Measurement of the Internationalization Function Development Level of the Guangdong-Hong Kong-Macao Greater Bay Area

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Abstract. Cities are the carriers of internationalization function development, and internationalization function is the core support for constructing international bay urban areas and world-class city clusters. This study measures the development level of internationalization functions in the Guangdong-Hong Kong-Macao Greater Bay Area using the Entropy-TOPSIS method. The results show that: (1) the importance ranking of internationalization function development level evaluation indicators is as follows: number of libraries > number of universities > airport throughput > number of inbound tourists > number of star-rated hotels > volume of foreign trade > GDP > port cargo throughput > number of museums; (2) the balance of the internationalization function development level in the Guangdong-Hong Kong-Macao Greater Bay Area is not high. Regions with middle to high levels of development center around Guangzhou, Shenzhen, Hong Kong, and Macao, while the internationalization development level of peripheral areas is relatively low.

Keywords: Internationalization function, development level, Guangdong-Hong Kong-Macao Greater Bay Area.

1. Introduction

In March 2016, the *13th Five-Year Plan for Economic and Social Development of the People's* Republic *of China* clearly proposed "to support Hong Kong and Macao to play an important role in cooperation in the Pan-Pearl River Delta region, and to promote the construction of major cooperation platforms in the Guangdong-Hong Kong-Macao Greater Bay Area and cross-provincial areas." In the same month, the State Council issued *Guiding Opinions on Deepening Regional Cooperation in the Pan-Pearl River Delta,* which explicitly requires Guangzhou and Shenzhen to join hands with Hong Kong and Macao to jointly create the Guangdong-Hong Kong-Macao Greater Bay Area and build a world-class city cluster. In an era of increasingly close international cooperation and rapid development of the global Internet, the Greater Bay Area urgently needs to find more experience and opportunities in the international perspective and locational advantages, to present a more vibrant, three-dimensional, and open international urban image to the outside world [1]. In recent years, the development of the core cities of the Guangdong-Hong Kong-Macao Greater Bay Area is showing a trend from early specialization and socialization transformation to branding and internationalization. As an important part of the Greater Bay Area, the construction and development of internationalization functions are core links and important ways to build international bay urban areas, enhance their international attractiveness, and influence [2-3]. The term "function" first appeared in the *Book of Han, Emperor Xuandi's Annals,* where it meant function or efficacy. Later, it was extended to refer to capabilities. Urban function represents a city's ability and role within a regional or radiating scope to promote urban development and maintain economic and social stability. The *Athens Charter* emphasizes that the normal operation of the four major urban functions: living, working, transportation, and recreation, is the primary purpose of urban planning. As society develops, the content of urban functions has gradually diversified, encompassing areas such as the economy, culture, administration, innovation, society, and services [4-5]. Therefore, this paper assesses the level of international function development in the Guangdong-Hong Kong-Macao Greater Bay Area based

on functions related to international economics, international hubs, international exchanges, international culture, and international services. The goal is to provide guidance for the construction of a world-class city cluster in the Greater Bay Area.

2. Research Methods and Data Sources

2.1. Research Methods

2.1.1 Entropy Method

The entropy method is an objective weighting method that calculates the information entropy of indicators and determines weights based on the degree of difference in the characteristic values of each indicator [6]. The main calculations include: data normalization Zij, calculating the proportion Pij of the i-th indicator, calculating the entropy value of the j-th indicator, and determining the weight wj.

$$Z_{ij} = \begin{cases} \frac{x_{ij}-x_{j,min}}{x_{j,max}-x_{j,min}} \\ \frac{x_{jmax}-x_{ij}}{x_{j,max}-x_{j,min}} \end{cases} \tag{1}$$

$$P_{ij} = \frac{Z_{ij}}{\sum_{i-1}^{m} Z_{ij}} \tag{2}$$

$$e_j = -k \sum_{i-1}^{m} P_{ij} \ln (P_{ij})\, d_j = 1 - e_j \tag{3}$$

$$w_j = \frac{d_j}{\sum_{i-1}^{m} d_j} \tag{4}$$

2.1.2 TOPSIS

The TOPSIS method is a common method for comprehensive evaluation within a group, which can fully utilize the information of the original data. Its results can accurately reflect the gap between each evaluation scheme [7]. The main calculations include: constructing the initial evaluation matrix, determining the best solution Z+ and the worst solution Z–, calculating the distance Di+ and Di– of each evaluation object from Z+ and Z–, and calculating the closeness degree Ci of each evaluation object to the best solution. The larger the Ci value, the better the evaluation object.

$$\boldsymbol{Z} = \begin{bmatrix} Z_{11} & Z_{12} & \cdots & Z_{1m} \\ Z_{21} & Z_{22} & \cdots & Z_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ Z_{n1} & Z_{n2} & \cdots & Z_{nm} \end{bmatrix} \tag{5}$$

$$Z^{+} = (\max\{Z_{11}, Z_{12}, \cdots, Z_{m1}\}, \max\{Z_{12}, Z_{22}, \cdots, Z_{m2}\}, \cdots, \max\{Z_{1n}, Z_{2n}, \cdots, Z_{mn}\}) = (Z_1^{+}, Z_2^{+}, \cdots, Z_n^{+})$$

$$Z^{-} = (\min\{Z_{11}, Z_{12}, \cdots, Z_{m1}\}, \min\{Z_{12}, Z_{22}, \cdots, Z_{m2}\}, \cdots, \min\{Z_{1n}, Z_{2n}, \cdots, Z_{mn}\}) = (Z_1^{-}, Z_2^{-}, \cdots, Z_n^{-}) \tag{6}$$

$$D_i^{+} = \sqrt{\sum_{i=1}^{n} (Z_j^{+} - Z_{ij})^2},\ D_i^{-} = \sqrt{\sum_{i=1}^{n} (Z_j^{-} - Z_{ij})^2} \tag{7}$$

$$C_i = \frac{D_i^{-}}{D_i^{+} + D_i^{-}},\ (0 < C_i < 1,\ C_i \to 1) \tag{8}$$

2.2. Data Sources

Due to the impact of the COVID-19 pandemic from 2020 to 2023, related data shows significant differences from the normal development of cities. Therefore, this paper takes 2019 as the base year to measure the development level of internationalization functions in the Guangdong-Hong Kong-Macao Greater Bay Area. The data sources of this paper include the *2019 Civil Aviation Airport Production Statistics Bulletin*, city statistical yearbooks, city yearbooks, the *Guangdong Province 2021 Museum Industry Development Report*, data from the Hong Kong Tourism Board, the Hong

Kong SAR Government Trade and Industry Department, the Macao SAR Government Public Security Police Force, and the National Economic and Social Development Bulletin.

Table 1. Index system construction

First level indicator	Secondary indices
Hub function	Airport throughput (per ten thousand passengers)
Function of economy	Port cargo throughput (per ten thousand tons)
Function of culture	Foreign trade volume (in billion yuan)
Service function	GDP (in billion yuan)
Function of communication	Number of museums (per museum)
First level indicator	Number of libraries (per library)
Hub function	Number of star-rated hotels (per hotel)
Function of economy	Number of universities (per university)
Function of culture	Number of inbound tourists (foreigners) (per ten thousand person-times)

3. Results Analysis

3.1. Weight Distribution

The study uses SPSS24.0 to analyze the 9 indicators of the 9 cities in the Guangdong-Hong Kong-Macao Greater Bay Area and the Hong Kong and Macao Special Administrative Regions using the entropy method and calculates their weights (table). The results show that the indicator weights are ranked from high to low as follows: number of libraries > number of universities > airport throughput > number of inbound tourists > number of star-rated hotels > volume of foreign trade > GDP > port cargo throughput > number of museums. Libraries and universities reflect the education level and knowledge resources of a country or region, which can attract international students and scholars, promote cultural exchange, and academic cooperation; airport throughput is an important indicator of international transportation, and large, efficient airports can provide a more convenient international transportation network, contributing to the flow and agglomeration of international development factors; the number of inbound tourists directly relates to the development of the tourism industry in a country or region and is an important manifestation of international exchange and cultural integration; the number of star-rated hotels can serve as an indicator of international tourism and business activities. They reflect the reception capacity and service level of a region, which is important for attracting international tourists and business travelers. Although the volume of foreign trade and GDP are important indicators of economic development, they rank lower in the proportion of internationalization development factors. This does not mean they are unimportant, but rather it is more likely that other factors (such as education, transportation, culture) have a more direct or significant impact on internationalization development; port cargo throughput and the number of museums are considered to have a smaller proportion in internationalization development factors. Port cargo throughput reflects logistics and trade activities, while the number of museums reflects cultural heritage and history. Although they have some impact on internationalization development, they are considered to have a smaller proportion in this assessment.

Table 2. Index entropy values and weights

Indicator:	Airport throughput	Port cargo throughput	Foreign trade volume	GDP	Number of museums	Number of libraries	Star rated hotel	Number of universities	Inbound tourist number
Entropy Value:	0.6004	0.7657	0.7288	0.7376	0.7795	0.5892	0.7239	0.5931	0.6986
Weight:	0.1436	0.0842	0.0974	0.0943	0.0792	0.1476	0.0992	0.1462	0.1083

3.2. Comprehensive Development Level Assessment

Using SPSS 24.0 for TOPSIS analysis, the comprehensive development scores of 9 cities in the Guangdong-Hong Kong-Macao Greater Bay Area, as well as Hong Kong and Macao Special Administrative Regions, were calculated and ranked (see Table). The analysis results demonstrate significant differences in the comprehensive development index and rankings among these cities. Guangzhou ranks first with a high comprehensive development index of 0.7238516, indicating comprehensive and balanced development in multiple aspects. Shenzhen and Hong Kong rank second and third, respectively, with slightly lower comprehensive development indices than Guangzhou but still exhibiting a high overall development level. However, cities like Dongguan, Macao, and Foshan have notably lower comprehensive development indices, placing them in the middle to lower ranks. These cities may require further attention and development in areas such as their economies, education, and infrastructure to enhance their comprehensive development levels. In this dataset, the comprehensive development index of each city reflects its overall strength and development status in economic, social, and cultural aspects, but further analysis of specific development factors and limitations is needed.

Table 3. Comprehensive Development Index and Rankings

Cities	The difference between the evaluation index and the optimal distance D+	The difference between the evaluation index and the worst distance D-	Comprehensive development index C	Sorting
Guangzhou	0.10706863	0.280653	0.7238516	1
Shenzhen	0.17586655	0.243533	0.5806703	2
Hong Kong	0.20186241	0.237513	0.5405701	3
Dongguan	0.27029661	0.156478	0.3666528	4
Macau	0.28781419	0.098815	0.2555806	5
Foshan	0.3084712	0.051024	0.1419323	6
Zhuhai	0.3117216	0.03985	0.1133488	7
Huizhou	0.32811876	0.018652	0.0537886	8
Zhaoqing	0.33676819	0.011389	0.0327128	9
Jiangmen	0.33605148	0.009476	0.0274252	10
Zhongshan	0.33698258	0.007031	0.020438	11

3.3. International Functional Development Pattern

The study employed ArcGIS 10.2 to reclassify the international development level index of the Guangdong-Hong Kong-Macao Greater Bay Area. Regions with comprehensive development indices within the range of 0-1 were categorized as low development levels, those within the range of 1-4 as middle development levels, and those exceeding 4 as high development levels. This information was visually represented, generating a distribution map of the international functional development level in the Greater Bay Area (see Figure). As shown in the figure, regions with high international functional development levels are concentrated around Guangzhou, Shenzhen, Hong Kong, and Macao, indicating the crucial leadership roles played by these areas in the international development of the Greater Bay Area, aligning with the national development strategy. Meanwhile, regions with lower international functional development levels are mainly situated on the periphery of the Greater Bay Area. This reflects potential deficiencies in resource allocation, policy support, and infrastructure in these areas, resulting in relatively lagging international development processes. Against the backdrop of regional coordinated development, it is essential to pay more attention to the actual situations in these relatively less developed regions and provide necessary support and assistance to achieve balanced development across the entire Greater Bay Area.

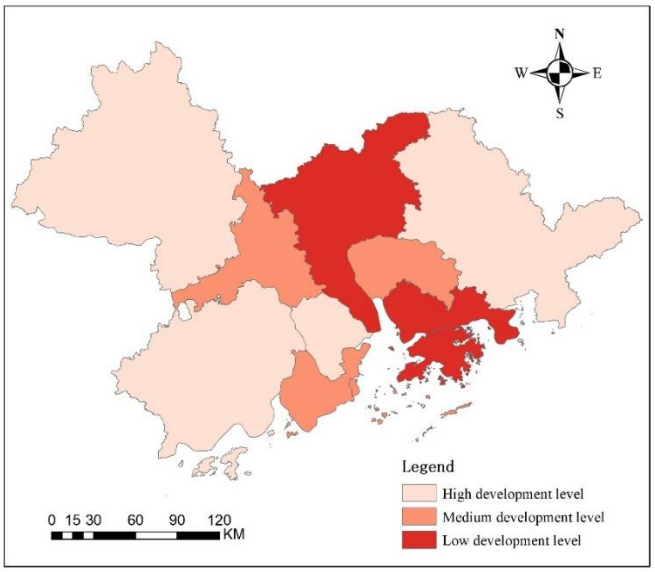

Figure 1. Spatial Layout of International Functional Development Level

4. Conclusion

This study conducted an analysis of the international development level in the Guangdong-Hong Kong-Macao Greater Bay Area using SPSS 24.0 and ArcGIS 10.2. The findings are as follows: (1) The importance ranking of evaluation indicators for international functional development level is as follows: the number of libraries > the number of universities > airport throughput > inbound tourist arrivals > the number of star-rated hotels > foreign trade volume > GDP > port cargo throughput > the number of museums. This ranking provides clear guidance for further understanding and evaluating the international development of the Greater Bay Area. (2) The study revealed the spatial distribution characteristics of international functional development levels in the Greater Bay Area. Regions with high and middle international functional development levels are centered around Guangzhou, Shenzhen, Hong Kong, and Macao, while the development level in peripheral areas is relatively lower. The study exposed the unevenness of internal development in the Greater Bay Area and provides strong evidence for future policy-making to promote balanced development. Analyzing the international development level of the Greater Bay Area from both a temporal and spatial perspective aids in better understanding the regional development disparities and serves as an important reference for future policy-making and development planning.

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