



Article Mismatch and Coupling: A Study on the Synergistic Development of Tourism-Economy-Ecology Systems in the Pearl River Delta

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Abstract: The integrated study of the tourism-economy-ecosystem plays a significant role in regional high-quality development. In this study, methods including the Spatial Mismatch Hypothesis (SMH), coupling coordination degree and a gravity model are adopted in combination to explore the evolution characteristics of the Tourism-Economy-Ecology (TEE) systems in the Pearl River Delta (PRD) from 2009 to 2019 from four perspectives: development level, spatial mismatch, coupling coordination and spatial mismatch-coupling coordination. The research results are presented as follows. Firstly, the overall development level of the three subsystems shows improvement, the overall pattern of tourism and economic development levels shows similarity, the polarization of tourism development reaches a relatively significant level, and the changes in the ecological subsystem are more significant than those in other subsystems. Secondly, the spatial mismatch direction and level of cities are relatively stable, and the mismatch index of high-grade cities varies considerably, while the tourism subsystem contributes significantly to the occurrence of spatial mismatch in the regional system. Thirdly, the coupling and coordination level of the system in the east is higher than in the west, with a vast majority of them in the state of near-mismatch, while the coupling and coordination state is more stable in most cities and tends to be coordinated. Guangzhou, Shenzhen and Foshan represent the crucial nodes of regional system coupling and coordination. The opening of high-speed railway lines enhances the connection between cities, and it remains necessary to enhance the coupling and coordination across various economic circles. Lastly, according to the comparison of spatial mismatch-coupling coordination linkage, these cities can be classified into three categories: prominent core cities, coordinating sub-cities, and potential peripheral cities. To be specific, Guangzhou and Shenzhen represent prominent core cities, Dongguan, Foshan and Huizhou represent coordinated secondary cities, and Zhuhai, Zhongshan, Jiangmen and Zhaoqing represent potential peripheral cities.

Keywords: TEE systems; spatial mismatch; coupling coordination; gravitational model; linkage intensity; PRD

1. Introduction

Enhancing the overall coordination and complementarity of advantages for a coupling system provides an important solution to regional synergy and high-quality development. First proposed in the 1960s, the Spatial Mismatch Hypothesis (SMH) deals with the relationship between housing and employment of specific groups in the context of urban spatial reconfiguration, as proposed by Kain [1]. Most of the prior studies adopting the theory have focused on such problems as group-specific disparities [2] and inner city–suburban disparities [3], both of which are important methodologies in relation to urban geography [4]. On the research scale, scholars have paid close attention to spatial mismatch studies of nations [5], economic zones [6], urban agglomerations [7] and provinces [8,9]. In terms of research methods, some of them compare the mismatch between various factors through



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Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). the construction of a two-dimensional combination matrix [10], while others evaluate it by building an index system in combination with a quantitative model. For example, Liu adopted the tourism spatial mismatch index to analyze the mismatch between the abundance of tourism resources and the foreign exchange income of tourism and the number of tourists in 53 coastal cities in China [11]. With regard to research content, scholars have focused their attention on the mismatch between tourism resources and tourism economic income [12], or the degree of dislocation between tourism resources, transportation location, as well as other factors and tourism economic income [10]. By taking into account the relationship between a single element and tourism development, they constructed an index system from the system perspective of Tourism-Economy-Ecology (TEE), and thoroughly analyzed the spatial mismatch of regional development and the integrity of the system [6]. From different perspectives, many scholars have conducted analyses of the development characteristics and driving forces of the tourism industry [13], tourism comprehensive competitiveness and tourism economy [14,15], so as to verify the synergy between culture and tourism, while exploring how to ensure its sustainability in the integration of the economic and tourism industries. In recent years, there has been an increase in the degree of discussion around the comprehensive relationship between tourism, economy and ecology [16]. These studies not only explored the relationship between tourism competitiveness and the economic growth of developing countries [17], but also assessed the evolution and sustainable development of urban economy-resource-environment (ERE) systems for the formulation of development strategies [18], which has contributed a lot of novel ideas and methods to the study of the synergistic development of tourism, economy and ecology.

As the research deepens, scholars have proposed the theory of regional coupling and coordinated development, which is based on the interaction and mutual restriction relationship between various element systems, representing another important perspective of research after the theory of SMH. Currently, plenty of research results have been achieved both at home and abroad. For example, Oh [19] conducted a thorough analysis of the relationship between tourism growth and economic expansion in Korea by using the Engle, Granger, and vector autoregressive models (VAR) in combination. As a commonly used econometric model, the VAR model is intended mainly to regress the current period variables on several lags of all variables. As confirmed by Oh, there is no long-term equilibrium relationship between the two locally, nor is there any long-run equilibrium relation between two series. Besides, the outcomes of the Granger causality test suggested a one-way causal relationship of economic-driven tourism growth. Considering tourism as a complex adaptive system, Day & Cai [20] explored the relationship between tourism, energy economy and the environment from the perspectives of tourists, tourism institutions and tourist destinations. Furthermore, multidisciplinary approaches have been taken to address these challenges within the tourism system, which have improved our understanding of the relationship between tourism and the environment. Cui [21] applied the coordinated development degree model to analyze the coordination of tourism economy and ecological environment in Shanghai. Despite an overall upward trend of the coordinated development of Shanghai's tourism economy and ecological environment, it remains in the category of moderate to good coordinated development. Although the ecological environment in Shanghai has shown significant improvement in recent years, there is still room for the further development of its tourism economy when compared with the ecological environment. By explaining the mechanism of action between regional tourism, economy and environment, Zhou [22] and Liu [23] et al. measured the coupling and coordination degree between these three subsystems. By taking the provinces and cities along the Yangtze River Economic Belt as an example, they discovered that the economic and tourism systems in the region are closely interrelated with each other, despite no severe conflict between environmental protection and economic development. The coupling coordination between the three systems is mainly stable and fluctuating, with the spatial development pattern being generally high in the east and low in the west. Based on the degree of coupling and coordination of 11 provinces and cities in the Yangtze River Economic Belt, Pan [24] further calculated the degree of tourism space attraction or radiation between provinces and cities. There are various research methods involved, such as the use of ecological niche theory to explore the coordinated development of tourism space with situational differentiation factors [25,26], and the application of certain development concepts or strategic ideas such as ecological civilization [27], coordination and sustainable development [28], etc., for discussion about how to promote the development of regional TEE systems in a relatively balanced and sustainable way. Therefore, maintaining a consistent orientation of tourism, economy and ecological environment has become one of the focal points of research on the coordinated development of regional TEE systems at this stage.

To sum up, SMH and coupling coordination research have led to plenty of results, from the monotonous research between two elements or systems to the development trend of multi-factor and multi-system research. Besides, the research methods and research perspectives have diversified further, so as to meet the constantly evolving needs for the development of the national economy and society. In essence, spatial mismatch theory is what reflects spatial heterogeneity [3], which indicates the imbalance of development between different regional systems. However, it is difficult to consider its internal mechanism comprehensively. Focusing on the connections and interactions between subsystems, the coupled harmony model provides an effective measure of the likelihood of regional synergy given this difference. Differently, most of the existing studies focus on the measurement of one aspect, with little attention paid to comparing the two.

In the context of the "One Belt, One Road" initiative and the "Outline Development Plan for the Guangdong-Hong Kong-Macao Greater Bay Area", enhancing the overall coordination and complementarity of the regional tourism-economy-ecosystem has been recognized as essential for achieving sustainable development of the Pearl River Delta (PRD). However, the significant variations in tourism, economic and ecological conditions between different cities in the region impede the coordinated development of tourismeconomy-ecology among the cities, which is a major constraint on the co-integration development of the PRD. Allowing for this, this paper is focused on analyzing the mismatch and coordination pattern of the three subsystems of tourism, economy and ecology in the PRD from 2009 to 2019, which relies on the construction of index systems, SMH, coupling coordination and spatial connection degrees. Through spatial mismatch, coupling coordination and gravitational force models, a discussion is conducted about the future path of coordinated development of tourism with the economy and ecosystem in different types of cities. This is intended to provide a theoretical reference for the sustainable development of coupled tourism-economy-ecology systems, and for high-quality development and coordinated construction in the PRD.

2. Methods

Through a review of both domestic and foreign literature, this paper starts by building a theoretical framework to finalize the index system from three perspectives: tourism industry, social economy and ecological environment. Then, the staggered index of each city is calculated on the basis of tourism, economic and ecological development indexes. Additionally, by calculating the citywide state of system coupling coordination at different time periods, the model of coupling coordination development is assessed for each city, and the intensity of spatial connection in system coupling between cities is analyzed. Finally, based on the results of analysis on spatial mismatch and the intensity of connection in coupling coordination, both spatial interaction and the core–periphery theory are applied to explore the path to coordinated development in tourism, economy and ecology between the cities across the PRD. Figure 1 shows how the article as a whole is structured.



Figure 1. The article structure.

2.1. Theoretical Framework

Spatial scale is regarded as an important background and method of geographical research. Moreover, the state of the entire regional system can be directly affected by the relationship between the city as a component of the region and its internal TEE systems. With this connection taken into account, this paper proposes a theoretical framework for the developing relationship and interactions of TEE systems at the "city + region" scale. As shown in Figure 2, on the urban scale, much significance is attached to the relationship between the subsystems within the TEE systems, which is affected by a range of different conditions such as urban development positioning, tourism resource endowments, social and cultural infrastructure construction, ecological environment quality, etc. When there is a considerable difference between these conditions, it is likely that an imbalance in the pace of development will arise from the subsystem [29]. On the regional (economic belt, urban agglomeration, metropolitan area, etc.) scale, more attention is directed towards the flow of development factors between various cities, as well as the market division or positioning of each city. Due to the differences in subsystems within cities, there are gradient differences in regional development. On the one hand, there has been a gradual increase in the development needs of marginal cities with potential under the regional development strategy [30]. On the other hand, there remains a lack of full accessibility to the factor flow channel between the core and peripheral cities in many parts of China, with the spatial polarization effect of market development reaching a significant extent [31]. In summary, whether at the urban scale or the regional scale, a spatial mismatch of TEE systems will result from the imbalance in the development speed of the internal components. Apart from the spatial mismatch of different scales caused by the above-mentioned speed imbalance, there is also a capacity of self-regulation, which enables coupling and coordination through the interaction and penetration between various subsystems [32].

In the meantime, ecology functions as the background of the tourism industry and socio-economic development, thus providing a resource base and place of activity for both. This is essential for the coordinated and sustainable operation of TEE systems. Tourism serves as a medium to promote the development of the social economy and ecological environment, and the process of industrial structure optimization can be accelerated by the increase of tourism income and the proportion of people employed in tourism. Additionally, tourism development is conducive to improving the ecological environment, and to increasing the awareness of environmental preservation in the process of resource development [33]. If there is no attention paid to development intensity and the scale of development, and the human–earth relationship is damaged, however, as a form of human activity, tourism and socio-economic construction will not only lead to negative feedback from the ecological environment but also reduce the coupling and coordination of the system [34]. Ultimately, both cities and TEE systems show complex and high openness through spatial interactions, while inter-city or internal sub-systems are interconnected

through the flow of elements, thus forming a "flow space" [35,36]. When the urban TEE systems are in a good state of coupling and coordination, this flow to other cities occurs in the surrounding system. When the city TEE systems are in a well-coupled and coordinated state, it will produce different degrees of radiation to the systems of other surrounding cities in the form of this flow, thus promoting the coordinated development of regional TEE systems.



Figure 2. Relationship and interaction between urban and regional TEE systems.

2.2. Construction of Indicator System

Referring to the regional tourism development competitiveness evaluation system constructed by Wang [37], the spatial mismatch and coupling coordination index of the PRD TEE systems was constructed by combining the factors influencing the tourists' motivations and decisions and the development of urban tourism, as shown in Table 1, with the following dimensions. (1) Tourism Industry dimension: tourism attractiveness, market scale, resource abundance, and hospitality facilities of the city are incorporated into the index system, where the calculation of tourism resource abundance is based on the number of national A-class scenic spots owned by the city [38]. (2) Socio-Economic dimension: in addition to the "hardware" environment, tourism development should also include social investment, infrastructure construction level, and other "soft environment" factors [39], such as the level of economic development of the city, personal economic ability, human resources of the service industry, as well as the social importance to tourism and other related industries. Therefore, the level of economic development of the city, the economic ability of individuals, the human resources of the service industry, the social importance of tourism and other related industries, and the construction of facilities for, e.g., transportation, electricity, and communication, are used as indicators of this dimension. (3) Ecological Environment dimension: this includes air, water, solid waste environment, climate environment, greening level, and overall ecological environment quality of the city. The climatic environment affects the comfort of tourists. Concerning research results on tourism climate [40], the temperature-humidity index (THI), wind-effect index (WCI), and index of clothing loading (ICL) are calculated, and each index is graded and assigned a value to obtain a value for comprehensive climate comfort. The ecological environment

index is the result of a comprehensive evaluation of biological abundance, vegetation cover, water network density, land degradation and environmental quality in the region [41], which can reflect the ecological environment condition of the city.

	Dimensions	Indicators	Indicator Meaning	
		Tourist arrivals (T1)	Tourism attractiveness	
		Tourism revenue (T2)	Tourism market size	
		The abundance of tourism resources $(T3)$	Resource endowment	
	Tourism Industry [11,13,37,38]	Number of travel agencies (<i>T4</i>)	Tour organization capability	
		Number of star-rated hotels (<i>T5</i>)	Visitor reception level	
		Number of intangible cultural heritage projects at the provincial level (<i>T6</i>)	Featured cultural heritage	
		GDP per capita (E1)	Economic level	
		Urban per capita disposable income (E2)	Personal financial ability	
		Share of the tertiary sector labor force in the social labor force (<i>E3</i>)	Service industry human resources	
TEE Systems Spatial mismatch	Socio-Economic	Percentage of fixed asset investment in the culture, sports and entertainment industry (<i>E</i> 4)	Related industry support	
and Coupling Coordination	[20,21,23,39]	Visitor Turnover (E5)	Traffic conditions	
		Electricity consumption per capita (<i>E6</i>)	Power supply capacity	
		Number of beds in health facilities per 10,000 people (<i>E</i> 7)	Medical and health care level	
		Per capita postal and telecommunications operations (<i>E8</i>)	Communication capability	
		Average PM2.5 concentration (<i>S1</i>)	Air Environment quality	
		Wastewater discharge per capita (S2)	Water Environment quality	
	Ecology [27,28,40,41]	Industrial solid waste generation (<i>S3</i>)	Solid waste discharge	
		Climate Comfort (S4)	Climate environment	
		Parkland area per capita (S5)	Greening level	
		Ecological Environment Index (<i>S6</i>)	Ecological quality	

 Table 1. Indicator System.

2.3. Weights Determination

The objective entropy weighting method was applied to determine the weights of each factor in order to avoid a bias of results due to subjective judgment [42]. To eliminate the effects of different magnitudes or excessive differences, the data for each index were processed without magnitudes, and all factors were positive, except for three factors—average PM2.5 concentration (*S1*), per capita wastewater discharge (*S2*), and industrial solid waste generation (*S3*)—which were negative indicators; the results of the weights are shown in Table 2. The specific formula is shown as follows:

(1) Building the original matrix

Build the matrix of *n* (year/city) \times *m* (index). Let the value of the *j*th index for the *i*th year (city) be X_{ij} .

(2) Standardizing the data

Assuming that the evaluation index X_j is a positive index or negative index, the following can be derived:

$$Positive \ index: X_{ij}^{*} = \frac{X_{ij} - \min\{X_j\}}{\max\{X_j\} - \min\{X_j\}}$$
(1)

Negative index :
$$X_{ij}^{*} = \frac{\max\{X_j\} - X_{ij}}{\max\{X_j\} - \min\{X_j\}}$$
 (2)

(3) Calculate the ratio P_{ij} of the *i*th city/year to the *j*th index

$$P_{ij} = \frac{X_{ij}^{*}}{\sum_{i=1}^{n} X_{ij}^{*}}$$
(3)

(4) Calculate the entropy value e_i of the *j*th index

$$e_j = -k \sum_{i=1}^m (P_{ij} \times ln P_{ij}), k = \frac{1}{lnm}, \ 0 \le e \le 1$$
 (4)

(5) Calculate the coefficient of variation d_i of the *j*th index

$$d_j = 1 - e_j \tag{5}$$

(6) Calculate the weight w_j of the *j*th index

$$w_j = \frac{d_i}{\sum_{j=1}^m d_i} (j = 1, 2, \dots, m)$$
 (6)

Indicators	T1	T2	T3	T4	T5	T6	E1	E2	E3	E4	E5	E6	E7	E8	S1	S2	S 3	<i>S</i> 4	<i>S</i> 5	S6
Nature	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(—)	(—)	(—)	(+)	(+)	(+)
2009	0.068	0.100	0.064	0.079	0.055	0.047	0.032	0.025	0.063	0.068	0.082	0.024	0.059	0.034	0.051	0.033	0.017	0.025	0.048	0.027
2010	0.063	0.106	0.064	0.091	0.056	0.046	0.032	0.024	0.062	0.054	0.076	0.024	0.049	0.032	0.028	0.028	0.016	0.063	0.057	0.027
2011	0.052	0.110	0.061	0.087	0.058	0.041	0.029	0.022	0.044	0.029	0.061	0.021	0.034	0.032	0.033	0.049	0.020	0.158	0.032	0.027
2012	0.064	0.134	0.058	0.105	0.057	0.047	0.034	0.024	0.049	0.052	0.063	0.023	0.041	0.034	0.032	0.035	0.029	0.067	0.022	0.031
2013	0.064	0.126	0.054	0.114	0.063	0.046	0.035	0.023	0.051	0.044	0.065	0.022	0.036	0.037	0.035	0.043	0.037	0.059	0.018	0.029
2014	0.069	0.117	0.050	0.108	0.061	0.047	0.037	0.027	0.040	0.065	0.118	0.022	0.033	0.037	0.026	0.032	0.031	0.024	0.018	0.040
2015	0.067	0.110	0.046	0.100	0.066	0.048	0.035	0.025	0.038	0.047	0.112	0.020	0.029	0.036	0.031	0.032	0.030	0.066	0.020	0.040
2016	0.073	0.112	0.047	0.106	0.063	0.052	0.037	0.027	0.053	0.042	0.053	0.022	0.031	0.037	0.028	0.031	0.030	0.081	0.023	0.054
2017	0.079	0.115	0.057	0.101	0.070	0.052	0.037	0.026	0.052	0.038	0.054	0.022	0.028	0.040	0.027	0.039	0.034	0.028	0.048	0.054
2018	0.072	0.106	0.049	0.100	0.080	0.058	0.037	0.027	0.054	0.041	0.062	0.022	0.030	0.037	0.031	0.040	0.035	0.028	0.041	0.052
2019	0.070	0.105	0.047	0.103	0.076	0.061	0.039	0.028	0.052	0.041	0.071	0.022	0.034	0.038	0.041	0.020	0.033	0.025	0.033	0.059

Table 2. The results of the weights.

Note: + is a positive index, - is a negative index.

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2.4. Spatial Mismatch Theory

As a common indicator applied in the coordination research of composite systems [43], the development index can calculate the city's tourism development index T_i , economic development index E_i and ecological development index S_i by combining with a weighted sum of the dimensionless value of various indicators. Meanwhile, based on spatial mismatch theory, the development index can build the dislocation model of TEE systems, clearly reflecting the heterogeneity of TEE systems inside the region [44]. The relative status of development speed among tourism, economy, and ecological subsystems of each city can be reflected by the spatial mismatch index SMI_i [45]. The detailed calculation method is as follows:

$$SMI_{i} = \frac{1}{T} \left\{ \left[\frac{1}{2} \left(\frac{E_{i}}{E} + \frac{S_{i}}{S} \right) \right] \cdot T - T_{i} \right\} \cdot 100$$

$$\tag{7}$$

T, *E* and *S* in the formula represent, respectively, the sum of regional tourism, economic and ecological development indexes in the PRD. When the value of SMI_i is greater than 0, it indicates that economy, ecology, and tourism development are in a positive mismatch. Otherwise, it is a negative mismatch. The greater the absolute value, the higher the degree of spatial mismatch. Based on this, the average spatial mismatch contribution R_i of each city to the region and the spatial mismatch contribution of three systems to the regional TEE systems can be calculated in sequence. The detailed calculation method is as follows:

$$R_i = \frac{1}{m} \sum_{k=1}^{m} \left[|SMI_i| / \left| \sum_{i=1}^{n} SMI_i \right| \right]$$
(8)

$$\begin{cases} R_{T} = \frac{1}{2} \sum_{i=1}^{n} \left| \left[\frac{T_{it'}}{T_{t'}} - \left(\frac{E_{it}}{E_{t}} + \frac{S_{it}}{S_{t}} \right) / 2 \right] \right| - \frac{1}{4} \sum_{i=1}^{n} \left| \left[\frac{T_{it'}}{T_{t'}} \times \left(\frac{E_{t}}{E_{t'}} + \frac{S_{t}}{S_{t'}} \right) - \left(\frac{E_{it'}}{E_{t'}} + \frac{S_{it'}}{S_{t'}} \right) \right] \right| \\ R_{E} = \frac{1}{2} \sum_{i=1}^{n} \left| \left[\frac{E_{it'}}{E_{t'}} - \left(\frac{T_{it}}{T_{t}} + \frac{S_{it}}{S_{t}} \right) / 2 \right] \right| - \frac{1}{4} \sum_{i=1}^{n} \left| \left[\frac{E_{it'}}{E_{t'}} \times \left(\frac{T_{t}}{T_{t'}} + \frac{S_{t}}{S_{t'}} \right) - \left(\frac{T_{it'}}{T_{t'}} + \frac{S_{it'}}{S_{t'}} \right) \right] \right| \\ R_{S} = \frac{1}{2} \sum_{i=1}^{n} \left| \left[\frac{S_{it'}}{S_{t'}} - \left(\frac{T_{it}}{T_{t}} + \frac{E_{it}}{E_{t}} \right) / 2 \right] \right| - \frac{1}{4} \sum_{i=1}^{n} \left| \left[\frac{S_{it'}}{S_{t'}} \times \left(\frac{T_{t}}{T_{t'}} + \frac{E_{t}}{E_{t'}} \right) - \left(\frac{T_{it'}}{T_{t'}} + \frac{E_{it'}}{E_{t'}} \right) \right] \right|$$
(9)

RT, *RE* and *RS* in Formula (9) represent the spatial mismatch contribution of the tourism, economy and ecology dimension respectively, while t' and t represent the initial stage (2009) and the final stage (2019) of research respectively.

2.5. Coupling Coordination Degree Model

Firstly, it is necessary to determine the evaluation value of each subsystem. The evaluation value of the system can be obtained by a weighted sum of various dimensionless system indicators. Therefore, the tourism, economic and ecological development indexes of TEE systems of each city shall be redefined as the tourism industry evaluation value T_i , the socio-economic evaluation value E_i and the ecological environment evaluation value S_i respectively, and then the coupling degree C_i of TEE systems of nine major cities can be calculated respectively [20]. The coupling degree is only capable of reflecting the strength of the interaction between systems. Therefore, the coupling coordination degree shall be calculated to reflect the coordinated development degree of the TEE system of each city:

$$\begin{cases} D_i = \sqrt{C_i \cdot A_i} \\ A_i = \alpha \cdot T_i + \beta \cdot E_i + \delta \cdot S_i \end{cases}$$
(10)

 D_i in the formula is the coupling coordination degree of TEE systems in city *i*. A_i is the comprehensive evaluation index of TEE systems in city *i*. α , β , δ are the undetermined weights of tourism, society, and ecology subsystems.

2.6. Gravity Model

In accordance with spatial interaction theory, the higher the degree of coupling and coordination of TEE systems in one city, the stronger the driving capability of the TEE

systems' coordination with surrounding areas. However, the strength of the driving capability is subject to spatial distance [46]. Taking the coupling coordination degree of TEE systems of each city as the fundamental index of link volume [21], and combining with the fact that tourists generally prefer the most convenient mode of transportation to reduce the travel time, in the article, the shortest time cost among cities is taken as the spatial distance index. The detailed calculation method is as follows:

$$\begin{cases} R_{ij} = K \cdot \frac{V_i \cdot V_j}{D_{ij}^2} \\ R_i = \sum_{j=1, j \neq i}^n R_{ij} \end{cases}$$
(11)

 R_{ij} in the formula represents the spatial connection strength of system coupling between city *i* and city *j*; *K* is the gravitational coefficient, and usually taken as 1; V_i and V_j represent the tourism, social and ecological coupling coordination degree of city *i* and city *j*; D_{ij} is the shortest time distance cost between cities; R_i represents the total linkage amount in city *i*. The main basis of shortest time distance is subject to the shortest travel time of high-speed rail and bullet trains between cities. In case there are no high-speed rail or bullet trains available between two cities, the shortest travel time by driving or transferring can be calculated.

3. Study Area and Data Sources

3.1. Study Area

The PRD consists of the Guangzhou-Foshan-Zhaoqing economic circle, the Shenzhen-Dongguan-Huizhou economic circle and the Zhujiang-Zhongshan-Jiangmen economic circle, and is a key region for the synergistic cooperation and in-depth development of the "Belt and Road" and the Guangdong-Hong Kong-Macao Greater Bay Area (Figure 3). In 2019, the resident population of the PRD cities was 64,468,900, the urbanization rate was 86.28%, and the GDP reached 8.69 trillion (about 80.7% of the province's total economy), making it an important force in Guangdong's regional development. There are still certain shortcomings in the integration and innovation of the PRD city cluster, in resisting risks, and in deepening the connection to the "Belt and Road" construction. For example, factors such as tight land use, serious damage to resources and environment, difficulties in economic structure transformation, and obvious differences in spatial structure hinder the sustainable development of the PRD.



Figure 3. Study area.

3.2. Data Sources

Data on national A-class tourist attractions and travel agencies in each city were obtained from the Guangdong Provincial Department of Culture and Tourism; data on provincial intangible cultural heritage items were obtained from the Chinese Minzu Cultural Resources Database [47]; data on the average PM2.5 concentration were obtained from the Atmospheric Composition Analysis Group of Dalhousie University [48]; the data of meteorological elements involved in climate comfort calculation were obtained from the National Meteorological Science Data Center [49]; the data of the Ecological Environment Index (EI) were obtained from the Department of Ecology and Environment of Guangdong Province; the data of the remaining indicators were obtained from the Guangdong Provincial Statistical Yearbook (2010–2020). The data of the shortest time distance involved in the gravitational force model were obtained from Ctrip.com (accessed on 31 December 2021).

4. Results

4.1. Level of Tourism-Economy-Ecology Development in the PRD

China proposed the initiative of "the Belt and Road" in 2013, and 2016 is the first year when all-area planning in the PRD was implemented. The implementation of these major national strategies and plans have had a significant influence on the tourism-economy-ecology development of the PRD [36]. The level of tourism-economy-ecology development in the PRD was analyzed by taking the mean values of the tourism-economy-ecology development index for each year in the periods 2009–2012, 2013–2015 and 2016–2019. The results are shown in Table 3.

- (1) Tourism development level: The tourism competitiveness of cities in the eastern part of the PRD was significantly stronger than that in the western part in 2009–2012, except for Guangzhou and Shenzhen. The tourism development index of the remaining cities is below 0.2, Zhongshan and Zhaoqing's tourism development level is at the edge of the region, and the development of core cities and peripheral cities is extremely unbalanced. This state did not change in 2013–2015 and 2016–2019, but in numerical terms, the tourism development index of Guangzhou and Zhuhai declined at different magnitudes in 2013–2015, implying that the tourism development rate of this part of the city declined compared to other cities. Zhuhai, Huizhou and the cities of Zhongshan and Jiangmen, with slow development tourism development levels, improved in 2016–2019, and this increase in tourism visits and income is the direct driving force for the improvement of the tourism subsystem in these cities.
- (2) Economic development level: Guangzhou and Shenzhen remain the stable and dominant cities in the PRD. The 2009–2012 economic development indexes of Foshan, Zhongshan, Zhuhai and Dongguan are all greater than 0.1 and are in the second echelon of regional economic development, which is relatively similar to the overall pattern of tourism development levels. The 2013–2015 economic development indexes of some cities decreased, with Shenzhen and Dongguan being the most prominent, from 0.188 and 0.102 to 0.166 and 0.084, respectively, which is related to the decrease in the urban per capita disposable income and the investment share of related industries in these cities themselves. The economic development indexes of Guangzhou and Zhongshan decreased from 0.246 and 0.117 to 0.222 and 0.077, respectively; and the remaining cities had different increases in 2016–2019, indicating that the regional economic development level improves in a relatively coordinated state.
- (3) Ecology development level: The temporal changes in this dimension are stronger than the above two, but Zhaoqing was always the dominant city in regional ecology. The ecological development indexes of cities with a certain scale of high energy consumption and high emissions manufacturing industries, such as Foshan and Dongguan, were at a lower level during the study period. Jiangmen and Huizhou have continued to improve their ecological development conditions due to the increased control of pollutant emissions in social production and living processes, while Zhaoqing, Guangzhou and Shenzhen have seen their ecological development indices decline

Cities		2009–2012			2013-2015			2016–2019			
	T _i	E _i	Si	T _i	E _i	S _i	T _i	E _i	Si		
Guangzhou	0.412	0.242	0.120	0.407	0.246	0.106	0.399	0.222	0.089		
Shenzhen	0.253	0.188	0.131	0.273	0.166	0.090	0.259	0.177	0.107		
Zhuhai	0.058	0.140	0.090	0.053	0.157	0.086	0.057	0.157	0.107		
Dongguan	0.076	0.102	0.071	0.074	0.084	0.061	0.071	0.085	0.060		
Foshan	0.081	0.106	0.027	0.087	0.103	0.060	0.085	0.114	0.047		
Zhongshan	0.013	0.105	0.073	0.013	0.117	0.093	0.019	0.077	0.080		
Jiangmen	0.040	0.034	0.093	0.035	0.052	0.103	0.041	0.062	0.132		
Huizhou	0.040	0.071	0.150	0.044	0.064	0.198	0.059	0.071	0.173		
Zhaoqing	0.026	0.011	0.245	0.013	0.012	0.202	0.010	0.034	0.205		

sharply due to the negative effects on the environment of economic activities, while also illustrating the relatively higher rate of ecological improvement in other cities.

Table 3. Tourism-economic-ecology development index.

4.2. Spatial Mismatch Pattern of the PRD TEE Systems

4.2.1. Spatial Mismatch Direction

The spatial mismatch index SMI_i of the TEE system of each city was obtained through the SMH (Table 4). Guangzhou, Shenzhen and Foshan showed negative mismatch, Zhuhai, Zhongshan, Jiangmen, Huizhou and Zhaoqing showed positive mismatch, Dongguan changed from positive to negative mismatch in 2013-2015 and then showed positive mismatch in 2016–2019. (1) A negative mismatch indicates that the development of urban socio-economic and ecological environmental conditions is slower than that of the tourism industry, and the value of the tourism industry far exceeds that of socioeconomic or ecological environmental conditions. For example, for Guangzhou and Shenzhen, being at the core of the Pearl River Delta, with a superior geographical location and the strategic policy support of the Greater Bay Area as well as other conditions, makes the attraction of tourists and socially relevant elements stronger, and the level of economic development and construction is much higher than in other cities. However, the process of development produces environmental pollution, resulting in a decline in the ecological development index, which is not conducive to the further development of the tourism industry. (2) A positive mismatch indicates that the development momentum of the socio-economic and ecological environment quality is fiercer than that of the tourism industry, in the stage of socio-economic construction or ecological advantage driven tourism development. For example, Zhuhai, as the key city in the Pearl River Economic Circle, has a certain economic strength, but due the lack of tourism resources, the attractiveness to tourists is limited, which is not conducive to the development of tourism, similar to Zhongshan and Jiangmen, while in Zhaoqing, despite the high ecological development index, socio-economic and infrastructure construction is still at a low level, with a poor tourism reception capacity which also causes slow tourism development. (3) The spatial mismatch index of Dongguan declined from 0.993 to -0.192 in 2013–2015, indicating that the development speed of tourism improved significantly compared with the socio-economic and ecological environment, and the spatial mismatch index was 0.149 in 2016–2019. Although the period showed positive mismatch, the absolute value of SMI_i was reduced, indicating that Dongguan is rapidly improving in the tourism dimension and the development differences within the TEE systems are shrinking, which is conducive to the overall coordinated development.

	2009–2012	2013-2015	2016-2019		2009–2012	2013-2015	2016-2019
Guangzhou	-23.091	-23.160	-24.322	Zhongshan	7.590	9.202	5.961
Shenzhen	-9.305	-14.509	-11.715	Jiangmen	2.373	4.235	5.584
Zhuhai	5.662	6.884	7.463	Huizhou	7.085	8.738	6.282
Dongguan	0.993	-0.192	0.149	Zhaoqing	10.152	9.382	11.027
Foshan	-1.460	-0.580	-0.430	1 0			

Table 4. Spatial mismatch index of PRD TEE systems from 2009 to 2019.

4.2.2. Spatial Mismatch Levels

Based on the absolute value of SMI_i , cities are classified into three types, namely, a low mismatch zone [0, 5), medium mismatch zone [5, 10), and high mismatch zone [10, ∞) [39]. In terms of the mismatch pattern, Dongguan, Foshan and Jiangmen are basically in the low mismatch zone, indicating that the development rate of the economic, ecological and tourism industries is more consistent; Zhuhai, Zhongshan and Huizhou belong to the stable medium mismatch zone, and there is still a gap between the development rates of economy, ecology, and tourism; Guangzhou, Shenzhen and Zhaoqing are in the high mismatch zone for most of the time (Figure 4). (1) Dongguan and Foshan are in a stable low mismatch state, and the spatial mismatch indexes of both have been reduced, but Foshan has been in a negative dislocation compared to Dongguan, which is due to the former's tourism resource endowment, higher tourism organization capacity, perfect reception facilities, plus Wing Chun, lion dance and other special culture and tourism attractions to form a variety of combined tourism projects that facilitate tourism system development level and speed compared to the socio-economic and ecological environment. (2) Zhuhai and Zhongshan belong to the positive middle mismatch area, the two places have a certain industrial base and improvement and control of the ecological environment quality. There is a positive effect on the improvement of the tourism industry, but the current tourism consumption level is low, the economic benefit brought to the local area is not high. There is a certain upside, for Huizhou, as because of the weak tourism organization ability, tourists mainly focus on Luofu Mountain, Xunliao Bay and other high-profile attractions. (3) Guangzhou belongs to the negative high mismatch area, and is much higher than other cities in terms of mismatch index, relying on its rich tourism resources and profound cultural heritage, coupled with its developed economic strength to support the improvement of tourism service levels. Its tourism competitiveness reaches the first place in the region, and its development speed is much higher than the economic and ecological dimensions.



Figure 4. Spatial mismatch pattern of TEE system in PRD. (a) Spatial mismatch pattern in 2009–2012;(b) Spatial mismatch pattern in 2013–2015; (c) Spatial mismatch pattern in 2016–2019.

In terms of mismatch evolution, the spatial mismatch indexes of Guangzhou, Zhuhai and Jiangmen have continued to rise, while Dongguan and Foshan showed a continuous decline, and the spatial mismatch indexes of Shenzhen, Zhongshan and Huizhou showed a fluctuating change of rising and then falling, and Zhaoqing showed a decline and then rise. Overall, the higher the spatial mismatch rank, the greater the ups and downs of change in the cities, but mismatch rank was kept unchanged. The spatial mismatch ranks of Shenzhen, Jiangmen and Zhaoqing shifted during the study period: (1) Shenzhen entered the high mismatch area from the medium mismatch area in 2013–2015, and remained in the negative high mismatch state in 2016–2019 although the spatial mismatch index declined, indicating that the difference in development rate between their socio-economic, ecological environment and tourism industry maintained a high level, mainly due to the fact that in recent years, Shenzhen's tourism organization capacity enhanced and the amount of overnight visitors rose, coupled with the economic development and construction of the foundation support, the tourism industry maintained a high growth momentum. However, the city's tourism climate comfort and greenery continued to b low, the difference in development speed between the systems increased and a high mismatch state remained. (2) Jiangmen in 2016–2019 transitioned from a low mismatch area to a middle mismatch area, belonging to the positive mismatch. This is due to the implementation of the "lucid water and lush mountains" project in its urban planning and the improvement of the ecological protection system, which has led to a continuous improvement in the quality of the ecological environment in recent years and an increasing difference in the development speed between the economic and tourism systems. (3) Zhaoqing in 2013–2015 moved from a high mismatch zone to a medium mismatch zone, indicating that the development rate gap between socio-economic, ecological environment and tourism industry is reduced. This phenomenon is actually due to the reduction of its per capita park green area and the reduction of tourism climate comfort, which makes the ecological dimension, which originally occupies an absolute advantage in its own TEE systems, weaken. The spatial mismatch index decreases because the development of the socio-economic and tourism industries has changed less, which is a typical example of a TEE system where the spatial mismatch improves but the overall development does not necessarily tend to be favorable. Due to the steady development of the social economy, the importance of culture, sports and other tourism-related industries increased, and the quality of the ecological environment also tended to recover, but the development of the tourism industry remained slow, and the mismatch level rose to high mismatch again.

4.2.3. Spatial Mismatch Contribution Rate

Calculating the average contribution of the spatial mismatch of the TEE systems of each city in the PRD from 2009 to 2019 (Figure 5), the nine cities can be roughly divided into four levels. The average contribution of Guangzhou is much higher than that of other cities, reaching 0.324, followed by Shenzhen and Zhaoqing, which had changed from medium to high mismatch, with an average spatial mismatch contribution of 0.158 and 0.141, respectively. The average contribution of Zhuhai, Zhongshan, Jiangmen and Huizhou is around 0.100; the contribution of Dongguan and Foshan, which are always located in the low mismatch area, is only around 0.01. It can be seen that Guangzhou, Shenzhen and Zhaoqing are the key to the obvious mismatch of the PRD.

At the same time, from the perspective of the full-time development of tourism, economic and ecological subsystems in the regional TEE systems, the sizes of the role of the contribution of mismatch are 0.0219, -0.0059 and -0.0094, respectively. The tourism subsystem contribution is positive, indicating that tourism is the main factor causing the regional TEE systems spatial mismatch, as shown in Guangzhou. Shenzhen's tourism industry level is much higher than for other cities; the polarization of regional tourism development is serious, and also causes a mismatch with its own economic and ecological development rates. The contribution of the economic and ecological subsystems is negative, but the value is small, indicating that both have a weak mitigating effect on the spatial

mismatch of the regional TEE systems, such as Zhuhai and Zhongshan. Despite the slow development of the tourism industry, the good tendency of the socio-economic and ecological conditions makes the spatial mismatch stable at a medium level.



Figure 5. Average spatial mismatch contribution of TEE systems from 2009 to 2019.

4.3. Coupling Coordination and Spatial Linkage of PRD TEE Systems4.3.1. Spatial Differentiation of Coupling and Coordination

Considering the increasing pulling role of the tourism industry on the economic growth of the PRD and the key sector for the future construction of regional coordination and cohesion, the ecological environment is an important aspect in measuring the ability of future coordinated and sustainable development, α , β and δ are set as 0.35, 0.3 and 0.35 [50]. A larger D_i value means a higher degree of coupling coordination [51], as in Table 5, reaching 0.5–0.6 when the system is in the basic coordination state.

Table 5. Coupling coordination state.

(D_i)	$0.8 < D_i \le 1$	$0.7 < D_i \leq 0.8$	$0.6 < D_i \le 0.7$	$0.5 < D_i \le 0.6$
State	Excellent	Intermediate	Primary	Basic
	coordination	coordination	coordination	coordination
	coordination	coordination	coordination	coordination
(D_i)	$0.4 < D_i \le 0.5$	$0.2 < D_i \le 0.4$	$0.0 < D_i \le 0.2$	
	-	Moderate	Extreme	
State	Near dissonance	dissonance	dissementes	
		dissonance	dissonance	

Overall, the degree of coordination in the PRD is mostly concentrated in the state of near-dissonance, followed by moderate dissonance and basic coordination, and the overall TEE systems coordination in the region needs to be improved. As shown in Figure 6, the stable coordination areas are mainly in the three major cities of the Pearl River Estuary, and the dysfunctional areas are mainly distributed in the western part of the Pearl River Delta, such as Zhaoqing, Foshan, Jiangmen, Zhongshan, etc. Spatially, the coupled coordination status of the TEE system in the eastern cities is better than that in the western cities. The spatial transformation of the overall regional state is less obvious, with Jiangmen and Huizhou rising from moderate dissonance and near dissonance to near coordination and basic coordination in 2013–2015, respectively, and Guangzhou declining from excellent coordination in 2016–2019.



Figure 6. Coupling coordination of PRD TEE systems.

4.3.2. Coupling Coordination Link Strength

The natural break point grading method is used to classify the total linkage and linkage strength into four levels from high to low, and the topological form of the chord diagram can reflect the linkage of each city's TEE systems more graphically (Figure 7). The results show that the coupled and coordinated linkage of the TEE systems of the whole PRD forms a pattern with Guangzhou as the prominent core city, Shenzhen and Foshan as the sub-center cities, radiating to and driving the neighboring cities, while the linkage strength between the eastern and western cities is weak, and the barrier effect of the Pearl River Estuary on the spatial linkage is significant.



Figure 7. Cont.





From the perspective of city units: (1) The total linkage of most cities in 2009 is lower than 1.147, with little difference in scale. The coupling and coordination of the TEE systems to drive outward is profoundly affected by the spatial distance, which shows that most cities only maintain a high linkage intensity with neighboring cities, such as Guangzhou–Foshan, Guangzhou–Dongguan, and Shenzhen–Dongguan. Guangzhou and Dongguan became the core nodes of regional TEE systems coupling and coordination by virtue of their central geographical location, while Huizhou, Zhaoqing and other cities located at the periphery of the regional space have weak radiation reception capacity to Guangzhou and Shenzhen, which have a high degree of coupling and coordination, due to the large cost of the shortest time, showing an "isolated island". (2) In 2014, eight cities in the PRD have opened highspeed railroads, making the absolute spatial distance to the TEE systems coupling and coordination of spillover barriers weaker, greatly enhancing the coupling and coordination of inter-city links. The total linkage of most cities is more than 3.00, with Guangzhou, Foshan and Huizhou rising most significantly, originally coexisting with Huizhou. This phenomenon is not only due to the improvement of transportation conditions, which makes the distance cost lower, but also directly related to the rapid growth of the tourism industry in Foshan, Huizhou and other cities in this year, and the increase in coupling and coordination of tourism, economic and ecological development levels. Although the overall coupling coordination status of Jiangmen became better toward the verge of disorder, in 2014, high-speed rail or other high-speed rail transportation had not yet been opened, and the barrier role of spatial distance remained significant, thus being at the very edge of the coupling coordination link of the regional TEE system. (3) The total coupling link of the TEE systems of each city in 2019 changed weakly, mainly in Guangzhou, and the originally marginal positions of Zhuhai, Jiangmen, and Zhaoqing increased, indicating that the TEE systems coupling coordination linkage among cities tends to be closer. In the aforementioned coupling coordination analysis, the coupling coordination degree of Guangzhou decreased throughout 2016–2019, but the coupling coordination degree in 2019 ($D_i = 0.824$) increased compared to 2014 ($D_i = 0.791$), and its core position in the system coupling coordination linkage network increased. Jiangmen was connected to the high-speed rail transportation network in 2018, which shortens the connection distance with other cities and facilitates system coordination and development driven by the two "power" cities of Guangzhou and Foshan.

From the perspective of regional linkages, the strength of TEE systems coupling and coordination linkages among cities in the east is higher than that in the west, with Guangzhou as the most stable core node, which controls the spillover channel of regional TEE systems coupling and coordination together with secondary core cities such as Foshan and Shenzhen, and the highest level of linkages also mainly appear between these cities. The strongest coupling and coordination linkage are Guangzhou–Foshan (0.415), followed by Guangzhou–Dongguan (0.344) and Shenzhen–Dongguan (0.294), implying that there may be close tourism, socio-economic, and even ecological resource elements transfer between these cities. In 2014, the strongest coupling and coordination linkage were Guangzhou–Foshan (4.460) and Shenzhen–Huizhou (2.639), as the largest linkage channels. Except for certain coupling and coordination-driven links with core cities such as Guangzhou and Foshan, the spatial links of most cities show closer links within the economic circle, such as Foshan–Zhaoqing (1.638) in the Guangzhou-Foshan-Zhaoqing economic circle, and Zhuhai–Zhongshan (1.328) in the Zhuhai-Zhongshan-Jiangmen economic circle, and the flow of tourism, economic and ecosystem factors across the economic circle was less active. This state was alleviated in 2019, as shown by a significant increase in the coupled and coordinated linkages of Guangzhou-Jiangmen (2.175) and Guangzhou-Shenzhen (2.640), in addition to the fact that in that year, Shenzhen–Huizhou (3.102) and Dongguan-Huizhou (3.582) linkages rose to the first rank, and the Shenzhen-Dongguan-Huizhou economic circle became the most closely coupled and coordinated block of the TEE systems in the PRD.

4.4. Spatial Mismatch-Coupling Coordination Comparison of the PRD TEE Systems

According to the core-periphery theory, combining two contrasting perspectives of spatial mismatch and coupled coordination linkage, the nine cities are classified into three major categories, as shown in Figure 8. (1) Prominent core cities, including Guangzhou and Shenzhen, which belong to cities with a high degree of spatial mismatch but also a high strength of coupled coordination linkage. The development state of the tourism industry in these cities is better than of the socio-economic and ecological environment, and this advantage on the other hand also pulls the socio-economic development and ecological environment quality improvement, and the TEE systems coordination is strong, which is the model of the coordination of the peripheral city system. (2) The coordination sub-cities, including Dongguan, Foshan and Huizhou, which belong to the cities with a lower degree of spatial mismatch and close coupling and coordination with other cities, and the tourism, economic and ecological development state is relatively close. The coupling and coordination links with the core city and other neighboring cities around are close, acting as a transitional role between the core city and peripheral cities. (3) Potential peripheral cities, including Zhuhai, Zhongshan, Jiangmen and Zhaoqing, belong to the general degree of spatial mismatch but the coupling and coordination links are weak, with limited coordinated radiation absorption capacity to the core city TEE systems, and the economic or ecological advantages of tourism development have not been fully exploited, which is a key area for future coordinated tourism development in the PRD.t. From the results of the spatial mismatch and coupling coordination analysis of the TEE systems in the PRD, the state presented by each city under the two methods is different. For example, although Guangzhou is in a high-mismatch state, the degree of coupling coordination among subsystems is higher, and the mobilization ability of coupling coordination to the TEE systems of the neighboring cities is outstanding, which verifies the inaccuracy of the assertion that "spatial mismatch \approx anti-coupling".



Figure 8. Spatial mismatch-coupling coordination comparison type classification in the PRD.

5. Discussions

It is confirmed by comparing the measurement results of the TEE systems in the PRD under the guidance of the two theories that the SMH is purposed to indicate the variations in the speed, state or level of development between systems or elements. When a subsystem reaches a higher level of development than other subsystems and gains a distinct advantage in the region, this often results in a severe mismatch between TEE systems. In contrast, the coupled coordination model pays more attention to the capability of synergistic development between systems or elements, and explores whether a better-coordinated state, driven by the advantageous system, can be reached on the whole. The difference between the two can be used to account for why Guangzhou and Shenzhen remain in a good coordination state despite their high mismatch. Through the comparison and comprehensive application of the two theoretical approaches, the individual and integrated interactions of the PRD tourism development subsystems can be better understood, which provides important insights into how the trade-offs between spatial mismatch and coupled coordination can be made through the future economic development of cities at different levels of the PRD. Besides, the two-way flow relationship between cities and subsystems can be taken advantage of to form complementary advantages. In addition to widening the scope and perspective of research on tourism spatial dislocation in China, this paper provides a practical reference for reducing the degree of dislocation in the process of regional development and contributes to promoting the high-quality development of tourism industry-regional economy-ecological environment systems. Of course, there remain some weaknesses in this paper. There is not only a failure to explore the spatial mismatch or coupling coordination between every two systems, but also a lack of in-depth exploration into the spatial mismatch and coupling coordination influence mechanism for the coordination development of tourism-economy-ecology in the PRD. Given the national strategy of the Guangdong-Hong Kong-Macao Greater Bay Area, culture and system (policy) play an increasingly significant role in the coordinated development of tourism-economy-ecology in the PRD. The two perspectives can be integrated into further research. Meanwhile, in the context of normalization of the pandemic, what new changes and challenges will arise from the coordinated development of the tourism-economyecological system in the PRD? And how should the influence of public health events

on regional coordinated development be dealt with? All of these questions are worth discussing in future research.

6. Recommendations and Conclusions

- 6.1. Recommendations
- (1) Highlight the organization and driving role of core cities: Guangzhou and Shenzhen should control the development speed of the tourism industry, and maintain a relatively consistent pace with the development of the social economy and ecological environment. Given the decline of ecological environment quality in recent years, the need to control the "three wastes" emissions, as far as possible to reduce the occupation of greenery and water space in the construction process, to maintain the self-regulating ability of the urban climate, and the ecological environment conditions for tourism development should be improved, thus reducing the spatial mismatch of the TEE systems. From the macro space, relying on Guangzhou's rich tourism resources and Shenzhen's good tourism organization and reception capacity, the market of high-quality visitor sources should be broadened, the interaction of tourism flows and linkage of facility construction be promoted, complementary advantages and value chain integrations should be formed, and the leading effect to drive the coordinated development of tourism in other cities should be brought into play.
- (2)Promote coordination and linkages between core and peripheral cities: For Dongguan and Foshan, the intensity of coupling and coordination links is high under the location advantage, but the poor ecological environment condition is the main reason for the poor coordination of the TEE systems, and the radiation drive to other cities is limited. In future the waste emission of manufacturing production needs to be controlled, energy conservation, and emission reduction must adhere to the concept of ecological civilization development and make up for the deficiencies of the ecological environment system in order to improve the coordination of the TEE systems. Huizhou is a typical city rich in tourism resources but not fully developed, which is ultimately weak in tourism reception capacity. In the future, we need to focus on the improvement of the tourism accommodation and tourism organization systems, increase the probability of overnight stays and the consumption by tourists, and improve the development level of the tourism industry to reduce the degree of spatial mismatch. From the macro spatial point of view, this type of city needs to plan tourism resources in-depth and combine local socio-economic, cultural, and natural elements to create special tourism projects, such as Dongguan's special food industry, Foshan's martial arts cultural festival and Huizhou's Daya Bay, to form their tourism brand symbols, use joint promotion, and better articulate the coordination linkage of TEE systems between core cities and peripheral cities.
- (3) Focus on tapping the development factors and advantageous conditions of potential cities: The biggest problem of this category of cities is the small development of tourism resources, limited local attractiveness, and the tourism industry lagging behind relative to socio-economic and ecological development. In the future, these cities need to fully release the dividends of geographical location, resources and other factors. For instance, Zhongshan, Zhuhai and Jiangmen can use the geo-space near the river or the sea to create a waterfront tourism industry belt, and Zhaoqing can use forest resources to develop ecological tourism through government guidance. The development of the tourism industry can reduce the degree of spatial mismatch of the TEE systems and improve the coupling and coordination of the system. From the macro space point of view, the cost of transportation distance is an important reason why the strength of coupling and coordination linkage of this type of city is at the edge of the region. In the future, it is necessary to increase the investment in transportation construction, shorten the time distance to core cities such as Guangzhou and Shenzhen, and open up the circulation channels of factors to fully accept the

coupling and coordination drive of the TEE systems in the core area and expand the tourism competitiveness of Zhaoqing and the Pearl River central economic circle.

6.2. Conclusions

In this paper, an exploration is conducted into the spatial characteristics and evolutionary trend of the synergistic development of a regional tourism-economy-ecosystem from the perspective of spatial dislocation and spatial coupling, which is conducive to fully understanding the sustainable development of coupled systems of urban agglomerations. Moreover, it is beneficial to enhance the overall coordination and complementary advantages of the tourism-economy-ecosystem of the PRD. Furthermore, the corresponding paths of development are indicated for different types of cities to promote the synergistic development of the PRD. From the three perspectives of tourism, economy and ecology, the spatial matching and the degree of coupling and coordination of the development of the TEE complex systems in the PRD are explored in line with the theory of spatial misalignment and coupled and coordinated development, respectively. On this basis, the gravitational model is adopted to analyze the coupled and coordinated linkages of the TEE systems among cities. Moreover, the cities are classified into different categories by combining the results of spatial mismatch analysis, which led to the following conclusions:

- (1) In the tourism and economic subsystems of the PRD, Guangzhou and Shenzhen represent the "power" cities. Furthermore, the overall patterns are relatively close to each other, with the development levels in both dimensions showing the pattern that the eastern cities are higher than the western ones, and there is an imbalance of development between the core cities and the peripheral cities. According to a comparison of the economic development level, the spatial polarization of the tourism development level reaches a more significant level, but this polarization has been reduced over time. Additionally, the tourism and economic development level of the whole region has shown improvement in a relatively coordinated state. In terms of ecology, Zhaoqing is the city with the most significant ecological advantage in the region, and the development changes of this subsystem are more notable compared to the tourism and economic subsystems. Moreover, the quality of the ecological environment tends to show improvement in most cities, despite a decline shown for Zhaoqing, Guangzhou and Shenzhen.
- (2)In respect of spatial mismatch, except for Dongguan, which shows changes in both negative and positive states, all the remaining cities perform more consistently. Guangzhou, Shenzhen and Foshan show a negative mismatch due to the development rate of the tourism industry being higher than in the socio-economic and ecological environments. By contrast, other cities such as Zhuhai, Zhongshan, and Jiangmen show a positive mismatch because the development level of the tourism industry relatively lags behind their own economic or ecological conditions. As for the spatial mismatch level, Dongguan, Foshan and Jiangmen are located in the low mismatch area, Zhuhai, Zhongshan, and Huizhou are located in the middle mismatch area, and Guangzhou, Shenzhen, and Zhaoqing are located in the middle mismatch area. This is because Guangzhou, Shenzhen and Zhaoqing show a significant mismatch due to the high value of the tourism industry or the ecological environment contributing significantly to the regional spatial mismatch. Although the whole region shows the characteristic that a higher ranking of the city leads to more significant changes in mismatch index, the rank state is stable, and the cities with changes in ranking include Shenzhen, Jiangmen and Zhaoqing, the first two of which show the development of dislocation to high rankings. Besides, Zhaoqing reverted to the high mismatch area after declining to the medium mismatch area in 2013–2015. Regarding the spatial mismatch contribution rate of subsystems, the economic and ecological subsystems contribute to the regional spatial mismatch of subsystems. The economic and ecological subsystems exert a limited mitigating effect on the spatial mismatch

of the TEE systems, while the tourism subsystem is crucial for the occurrence of spatial mismatch.

- (3) The coupling and coordination level of the TEE systems in the east of the PRD is higher than in the west, where the coordination area covers Guangzhou, Shenzhen, Zhuhai and Huizhou, and the dysfunctional area covers Dongguan, Foshan, Zhongshan, Jiangmen and Zhaoqing. Furthermore, the coupling and coordination status shows a greater stability in most cities, and the coupling and coordination degree shows a slight increase. Guangzhou is the core city of regional TEE systems coupling and coordination linkage, while Shenzhen and Foshan are the secondary cores. High-level linkage also exists among these three cities, with the Guangzhou–Foshan one as the closest. During the period from 2016 to 2019, the economic circle of Shenzhen-Dongguan-Huizhou surpassed the economic circle of Guangzhou-Foshan-Zhaoqing, becoming the most closely coupled and coordinated linkage in the Pearl River Delta.
- (4) According to the results of strength analysis for spatial mismatch and coupling coordination linkage, there are nine cities classified, among which Guangzhou and Shenzhen represent the prominent core cities; Dongguan, Foshan and Huizhou represent the secondary coordinating sub-cities; and Zhuhai, Zhongshan, Jiangmen, and Zhaoqing represent the potential peripheral cities. Regarding the prominent core cities, the priority in the future is to improve the quality of the ecological environment and reduce the mismatch between the TEE systems. Different from the core cities, there remains a lot of potential space for the level of tourism development in the coordinating sub-cities and potential peripheral cities. In addition, to strengthen the connection of the urban TEE systems and promote the coordinated development of regional tourism, the focus of further research should be placed on the insufficient development of tourism resources and the backwardness of tourism transportation, accommodation and other relevant facilities.

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