comprehensive dynamics were in the "Low" and "Poor" statuses, and only 44.12% of the samples exceeded the average value (0.199). Hence, the overall dynamics of Chinese smart low-carbon city development are still underpowered, and they performed poorly in promoting smart low-carbon city construction, and the operation status was relatively poor.

Table 4. The optimal approach degree of driving force utility (C^*) of sample cities.

City	C*	Rank	City	C*	Rank	City	C*	Rank
Beijing	0.479	1	Hohhot	0.166	44	Zhuhai	0.226	18
Tianjin	0.317	4	Taiyuan	0.206	25	Guilin	0.157	48
Shanghai	0.473	2	Zhengzhou	0.201	28	Liuzhou	0.124	59
Chongqing	0.311	5	Hefei	0.195	32	Hulunbuir	0.107	66
Shenyang	0.200	30	Nanchang	0.200	29	Qiqiha	0.121	62
Dalian	0.220	21	Changsha	0.213	23	Jilin	0.110	65
Qingdao	0.240	14	Guiyang	0.177	41	Jiyuan	0.103	67
Jinan	0.203	26	Kunming	0.175	43	Luoyang	0.135	55
Nanjing	0.267	11	Lanzhou	0.179	38	Jincheng	0.122	60
Hangzhou	0.279	9	Xining	0.152	49	Zhuzhou	0.140	52
Ningbo	0.306	6	Lhasa	0.211	24	Jinchang	0.113	64
Xiamen	0.216	22	Yinchuan	0.179	39	Yan'an	0.149	50
Guangzhou	0.283	8	Urumqi	0.138	53	Zunyi	0.122	61
Shenzhen	0.375	3	Langfang	0.237	16	Xianyang	0.143	51
Harbin	0.183	36	Qinhuangdao	0.162	46	Shizuishan	0.182	37
Changchun	0.197	31	Yantai	0.166	45	Karamay	0.202	27
Wuhan	0.262	12	Huaian	0.135	54	Kunshan	0.223	19
Chengdu	0.237	15	Yangzhou	0.185	35	Xinzheng	0.128	58
Xi'an	0.226	17	Nantong	0.192	33	Yining	0.131	57
Shijiazhuang	0.221	20	Suzhou	0.296	7	Korla	0.116	63
Fuzhou	0.178	40	Zhenjiang	0.189	34	Dunhuang	0.269	10
Haikou	0.175	42	Wenzhou	0.244	13	Mile	0.090	68
Nanning	0.160	47	Putian	0.134	56	-	-	-

Table 5. Dynamic operation level of smart low-carbon city development.

*C**	Level	Status	Main Cities
[0.75, 1.0]	First echelon	Excellent	-
[0.45, 0.75)	Second echelon	Good	Beijing, Shanghai
[0.3, 0.45)	Third echelon	Medium	Shenzhen, Tianjin, Chongqingm Ningbo
[0.15, 0.3)	Fourth echelon	Low	Suzhou, Guangzhou, Hangzhou, Dunhuang, Nanjing, Wuhan, Wenzhou, Qingdao, Chengdu, Langfang, Xi'an, Zhuhai, Kunshan, Shijiazhuang, Dalian, Xiamen, Changsha, Lhasa, Taiyuan, Jinan, Karamay, Zhengzhou, Nanchang, Shenyang, Changchun, Hefei, Nantong, Zhenjiang, Yangzhou, Harbin, Shizuishan, Lanzhou, Yinchuan, Fuzhou, Guiyang, Haikou, Kunming, Hohhot, Yaitai, Qinhuangdao, Nanning, Guilin, Xining
[0, 0.15)	Fifth echelon	Poor	Yan'an, Xianyang, Zhuzhou, Urumqi, Huaian, Luoyang, Putian, Yining, Xinzheng, Liuzhou, Jincheng, Zunyi, Qiqihar, Korla, Jinchang, Jilin, Hulunbuir, Jiyuan, Mile

3.2. Results of Regional Differences

According to the calculations, regional differences in the dynamic mechanism of Chinese smart low-carbon city development can be observed (Figure 1). In the northeastern and middle regions of China, the institutional and cultural conditions, the facilities and functions conditions and the economy and industry conditions were three main dynamic types in pushing smart low-carbon city construction, and the other three were influential only for a few cities. The overall optimal approach degrees were both on the low side; few cities showed a poor dynamic operation status, which indicated a limited effect on smart low-carbon city development. In the eastern region, the institutional and cultural conditions and the facilities and functions conditions were the two fundamental dynamic types, with great impact from the economy and industry conditions and the science and technology conditions. Most cities had a relatively good optimal approach degree, but there were great differences within this area, indicating a regional imbalance. In the western region, in addition to the top two key dynamics—the institutional and cultural conditions and the facilities and functions conditions—the driving and stimulating role of the science and technology conditions should also not be ignored. Although few cities showed a better dynamic operation status, the overall optimal approach degree remained low and its impact on facilitating smart low-carbon city development was weak. Hence, the level of the dynamic operation mechanism of China's smart low-carbon city development was distinct between different economic regions, and the overall dynamic operation status in the eastern region was significantly better than that of the other three economic regions. Generally, the better the regional foundation and economic and social development, the better the comprehensive dynamic operation status and the higher the cities rank, which indicates a diminishing spatial change law from the east to the west and differences within regions (Figure 2).

3.3. Results of City Type Differences

3.3.1. Differences in City Scale

Based on the calculated results, the urban scale differences in the dynamic mechanism of Chinese smart low-carbon city development can be investigated (Figure 1). For the supercities, the most powerful driving forces included the institutional and cultural conditions, the critical capital conditions and the facilities and functions conditions; furthermore, the overall optimal approach degree performed better which suggests a strong development dynamic. However, the operation status had not reached the level "Excellent", and still has some room for improvement. For the megacities, the top two dynamic types were the institutional and cultural conditions and the facilities and functions conditions, while the economy and industry conditions and the critical capital conditions also played an important role. However, the overall optimal approach degree was on the low side, indicating a great potential for future development. For the big cities, the two foremost impetuses were still the institutional and cultural conditions and the facilities and functions conditions; at the same time, the economy and industry conditions, the resource and environment conditions and the science and technology conditions have begun to expand their influence. However, the overall optimal approach degree was lower, suggesting a further enhancement of these dynamics on smart low-carbon city development. For the medium-sized cities, besides the fundamental dynamic types of the institutional and cultural conditions and the facilities and functions conditions, the stimulating role of the resource and environmental conditions and the economy and industry conditions should also be noticeable. Nonetheless, the overall optimal approach degrees of most medium-sized cities were low and greater effort should be made to improve and strengthen their influence. For the small cities, the impact from the institutional and cultural conditions and the facilities and functions conditions decreased slightly, while the support from the science and technology conditions and the pressure from the resource and environmental conditions became more important. The overall optimal approach degree was low, which suggest room for great enhancement and improvement. Hence, the level of the dynamic operation mechanism of China's smart low-carbon city development was divergent at different urban scales, and the bigger the city size and the better the development foundation, the higher the overall optimal approach degree and its ranking, showing a decreasing urban scale change law from the big to the small and differences within each scale as well as a descending administration hierarchy change law from the high to the low and differences within each scale (Figure 2).

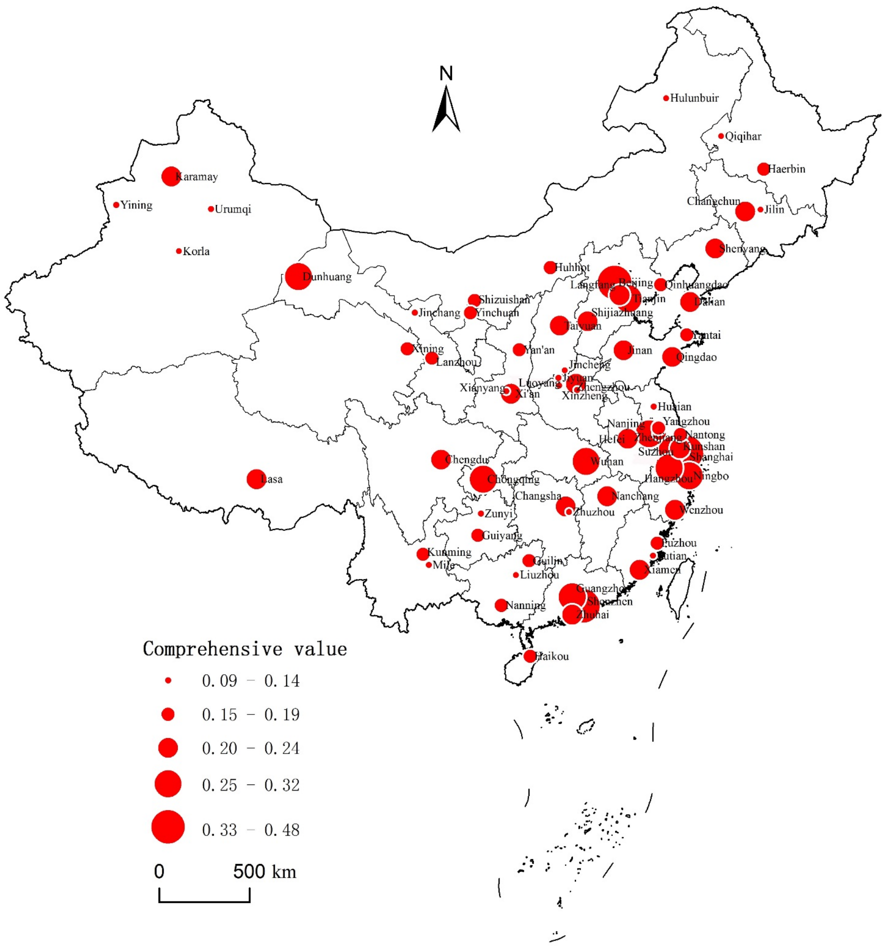
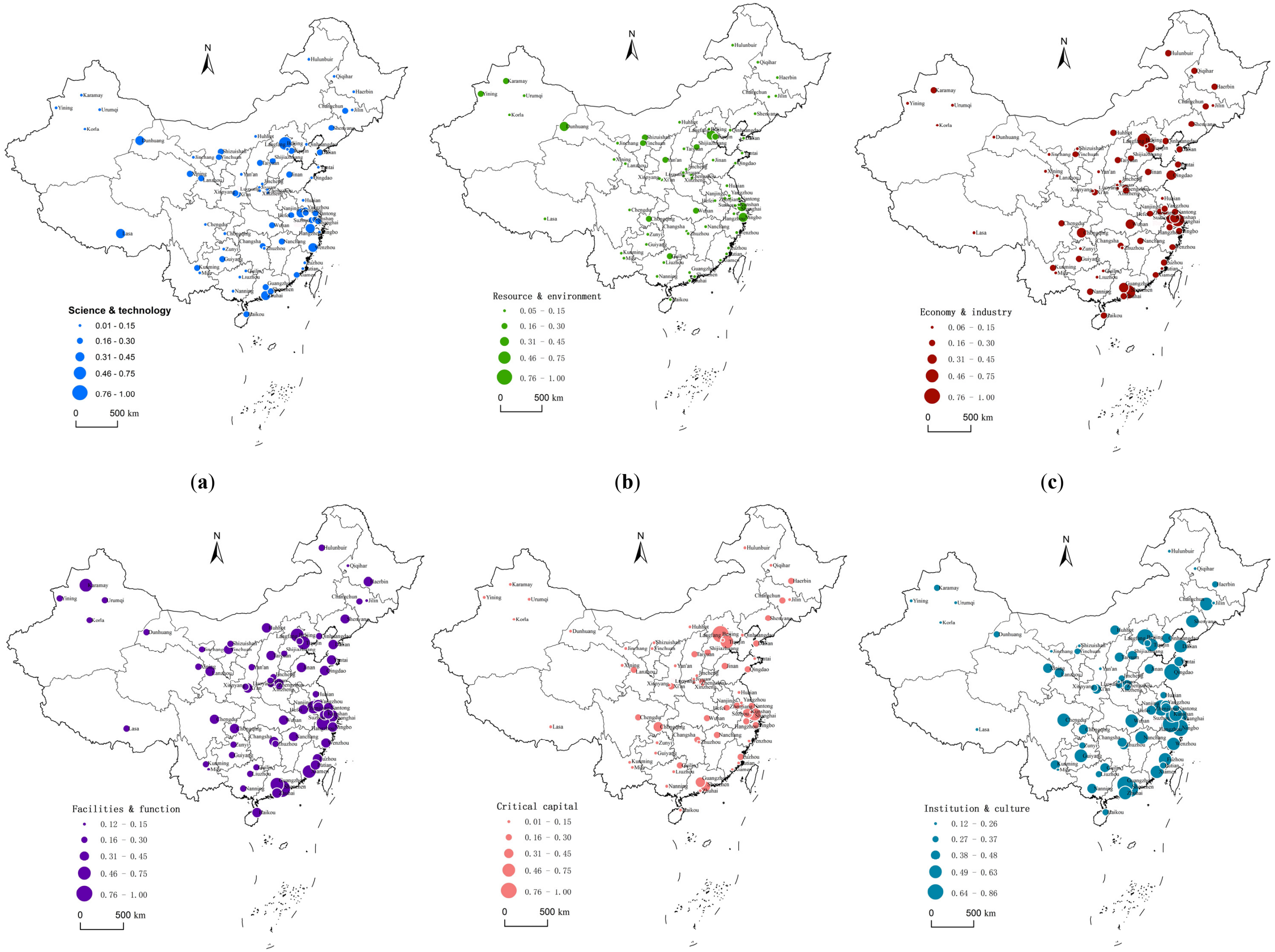


Figure 1. The optimal approach degree of driving force utility of smart low-carbon city.



(**a**) (**b**) (**c**)

(**d**) (**e**) (**f**)

Figure 2. The optimal approach degree of different kinds of driving force utility of smart low-carbon cities: (**a**) Science and technology; (**b**) resource and environment; (**c**) economy and industry; (**d**) facilities and functions; (**e**) critical capital; and (**f**) institution and culture.

3.3.2. Differences on Administrative Division

On the basis of the calculated results, the administration hierarchy differences in the dynamic mechanism of Chinese smart low-carbon city development can be explored (Figure 1). For the municipalities, the foremost dynamics included the institutional and cultural conditions and the critical capital conditions, with a better overall optimal approach degree that strongly propelled the development of smart low-carbon cities. For the sub-provincial cities, the leading dynamics were the institutional and cultural conditions and the facilities and functions conditions, while the economy and industry conditions and the science and technology conditions also played an important role. However, the overall optimal approach degree did not reach the medium level and the expected promoting effect has not been brought into full play. For the other capital cities, the major dynamic types were the institutional and cultural conditions and the facilities and functions conditions. Meanwhile, the economy and industry conditions and the science and technology conditions gradually stepped into the top of the list. However, the overall optimal approach degree was at a lower level that showed a weaker influence on smart low-carbon city development. For the prefecture-level cities, besides the two basic dynamics of the institutional and cultural conditions and the facilities and functions conditions, the resource and environmental conditions and the science and technology conditions should also be noticeable. However, the overall optimal approach degree performed poorly and suggested little impact on pushing smart low-carbon city development forward. For the county-level cities, in addition to the traditional two main dynamics of the institutional and cultural conditions and the facilities and functions conditions, the influences of the resource and environmental conditions and the economy and industry conditions have also gained significance. Nonetheless, the overall optimal approach degree was no doubt the lowest and the dynamic operation status was poor, requiring the most effort to upgrade in the future. Hence, the level of the dynamic operation mechanism of China's smart low-carbon city development was different in accordance with the administration hierarchy. On the whole, the higher the city's administration level, the more sufficient its dynamics and the better its comprehensive dynamic operation status, suggesting a descending administration hierarchy change law from the high to the low and differences within each level (Figure 2).

4. Conclusions and Discussion

On the basis of the above quantitative studies, it can be concluded that the development of Chinese smart low-carbon cities was affected by six major driving forces and the coupling interactions between them. In general, the integrated mechanism can be expressed as follows: the development of the smart low-carbon city is affected by internal and external factors. On the one hand, the interaction of science and technology innovation and the low-carbon economy is the internal core driving force, environmental change and resource depletion pressure are the inherent fundamental driving forces, and economic and financial development and industrial structure growth are the internal foundations. On the other hand, the optimization and upgrading of urban functions and development transformation are the external preconditions, the high quality human capital and adequate financing capital are the key external driving forces, and the socio-cultural environment and institutional reform and innovation are the important external supports. As a non-equilibrium dynamic system, the general rules for smart low-carbon city development are: it rises rapidly with the core of the interactive innovation, progress and application between science and technology and the low-carbon economy, and is driven gradually by institution innovation and reform, high quality human capital, adequate supply of capital and social, cultural and environmental improvement. Then, it steps into the mature stage where the wealth generation and creating capacity based on science and technology innovation are the powerful internal driving forces, which is indeed a non-linear, spiral, integrated, continuous dynamic system chain driven by layers of interlocking partial circularity. Overall, the quantitative measurement results suggest that: (1) the three major dynamics in China's smart low-carbon city development are institutional and cultural conditions, facilities and functions conditions, and economy and industry conditions, though the overall optimal approach degree of driving force utility is relatively low, indicating a not-fully-played effect of promotion and facilitation; (2) the level of the dynamic operation mechanism of China's smart low-carbon city development is distinct between different economic regions, indicating a diminishing spatial change law from the east to the west and differences within regions; (3) the imbalance of the comprehensive dynamic mechanism and the operation status between China's smart low-carbon city is more prominent, showing a decreasing urban scale change law from the big to the small and differences within each scale, as well as a descending administration hierarchy change law from the high to the low and differences within each class.

Meanwhile, according to the main driving forces and their influence in the quantitative dynamic mechanism analysis, seven basic development patterns can be obtained (Table 6): (1) The internal strong mode (IS) which means all the top three driving forces of the smart low-carbon city are internal elements, indicating a strong endogenous motivation; (2) the external strong mode (ES) which means all the top three driving forces of the smart low-carbon city are external elements, indicating a strong exogenous motivation; (3) the both strong mode (BS) which shows the top two driving forces of the smart low-carbon city are internal and external elements with higher value, indicating strong endogenous and exogenous motivations; (4) the internal strong/external weak mode (ISEW) which indicates that in the top three driving forces of the smart low-carbon city, the top two are internal elements and the third one is an external element, indicating strong endogenous but weak exogenous motivation; (5) the external strong/internal weak mode (ESIW) which suggests that in the top three driving forces of the smart low-carbon city, the top two are external elements and the third one is an internal element, indicating strong exogenous but weak endogenous motivation; (6) the both weak (BW) mode which means the top two driving forces of the smart low-carbon city are internal and external elements with lower value, indicating weak endogenous and exogenous motivations; (7) the balance steady mode (BaS) which shows the top two driving forces of the smart low-carbon city are internal and external elements with medium value, indicating a relatively balanced impact of endogenous and exogenous motivations. While the internal strong mode includes type I with a better overall optimal approach degree and type II with a lower overall optimal approach degree, the external strong mode also contains type I with a better overall optimal approach degree and type II with a lower overall optimal approach degree, and the balance steady mode has both strong BaS and weak BaS. In this study, five modes appear in the samples where 38 of them are the ESIW mode, six of them are the ES II mode and one is the ES I mode (Shanghai), seven of them are the BW mode, 14 of them are the weak BaS mode and two are the strong BaS mode (Suzhou and Kunshan). Consequently, most Chinese smart low-carbon cities belong to the external strong/internal weak mode, some of them belong to the weak balance steady mode, and few of them belong to the strong balance steady mode. The institutional and cultural factors led by the government are the main content and path of the development patterns. In other words, the main development pattern of China's smart low-carbon cities at present is driven by external factors and it basically matches with the cities' development realities and stages.

In summary, this paper reveals five basic characteristics of Chinese smart low-carbon city development: First, the relevance of urban scale and the dynamic development mode is limited. Second, regional differences in the development mode are more obvious. Third, the fundamental mode is mainly driven by external factors. Fourth, there are some differences in the nature of the dynamic modes. Last, the development is definitely in its early infancy and large-scale construction is on the way. Therefore, considering the current status of Chinese smart low-carbon city development and its future progress, general policy recommendations and countermeasures of optimization and improvement are proposed: (1) actively encourage scientific and technological innovation and expand the application of appropriate smart low-carbon technologies to advance the pace of smart low-carbon industries and improve industrial chain efficiency; (2) focus on promoting industrial upgrading and propel the formation of a smart low-carbon industrial system, while strengthening the capability of financial services to ensure the material foundations for smart low-carbon city development; (3)

improve the ecological environment continuously and realize the urban spatial optimization through appropriate policies and practical measures to protect the basis of smart low-carbon cities; (4) accelerate infrastructure construction and improve all kinds of urban services and functions, such as ah smart transportation, a green energy supply system, a smart disaster prevention and mitigation system and a smart governance system; (5) guide the promotion of the smart low-carbon concept and establish the cultural value of smart low-carbon development while completing and improving relevant policies such as economic policy, land policy, innovation policy, industry policy and human capital introduction policy and systems to ensure the long-term development of smart low-carbon cities.

Table 6. Main development patterns of smart low-carbon city in China pertaining to the following modes: internal strong (IS); external strong (ES); both strong (BS); internal strong/external weak (ISEW); external strong/internal weak mode (ESIW); both weak (BW); balance steady (BaS).

City	Pattern	City	Pattern	City	Pattern	City	Pattern
Beijing	ESIW	Chengdu	ES II	Yinchuan	ESIW	Jilin	Weak BaS
Tianjin	ES II	Xi'an	ES II	Urumqi	Weak BaS	Jiyuan	Weak BaS
Shanghai	ES I	Shijiazhuang	Weak BaS	Langfang	Weak BaS	Luoyang	ESIW
Chongqing	ES II	Fuzhou	ESIW	Qinhuangdao	ESIW	Jincheng	ESIW
Shenyang	ESIW	Haikou	Weak BaS	Yantai	ESIW	Zhuzhou	ESIW
Dalian	ES II	Nanning	ESIW	Huaian	Weak BaS	Jinchang	Weak BaS
Qingdao	ESIW	Hohhot	ESIW	Yangzhou	ESIW	Yan'an	BW
Jinan	ESIW	Taiyuan	ESIW	Nantong	Weak BaS	Zunyi	Weak BaS
Nanjing	ESIW	Zhengzhou	ESIW	Suzhou	Strong BaS	Xianyang	ESIW
Hangzhou	ESIW	Hefei	ES II	Zhenjiang	ESIW	Shizuishan	BW
Ningbo	ESIW	Nanchang	ESIW	Wenzhou	ESIW	Karamay	ESIW
Xiamen	ESIW	Changsha	Weak BaS	Putian	ESIW	Kunshan	Strong BaS
Guangzhou	ESIW	Guiyang	ESIW	Zhuhai	ESIW	Xinzheng	ESIW
Shenzhen	ESIW	Kunming	ESIW	Guilin	ESIW	Yining	Weak BaS
Harbin	Weak BaS	Lanzhou	ESIW	Liuzhou	ESIW	Korla	Weak BaS
Changchun	ESIW	Xining	ESIW	Hulunbuir	BW	Dunhuang	BW
Wuhan	ESIW	Lhasa	BW	Qiqihar	BW	Mile	BW

Smart low-carbon city development and construction is an important part of China's new-type urbanization strategy, as well as a novel pattern of China's urban modernization, which calls for progressive and comprehensive realization. Therefore, the main steps of the corresponding optimization should include the following: First, through the diagnosis of the practical foundation of smart low-carbon city development, including the analysis of natural conditions, resources and location advantages, the total amount of the economy, industry structure, the distribution and total amount of key capitals, and institutional and cultural ambience, *etc.*, the city can propose the preliminary development vision. Second, by identifying the relevant elements of smart low-carbon city development, including the factors of production, related industrial and facilities conditions, market demand, development of competitiveness and external opportunities and challenges, analyze and determine whether the proposed vision is consistent with the city's own capability. Third, based on the above work, the orientation and position of the city can be settled and clarified, including the core contents, main paths and direction. Finally, according to scientific and rational proposals and planning, the city can start its sequential construction and take appropriate corrective measures in a timely manner according to the actual situation changes to ensure the correctness of the development direction.

In this paper, 68 typical smart low-carbon cities are considered for quantitative research to analyze the dynamic mechanism of Chinese smart low-carbon city development, from which the basic development patterns and the further optimization countermeasures are put forward. Since the research is a novel design and investigation, there are inevitably some shortages. Therefore, further study should be taken to complete and perfect the index system and method and to improve the quantitative research framework to identify the features and development rules of Chinese smart low-carbon city development, and widely expand its range of applicability and good operability.

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Appendix

Table A1. The optimal approach degree of driving force utility outcomes of sample cities.

City	Science and Technology	Resource and Environment	Economy and Industry	Facilities and Function	Critical Capital	Institution and Culture	Comprehensive Value
Beijing	0.566	0.090	0.499	0.542	0.797	0.862	0.479
Shanghai	0.219	0.400	0.598	0.658	0.685	0.782	0.473
Shenzhen	0.255	0.070	0.619	0.795	0.421	0.774	0.375
Tianjin	0.230	0.173	0.371	0.469	0.462	0.525	0.317
Chongqing	0.077	0.289	0.333	0.351	0.447	0.421	0.311
Ningbo	0.144	0.366	0.223	0.436	0.198	0.743	0.306
Suzhou	0.261	0.119	0.443	0.443	0.333	0.531	0.296
Guangzhou	0.201	0.081	0.417	0.459	0.302	0.744	0.283
Hangzhou	0.302	0.094	0.273	0.497	0.283	0.733	0.279
Dunhuang	0.305	0.339	0.069	0.212	0.044	0.367	0.269
Nanjing	0.303	0.082	0.270	0.470	0.263	0.667	0.267
Wuhan	0.266	0.152	0.322	0.428	0.237	0.593	0.262
Wenzhou	0.334	0.144	0.159	0.364	0.122	0.509	0.244
Qingdao	0.148	0.099	0.354	0.378	0.201	0.721	0.240
Chengdu	0.132	0.112	0.284	0.344	0.296	0.596	0.237
Langfang	0.079	0.334	0.128	0.295	0.080	0.353	0.237
Xi'an	0.249	0.102	0.217	0.349	0.260	0.442	0.226
Zhuhai	0.308	0.051	0.197	0.388	0.144	0.558	0.226
Kunshan	0.222	0.052	0.368	0.356	0.130	0.520	0.223
Shijiazhuang	0.217	0.245	0.171	0.258	0.156	0.380	0.221
Dalian	0.176	0.100	0.219	0.384	0.261	0.626	0.220
Xiamen	0.189	0.067	0.243	0.491	0.149	0.573	0.216
Changsha	0.233	0.104	0.245	0.364	0.203	0.385	0.213
Lhasa	0.368	0.064	0.095	0.197	0.075	0.224	0.211
Taiyuan	0.242	0.111	0.193	0.351	0.169	0.448	0.206
Jinan	0.201	0.118	0.212	0.339	0.191	0.476	0.203
Karamay	0.136	0.219	0.171	0.457	0.069	0.312	0.202
Zhengzhou	0.143	0.108	0.298	0.325	0.172	0.454	0.201
Nanchang	0.187	0.092	0.244	0.300	0.197	0.538	0.200
Shenyang	0.181	0.100	0.234	0.308	0.176	0.535	0.200
Changchun	0.199	0.097	0.187	0.300	0.177	0.597	0.197
Hefei	0.179	0.109	0.196	0.314	0.220	0.408	0.195
Nantong	0.174	0.119	0.236	0.358	0.154	0.338	0.192
Zhenjiang	0.192	0.081	0.245	0.330	0.149	0.401	0.189
Yangzhou	0.195	0.078	0.191	0.377	0.111	0.450	0.185
Haerbin	0.124	0.145	0.226	0.311	0.151	0.371	0.183
Shizuishan	0.257	0.177	0.121	0.192	0.034	0.200	0.182
Lanzhou	0.200	0.126	0.106	0.320	0.160	0.385	0.179
Yinchuan	0.184	0.164	0.181	0.322	0.068	0.302	0.179
Fuzhou	0.119	0.088	0.175	0.360	0.171	0.505	0.178
Guiyang	0.163	0.097	0.195	0.295	0.124	0.557	0.177
Haikou	0.208	0.074	0.164	0.350	0.118	0.354	0.175
Kunming	0.170	0.094	0.214	0.275	0.149	0.417	0.175
Huhhot	0.143	0.112	0.171	0.301	0.147	0.395	0.166
Yantai	0.080	0.080	0.219	0.322	0.143	0.455	0.166
Qinhuangdao	0.087	0.132	0.181	0.287	0.139	0.415	0.162
Nanning	0.128	0.115	0.152	0.295	0.117	0.448	0.160
Guilin	0.099	0.155	0.112	0.202	0.158	0.450	0.157
Xining	0.177	0.123	0.069	0.240	0.104	0.383	0.152
Yan'an	0.018	0.222	0.129	0.164	0.059	0.199	0.149
Xianyang	0.155	0.093	0.138	0.234	0.111	0.325	0.143
Zhuzhou	0.088	0.078	0.137	0.287	0.127	0.392	0.140
Urumqi	0.135	0.123	0.144	0.233	0.069	0.260	0.138
Huaian	0.113	0.100	0.144	0.272	0.087	0.280	0.135
Luoyang	0.086	0.115	0.112	0.275	0.099	0.314	0.135
Putian	0.085	0.066	0.130	0.346	0.064	0.270	0.134
Yining	0.030	0.173	0.139	0.198	0.023	0.182	0.131
Xinzheng	0.090	0.045	0.205	0.217	0.040	0.347	0.128
Liuzhou	0.077	0.103	0.077	0.244	0.082	0.368	0.124
Jincheng	0.096	0.099	0.107	0.201	0.090	0.341	0.122
Zunyi	0.087	0.122	0.140	0.154	0.072	0.283	0.122
Qiqihar	0.073	0.127	0.161	0.117	0.071	0.261	0.121
Korla	0.029	0.139	0.148	0.160	0.065	0.176	0.116
Jinchang	0.137	0.104	0.058	0.172	0.083	0.205	0.113
Jilin	0.110	0.103	0.128	0.149	0.064	0.183	0.110
Hulunbuir	0.039	0.102	0.154	0.207	0.043	0.146	0.107
Jiyuan	0.067	0.105	0.098	0.196	0.039	0.236	0.103
Mile	0.010	0.125	0.077	0.134	0.013	0.118	0.090

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