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Article

Measuring and Analysis of Urban Competitiveness of Chinese Provincial Capitals in 2010 under the Constraints of Major Function-Oriented Zoning Utilizing Spatial Analysis

Qingyun Du [1,2], Yanxia Wang [1,2], Fu Ren [1,2,*], Zhiyuan Zhao [3], Hongqiang Liu [3], Chao Wu [1,2], Langjiao Li [1,2] and Yiran Shen [1,2]

[1] School of Resource and Environmental Science, Wuhan University, 129 Luoyu Road, Wuhan 430079, China; E-Mails: wangwangyanxia@163.com (Y.W.); hw1992@163.com (C.W.); lilangjiao299@163.com (L.L.); yiranshen_whu@163.com (Y.S.)

[2] Key Laboratory of GIS, Ministry of Education, Wuhan University, 129 Luoyu Road, Wuhan 430079, China; E-Mail: qydu@whu.edu.cn (Q.D.)

[3] State Key Laboratory of Information Engineering in Surveying, Mapping, and Remote Sensing, Wuhan University, 129 Luoyu Road, Wuhan 430079, China; E-Mails: zhaozhiyuan2012@gmail.com (Z.Z.); u-liuhongqiang@163.com (H.L.)

* Author to whom correspondence should be addressed; E-Mail: renfu@whu.edu.cn; Tel.: +86-27-8766-4557; Fax: +86-27-6877-8893.

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Abstract: Urban competitiveness aids local development by encouraging the exploitation of opportunities for economic development and by enhancing overall performance. Previous studies have evaluated urban competitiveness primarily from an economic perspective and few studies have considered locational conditions as factors that might influence local industrialization and urbanization. In response to the publishing of a national plan for the development of major function-oriented zones (MFOZs) in 2010, the present essay employs MFOZs as constraints to enable a balanced and comprehensive study of urban competitiveness that includes four dimensions of competitiveness: Economic, social-cultural, environmental, and locational (accessibility and hypsography). A four-level hierarchical indicator system and an entropy weighting method were used to assess the urban competitiveness of 31 Chinese provincial capitals based on a spatial analysis of data acquired in 2010 using Geographic Information System technology. The results reveal the overall ranking of provincial capitals in terms of urban competitiveness and their performances with respect to the four dimensions of competitiveness. Unlike previous studies, this analysis was performed by overlaying the strategy of the national MFOZ with the urban competitiveness rankings. The development orientation of each provincial city is discussed according to its characteristics of urban competitiveness under the conditions of a MFOZ.

Keywords: urban competitiveness; major function-oriented zoning; entropy weighting; accessibility; China

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1. Introduction

China is a hierarchically administered country in which the top administrative level is the central government (the State Council), and the lower administrative levels consist of provincial, city, county, and town/township governments [1]. However, as fiscal and economic administration has gradually become more decentralized during the Reform and Opening period, urban governments have played an increasingly prominent role in local development and have enjoyed some autonomy in resource allocation, urban planning, and economic policy [2]. At the same time, several cities face developmental problems involving economic decline, social instability, and/or environmental and infrastructural issues that have accompanied economic globalization [3]. Consequently, the study of cities and of urban competitiveness has become increasingly important, as cities must compete for foreign investment, national projects, strategic preferential policies, *etc.*, to enhance their development prospects.

Urban competitiveness is the ability to attract factors, utilize environment, develop industry, produce products, provide service, capture the market, and create the largest fortunes in a fast, effective manner and supply welfare to citizens in the process of competition, cooperation and development in comparison with other cities [4]. Various analytical approaches to urban competitiveness, such as the urban competitiveness measurement model [5–7]—which includes an indicator system [8,9] and a weighting method [10]—have been used to evaluate urban competitiveness indices [11,12] and urban competitiveness rankings [13]. The Diamond of National Advantage has been one of the most popular models of competitiveness studies since it was put forward by Porter in 1990. Porter believed that a nation's competitiveness depended upon the capacity of its industry to innovate and upgrade and that in terms of industry, national competitiveness was affected by the four attributes that comprise the diamond (as a system)—factor conditions, demand conditions, related and supporting industries, and firm strategy, structure, and rivalry. In addition, challenges and governments indirectly affect national competitiveness through the four attributes [14]. Although the diamond model bridges the macroscopic and microscopic competitiveness, it is not appropriate for urban competitiveness because industrial competitiveness is only one important component of urban competitiveness, which includes other factors, such as environmental competitiveness. To quantify urban competitiveness, Kresl introduced a method for calculating urban competitiveness rankings based on the growth of manufacturing value added, retail sales, and business services' receipts. The method includes a model consisting of economic determinants (composed of factors of production, infrastructure, location, economic structure, and urban amenities) and strategic determinants (composed of governmental effectiveness, urban strategy, public-private sector cooperation, and institutional flexibility) to explain urban competitiveness [15]. As the nation state becomes more open to capital and trade flows, urban regions become more exposed to global forces, *i.e.*, cities must address the threat of rapid changes in capital and trade markets and embrace the opportunity of having a wider scope to develop their own competitiveness strategies and access to world markets, global labor, and capital. At the World Bank Course "Towards a Methodology for Conducting City Development Strategies" 2000, Douglas Webster proposed four assessment categories—economic structure, territorial endowment, human resources, and institutional milieu—for urban competitiveness [16]. The Douglas Webster urban competitiveness model considers the effects from human resources and institutional milieu. Furthermore, Ni and Kresl used factor environment, industry system and value profits jointly to determine urban competitiveness of the global 500 cities [4]. Unfortunately, most of these models and methods neglect cultural activities and environmental hospitableness, which are becoming more important to urban competitiveness.

In addition, a substantial amount of research on urban competitiveness has focused on Western countries and/or global metropolitan centers [5,12,17–23]. Thus, only a limited volume of research has focused on the competitiveness of rapidly changing cities in emerging economies—for example, in cities in China and India—that are potential locations for investment and important centers of international political, economic, and cultural activities [2,6,24,25]. Notably, China ranked 27th in 2010–2011 in the global competitiveness index [26]. Unfortunately, most models employed in the literature evaluate urban competitiveness based on a weighted means of indicators (*i.e.*, statistical data or attribute data for a given city) rather than from a spatial perspective. Furthermore, a national plan (2010–2020) for the development of major function-oriented zones (MFOZs) was published by the State Council in 2010. This plan is a spatial pattern planning of territorial development to 2020 and serves as a guideline for the creation of national, regional, and urban development policies [27]. Thus, the urban competitiveness in China must be studied under the constraints of major function-oriented zoning from the perspective of spatial analysis and sustainable development so that the policy makers and governments can formulate urban development polices and allocate the corresponding resources.

In China, there are four municipalities directly under the central government as well as 23 provinces, five autonomous regions, and two special administrative regions. The four municipalities are Beijing, Shanghai, Tianjin, and Chongqing. The 22 provincial capital cities in mainland China are Harbin, Changchun, Shenyang, Shijiazhuang, Lanzhou, Xining, Xi'an, Zhengzhou, Jinan, Taiyuan, Hefei, Wuhan, Changsha, Nanjing, Chengdu, Guiyang, Kunming, Hangzhou, Nanchang, Guangzhou, Fuzhou, and Haikou. The five capital cities of autonomous regions are Huhhot, Nanning, Lhasa, Yinchuan, and Urumqi. The development of provincial capitals influences not only the city itself and the interior of their respective provinces but also the bordering provinces, the nation, and even the world (particularly cosmopolitan centers, such as Beijing and Shanghai) because of the central radiation effect in regional and national development. Hence, these 31 provincial capitals (four municipalities, 22 provincial capital cities, and five capital cities of autonomous regions) in mainland China are the study areas for urban competiveness in this paper. Taiwan, Hong Kong, and Macao are not included, because they utilize different administrative mechanism and economic system from the mainland provincial capitals.

The purpose of this paper is to provide a new evaluation and analysis of the urban competitiveness of provincial capitals from the perspective of sustainable development and spatial analysis, viewed as an aspect of urban performance [28,29]. On the basis of previous research, the evaluation employed in this study adds certain spatial data (e.g., accessibility, elevation, and slope) and many environmental indices accompanied by economic and social-cultural indices to calculate urban competitiveness according to the index system used to define MFOZs. In addition, this study utilizes hierarchical structure to establish its indicator system and the entropy method to determine weightings. Moreover, provincial capitals are analyzed in terms of the national MFOZ. As a result, this analysis improves upon previous studies that base analytical results exclusively on urban competitiveness evaluations.

The remainder of the paper is organized as follows. The next section introduces the meanings and categories of the major function zones. The third section uses previous studies to establish a four-level hierarchical indicator system under the guidance of MFOZs to benchmark urban competitiveness and introduces the weighting method utilized in this study. The fourth section describes the primary data on the cities studied and the spatial data processing methods utilized. The fifth section presents the results and discusses urban competitiveness under MFOZ constraints. A final section concludes the paper.

2. Major Function-Oriented Zones (MFOZs)

MFOZs are defined as areas in which certain products or services are produced according to the carrying capacity of resources and the environment, existing development intensity, and the development potential of a given area for planning population distribution, the geographic distribution of different economic sectors, and patterns of land use and urbanization [27,30]. The planning of MFOZs is based on a comprehensive evaluation of the suitability of territorial functions using an index system that consists of six indices related to environmental resources (*i.e.*, available land resources, available water resources, environmental capacity, ecological importance, and natural disaster potential), one index of population agglomeration, one index of economic development, and two indices related to development potential (*i.e.*, transport dominance and strategic selection) [31–33]; all of the indices are quantitative except for strategic selection. Therefore, evaluations of potential MFOZs can not only take into account the economic and social development of an area but can also consider the natural environment and limits to ensure sustainable development. Each MFOZ is divided into four categories—a development-optimized zone (DOZ), a development-prioritized zone (DPZ), a development-restricted zone (DRZ), and a development-prohibited zone (PDZ). These zones represent the different roles and functions in urbanization and industrialization, ecologically appropriate development, grain production, and the protection of natural and cultural heritage [34] (Table 1).

DOZs include the metropolitan regions in China, which have experienced the greatest economic development. These zones are central hubs for the broader regional economy and population, and they have experienced a significant degree of integration with the international economy. Thus, these areas exhibit optimal characteristics for the continued promotion of development and can serve as central axes for the ongoing improvement of national competitiveness in the global economy.

DPZs are areas intended to support regional development and to serve as components of metropolitan networks now or in the future. DPZs will develop into new centers of growth, leading national/regional development and becoming modern metropolitan areas through large-scale urbanization and industrialization.

DRZs include two types of areas: Major grain-producing zones and key ecological function zones. Major grain-producing zones are important for safeguarding the grain and meat supply of the country.

As a result, these areas will undergo the process of urbanization and industrialization under the conditions of conserving cultivated land and pasture land to ensure the country's ability to maintain agricultural production. Key ecological function zones are important for restoring ecosystems and safeguarding the ecological security of the country or a region. Hence, these areas will be allowed to undergo socio-economic development within the carrying capacity of local resources and ecosystems to maintain their ability to provide ecological services. Generally, only appropriate urbanization and industrialization suitable to local conditions will be undertaken in these zones to ensure sustainable development (while large-scale urbanization and industrialization are restricted).

PDZs are areas in which the development of urbanization and industrialization are strictly prohibited. These zones consist of natural or cultural sites with special value, natural habitats of rare endangered wild species, and representative natural ecosystems. These areas are often embedded within DOZs, DPZs, and/or DRZs.

Therefore, development and protection are combined together in MFOZs. For example, DOZs and DPZs are development-oriented areas with similar development potential but different development strategies, and DRZs and PDZs are protection-oriented areas with similar protection potential but different targets for protection and different levels of development permitted [35].

Furthermore, from an administrative perspective, major function zones can be divided into national and provincial levels. The national-level planning of MFOZs covers only approximately 40% of the total national territory, and the remaining territory is considered by each province individually at the provincial-level planning of MFOZs.

Table 1. The four major function-oriented zone categories.

Category	Characteristics	Major function
DOZ	Advanced economy; High population density; High development intensity; and Severe environmental and resource problems.	Providing industrial and service products
DPZ	Sufficient economic foundation; High resource and environmental carrying capacities; High development potential; and Attractive for developing populations and economies.	Providing industrial and service products
DRZ	Agricultural main production area: sufficient arable land and favorable conditions for agricultural development; and/or Key ecological function area: fragile ecosystem or important ecological function with a low resource and environmental carrying capacity.	Providing agricultural or ecological products
PDZ	Various natural resources and cultural preserves established by law; Industrial and urban development is prohibited; and/or Key ecological function area that is protected.	Providing ecological or cultural products

[a] Source: National planning of major function-oriented zones (2010–2020).

3. Methods

The concept of competitiveness has been increasingly applied over the past two decades and can be assessed at the national (national competitiveness), regional (regional competitiveness), and city (urban competitiveness) levels. Urban competitiveness is complex and multidimensional (including environment, industry development, services, welfare, *etc.*), and cannot be captured by a single indicator; thus, it is typically evaluated by multiple indicators. Generally, the degree of urban competitiveness is calculated by the following weighted average:

$$UC = \sum_{i=1}^{n} W_i I_i \quad (1 \le i \le n) \tag{1}$$

where n is the number of indicators, W_i is the weight of the ith indicator, and I_i is the value of the ith indictor. Therefore, determining the indicators and the weighting method are key to measuring urban competitiveness.

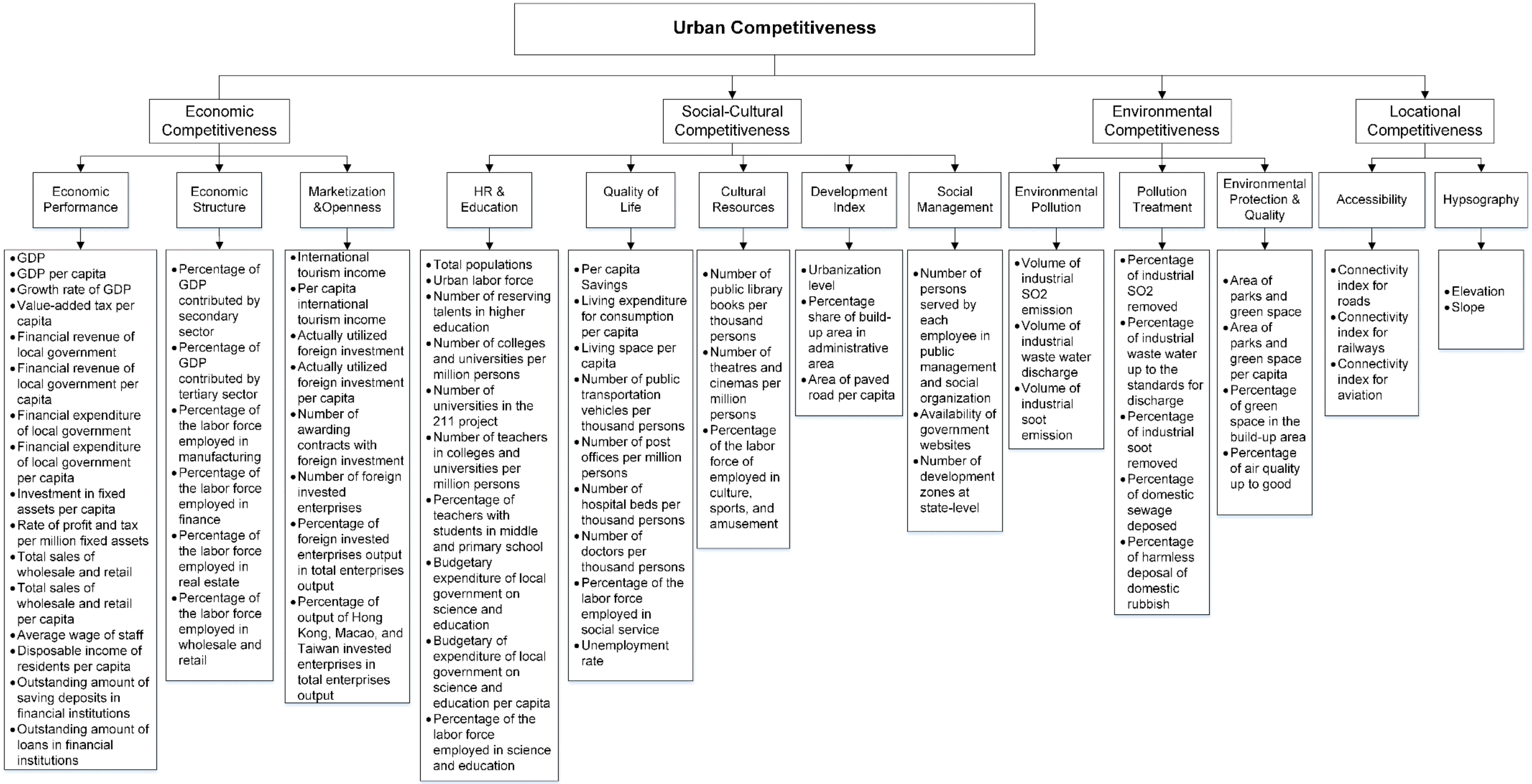
3.1. The Indicator System

Indicator systems employed in previous studies can be classified into simple arrangement, multi-hierarchy, and in-out models. Simple arrangement models typically utilize several indicators to capture urban competitiveness as a weighted sum [19,23]. A multi-hierarchy model employs several indicators and categorizes them in terms of similarity to form a multi-hierarchy structure of indicators. Weighted sums of the indicators are then calculated from the lowest level to the highest level to capture urban competitiveness [2,5,6,11]. In-out models adopt three categories of indicators—input factors, output factors, and outcome factors—to analyze urban competitiveness based on a linear weighted sum [12].

The hierarchical structure is one of the most widespread methods used to solve numerous ranking problems in different fields and is systematically used to represent the elements of a problem hierarchically [36]. In addition, a MFOZ is designated as an area with a specific primary function, which guides the planned development of this area through policies directing industrialization, investment, population distribution and land use practices to optimize the spatial distribution of development activities. That is to say, MFOZs will have an important influence on urban economic activity and development for the next several decades. Therefore, in this study, following previous literature [10,37], the overall competitiveness index system of the China Institute of City Competitiveness [38] and the index system of MFOZ, urban competitiveness are divided into multiple levels of interrelations and orderings to establish a four-level hierarchical system of indicators (Figure 1). In this system, urban competitiveness is in Level I, while Level II contains the four dimensions of urban competitiveness. These dimensions are then further broken down into several subgroups in Level III. The first dimension, Economic Competitiveness, consists of three subgroups: Economic Performance, Economic Structure, and Marketization & Openness. The second dimension, Social-Cultural Competitiveness, consists of five subgroups: Human Resources (HR) & Education, Quality of Life, Cultural Resources, Development Index, and Social Management. The third dimension, Environmental Competitiveness, consists of three subgroups: Environmental Pollution, Pollution Treatment, and Environmental Protection & Quality. The fourth dimension, Locational Competitiveness, consists of two subgroups: Accessibility and Hypsography. Level IV contains a total of 75 evaluative indicators that are members of each subgroup in Level III. For MFOZs, the social-cultural, environmental and locational advantages have an important influence on urban competitiveness in addition to economic advantages to promote sustainable development and national optimization.

As shown in Figure 1, the dimension of Economic Competitiveness is used to represent the economic development of a MFOZ and the city's own economic advantages. Economic Performance has 16 indicators, and Economic Structure has six indicators. Marketization & Openness has eight indicators. To represent the scale and average levels of local economies, relative indicators are used in addition to absolute indicators in assessing Economic Performance and Marketization & Openness. The dimension of Social-Cultural Competitiveness is used to represent the attraction level of population aggregation (in MFOZs) and the social-cultural advantage of a city. HR & Education has 10 indicators, of which the *number of universities in the 211 project* indicates the level of higher education in provincial capitals and the *number of reserve talents in higher education* represents the number of high-quality talents to be added in the near future. The 211 project is an important national development project for higher education that aims to strengthen approximately 100 universities and a group of key disciplines with respect to education quality, scientific research, management, educational efficiency, *etc.* Quality of Life has nine indicators on four levels: (a) *per capita savings*, the *percentage of the urban labor force employed in social services*, and the *unemployment rate*, which comprise the security level; (b) *living expenditure for consumption per capita*, which is the only indicator of the consumption level; (c) *living space per capita*, an index of comfort level; and (d) additional indicators that pertain to the service level of infrastructure and medical treatment. Cultural Resources, the Development Index, and Social Management each have three indicators. In this study, the *urbanization level* is the ratio of the urban population to the total population. *Availability of government websites* represents the level of E-Government services, and *number of development zones at state-level* indicates existing national preferential policies for provincial capitals. Because environmental-related factors are more than half of the factors in the category of a MFOZ (6/10), there are many indicators added in the dimension of Environmental Competitiveness: Environmental Pollution has three indicators of inverted sequence, Pollution Treatment has five indicators, and Environmental Protection & Quality has four indicators. One indicator of Environmental Protection & Quality is the *percentage of air quality up to good*, which is defined as the ratio of days per year with air quality measuring at least "good". In the dimension of Locational Competitiveness, Accessibility refers to traffic networks and the connectivity between cities, which is a component in the index system of MFOZs that represents development potential. The *connectivity index for roads*, the *connectivity index for railways* and the *connectivity for aviation* (in Level IV) represent urban accessibility in the provincial capitals. Hypsography refers to the relative elevations of different land areas, including *elevation* and *slope* (in Level IV), which are taken as the main variables for selecting available land resources in the evaluation of MFOZs [33]. *Elevation* and *slope* are used to represent the convenience of industrialization and urbanization. Therefore, the accessibility and hypsography of MFOZs are used to simply represent urban locational conditions because the geographic characteristics and accessibility of an area greatly influence its urban competitiveness and economic globalization potential [39].

Figure 1. Indicator system evaluating urban competitiveness.



3.2. Weighting Method

Many weighting methods can be used to evaluate composite indicators [36,40–42]. One popular weighting method in composite evaluations is the expert weighting system. However, this method is subjective and may lead to divergent results when different experts are invited to assign weights to indicators. To maintain the objectivity of research findings, many objective weighting methods can be utilized. According to previous studies, principal component analysis (PCA) can assign negative weights to indicators that should be positive [10]. Equal weighting (EW) accords equal weights to all indicators, which may be improper as, in reality, indicators used to evaluate urban competitiveness differ in their importance or usefulness. By contrast, information entropy can be a useful measure of the information content of data. If there are great differences in value among the items that compose an indicator, then the information entropy of the indicator is relatively small, *i.e.*, the indicator provides useful information and therefore should be weighted heavily [43]. Accordingly, we adopt the entropy method in this study to determine the weights of the indicator system used to evaluate urban competitiveness.

Suppose there are m evaluating objects and n indicators. Then, the indicators value matrix can be formed as:

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} = \{x_{ij}\}_{m\times n} (1 \le i \le m, 1 \le j \le n)$$

where x_{ij} is the value of the ith object of the jth indicator.

The dimensions of indicators typically differ from one another, which is not conducive to evaluation; thus, the original indicators' value matrix X should first be normalized. The normalized matrix is denoted by $R = \{r_{ij}\}_{m\times n}$ $(1 \le i \le m, 1 \le j \le n)$, where r_{ij} is the normalized value of the ith evaluating object of the jth indicator ($r_{ij} \epsilon [0, 100]$) and is calculated as follows:

$$r_{ij} = \begin{cases} (x_{ij} - \min_i\{x_{ij}\})/(\max_i\{x_{ij}\} - \min_i\{x_{ij}\}) \times 100, if\ x_{ij}\ is\ a\ positive\ index \\ (\max_i\{x_{ij}\} - x_{ij})/(\max_i\{x_{ij}\} - \min_i\{x_{ij}\}) \times 100, if\ x_{ij}\ is\ a\ negative\ index \end{cases} \quad (2)$$

The entropy value E_j $(1 \le j \le n)$ of the jth indicator can be calculated as:

$$E_j = -k \sum_{i=1}^{m} f_{ij} \ln f_{ij} \quad (3)$$

where $k = 1/\ln m$, $f_{ij} = r_{ij}/\sum_{i=1}^{m} r_{ij}$, and $f_{ij} \ln f_{ij} = 0$ if $f_{ij} = 0$.

The entropy weight W_j $(1 \le j \le n)$ of the jth indicator can then be defined as:

$$W_j = (1 - E_j)/(n - \sum_{j=1}^{n} E_j) \quad (4)$$

3.3. Integrated Assessment

A composite score related to an urban competitiveness index would appear to be a feasible way to convey the ranking of provincial capitals. First, each subgroup value for provincial capitals in Level III is calculated according to Equations (1)–(4), e.g., Economic Performance is calculated as $EC1 = \sum_{j1=1}^{n_{EC1}} W_{j1} r_{ij1}$, where n_{EC1} is the number of indicators in the category of Economic Performance, W_{j1} is the weight of the $j1$th indicator determined by the entropy method, and r_{ij1} is the normalized value of the ith provincial capital of the $j1$th indicator according to Equation (2). Next, Economic Competitiveness, Social-Cultural Competitiveness, Environmental Competitiveness, and Locational Competitiveness are evaluated similarly through a process of normalization, weight determination, and weighted sum calculation. Finally, urban competitiveness is assessed as a composite score via the entropy-weighted sum of Economic Competitiveness, Social-Cultural Competitiveness, Environmental Competitiveness, and Locational Competitiveness.

4. Materials and Experiments

4.1. Data Description

Based on the indicator system and the purpose of the study, the following data of each study city (containing both districts and counties) were collected:

(a) Statistical data: to obtain statistical indicator values for 2010, data were collected from the China City Statistical Yearbook of 2011 and the Statistical Yearbook of 2011 for each provincial capital.
(b) DEM data: to obtain elevation and slope data, Digital Elevation Models (DEMs) of provincial capitals with a spatial resolution of 30 m (2009) were downloaded from the International Scientific Data Service Platform.
(c) Traffic network data: national trunk highway system and railway network data were collected to calculate the *connectivity index for roads* and the *connectivity index for railways*, respectively. In addition, the flight information among the provincial capitals was collected from a travel website to calculate the *connectivity index of aviation*.
(d) MFOZ data: the National Planning of Major Function-Oriented Zones (2010–2020) was obtained to determine the major functions of provincial capitals.
(e) Auxiliary data: other data were collected to supplement the indicator values that could not be obtained from the data described above, including data from the Environmental State Bulletin of provincial capitals (2010), the Social and Development Bulletin of provincial capitals (2010), government websites, *etc.*

4.2. Accessibility Calculation

Accessibility measures connectivity and is defined as the ease with which activities can be reached from given locations using existing transport systems [44]. This index is typically measured by the shortest distance or the minimum time model [32], with the transport system frequently consisting of roads, railways, and aviation facilities. In the present study, all three connectivity indices were used to calculate Accessibility.

Based on previous studies [45], the shortest distances are used to represent the connectivity for roads or railways due to the collected data of national road and railway networks, *i.e.*,

$$L_i = \sum_{j=1}^{m} l_{ij} \tag{5}$$

where $l_{ij} = \min_k\{l_{ik} + l_{kj}\}$ (k=1, 2, …, m) represents the shortest distance between the ith city and the jth city, $l_{ii} = 0$, m is the number of evaluating objects, and L_i is the connectivity index. Thus, a larger connectivity index indicates poorer Accessibility. However, the minimum time is used to represent the connectivity for aviation due to the collected flight information of arrivals and departures. The calculation is the same as Equation (5) with the difference that l_{ij} represents the minimum time between the ith city and the jth city, and l_{ij} is assigned to plus 120 minutes to represent the mean waiting time if there is no direct flight between the two cities to maintain a lower value for direct flights with a stopover than for connecting flights.

To calculate Accessibility, traffic network data, which include information on national trunk roads, national railways, and flight information, were collected and processed (Figures 2 and 3). The *connectivity index for roads* and the *connectivity index for railways* were calculated based on national trunk road and national railway data according to Equation (5), and the connectivity index for aviation was similarly calculated based on the flight information (Table 2). Figure 4 shows the normalized connectivity indices calculated according to Equation (2). The *St_CI_road*, *St_CI_railway*, and *St_CI_aviation* are the *connectivity index for roads*, the *connectivity index for railways*, and the *connectivity index for aviation,* respectively. The provincial capitals in the middle have better accessibility in the country than those on the periphery. In particular, Zhengzhou has the highest connectivity convenience of roads and railways, and Xi'an has the highest connectivity convenience in terms of aviation. Urumqi has the lowest connectivity convenience of roads, and Lhasa has the lowest connectivity convenience of railways and aviation.

Figure 2. National road and railway network data on the scale of 1:4,000,000.

Figure 3. The flight information among provincial capitals.

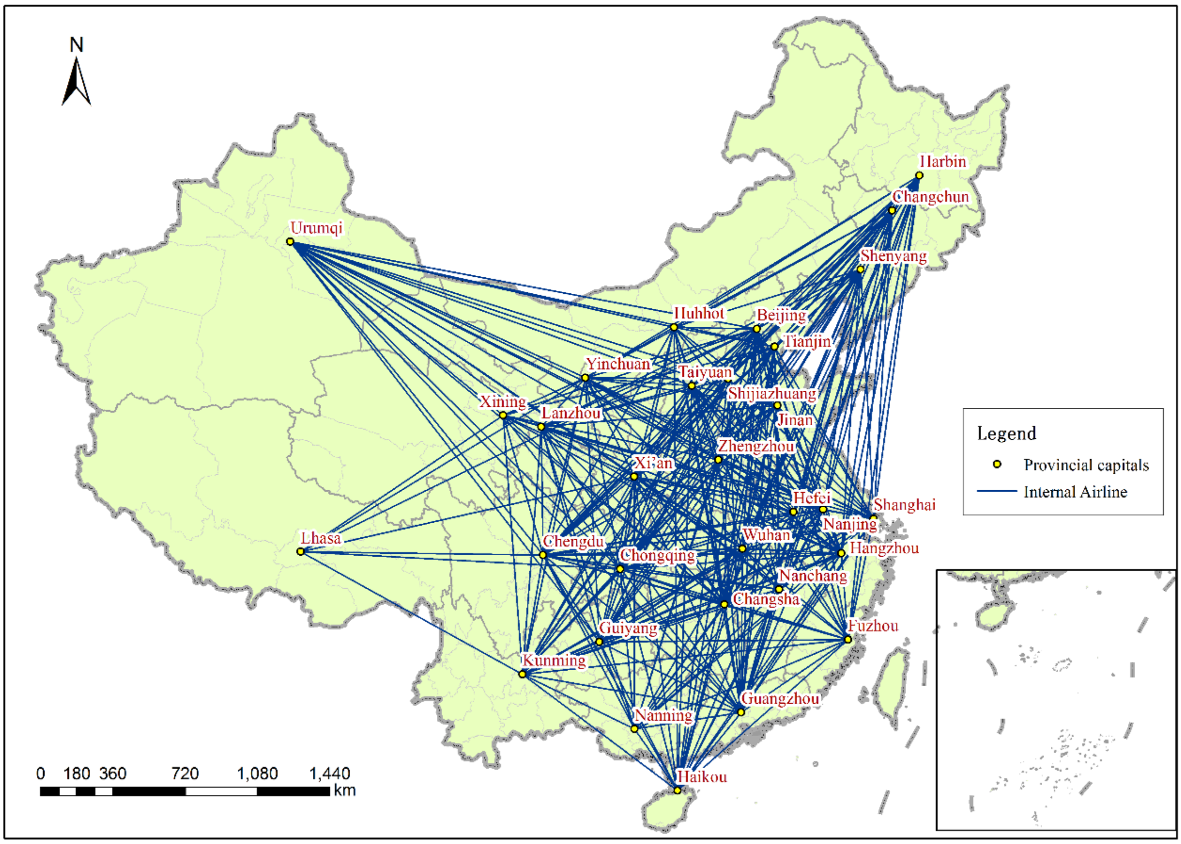


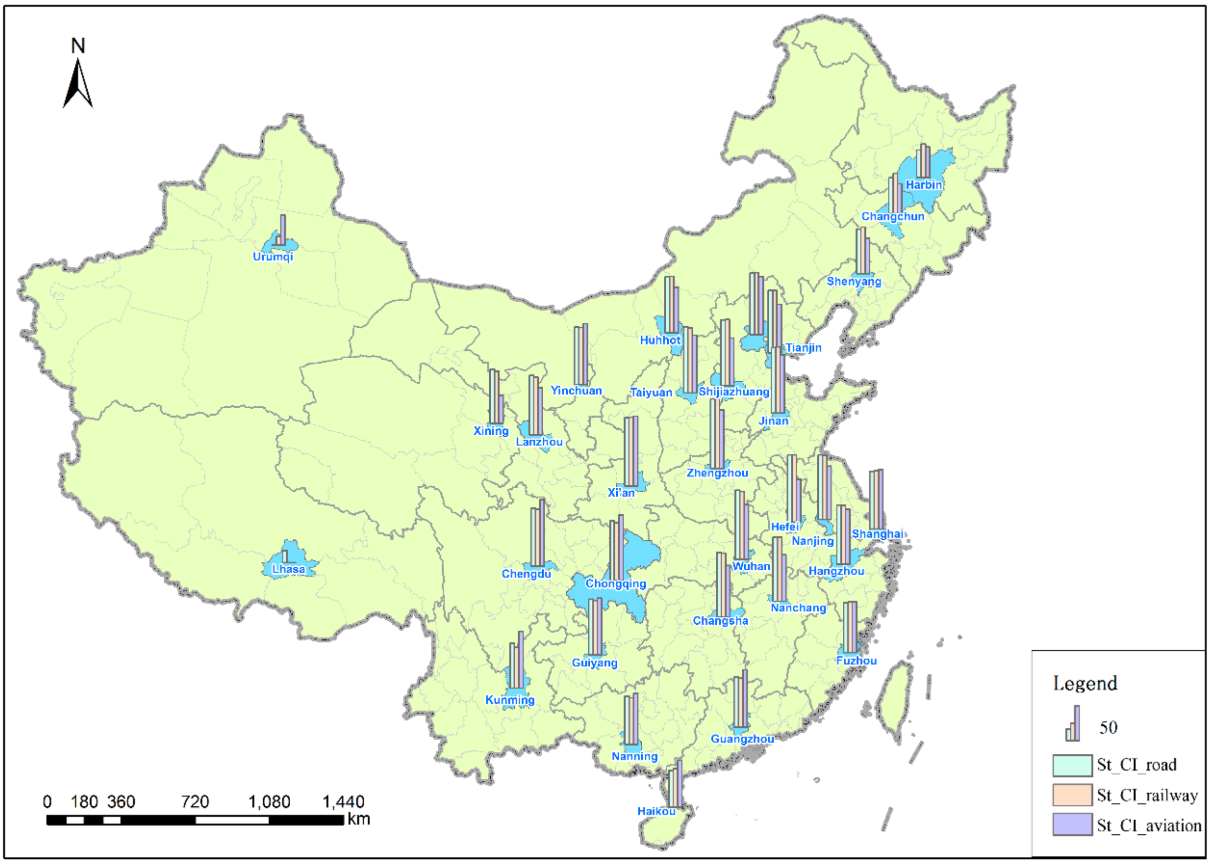
Table 2. The connectivity index for roads, railways, and aviation of provincial capitals.

Cities	Roads (km)	Railway (km)	Aviation (minute)
Beijing	42953	46321	4760
Tianjin	42214	45775	5905
Shijiazhuang	39383	41651	6025
Taiyuan	39086	43325	4770
Huthot	47726	51966	6280
Shenyang	57836	62315	7545
Changchun	65490	69049	8265
Harbin	72651	75936	8135
Shanghai	46579	50339	4565
Nanjing	40491	44124	5330
Hangzhou	45159	49567	5120
Hefei	38177	40919	6635
Fuzhou	53107	57991	5660
Nanchang	40689	44050	6190
Jinan	39658	41958	4715
Zhengzhou	35898	38147	4670
Wuhan	36252	39890	5115
Changsha	40605	44550	5580
Guangzhou	53127	59861	4850
Nanning	54751	62465	5620
Haikou	64682	70684	6115

Table 2. *Cont.*

Cities	Roads (km)	Railway (km)	Aviation (minute)
Chongqing	44613	50617	3845
Chengdu	46109	51452	3685
Guiyang	48154	54245	4905
Kunming	57554	68315	4895
Lhasa	86078	111000	11935
Xi'an	37336	39341	3295
Lanzhou	44814	50964	6100
Xining	49823	56542	8480
Yinchuan	46484.33	51389	4375
Urumqi	96704.78	101785	8185

Figure 4. Normalized connectivity index of provincial capitals.



4.3. Hypsography Calculation

Hypsography refers to the graphical representation of the earth's topological features above sea level, as on a map. China is well known for its vast territory and highly diverse hypsography. As a country's hypsography affects its population distribution, economic development, industrial scale, *etc.*, hypsography is an important factor in urban development. To assess urban competitiveness quantitatively, hypsography is calculated as the average elevation and average slope of a given area. Generally, cities with lower elevations and smaller slopes are more amenable to economic development and thus tend to be more urban.

In the present study, the elevations and slopes of provincial capitals were calculated based on the national DEM with a spatial resolution of 30 m (2009). The national DEM was extracted using the administrative boundaries of each provincial capital and 3D analysis to obtain the slope map. Average elevations and slopes were then calculated for each provincial capital through statistical analysis (Figures 5 and 6). Figure 5 shows that Lhasa and Haikou have the highest and lowest elevations among provincial capitals, respectively, and that the western provincial capitals generally have higher elevations than the eastern provincial capitals. Figure 6 shows that the provincial capitals with the highest and lowest slopes are Lhasa and Shanghai, respectively.

Figure 5. Average elevations of provincial capitals.

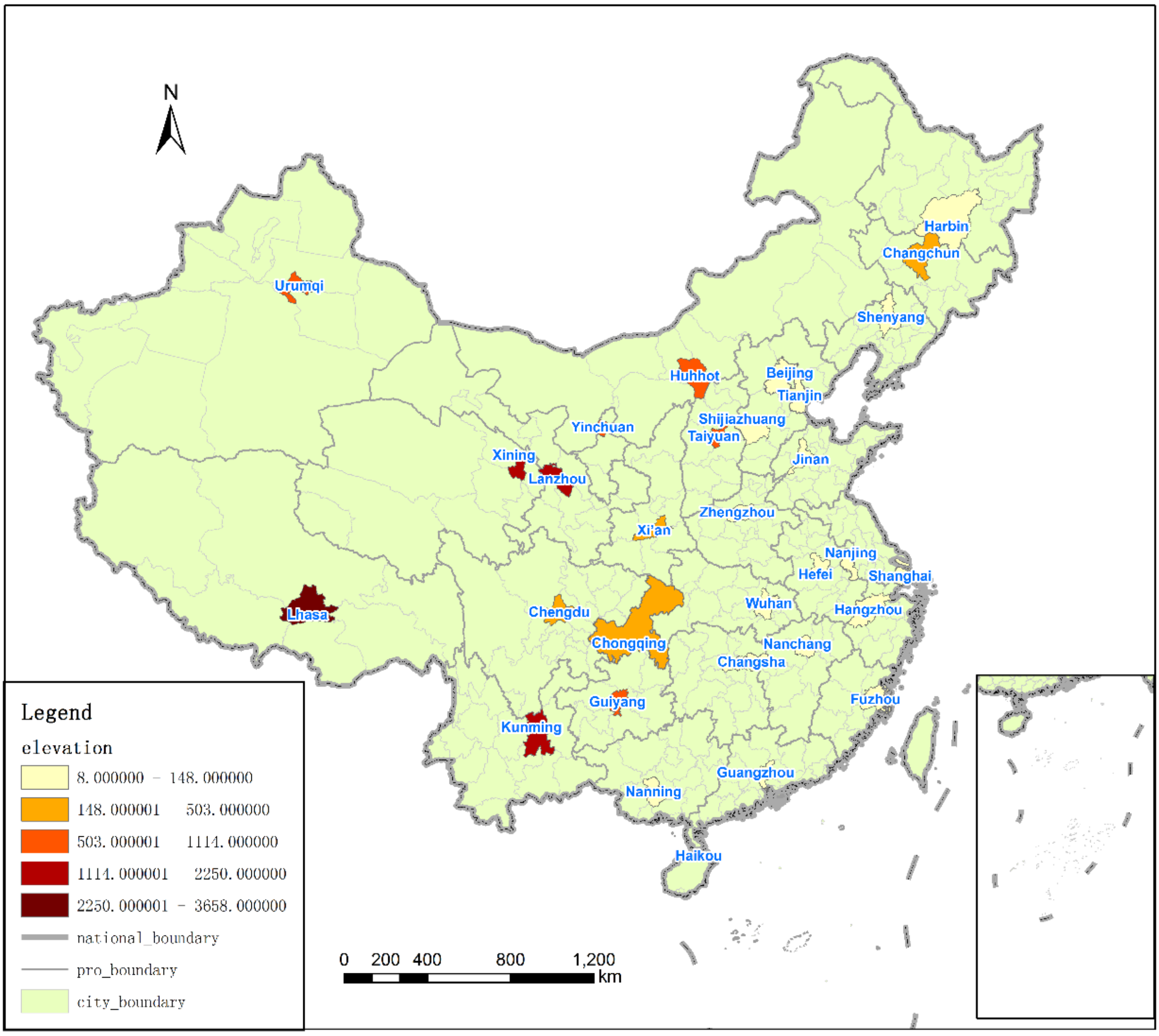
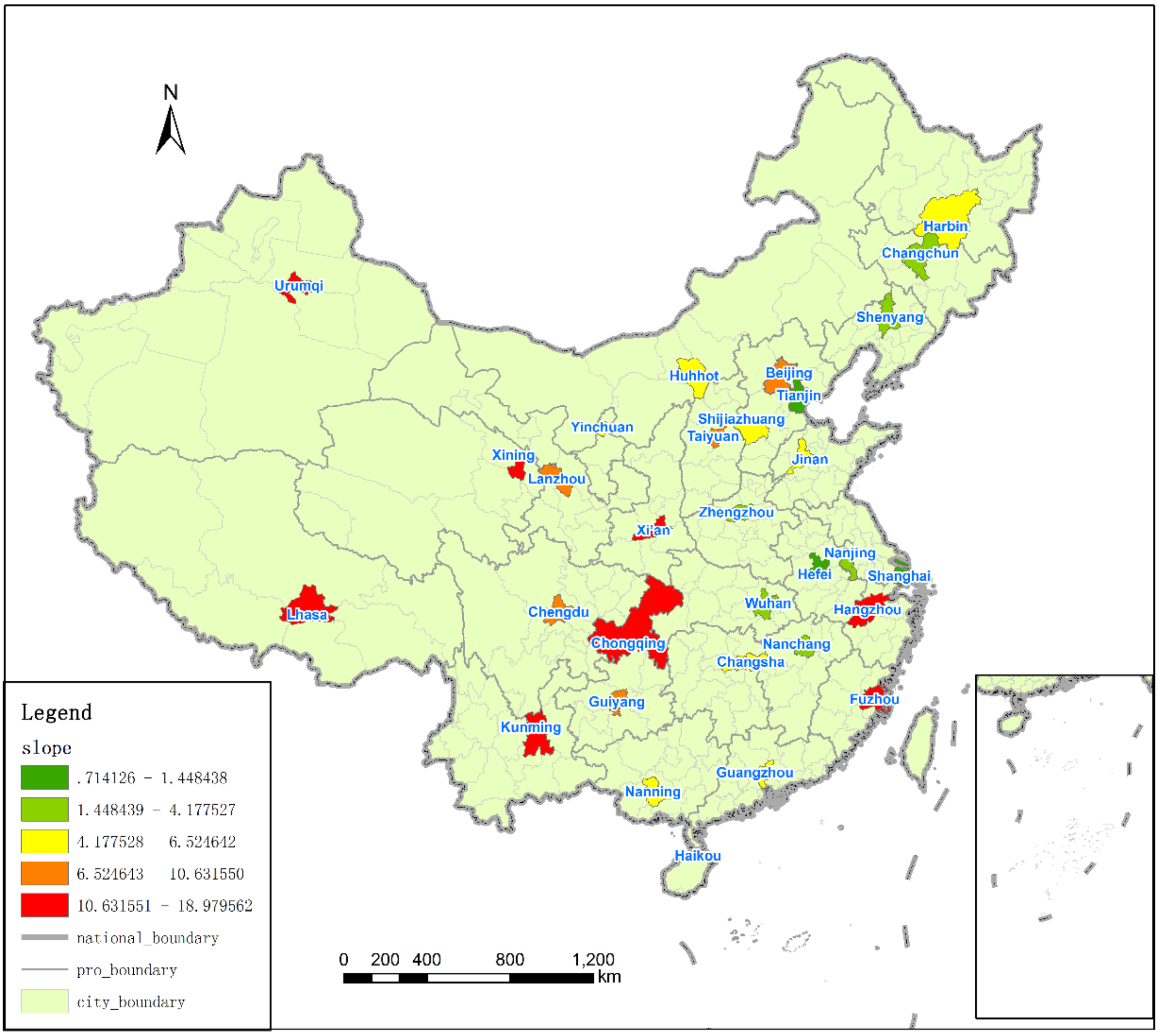


Figure 6. Average slopes of provincial capitals.



5. Results and Discussions

5.1. Results of Urban Competitiveness

Urban competitiveness and its four dimensions were calculated for the provincial capitals for 2010 by applying the integrated assessment method, described in Section 3.3, to the data processed as described in Sections 4.2 and 4.3 (Figures 7 and 8, Table 3). Figure 7 uses different colors to represent the four dimensions for each provincial capital (EC represents Economic Competitiveness, SC represents Social-Cultural Competitiveness, ENC represents Environmental Competitiveness, and LC represents Locational Competitiveness), and the size of each "bar" indicates the score of each dimension. Furthermore, the color of each provincial capital represents its urban competitiveness (UC) according to the classification. Generally, the provincial capitals in the east exhibit higher urban competitiveness than the provincial capitals in the west, and the coastal provincial capitals score higher in urban competitiveness than the inland provincial capitals as the former have an economic environment more amenable to foreign investment and economic activity than the latter. The results also show that most provincial capitals were not balanced across the four dimensions, *i.e.*, each showed strong competitiveness in only one or two dimensions. For example, Urumqi was competitive in the environmental dimension but performed poorly in the other three dimensions. Furthermore, urban competitiveness has a large decline among the eight top-ranked provincial capitals, a small change in the 20 middle ranked provincial capitals (from 13.73–28.33), and a moderate decline among the three lowest-ranked provincial capitals (Figure 8).

Figure 7. The four dimensions of urban competitiveness, Chinese provincial capitals, 2010.

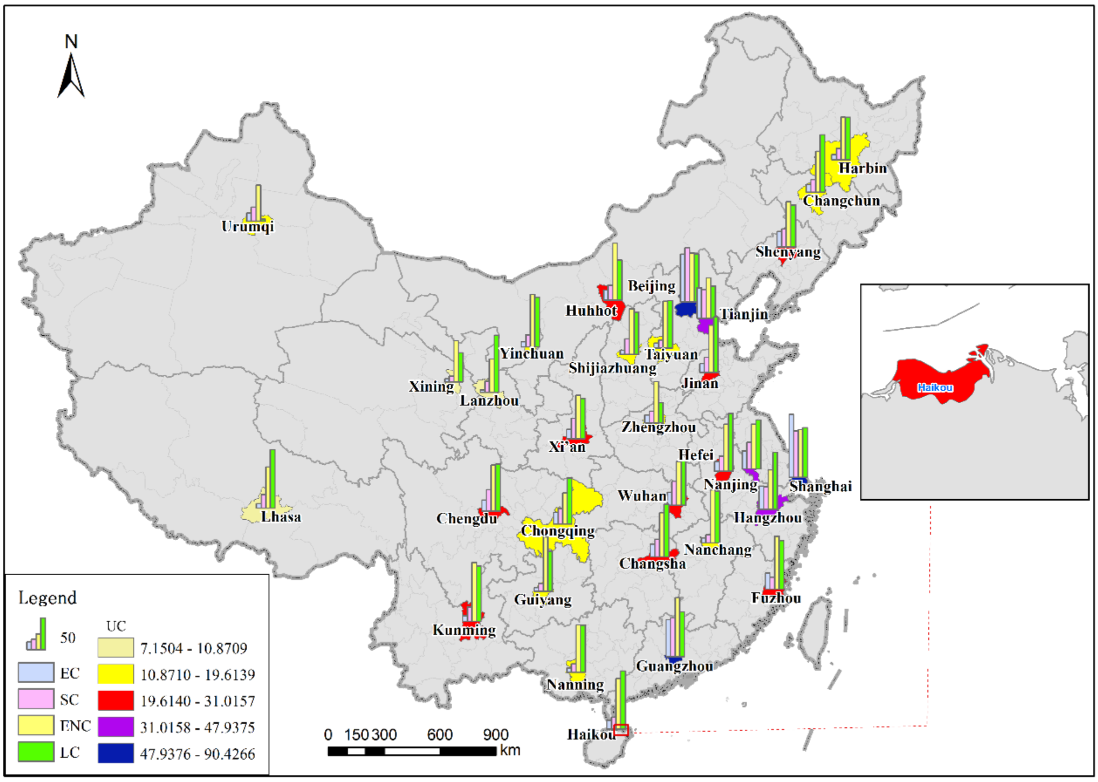


Figure 8. Urban competitiveness and its dimensions in Chinese provincial capitals, 2010.

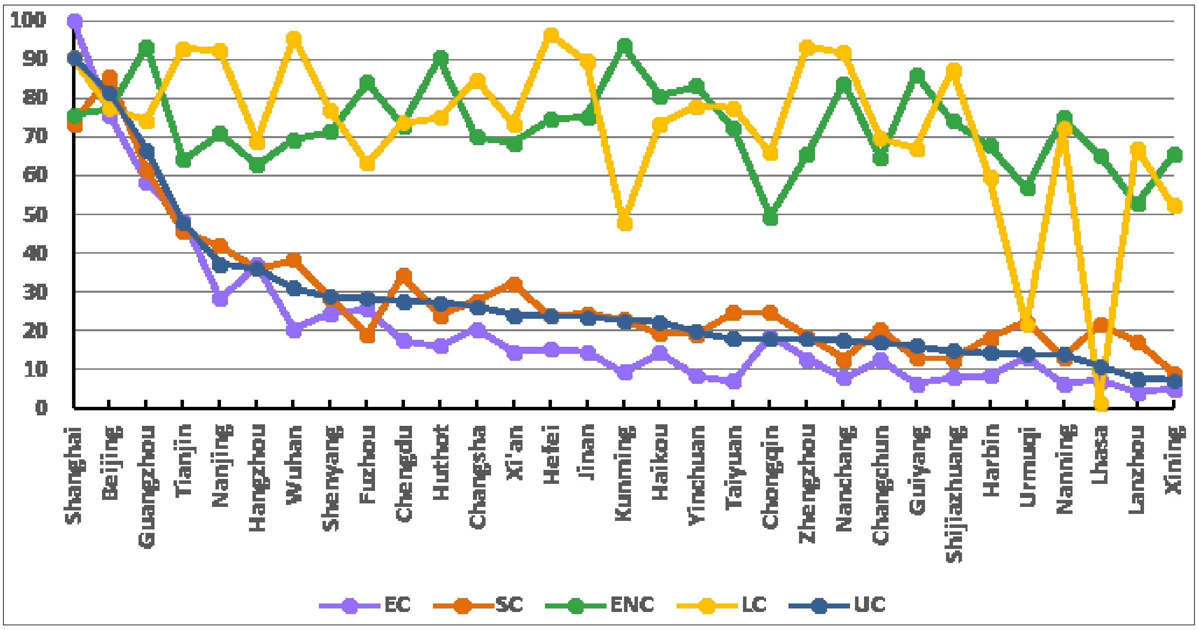


Table 3. The scores and ranks of urban competitiveness in Chinese provincial capitals, 2010.

Cities	UC		EC		SC		ENC		LC	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
Shanghai	90.43	1	100.00	1	73.53	2	75.83	10	92.13	2
Beijing	81.42	2	75.48	2	85.79	1	77.37	9	75.92	15
Guangzhou	66.61	3	58.46	3	61.57	3	93.40	2	77.49	13
Tianjin	47.94	4	48.43	4	45.65	4	64.22	27	90.94	4
Nanjing	37.20	5	28.35	6	41.95	5	71.03	18	90.38	6
Hangzhou	36.03	6	36.93	5	36.05	7	62.71	28	67.16	23
Wuhan	31.02	7	20.31	10	38.25	6	69.38	20	92.59	1
Shenyang	28.86	8	24.37	8	28.23	10	71.45	17	77.31	14
Fuzhou	28.33	9	25.51	7	19.06	23	84.26	5	63.69	26
Chengdu	27.76	10	17.47	12	34.15	8	72.97	15	75.50	16
Huhhot	27.24	11	15.99	13	23.95	15	90.47	3	73.11	19
Changsha	26.37	12	20.38	9	27.70	11	70.04	19	81.95	10
Xi'an	24.01	13	14.57	15	32.26	9	68.43	21	71.59	20
Hefei	23.68	14	15.19	14	23.75	16	74.61	13	91.69	3
Jinan	23.53	15	14.55	16	24.37	14	75.26	11	87.93	8
Kunming	22.69	16	9.30	21	22.85	17	93.66	1	51.03	28
Haikou	22.21	17	14.27	17	19.30	21	80.64	8	78.96	12
Yinchuan	19.614	18	8.40	23	19.08	22	83.31	7	79.04	11
Taiyuan	17.96	19	6.89	27	24.71	12	72.31	16	74.75	18
Chongqing	17.93	20	18.57	11	24.70	13	49.43	31	66.17	24
Zhengzhou	17.79	21	12.61	19	18.57	24	65.58	23	90.50	5
Nanchang	17.51	22	7.91	24	12.78	29	83.89	6	88.56	7
Changchun	17.01	23	12.37	20	20.29	20	64.73	26	71.08	21
Guiyang	16.09	24	6.31	29	12.93	28	86.27	4	67.21	22
Shijiazhuang	14.66	25	7.81	25	12.78	30	74.26	14	83.27	9
Harbin	14.33	26	8.44	22	18.14	25	67.73	22	63.43	27
Urumqi	13.85	27	13.05	18	22.13	18	56.92	29	31.96	30
Nanning	13.73	28	6.32	28	13.13	27	75.14	12	74.77	17
Lhasa	10.87	29	7.13	26	21.53	19	65.29	25	2.93	31
Lanzhou	7.70	30	3.96	31	17.25	26	52.90	30	63.72	25
Xining	7.15	31	4.92	30	9.02	31	65.45	24	46.06	29

5.2. Coupling Analysis of MFOZs and Urban Competitiveness

By the year 2020, the zoning of MFOZs for provincial capitals will be distributed as shown in Figure 9, in which the major function of a city is defined statistically by the major functions of its administrative counties. For example, Jinan is considered to be a DRZ because almost half of the administrating counties are national major grain-producing zones or key ecological function zones. However, the other counties are undefined in the national planning of MFOZs (only 40% of the national territory is covered).

Figure 9. The national major function regionalization of provincial capitals.

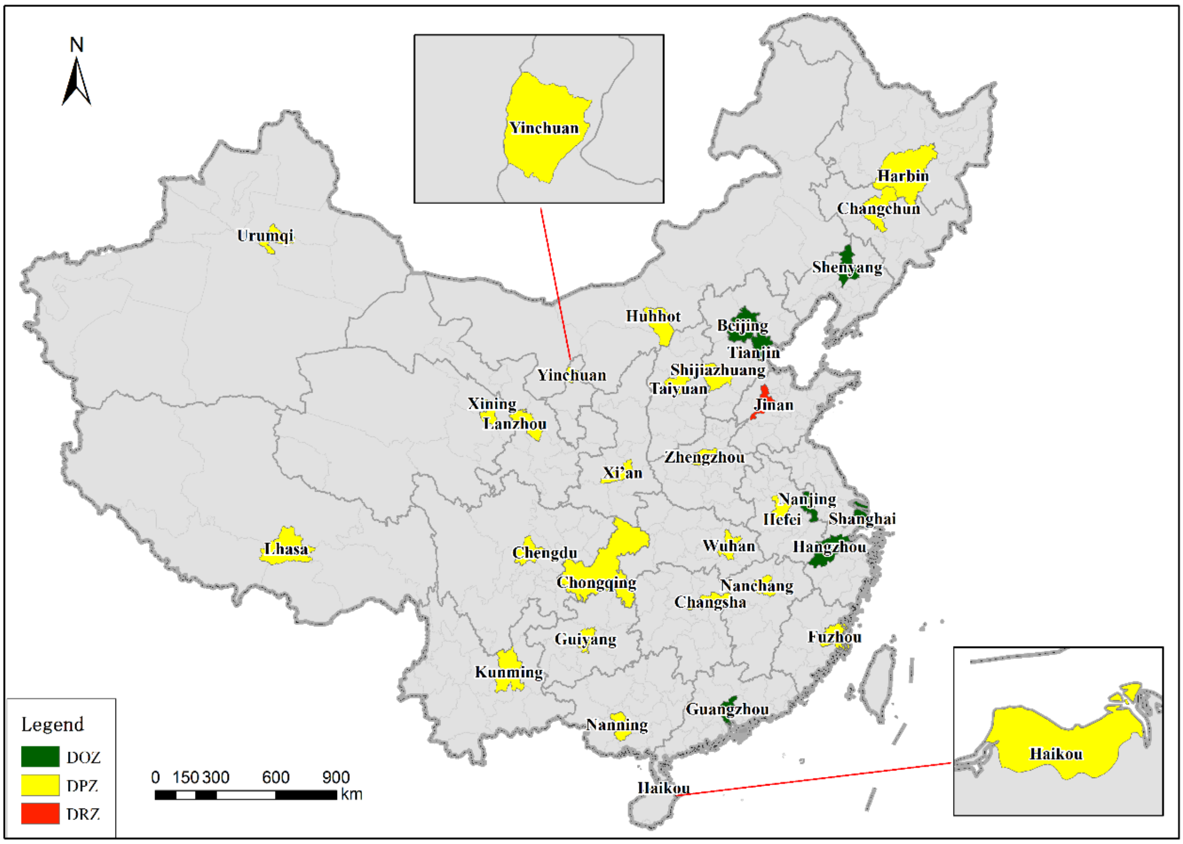
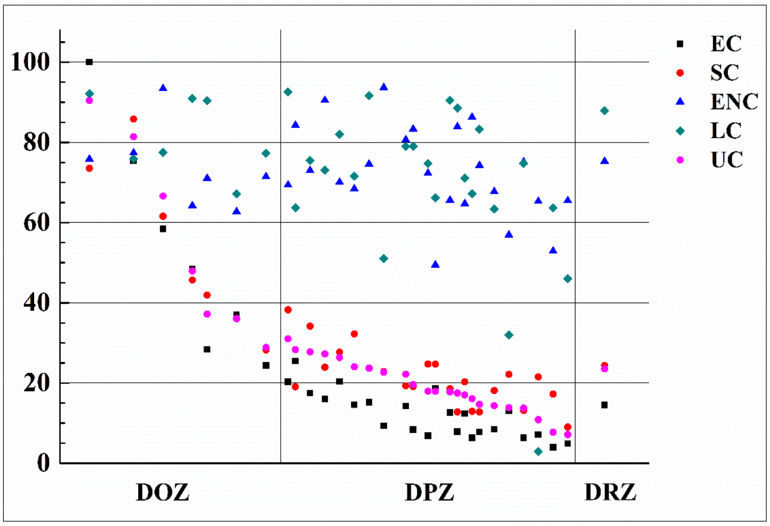


Figure 10. The coupling of MFOZs and urban competitiveness in Chinese provincial capitals.



The coupling of MFOZs and urban competitiveness in Chinese provincial capitals is shown in Figure 10: (a) for provincial capitals listed as DOZs, urban competitiveness and its two dimensions of Economic Competitiveness and Social-Cultural Competitiveness exhibit a similar change distribution but different performance; *i.e.*, these cities perform well in urban competitiveness, but only half of them perform well in Economic Competitiveness and Social-Cultural Competitiveness. In the other two dimensions, Environmental Competitiveness and Locational Competitiveness, these cities all perform at a high level; (b) for the provincial capitals listed as DPZs, although urban competitiveness has a linear distribution similar to the provincial capitals listed as DOZs, these provincial capitals perform poorly. The four dimensions exhibit similarly concentrated distributions but with opposite performance strengths. They perform more poorly in Economic Competitiveness and Social-Cultural Competitiveness and better in Environmental Competitiveness and Locational Competitiveness except for three cities; (c) for the provincial capital listed as a DRZ (*i.e.*, Jinan), the score for urban competitiveness is in the middle, and the scores for Economic Competitiveness and Social-Cultural Competitiveness are much lower. The scores for the other two dimensions are much higher. In general, the provincial capitals as DOZs are much more competitive than the provincial capitals for the other two categories of MFOZs in Economic Competitiveness, Social-Cultural Competitiveness, and urban competitiveness. The provincial capitals are not significantly different for any of the three MFOZ categories in terms of Environmental Competitiveness and Locational Competitiveness.

5.3. Discussions

Because urban planning policies will be devised based on the MFOZs, all provincial capitals should be developed according to their corresponding major function in the future, as opposed to only considering their weakness, as was previously done.

5.3.1. Development-Optimized Provincial Capitals

Beijing, Shanghai, Tianjin, Shenyang, Nanjing, Hangzhou, and Guangzhou are DOZs. Consequently, these seven cities should be competitive in the economic and social-cultural dimensions. These cities should increase their Environmental Competitiveness to achieve the final goal of a high level of global specialization and competition while overcoming their severe environmental problems, such as controlling the expansion of built-up areas, improving urban conditions, and continuing with industrial development and capacity-building.

Beijing (81.42), Shanghai (90.43), and Guangzhou (66.61) scored high in urban competitiveness and its four dimensions. However, they are not identical. In particular, Beijing showed the best results for Social-Cultural Competitiveness, while Shanghai performed best in Economic Competitiveness, and Guangzhou exhibited balanced development of Economic, Social-Cultural, and Environmental Competitiveness (*i.e.*, Guangzhou ranked 3rd, 3rd, and 2nd, respectively, in those three dimensions). However, Shanghai performed much more poorly in Environmental Pollution (28th). Furthermore, there was a large gap between Shanghai and Beijing in Marketization & Openness, although Beijing was competitive in this subgroup (specifically, Shanghai scored 92.04, and Beijing scored 51.25, so that Shanghai and Beijing ranked 1st and 3rd, respectively). Consequently, these cities should adopt differently biased urban development policies to increase their urban competitiveness: (a) Beijing should strengthen its economic development, especially in Marketization & Openness, such as building preferential foreign investment polices to attract more investments and formulating enterprise incentives to achieve high output and availability of foreign investment; (b) Shanghai should strengthen its environmental competitiveness by heightening the pollutant charges and providing supports for pollutant treatment to decrease the discharge of pollutants and increase the intensity of pollution treatment while maintaining its status as the economic leader of the country (as an international finance center), particularly with respect to Marketization & Openness and Economic

Performance; and (c) Guangzhou should be developed harmoniously along each dimension in the future and should seek to increase Accessibility in particular (where it ranked 13th), such as building more high railways to connect with other provincial capitals and more air routes to fly directly to other provincial capitals.

Some similarities are observed among Tianjin (47.94), Nanjing (37.20), Hangzhou (36.03), and Shenyang (28.86). Each scored high in urban competitiveness and had an unbalanced Economic Structure (14th, 23rd, 13th, and 15th in Economic Structure, respectively). Although these cities performed well in Economic Competitiveness, they scored poorly in Environmental Competitiveness (27th, 18th, 28th, and 17th, respectively). Although they performed well in Social-Cultural Competitiveness, the four provincial capitals exhibited different weaknesses in this dimension: Tianjin was weak in Cultural Resources (26th), Nanjing in Quality of Life (16th), Hangzhou in the Development Index (23rd), and Shenyang in all of the subgroups except Cultural Resources (where it ranked 5th), which was the opposite of Tianjin. Therefore, these four cities should undertake economic policies, subsidize weak industries and support the leading industries to optimize Economic Structure and to promote Economic Performance. Furthermore, they should develop differently biased Social-Cultural policies and activities depending on their specific weaknesses noted above. Tianjin should provide more cultural services, such as public library books, theatres and cinemas, to promote its Social-Cultural Competitiveness, as well as taking heavier pollutant charges to decrease the pollutant discharges and building more parks and green space to improve the environmental quality. Nanjing should increase its social service level to increase the citizens' Quality of life, such as post office service, hospital service, social service employees, *etc.*, and it might adopt similar polices to Tianjin to promote Environmental Competitiveness. Hangzhou and Shenyang both have a low Development Index compared with the characteristics of DOZ (which have high development intensity), hence they might enlarge the built-up area and paved road area to achieve the level of development intensity of DOZ, and they both should strengthen the educational level through building comprehensive-ability universities, increasing budgetary expenditure on science and education and so on to promote its Social-Cultural Competitiveness. Furthermore, Hangzhou also should implement heavier pollutant charges to decrease the pollutant discharges to get a much higher score of Environmental Competitiveness. Shenyang should promote post office service level and government informatization to improve its Social-Cultural Competitiveness.

5.3.2. Development-Prioritized Provincial Capitals

Most of the provincial capitals are classified as DPZs, including Chongqing, Harbin, Changchun, Huhhot, Shijiazhuang, Taiyuan, Zhengzhou, Xi'an, Lanzhou, Yinchuan, Xining, Urumqi, Hefei, Changsha, Nanchang, Wuhan, Chengdu, Guiyang, Fuzhou, Haikou, Nanning, Kunming, and Lhasa. Consequently, on the one hand, economic and social-cultural development is most important for these 23 cities through appropriate large-scale urbanization and industrialization to form modern metropolitan areas and to promote regional development. On the other hand, the Environmental Competitiveness of these cities can be ignored provisionally due to their high carrying capacity with regard to available resources and the local environment.

As middle provincial capitals, Wuhan (31.02), Changsha (26.37), Nanchang (17.51), Zhengzhou (17.79), and Hefei (23.68) scored high in Locational Competitiveness, with high Accessibility and Hypsography (specifically, they ranked 1st, 10th, 7th, 5th, and 3rd in Locational Competitiveness, respectively). However, their performances in Economic Competitiveness and Social-Cultural Competitiveness were varied—Wuhan and Changsha fared well, Hefei ranked in the middle, and Zhengzhou and Nanchang performed much more poorly. Therefore, Zhengzhou and Nanchang should focus on developing their economic and social-cultural dimensions more than the other three middle provincial capitals. Additionally, the keys to their respective development paths differ as follows. In the economic construction, Wuhan and Nanchang should seek to subsidize the development of weak industries to optimize their Economic Structures (where they ranked 19th and 31st, respectively) when encouraging the development of leading industries to increase Economic Performance, while the others should take more balanced approaches. In the social-cultural construction, Quality of Life should be developed in all the middle provincial capitals (except for Changsha), Cultural Resources should be prioritized in Changsha, Zhengzhou, and Hefei, and the Development Index should be an additional area of focus for Changsha. Therefore, Wuhan should increase the social service employees to promote Social-Cultural Competitiveness along with the improvement of Economic Competitiveness. Nanchang should increase the hospital service level by increasing the counts of hospital beds and doctors, promoting cultural service level by building libraries and theatres and cinemas, and speeding up urbanization through paved road and built-up area constructions to improve its Social-Cultural Competitiveness. Zhengzhou should increase the count of doctors, library books and theatres and cinemas, and take rapid urbanization especially road construction to get a higher score in Social-Cultural Competitiveness. Hefei should lead more teachers to middle and primary school, build more post offices, libraries, and theatres and cinemas, improve the urbanization level and enlarge the built-up area to be more competitive in the social-cultural dimension. Changsha should build more theatres and cinemas, take rapid urbanization process with respect to urbanization level and the ratio of built-up area.

Among western provincial capitals, Chongqing (17.93), Chengdu (27.76), Kunming (22.69), Guiyang (16.09), Nanning (13.73), Lhasa (10.87), Urumqi (13.85), Lanzhou (7.70), Xining (7.15), Yinchuan (19.61), Xi'an (24.01), and Huhhot (27.24), mostly scored poorly in Economic Competitiveness and Social-Cultural Competitiveness, although exceptions were Chongqing, Chengdu, Xi'an, and Huhhot. Thus, most of these cities should undertake strong economic and social-cultural development—particularly Nanning, Guiyang, Xining, and Lanzhou as they ranked near the bottom. Specially, these western provincial capitals should provide preference investment polices to attract foreign and internal investment funds to speed up industrialization, and increase local GDP, fiscal revenue, and resident income, as well as strengthening publicity to attract more foreign tourists. In addition, they should improve the comprehensive ability of universities, lead more teachers into middle and primary school, increase the budgetary expenditure on science and education, *etc.* to be more competitive in HR & Education. Chengdu, Chongqing, and Urumqi should support the weak industries and encourage the inexistent industries to promote their Economic Structure (ranked 29th, 28th, and 26th, respectively). Xining, Kunming and Guiyang should speed up the construction of built-up area and paved road to increase the Development Index. In addition, Lhasa and Urumqi should increase their Accessibility in urban construction, in which they ranked 31st and 30th, respectively;

however, Lhasa might build more high speed railways to connect with other provincial capitals and air routes to fly directly to other provincial capitals, while Urumqi might build more highways to connect with other provincial capitals.

Changchun (17.01) and Harbin (14.33), the northeastern provincial capitals, performed poorly in urban competitiveness and in all four dimensions. Consequently, they should implement related policies to strongly develop their Economic and Social-Cultural Competitiveness. Changchun should especially focus on building more post offices to develop Quality of Life in the social-cultural construction (24th), and Harbin should focus on speeding up the construction of built-up areas and paved road and taking government informatization to improve the Development Index and the Social Management, in addition to decrease local price of daily supplies and to lead more doctors into hospitals to increase the Quality of Life (Harbin ranked 23rd in Social Management, 31st in the Development Index, and 25th in Quality of Life).

Fuzhou (28.33) and Haikou (22.21), both coastal provincial capitals, were both more competitive economically than social-culturally. While there was a large gap between them in Economic Competitiveness, they ranked nearly the same in Social-Cultural Competitiveness (7th and 17th in Economic Competitiveness and 23rd and 21st in Social-Cultural Competitiveness, respectively). Thus, both cities should implement policies that provide more support for social-cultural construction. Particularly, they both should increase the budgetary expenditure on science and education. In addition, Haikou might take government informatization more quickly. Furthermore, as an island city, Haikou should increase its Accessibility ranking (27th) to create a traffic environment more amenable to a growing population and economy.

Both Shijiazhuang (14.66) and Taiyuan (17.96) performed poorly in Economic Competitiveness (25th and 27th, respectively); however, Taiyuan did much better than Shijiazhuang in Social-Cultural Competitiveness as Shijiazhuang was nearly last in that dimension. As a result, both should strongly take industrialization, such as provide preference polices to attract enterprises entering and capital investing, to improve their economic performance, particularly, they should strengthen publicity to attract foreign enterprises and capitals and enhance the availability and output of foreign investment to promote their competitiveness in Marketization & Openness. Shijiazhuang should emphasize the construction of post offices and hospitals and its related manpower and material resources to improve local Quality of Life, and take rapid government informatization to promote Social Management, in addition to promote the comprehensive ability of universities and increase the budgetary expenditure on science and education to enhance the competitiveness of HR & Education, which should be taken by both of Shijiazhuang and Taiyuan.

5.3.3. Development-Restricted Provincial Capital

As a DRZ, Jinan (23.53) is not as economically competitive as other provincial capitals. The Development Index was much higher in Jinan (7th), with a leading ranking for *percentage share of built-up area in administrative area* (10th); thus, the future intensity of development in Jinan should be controlled to prevent the overdevelopment of an important national agricultural production area and ecological function area, which could threaten agricultural production and ecosystem integrity. Unlike the other two categories of MFOZs, DRZs provide agricultural and ecological products and must have restricted development of urbanization and industrialization. Thus, Jinan might promote its Social-Cultural Competitiveness and Environmental Competitiveness to increase its Urban Competitiveness. Specially, Jinan should implement policies that favor social-cultural construction, particularly with respect to Cultural Resources and Social Management (where it ranked 21st and 28th, respectively), such as building more theatres and cinemas, and government informatization.

6. Conclusions

The pursuit of urban competitiveness will require changes in policies with respect to urban development and planning. The analysis of provincial capitals presented here may be useful for national and local policymakers, in addition to foreign and domestic investors. This paper adopts benchmarking and addresses facets of urban sustainability, economic development, and geographic superiority in assessing urban competitiveness, taking MFOZs into account, specifically, the four dimensions of Economic, Social-Cultural, Environmental, and Locational Competitiveness. A four-level hierarchical model, building under the index system of MFOZs, and an entropy weighting method, are used to evaluate urban competitiveness. The capacity of the model to evaluate the 31 provincial capitals of China demonstrates its adaptability and applicability. Furthermore, the study may be especially relevant—given the prevalence of the four dimensions of competitiveness analyzed here in public discussion—in light of the increasing social and environmental problems that accompany rapid economic development. For example, many environmental indices and some locational indices are added to urban competitiveness, accompanying economic and social-cultural indices to account for accessibility and hypsography. These factors influence industrialization and economic development and are components of the index system for MFOZs.

The findings from our experiments indicate that Shanghai, Beijing, Guangzhou, and Tianjin perform best among the 31 provincial capitals, with well-balanced development in all four dimensions of urban competitiveness. However, Urumqi and Lhasa lag behind the other provincial capitals in urban competitiveness. Furthermore, the provincial capitals classified as DOZs are performing well in urban competitiveness, whereas half of them have poor performance in Economic Competitiveness or Social-Cultural Competitiveness, such as Nanjing, Hangzhou, and Shenyang. The provincial capitals classified as DPZs are performing poorly in urban competitiveness as well as in Economic Competitiveness and Social-Cultural Competitiveness. The provincial capital classified as a DRZ (*i.e.*, Jinan) is not performing well or poorly in urban competitiveness, whereas its performance in the four dimensions is similar to the provincial capitals classified as DPZs. Finally, the analysis indicates the need to create prioritized development policies on the basis of existing advantages and disadvantages of these areas according to the conditions of their major function categories, DOZ, DPZ, and DRZ.

The significance of sustainable development to the evaluation of urban competitiveness has been highlighted in this study using data from 2010. These results can serve as a baseline for further investigation using the same model to monitor dynamic changes in related industries.

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Author Contributions

Qingyun Du, Yanxia Wang, Fu Ren, Zhiyuan Zhao, Hongqiang Liu, Chao Wu, Langjiao Li, and Yiran Shen work together. Specifically, Qingyun Du brings the ideas, guide the experiments, and conducts the organization of the content. Yanxia Wang carries out the main experiments of measuring the urban competitiveness and gives some analysis of the results. Fu Ren provides the literature guidance and gives proposal about the study. Zhiyuan Zhao and Hongqiang Liu take the process of spatial data. Chao Wu, Langjiao Li, and Yiran Shen collect the data from the statistical yearbooks and preprocess them.

Conflicts of Interest

The authors declare no conflict of interest.

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