Journal of Economic Analysis

Homepage: https://www.anserpress.org/journal/jea

Evaluation of Urban High-quality Development Level based on Entropy Weight-TOPSIS Two-step Method

Yushan Qiu [a], Shuaishuai Jia [b], Jianping Liao [a, *], Xiaohan Yang [c]

[a] *School of Economics and Statistics, Guangzhou University, Guangzhou, China*

[b] *Institute of Finance, Guangzhou University, Guangzhou, China*

[c] *Queen Mary University of London, School of Economics and Finance, London, United Kingdom*

ABSTRACT

Based on fully considering the actual differences in statistical indicators between Hong Kong, Macao, and the nine cities in the Pearl River Delta, this paper constructs a high-quality urban development evaluation system that is suitable for the actual development of the Guangdong-Hong Kong-Macao Greater Bay Area. The Entropy Weighted TOPSIS two-step method is used to process data and systematically investigate the changes in the high-quality development index of 11 cities in the Guangdong-Hong Kong-Macao Greater Bay Area from 2013 to 2020. The study found that the Guangdong-Hong Kong-Macao Greater Bay Area has thoroughly implemented the new development concept, and the level of high-quality development has continued to improve. The profound integration effect of the Guangdong-Hong Kong-Macao Greater Bay Area has appeared, and it has promoted the high-quality development of the region in coordination. The construction of the Guangdong-Hong Kong-Macao Greater Bay Area has strongly promoted the great practice of "one country, two systems" to achieve stability and prosperity.

KEYWORDS

Guangdong-Hong Kong-Macao Greater Bay Area (GBA); High-quality development; New development concept; Entropy Weight-TOPSIS Method; Urban evaluation

*Corresponding author: Jianping Liao
E-mail address: 2112264112@e.gzhu.edu.cn

ISSN 2811-0943
doi: 10.58567/jea01020004

Received 5 November 2022, Accepted 17 December 2022, Available online 22 December 2022

1. Introduction

As one of the regions with the highest degree of openness and the most vigorous economic vitality in China, the Guangdong-Hong Kong-Macao Greater Bay Area is composed of nine cities in Guangdong Province, including Guangzhou, Shenzhen, Zhuhai, Foshan, Huizhou, Dongguan, Zhongshan, Jiangmen, and Zhaoqing, as well as two particular administrative regions, Hong Kong and Macao. The Guangdong-Hong Kong-Macao, Greater Bay Area, has an essential strategic position in the national development landscape. President Xi has always been concerned about the development planning of the Greater Bay Area. In December 2012, President Xi, who took over the historical baton after the 18th National Congress of the Communist Party of China, came to Shenzhen and other cities in the Guangdong-Hong Kong-Macao Greater Bay Area on the first stop of his investigation and issued the mobilization order of "pushing forward the reform and opening up." In October 2018, on the occasion of the 40th anniversary of reform and opening up, President Xi came to Guangdong again, calling on Guangdong to "continue to comprehensively deepen reform, comprehensively expand opening up, and strive to create a new and greater miracle that will impress the world." Building the Guangdong-Hong Kong-Macao Greater Bay Area is a major national strategy President Xi planned, deployed, and promoted. On February 18, 2019, the Outline of the Development Plan of the Guangdong-Hong Kong-Macao Greater Bay Area was officially released, marking that the construction of the Guangdong-Hong Kong-Macao Greater Bay Area has entered the stage of full implementation.

Since the 18th National Congress of the Communist Party of China (CPC), the Guangdong-Hong Kong-Macao Greater Bay Area has implemented the new development concept and worked hard to take the lead in building a system and mechanism to promote high-quality economic development. In the past decade, the people of the Greater Bay Area of Guangdong, Hong Kong, and Macao have overcome difficulties, worked tirelessly, and delivered outstanding answers to the times. According to the data of the Ministry of Industry and Information Technology, the total economic output of the Guangdong-Hong Kong-Macao Greater Bay Area will be about 12.6 trillion yuan in 2021, double the 6.6 trillion yuan in 2012, with an average annual growth rate of 7.45%. Among them, the total economic output of the nine cities in the Pearl River Delta increased from 478 million yuan in 2012 to 1.006 billion yuan in 2021, with an average annual growth rate of 8.63%.

On October 29, 2015, President Xi's speech at the second plenary session of the Fifth Plenary Session of the 18th Central Committee of the Communist Party of China (CPC) put forward the development concept of innovation, coordination, green, openness, and sharing for the first time. On March 11, 2018, the first session of the 13th National People's Congress adopted an amendment to the Constitution of the People's Republic of China, which included "implementing the new development concept" in the Constitution. The new development concept is the main content of President Xi's economic thought, which must be adhered to for a long time. The report of the 20th National Congress of the Communist Party of China pointed out that high-quality development is the primary task of building a socialist modern country in an all-around way and that the new development concept must be ultimately, accurately, and comprehensively implemented. Systematically analyzing the achievements of the new development concept in guiding the high-quality development of the Guangdong Hong Kong Macao Greater Bay Area and summarizing experiences based on the new development concept can promote the stability of the Guangdong Hong Kong Macao Greater Bay Area on the road to high-quality development.

2. Construction of a High-quality Urban Development Evaluation System in Guangdong Hong Kong Macao Greater Bay Area

2.1. Construction of High-quality Urban Development Evaluation System

To correctly evaluate the development level of the Guangdong Hong Kong Macao Greater Bay Area, a good

evaluation index system is a prerequisite for analysis. The construction of the indicator system should follow the principles of scientific rigor, systematicity, and operability. The construction of the evaluation system for the high-quality development of the Guangdong Hong Kong Macao Greater Bay Area should also adhere to these principles.

2.1.1. Scientific nature

The construction of indicators to measure the high-quality development level of the Guangdong Hong Kong Macao Greater Bay Area must be scientific and should accurately and comprehensively reflect the development status of each city in the Greater Bay Area. It should closely rely on the connotation of high-quality development. "High-quality development is the development that can well meet the people's growing needs for a better life, that reflects the new development concept, that has innovation as the first driving force, coordination as an endogenous feature, green as a universal form, openness as the only way, and sharing as the fundamental goal." To build a high-quality development evaluation system for the Guangdong Hong Kong Macao Greater Bay Area, it is necessary not only to reflect the requirements of the new development concept but also to scientifically select statistical indicators and set up a weighted summary plan for indicator information. At the same time, the corresponding indicator system must scientifically reflect the differences and consistency between the nine cities in the Pearl River Delta and Hong Kong and Macao in their political systems and economic management practices.

2.1.2. Systematicity

The high-quality evaluation indicator system of the Guangdong Hong Kong Macao Greater Bay Area should be logical and hierarchical. The indicator system should reflect the high-quality development results of the Guangdong Hong Kong Macao Greater Bay Area from different dimensions, and each dimension should include several complementary statistical indicators. The indicators measuring the development level of the Guangdong Hong Kong Macao Greater Bay Area should have a clear and logical relationship. Each indicator should jointly reflect the level of high-quality development from different angles.

2.1.3. Operability

The construction of indicators to measure the high-quality development level of the Greater Bay Area must be operable and strive to be simple and effective. On the one hand, the first-level indicators should be determined first, and representative second-level indicators should be selected under the first-level indicators to avoid indicator duplication. On the other hand, easily obtainable and credible indicators should be selected. The selected indicators should come from officially published statistical data to ensure the reliability and objectivity of the data. At the same time, to better carry out a comparative analysis, this study intends to conduct an overall analysis of the 11 cities in the Greater Bay Area and a detailed analysis of the nine cities in the Pearl River Delta from an operability perspective in two sets of indicator systems.

2.2. Overview of Index Selection and Research

High-quality development is not only an economic requirement but a requirement that spans across all aspects of economic and social development. It is unreasonable for a single indicator to describe the multi-dimensional characteristics of high-quality development. Therefore, it has become a hot topic for scholars to explore and measure high-quality development indicators and establish a feasible statistical indicator system. Many scholars have focused their research on the "five development concepts" when selecting high-quality development indicators. For instance, Huang X et al. (2020) established a high-quality development evaluation indicator system from five aspects: innovative development, urban-rural coordination, ecological environment, opening up, and people's livelihood. Sun X et al. (2021) built a comprehensive evaluation index system for 25 cities from four aspects:

economic vitality, innovation efficiency, green development, and quality of life. Some scholars also consider the "five development concepts" and take into account factors such as comprehensiveness, typicality, and representativeness, selecting several dimensions that best represent people's yearning for a better life. For example, Yan C et al. conducted an empirical analysis of the urban centrality of significant cities in northern Jiangsu based on seven aspects: comprehensive economy, scientific and technological innovation, competitiveness, agglomeration capacity, traffic accessibility, traffic convenience, and urban competitiveness. Zheng X Y et al. (2018) studied sustainable urban development from the aspects of economic development, resource allocation, environmental protection, and social humanities. Deng F et al. (2021) established a high-quality development evaluation index system for urban agglomeration from three aspects: human capital, infrastructure construction, and ecological capital construction.

2.3. Statistical index system adopted in this paper

To scientifically construct a high-quality development evaluation index system, we need to proceed according to not only the new development concept and high-quality development requirements but also its connotation from the perspective of statistical measurement. Its notable characteristics are a more sufficient and balanced development, and the dynamic balance between supply and demand needs to be achieved at a higher level. When selecting indicators, their data sources and statistical data availability should be considered, and the evaluation modeling method should be scientific and focused.

2.3.1. Economic development dimension

High-quality development requires a dynamic national economy. High-quality economic development requires not only stable growth in GDP, which reflects the overall economic situation, but also constant optimization of resource allocation and industrial structure and maintaining a coordinated "three carriages," i.e., the proportion of consumption, investment, and exports. Therefore, this paper selects the proportion of GDP, capital productivity, labor productivity, and total retail sales of consumer goods to reflect the economic development level of the Guangdong Hong Kong Macao Greater Bay Area. All four indicators are positive. The growth of regional GDP, the increase in capital or labor productivity, and the increase in the proportion of total retail sales of consumer goods all indicate an improvement in local economic development.

2.3.2. Innovative development dimension

Innovation is the driving force of high-quality development, and innovative development is an essential aspect of it. The key to achieving high-quality development is innovation. We need to accelerate the establishment of a technological innovation system, pay attention to the investment in scientific research funds and the training of scientific research personnel, and achieve efficient development based on innovation. This paper selects three indicators to reflect the innovation level of the Guangdong Hong Kong Macao Greater Bay Area, namely the number of patents granted per capita, R&D investment intensity, and R&D personnel of industrial enterprises above a designated size. All three indicators are positive, and an increase in the number of patent authorizations per capita, the intensity of R&D investment, and the number of R&D personnel of industrial enterprises above the designated size all indicate an improvement in the local innovation level.

2.3.3. Coordination and sharing dimensions

High-quality development emphasizes the coordination and sharing of development. Coordination is an endogenous feature of high-quality development, and sharing is the fundamental goal of high-quality development. The concept of coordinated development and shared development focuses on solving social fairness and justice problems and realizing the benefits and sharing of development achievements. Coordinated regional development,

balanced distribution of education, medical care, elderly care, and other resources, and shared development emphasize the universality of per capita income. Therefore, this paper selects per capita disposable income, per capita education expenditure, and the number of hospital beds owned per 10,000 people to reflect the sharing and coordination level of Guangdong Hong Kong Macao Greater Bay Area. The three indicators are all positive. The increase in per capita disposable income, per capita education expenditure, and the number of hospital beds owned per 10,000 people indicates the improvement of local sharing and coordination levels.

2.3.4. Green development dimension

High-quality development requires green development. The key to green development lies in protecting the ecological environment, conserving energy, promoting environmental protection, improving the ecological environment, and achieving a high level of sustainable development in the ecological industry. Therefore, this paper selects the green coverage rate, energy consumption per unit of GDP, and power consumption per unit of GDP in built-up areas to reflect the level of green development in the Guangdong Hong Kong Macao Greater Bay Area. The green coverage rate of the built-up area is a positive indicator, and energy consumption per unit of GDP and power consumption per unit of GDP are negative indicators. The growth of green coverage in built-up areas and the decrease in energy consumption per unit of GDP and power consumption per unit of GDP indicate an improvement in the local level of green development.

2.3.5. Open development dimension

The opening is essential for high-quality development. The key to measuring the degree of open development is to reflect the strength and effect of the economy's opening. Therefore, this paper selects total exports and imports to reflect the strength of the open environment and uses foreign trade dependence to reflect the effect of opening. The opening level of the Guangdong Hong Kong Macao Greater Bay Area will be measured through the above indicators. The three indicators are all positive. The growth of total exports and imports and the increase in foreign trade dependence indicate an improvement in local openness.

Table 1 presents the high-quality development evaluation indicator system of the Guangdong Hong Kong Macao Greater Bay Area established in this study and provides a detailed description of the names, units, meanings, and attributes of all secondary indicators.

3. Measuring method of high-quality development in Guangdong Hong Kong Macao Greater Bay Area

In this paper, the Entropy Weight-TOPSIS two-step method is used to process the index data. In the first step, the entropy weight method is used to determine the weight of each index. In the second step, based on index weight, the TOPSIS method is used to calculate the scores of evaluation objects and rank them.

3.1. Weighting by entropy weight method

The amount of information contained in each indicator differs, and it is not scientific to measure directly without considering weights. The entropy weight method objectively measures the weight of each index using information entropy based on the dispersion of each index data. Its objectivity ensures the scientific and rational nature of the research.

Step 1, data processing. There are n cities to be evaluated and m evaluation indicators to form the original data matrix. Where, $X_{i,j}$ represents the j-th index of the i-th city.

Table 1. Evaluation index system for high-quality development of Guangdong Hong Kong Macao Greater Bay Area.

Primary indicators	Secondary indicators	unit	Index meaning	Attribute
Economic development	GDP	RMB100mn	——	+
	capital productivity	——	GDP divided by Investment in fixed assets of the whole society	+
	labor productivity	10000 yuan/person	GDP divided by Employees of the whole society	+
	proportion of total retail sales of consumer goods	%	Total retail sales of consumer goods divided by GDP	+
Innovation	number of patents granted per capita	Number/10000 persons	Number of patents granted at the end of the year divided by permanent population at the end of the year	+
	R&D investment intensity	%	R&D expenditure/GDP	+
	R&D personnel of industrial enterprises above the designated size	Person/10000	R&D personnel of industrial enterprises above designated size divided by total population at the end of the year	+
Shared coordination	per capita disposable income	yuan	——	+
	per capita education expenditure	10000 people/100 million yuan	——	+
	ten thousand people have hospital beds	10000 persons/bed	——	+
Openness	total exports	RMB100mn	——	+
	total imports	RMB100mn	——	+
	dependence on foreign trade	%	Total import and export divided by GDP	+
Green	greening coverage rate of built-up area	%	Green coverage area of built-up area divided by the built-up area	+
	energy consumption per unit GDP	Ton of standard coal/10000 yuan	Total standard coal consumption divided by GDP	-
	power consumption per 10000yuan GDP	KWh/10000 yuan	Total electricity consumption divided by GDP	-

Note: The data used in this paper are from the China Statistical Yearbook, Guangdong Statistical Yearbook, statistical yearbooks of various cities in Guangdong, statistical bulletins of national economic and social development of various cities in Guangdong, China Urban Statistical Yearbook, Hong Kong Statistical Yearbook, Macao Statistical Yearbook, etc. Some index data were obtained through calculation, and a small amount of missing data was supplemented by interpolation. Index data involving Hong Kong dollars and Macao dollars were converted using the current year's RMB exchange rate.

$$X = \begin{bmatrix} X_{1,1} & X_{1,2} & \cdots & X_{1,m} \\ X_{2,1} & X_{2,2} & \cdots & X_{2,m} \\ \vdots & \vdots & \ddots & \vdots \\ X_{n,1} & X_{n,2} & \cdots & X_{n,m} \end{bmatrix} \tag{1}$$

The measurement system includes 16 measurement indicators, including both positive and negative indicators. A higher value indicates better performance for positive indicators, while for negative indicators, a lower value indicates better performance. Therefore, it is necessary to convert the negative indicators into positive ones so that each indicator value represents the same meaning. The negative indicators can be converted into positive ones using the following formula:

$$Y_{i,j} = \frac{\max(X_{i,j}) - X_{i,j}}{\max(X_{i,j}) - \min(X_{i,j})} \tag{2}$$

$X_{i,j}$ and $Y_{i,j}$represents the original data and the data after forward processing respectively.

Since the measurement units of each indicator in the evaluation system are different, in order to make the indicators comparable and objective, each indicator needs to be standardized before calculating the comprehensive indicators to eliminate the dimensions of each indicator. Since the dimension of negative indicators has been eliminated through positive transformation, only positive indicators need to be processed. This paper selects the normalization method, and the calculation formula is:

$$Y_{i,j} = \frac{X_{i,j} - \min(X_{i,j})}{\max(X_{i,j}) - \min(X_{i,j})} \tag{3}$$

$X_{i,j}$ and $Y_{i,j}$ represents the original data and the normalized data respectively. Step 2, Calculation of index entropy.

$$H_j = -k \sum_{i=1}^{m} w_{i,j} \cdot \ln w_{i,j} \tag{4}$$

$$w_{i,j} = \frac{Y_{i,j}}{\sum_{i=1}^{m} Y_{i,j}}, k = \frac{1}{ln\, m} \tag{5}$$

H_j represents the information entropy of different indicators, $w_{i,j}$ refers to the weight of the index value of the i-th item under the j-th index. Step 3, Calculation index entropy weight.

$$f_j = \frac{1 - H_j}{\sum_{j=1}^{n}(1 - H_j)} = \frac{1 - H_j}{n - \sum_{j=1}^{n} H_j} \tag{6}$$

f_j represents the entropy weight of different indicators.

3.2. TOPSIS calculated comprehensive score

TOPSIS, short for Technique for Order of Preference by Similarity to Ideal Solution, is a comprehensive evaluation method used to accurately reflect the gap between cities by making full use of the original data information. The Entropy weighted TOPSIS method searches for the best and worst scheme in a limited number of schemes and uses the distance between the evaluation object and the best and worst scheme as the judgment basis for the evaluation grade.

In step 1, the analysis data matrix is established and finally obtained through data processing:

$$Z = \begin{bmatrix} Z_{1,1} & Z_{1,2} & \cdots & Z_{1,m} \\ Z_{2,1} & Z_{2,2} & \cdots & Z_{2,m} \\ \vdots & \vdots & \ddots & \vdots \\ Z_{n,1} & Z_{n,2} & \cdots & Z_{n,m} \end{bmatrix} \tag{7}$$

$$Z_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}} \tag{8}$$

Step 2, Construct weighting matrix.

$$Z^* = \left[\begin{pmatrix} Z_{11} \cdot f_1 & Z_{12} \cdot f_2 & \cdots & Z_{1m} \cdot f_m \\ Z_{21} \cdot f_1 & Z_{22} \cdot f_2 & \cdots & Z_{2m} \cdot f_m \\ \vdots & \vdots & \ddots & \vdots \\ Z_{n1} \cdot f_1 & Z_{n2} \cdot f_2 & \cdots & Z_{nm} \cdot f_m \end{pmatrix}\right] \tag{9}$$

Step 3, Proximity between the evaluation object and the optimal plan.

$$\begin{cases} Z_{ij}^{*+} = \max\limits_{n,m}(Z_1^{*+}, Z_2^{*+}, \cdots, Z_m^{*+}) \\ Z_{ij}^{*-} = \min\limits_{n,m}(Z_1^{*-}, Z_2^{*-}, \cdots, Z_m^{*-}) \end{cases} \tag{10}$$

Step 4, Calculate the gap between each evaluation index and the best and worst vectors.

$$D_i^+ = \sqrt{\sum_{j=1}^{m}\left(Z_j^{*+} - Z_{ij}^*\right)^2}, D_i^- = \sqrt{\sum_{j=1}^{m}\left(Z_j^{*-} - Z_{ij}^*\right)^2} \tag{11}$$

Step 5, Relative proximity and sequencing of structures.

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{12}$$

Sort according to the size of C_i. The larger the C_i is, the closer the evaluation object is to the optimal value.

4. Assessment of the high-quality development of Guangdong Hong Kong Macao Greater Bay Area

4.1. Assessment of the high-quality development of Guangdong Hong Kong Macao Greater Bay Area

The indicators constructed in this paper include positive and negative indicators, and the original data needs to be standardized before calculating the weights. Please see Table 2 for the weight coefficients of the indicators.

It can be observed from Table 2 that the GDP, total exports, energy consumption per unit of GDP, and power consumption per 10,000 yuan of GDP in the secondary indicators of the system all have values above 0.1. This implies that the indicators of economic development, openness, and green development have a significant impact on high-quality development. Among them, economic indicators have a relatively high weight, indicating that economic development plays a vital role in urban development. GDP is not only a primary indicator reflecting a region's economic growth, economic scale, and per capita economic development level, but it is also a yardstick for measuring the development of various undertakings. Therefore, there is no doubt about the high proportion of the weight of GDP. Opening up is the only way to achieve prosperity, and green development is an inevitable requirement for sustainable development. Innovation is the primary driving force for development and an inexhaustible driving force for regional development. The weight coefficients of the number of patents granted per capita, the dependence on foreign trade, and the intensity of investment above the designated size are all between 0.05 and 0.1, which means that the index weights of the city's innovation ability and scientific research investment are high, conforming to the law of urban development. Among the indicators for measuring sharing and coordination, the weights of per capita disposable income, per capita education expenditure, capital productivity, and labor productivity are relatively low, indicating that sharing and coordination indicators have a certain impact on measuring urban development and evaluating high-quality development.

4.2. Assessment of the High-quality Development of nine cities in the Pearl River Delta of Guangdong Hong Kong Macao Greater Bay Area

Table 2. Index weight coefficient calculated by entropy method.

Primary indicators	Secondary indicators	weight
Economic development	capital productivity	0.1612
	labor productivity	0.0425
	proportion of total retail sales of consumer goods	0.0214
	per capita disposable income	0.0082
Shared coordination	per capita education expenditure	0.0168
	ten thousand people have hospital beds	0.0255
Openness	total exports	0.0091
	total imports	0.2157
	dependence on foreign trade	0.0610
Innovation	number of patents granted per capita	0.0749
	R&D investment intensity	0.0281
Green	greening coverage rate of built-up area	0.0542
	energy consumption per unit GDP	0.0022
	power consumption per 10000 yuan GDP	0.1727
	capital productivity	0.1065

After obtaining the weight of each index using the entropy weight method, the grade of each sample can be evaluated by the degree of proximity to the ideal solution. Based on this, the cities in the Guangdong-Hong Kong-Macao Greater Bay Area can be used as samples to conduct assessments of high-quality development. However, due to differences in statistical rules and data comparability between Hong Kong, Macao, and the nine cities in the Pearl River Delta, this study first plans to carry out a high-quality development assessment of the nine cities in the Pearl River Delta within the Greater Bay Area of Guangdong, Hong Kong, and Macao. Then, they will be incorporated into Hong Kong and Macao for systematic analysis to achieve effective linkage.

The first step is to calculate the comprehensive index and ranking of the urban high-quality development level of the nine cities in the Pearl River Delta from 2013 to 2020. The specific results are shown in Table 3, while Figure 1 displays the average comprehensive index score of high-quality urban development of the nine cities in the Pearl River Delta from 2013 to 2020.

Table 3. Scores of nine cities in the Pearl River Delta with high-quality development level calculated by TOPSIS over the years.

	2013	2014	2015	2016	2017	2018	2019	2020	Mean	Rank
Guangzhou	0.525	0.530	0.503	0.525	0.539	0.567	0.547	0.564	0.5375	2
Shenzhen	0.705	0.702	0.685	0.710	0.678	0.727	0.717	0.749	0.7091	1
Zhuhai	0.477	0.496	0.458	0.467	0.446	0.469	0.487	0.460	0.4700	3
Foshan	0.351	0.367	0.390	0.375	0.355	0.391	0.380	0.414	0.3779	5
Huizhou	0.212	0.217	0.252	0.242	0.281	0.244	0.212	0.273	0.2416	8
Dongguan	0.361	0.369	0.400	0.442	0.472	0.489	0.464	0.504	0.4376	4
Zhongshan	0.356	0.374	0.355	0.345	0.337	0.376	0.362	0.355	0.3575	6
Jiangmen	0.265	0.263	0.133	0.285	0.236	0.261	0.316	0.303	0.2578	7
Zhaoqing	0.131	0.128	0.242	0.200	0.186	0.225	0.200	0.271	0.1979	9

It can be seen from Table 3 that since 2013, the development of the nine cities in the Pearl River Delta has shown a steady upward trend. Among them, Shenzhen has always been in the leading position, ranking first every year. It can also be seen from Figure 1 that Shenzhen has the highest level of high-quality development, with a comprehensive index of 0.71. In fact, since 2018, Shenzhen's GDP has surpassed that of Hong Kong, ranking first in the Guangdong-Hong Kong-Macao Greater Bay Area. In 2019, the Central Committee of the Communist Party of China and the State Council issued the Opinions on Supporting Shenzhen to Build an Advanced Demonstration Zone

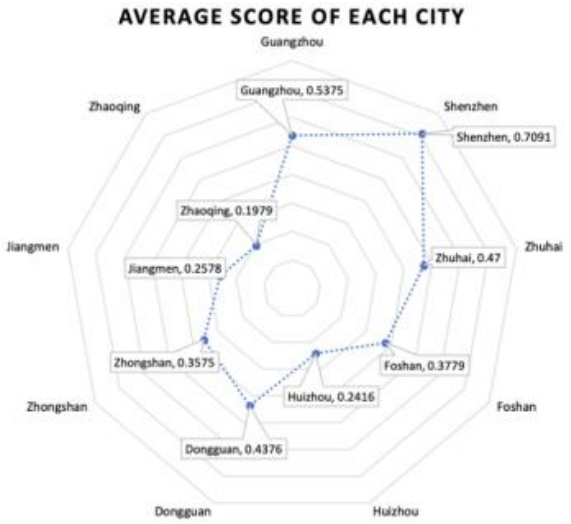

Figure 1. The comprehensive score of each city from 2013 to 2020 (excluding Hong Kong and Macao).

of Socialism with Chinese Characteristics, which kicked off the construction of an advanced demonstration zone in Shenzhen. So far, Shenzhen has accelerated the implementation of the innovation-driven strategy and the upgrading of its industrial structure, becoming a vibrant city of innovation, entrepreneurship, and creativity. Under the historical opportunity of dual-zone construction, Shenzhen has taken advantage of the benefits of leading in reform and innovation to enter a new era of green and low-carbon development, becoming the city with the lowest energy consumption and carbon emission intensity among the super cities in China. Based on these advantages, Shenzhen deserves to be the first city in the Guangdong-Hong Kong-Macao Greater Bay Area. As the provincial capital, Guangzhou is second only to Shenzhen in terms of development, with good performance in all indicators. Zhuhai, Dongguan, Foshan, and Zhongshan have developed steadily, ranking third, fourth, fifth, and sixth. In 2013, Zhuhai formulated, promulgated, and implemented the "Three Highs and One Special" Modern Industrial System Plan of Zhuhai. In 2015, Zhuhai Hengqin New Area, a pilot free trade zone, was officially established. Its score decreased slightly in 2017 but then increased steadily. With the completion of the Hong Kong-Zhuhai-Macao Bridge in 2018, Zhuhai's crucial geographical location in the Dawan District is prominent, which will surely bring about more significant development. Dongguan, Foshan, and Zhongshan are known for their manufacturing industry as "world factories." The investment in infrastructure construction of these cities has increased in recent years, so the economic development trend is quite good. Jiangmen, Huizhou, and Zhaoqing still have a large gap with other cities. They belong to the peripheral cities of the Pearl River Delta, and their geographical locations are at a disadvantage. It can be seen that the urban development level of the Guangdong-Hong Kong-Macao Greater Bay Area is uneven. It can also be seen from Figure 1 that Guangzhou, Shenzhen, and Zhuhai extend outward. At the same time, Jiangmen, Huizhou, and Zhaoqing are close to the center of the radar map, showing a "shoe" shape as a whole, consistent with the specific results shown in Table 3.

4.3. Measurement of high-quality development level of 11 cities in Guangdong Hong Kong Macao Greater Bay Area, including Hong Kong and Macao

According to the Outline of the Development Plan for the Guangdong Hong Kong Macao Greater Bay Area, the construction of the Greater Bay Area needs to adhere to the new development concept and make full use of the advantages of the "one country, two systems" system and the unique advantages of Hong Kong and Macao. To continuously deepen the mutually beneficial cooperation between Guangdong, Hong Kong, and Macao, it is necessary to further establish a mutually beneficial and win-win regional cooperation relationship, promote the

coordinated development of regional economies, and inject new momentum into the development of Hong Kong and Macao. Hong Kong, Macao, and mainland China belong to different economic systems, which leads to the fact that the statistical indicators used by these two cities are not the same as those used by the mainland. Therefore, the indicators used to measure the high-quality development level of these two cities are no longer applicable, and new indicators need to be developed to measure their development level. Based on the basic principles of scientific, systematic, and operable index selection, the following index system is established, as shown in Table 4.

According to Table 4, the innovation index has the most significant weight value, followed by the economic and opening indexes, while the green index has the smallest weight value. This shows that the innovation indicators have the most significant impact on the urban development level of the Guangdong Hong Kong Macao Greater Bay Area, and the economic and open indicators also have a considerable impact. In contrast, the green indicators have less impact on the evaluation of the high-quality development of the Greater Bay Area. According to the basic principle of "innovation-driven and reform-led" in the Outline of the Development Plan for the Guangdong Hong Kong Macao Greater Bay Area, it is reasonable that the proportion of innovation indicators is the largest.

Table 4. Index weight coefficient calculated by entropy method (including Hong Kong and Macao).

Level I indicators	Secondary indicators	Entropy weight
Economic development	GDP	0.261738
Innovation	Number of national invention patents	0.321825
Shared coordination	Ten thousand people have hospital beds	0.101938
Openness	Dependence on foreign trade	0.26615
Green	Power consumption per 10000-yuan GDP	0.048363

According to the entropy weight method and the TOPSIS method, the annual scores of high-quality development levels in the Guangdong Hong Kong Macao Greater Bay Area are obtained. Observing Tables 3 and 5, it can be found that the analysis results are highly consistent, reflecting a strong connection between the two sets of indicator systems and their evaluation results.

Table 5. Comprehensive scores before the issuance of the Outline of the Development Plan for the Greater Bay Area of Guangdong, Hong Kong, and Macao.

Area	2013	2014	2015	2016	2017	2018	Mean 2013~2018	Rank
Guangzhou	0.505	0.518	0.504	0.523	0.542	0.54	0.522	3
Shenzhen	0.577	0.585	0.572	0.616	0.626	0.629	0.601	1
Zhuhai	0.263	0.251	0.263	0.289	0.288	0.291	0.274	5
Foshan	0.281	0.272	0.286	0.303	0.309	0.305	0.293	4
Huizhou	0.217	0.19	0.221	0.233	0.222	0.196	0.213	8
Dongguan	0.239	0.211	0.222	0.295	0.309	0.329	0.268	6
Zhongshan	0.235	0.221	0.201	0.194	0.204	0.198	0.209	10
Jiangmen	0.22	0.176	0.192	0.238	0.252	0.258	0.223	7
Zhaoqing	0.193	0.164	0.168	0.198	0.199	0.21	0.189	11
Hong Kong	0.596	0.57	0.563	0.574	0.563	0.565	0.572	2
Macao	0.149	0.227	0.236	0.227	0.215	0.217	0.212	9

Figure 2 shows the average composite index score of the high-quality development level of the Greater Bay Area cities, including Hong Kong and Macao, from 2013 to 2020. By observing Figure 2, we can see that Hong Kong, Shenzhen, and Guangzhou were far ahead in the total index scores before the issuance of the Outline of the Development Plan for the Guangdong Hong Kong Macao Greater Bay Area, which is reasonable. It can be observed from Tables 5 and 6 that the development of Hong Kong and Macao is highly volatile and complex. Hong Kong's

score ranges between (0.555, 0.596), ranking second among the cities in the Greater Bay Area, between Shenzhen and Guangzhou. Macao's score fluctuates between (0.149, 0.23), with Macao being more volatile. According to the leading role of the combination of Hong Kong-Shenzhen, Guangzhou-Foshan, and Macao-Zhuhai in the spatial layout pole driven by the Outline of the Development Plan for the Greater Bay Area of Guangdong, Hong Kong, and Macao, the comprehensive scores and rankings in Tables 5 and 6 are relatively scientific. To improve the total score of each city, promote the rational division of labor among them, and optimize the development pattern of the Guangdong Hong Kong Macao Greater Bay Area, it is necessary to strengthen the links between cities and speed up the construction of transportation facilities among them.

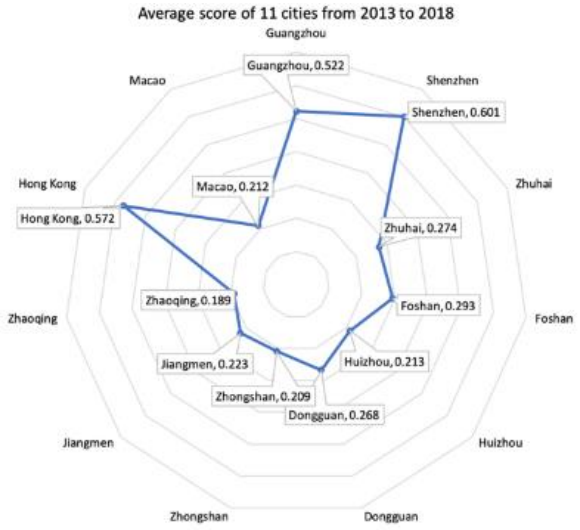

Figure 2. The comprehensive score of each city from 2013 to 2018.

Hong Kong is an international financial, shipping, and trade center, and international aviation hub. However, with the continuous promotion of reform and opening up and the drive of Hong Kong, Shenzhen, as a special economic zone, has achieved all-around development in finance, science and technology, manufacturing, and other aspects. With the continuous improvement of Shenzhen's comprehensive strength, Hong Kong has gradually shifted its focus from manufacturing, scientific and technological innovation to financial services, foreign trade, real estate, and investment industries. Hong Kong and Shenzhen have strengthened their linkage effect and deepened their division of labor, but Hong Kong's comprehensive strength has also declined. Based on the effect of the interaction between Hong Kong and Shenzhen, Shenzhen, which is at the forefront of reform and opening up, should surpass Hong Kong in its total score at a particular time point, and Hong Kong's innovation dimension score should gradually decrease while its opening dimension score should continue to remain high.

Table 6 and Figure 3 both reflect the total scores after the issuance of the Outline of the Development Plan for the Greater Bay Area of Guangdong, Hong Kong, and Macao. Figure 3 shows the average comprehensive index scores of the high-quality development level of the Greater Bay Area cities, including Hong Kong and Macao, from 2019 to 2020. It is apparent from Figure 3 that Hong Kong, Guangzhou, and Shenzhen are still the top three cities. According to the modeling results in Table 6, from the scores in 2013, we can see that Hong Kong ranks first in terms of comprehensive ranking. Since 2014, Shenzhen has surpassed Hong Kong as the city with the highest score.

According to the data from 2013 to 2020, Hong Kong, Shenzhen, and Guangzhou are far ahead of other Greater Bay Area cities in terms of economic development. Hong Kong leads the way in terms of openness, with an average dependence on foreign trade of 381%. However, Hong Kong's scientific and technological innovation level is far lower than that of Guangzhou and Shenzhen, and the number of national patent inventions in Hong Kong in 2020 is only 2% of that of Shenzhen.

Table 6. Outline of the Development Plan for the Greater Bay Area of Guangdong, Hong Kong, and Macao.

Area	2019	2020	Mean	Rank
Guangzhou	0.532	0.534	0.533	3
Shenzhen	0.635	0.633	0.634	1
Zhuhai	0.274	0.279	0.2765	6
Foshan	0.295	0.295	0.295	5
Huizhou	0.184	0.185	0.1845	10
Dongguan	0.337	0.324	0.3305	4
Zhongshan	0.191	0.177	0.184	11
Jiangmen	0.261	0.26	0.2605	7
Zhaoqing	0.223	0.223	0.223	9
Hong Kong	0.563	0.555	0.559	2
Macao	0.23	0.227	0.229	8

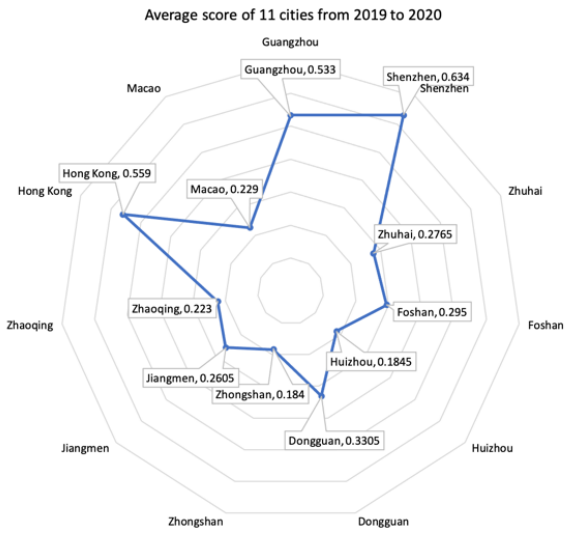

Figure 3. The comprehensive score of each city from 2019 to 2020.

Before issuing the Outline of the Development Plan for the Greater Bay Area of Guangdong, Hong Kong, and Macao, Hong Kong's average score was 0.572. After that, Hong Kong's score decreased to 0.559, a difference of 0.013, a decrease of 2.27%. There are two reasons for the decline in Hong Kong's total score. On the one hand, Hong Kong's service industry accounts for a large proportion, and its economic structure is not reasonable, which has led to a sharp decline in mainland tourists to Hong Kong under the impact of COVID-19 and the Sino-US trade war, and the volume of international trade transactions has decreased. The tourism, transportation, and retail industries have been hit unprecedentedly. On the other hand, Hong Kong is a transit station for the import and export of goods from the mainland, which is both a strength and a weakness. That is, Hong Kong is hollow and depends more on the development of the real inland industry. Due to the sluggish development of the real mainland industry in recent years, the development of Hong Kong has also shown an idle state. In addition, in 2014, some people caused a disaster in Hong Kong linked with the occupying of the Central Plains event launched by foreign forces, and the Hong Kong amendment storm in 2019 also objectively caused a severe impact on the overall trend of Hong Kong's economic and social development, partially offsetting the effects of the Central Government's series of measures to benefit Hong Kong, and forming a profound lesson. With the promulgation and implementation of the National Security Law of Hong Kong, Hong Kong has achieved a positive transformation from chaos to governance. In 2021, the Hong Kong SAR government proposed a policy program to promote the integrated development of Hong Kong and Shenzhen, build a global innovation and technology center, and build a northern metropolis. It is believed that

it will help Hong Kong make up for its weaknesses in the field of scientific and technological innovation and usher in significant new development opportunities.

According to Table 6, it can be seen that Macao's ranking before and after the issuance of the Outline of the Development Plan for the Greater Bay Area of Guangdong, Hong Kong, and Macao was not high. However, with the introduction of the Outline of Development, the score and ranking of the Greater Bay Area have improved, from 0.212 to 0.229 and from ninth to eighth, respectively. From an economic perspective, Macao's GDP is close to Zhuhai's and has a large gap compared with Hong Kong, Guangzhou, and Shenzhen's GDP. However, in terms of per capita GDP, Macao's economy is superior. As the gambling and tourism industries contribute up to 70% to Macao's economy, the total GDP of Macao in 2020 fell by 56.3% compared to that in 2019 due to the impact of the epidemic, resulting in a low economic score after the establishment of the Guangdong Hong Kong Macao Greater Bay Area.

From an innovation perspective, Macao's innovation sector scored extremely low due to its reliance on the gambling, tourism, and service industries. Its technological industrialization is insufficient, and it lacks innovative enterprises. The proportion of R&D investment in GDP is low, and there is a lack of training for innovative talents. This has led to a low number of exclusive national inventions obtained and resulted in Macao's insufficient innovation capacity. In 2016, the Five-Year Development Plan of the Macao Special Administrative Region (2016-2020) was issued in response to Macao's scientific and technological innovation, putting forward requirements for "enhancing innovation concepts, enhancing innovation capabilities, and gradually strengthening innovation and scientific and technological progress." So far, Macao's scientific and technological innovation capacity is slowly improving, and efforts have been made to join the ranks of innovative cities, but the effect is not very significant.

In terms of openness, Macao is second only to Hong Kong, but it can only match Hong Kong's openness, so the score of the openness dimension is also reasonable. On September 5, 2021, the Central Committee of the Communist Party of China and the State Council issued the Overall Plan for the Construction of the Hengqin Guangdong Macao Deep Cooperation Zone, which is of great significance for promoting the moderate and diversified development of Macao's economy and promoting deep cooperation in the Guangdong Hong Kong Macao Greater Bay Area. With the support of this plan, Macao's development will surely reach a higher level.

5. Research summary and prospect

In order to measure the development of the Guangdong Hong Kong Macao Greater Bay Area from 2013 to 2020, a high-quality development evaluation index system of the Greater Bay Area has been constructed in this paper under the guidance of the five major development concepts. The paper evaluates the leading role and effect of the new development concepts on the Greater Bay Area of Guangdong, Hong Kong, and Macao. Based on the entropy weight method used to determine the index weight coefficient, the TOPSIS method is used to evaluate and analyze the development of each city. A two-step method is used to evaluate the high-quality development of the Greater Bay Area cities that include Hong Kong and Macao and those that do not include them. The following conclusions have been drawn:

First of all, the Guangdong Hong Kong Macao Greater Bay Area has thoroughly implemented the new development concept and continued to improve the level of high-quality development. From 2013 to 2020, the Guangdong Hong Kong Macao Greater Bay Area thoroughly implemented the new development concept and led the country in building a system and mechanism to promote high-quality economic development, build a modern economic system, form a new pattern of all-round opening up, and create a pattern of social governance of joint construction, governance, and sharing. The development level of the 11 cities in the Guangdong Hong Kong Macao Greater Bay Area is steadily rising. From the perspective of fluctuation, the score in 2019 declined slightly, but from an overall perspective, it still maintained a consistent good development trend. According to the current development situation, the cities in the Guangdong Hong Kong Macao Greater Bay Area can achieve the development

goal of enhancing their comprehensive strength in 2022 in the Outline of the Development Plan for the Guangdong Hong Kong Macao Greater Bay Area.

Secondly, the profound integration effect of the Guangdong Hong Kong Macao Greater Bay Area has emerged to promote high-quality regional development. The Outline of the Guangdong Hong Kong Macao Greater Bay Area Development Plan plays a vital leading role in promoting high-quality regional development. Since the construction of the Guangdong Hong Kong Macao Greater Bay Area, new achievements have been made, and it has gradually entered a new stage of integrated development. The "hard connectivity" of infrastructure and the "soft connectivity" of rules and mechanisms were developed simultaneously. The Hong Kong-Zhuhai-Macao Bridge and Nansha Bridge were opened in parallel. The Shenzhen China Channel was promoted orderly, and Hong Kong was integrated into the national high-speed rail network, promoting the overall high-quality development of the region. In addition, Guangdong has launched more than 30 Guangdong Hong Kong and Guangdong Hong Kong Macao science and technology cooperation funding projects, and the regional scientific and technological innovation achievements will also reach a higher level. Among them, Hong Kong-Shenzhen, Guangzhou-Foshan, and Macao-Zhuhai have joined forces to promote deep cooperation between the cities in the Greater Bay Area and jointly develop high-quality.

Finally, Hong Kong has achieved a transformation from chaos to governance, Macao has achieved diversified development, and the construction of the Guangdong Hong Kong Macao Greater Bay Area has effectively promoted the great practice of one country, two systems to achieve stability and prosperity. Hong Kong and Macao have returned to the motherland for over 20 years. During these 20 years, they have experienced many ups and downs, including the mid-occupation event in 2014 and the Hong Kong case revision storm in 2019. However, Hong Kong has also made many remarkable achievements. To safeguard the long-term prosperity and stability of Hong Kong and Macao and to safeguard the fundamental interests of Hong Kong and Macao, one country, two systems is the fundamental principle. For Hong Kong and Macao, one country, two systems are the most significant advantage, and the construction of the Guangdong Hong Kong Macao Greater Bay Area is a new major opportunity. Today, Hong Kong has become more stable, and the social atmosphere has become more harmonious through the "Patriot Governing Hong Kong." Macao is also actively seeking urban transformation, giving full play to its advantages of being at the intersection of the national double cycle and having extensive external contacts, further expanding foreign exchanges, and promoting the moderate and diversified development of the local economy. Hong Kong and Macao should seize new opportunities to jointly build the Guangdong Hong Kong Macao Greater Bay Area and promote the implementation of the great practice of one country and two systems.

Although we have obtained satisfactory answers and reasonable explanations through careful data analysis, there are still some areas that need to be improved. On the one hand, this paper does not use a variety of comprehensive evaluation methods to compare the scores of cities, which can easily cause differences in results. On the other hand, in the selection of indicators, the evaluation indicators are mainly selected around the "five development concepts." In addition, in the comprehensive evaluation of the city, we should also increase the dimensions of indicators selected around the people's livelihood and other issues that are most concerned about to accurately and comprehensively reflect the level of urban development.

Future research will be discussed from the following aspects: First, further subdividing the division of urban development stages, clarifying the development characteristics of different stages of the city, comprehensively considering all aspects of urban development, and further refining and improving the evaluation system, so that it is more scientific and rational and can comprehensively reflect the high-quality development of the city. Secondly, for the unique situation of Hong Kong and Macao, we should explore establishing a unified evaluation system that can link the mainland and the two particular administrative regions, which are both scientific and operational. Finally, we can start from the subjective feelings of urban residents, investigate the residents' feelings of high-quality urban development through questionnaires, and incorporate urban happiness into the evaluation indicators of

high-quality development to truly reflect the needs of the people.

Funding Statement

This research received no external funding.

Acknowledgment

Acknowledgments to anonymous referees' comments and editor's effort.

Conflict of interest

The author claims that the manuscript is completely original. The author also declares no conflict of interest.

References

Deng, F., Yang, L., Gong, Q., et al. (2021). Evaluation of High-quality Economic Development Based on Entropy Weight Method: Taking Chengdu-Chongqing City Agglomeration as Example. *2021 The 4th International Conference on Computers in Management and Business*. https://doi.org/10.1145/3450588.3450594

Ding, L., Shao, Z., Zhang, H., Xu, C., Wu, D. (2016). A Comprehensive Evaluation of Urban Sustainable Development in China Based on the TOPSIS-Entropy Method. *Sustainability* 8, 746. https://doi.org/10.3390/su8080746

Wang, E., Liao, A. (2021). Research on High Quality Development Evaluation of Pearl River Delta Urban Agglomeration. *2021 5th International Seminar on Education, Management and Social Sciences (ISEMSS 2021)*

Huang X, Cai B, Yalin L I. (2020). Evaluation Index System and Measurement of High-quality Development in China. *REVISTA DE CERCETARE SI INTERVENTIE SOCIALA*, 68: 163-178. https://doi.org/10.33788/rcis.68.11

Li B, Wang H. (2022). Comprehensive evaluation of urban high-quality development: a case study of Liaoning Province. *Environment, Development and Sustainability*, 1-23. https://doi.org/10.1007/s10668-022-02129-5

Li J, Shi L, Xu A. (2019). Probe into the Assessment Indicator System on High-quality Development. *Statistical Research* 36(01). https://doi.org/10.19343/j.cnki.11-1302/c.2019.01.001

Lichi, Y. E. (2019). Evaluation of urban development quality based on the connotation of high-quality development: a case study of Guangdong province. *Journal of Landscape Research*, 11(02), 87-93+98. https://doi.org/10.16785/j.issn1943-989x.2019-2.020

Mei D, Hao X H, Gao S Y, et al. (2011). The evaluation of the urban evolution of Binhai New Area. *International Conference on Management Science & Engineering. IEEE*. https://doi.org/10.1109/ICMSE.2011.6070030

Qin C, Liu L, Qin W. (2017). On the Development Strategy of the Urban Agglomeration in the Guangdong-Hong Kong-Macao Greater Bay Area. *Regional Economic Review* 05. https://doi.org/10.14017/j.cnki.2095-5766.2017.0173

Sarmento R, Zorzal F M B, Serafim A J, et al. (2000). Urban environmental quality indicators. *WIT Transactions on Ecology and the Environment*, 39. https://doi.org/10.2495/URS000111

Wang J, Zhang M, Wang S. Shenzhen Port Competitiveness Evaluation Based on the Construction of the Guangdong-Hong Kong-Macao Greater Bay Area. *19th COTA International Conference of Transportation Professionals*. 2019. https://ascelibrary.org/doi/epdf/10.1061/9780784482292.469

Yan C, Jiang Y N, Xue L F. (2016). Evaluation on Urban Centricity of the Regions in Northern Jiangsu Based on Entropy-weight TOPSIS Method. *Journal of Huaiyin Teachers College (Natural Science Edition)* 15(03). https://doi.org/10.16119/j.cnki.issn1671-6876.2016.03.011

Yang J, Han M M, Yao H M, et al. (2020). Comprehensive evaluation of urbanization development quality in Four East China Provinces. *IOP Conference Series Earth and Environmental Science*, 594: 012005. https://doi.org/10.1088/1755-1315/594/1/012005