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Computational Simulation of the Correlations in a Port–Hinterland System from a Tourism Spatial Optimization Perspective

Rui Wang [1,2,†], Dashuai Gao [1,†], Huasong Luo [1,3], Yong Chen [4,*], Hang Liu [1] and Jingjing Chen [5,*]

[1] Faculty of Geography, Yunnan Normal University, Kunming 650500, China
[2] School of Geographical Sciences, China West Normal University, Nanchong 637009, China
[3] Graduate School of Yunnan Normal University, Kunming 650500, China
[4] School of Civil Engineering & Architecture, Zhejiang University of Science & Technology, Hangzhou 310023, China
[5] School of Economics, Fudan University, Shanghai 200433, China
* Correspondence: 121106@zust.edu.cn (Y.C.); joyjchan@gmail.com (J.C.)
† These authors have contributed equally to this work and share first authorship.

Abstract: From the perspective of tourism space optimization, the application of computer technology in creating computational simulations of correlation effects in tourism space systems is a core issue in research related to ports and hinterlands. Using a computer simulation analysis of the gray correlation, taking Mohan port–Yunnan economic hinterland as an example, the relationship between Mohan port and the Yunnan economic hinterland was quantitatively measured based on the indicators of cross-border tourism from 2006 to 2020. The study aimed to identify the driving mechanisms behind the synchronized development of Mohan port–Yunnan economic hinterland. The results are as follows: (1) due to the influence of administrative interventions and the competition of the neighboring ports, the correlation between the Mohan port and the Yunnan hinterland from 2006 to 2020 showed a rising–falling trend; (2) the correlation between the Mohan port and Xishuangbanna prefecture showed an obvious fluctuating trend, and the original port–city development relationship evolved to a competitive status; (3) the degree of spatial correlation of the Mohan port–Yunnan hinterland system evolved in a north–south-central–south direction, with "border zone–central region–northern region" distribution characteristics; (4) the natural conditions of the location, national policies, competition of nearby ports, infrastructure and traffic conditions, and economic strength are the main driving factors affecting the correlation change between Mohan port and the Yunnan hinterland. These findings can help enrich the theoretical research system of buildings economics, and expand the application of computational decision-making support in tourism spatial optimization.

Keywords: building planning; hinterland system; correlation effect; computer technology; spatial evolution

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1. Introduction

Driven by various strategies such as global economic integration, trade globalization and information globalization, it is essential to strive to promote the spatial optimization of cross-border tourism in China [1]. Based on advances in computer technology in recent years, computer simulation support is useful in the context of tourism spatial optimization and regeneration, as it aims to represent the operation of the tourism development process. As micro-spatial study areas of cross-border tourism, port–hinterland systems have gradually become some of the most active areas for research into the economics of buildings via computational simulation, that is, in finding correlation degrees with the help of computer technology [2–4]. In recent years, with the development of computer science and information technology, the economic, material–energy, cultural, and spatial linkages of port–hinterland systems are undergoing fundamental changes [5]. Based on the decision-making support role of computer technology in the port–hinterland system concerning cross-border tourism, clarifying the roles and relationships that exist within this system of cross-border tourism is the key to improving the management of the ports and developing hinterland economies [6,7].

In recent years, local and international scholars have made great achievements in port–hinterland system research. Foreign scholars have tended to explore the affiliation among port–hinterland systems [8], transportation links [9], economic links [10], etc., and as such, research on port–hinterland systems concerning cross-border tourism is more abundant [11–14]. In terms of transportation links, Notteboom [15] believes that the economic development of ports is greatly influenced by the accessibility of port–hinterland transportation and its convenience. Research on port–hinterland systems by domestic scholars started relatively late, mainly focusing on the synergistic development and spatio-temporal patterns of port–city systems [16,17], computational simulation of port–hinterland systems [18,19], mechanisms influencing the evolution of port–hinterland systems [20,21], etc. For example, Zhu Chuangeng et al. [22] used the Lianyungang–Huaihai Economic Zone as a case study to quantitatively analyze the degree of association in the port–hinterland system using a computational simulation model. However, quantitative research on the relationship between ports and hinterlands concerning cross-border tourism is still insufficient. The basic unit of analysis for hinterlands is either the whole study area or a micro-scale county, while research on the relationship between macro-scale provincial units and border ports is relatively weak. Computer simulation analyses of previous studies on the spatial association effects of port–hinterland systems on cross-border tourism are relatively inadequate.

Therefore, based on the perspective of tourism spatial optimization, this study focused on cross-border tourism in the Mohan Port–Yunnan economic hinterland area. The spatial evolution characteristics of the association between the border crossing and the economic hinterland of Yunnan are analyzed quantitatively using a computer simulation of gray correlations over a research period spanning 2006–2020, revealing the mechanisms driving the association. These findings can not only enrich the theoretical research system of buildings economics, but also expand the application of computational decision-making support in tourism spatial optimization.

The Innovative contributions are summarized as follows: (1) this study aims to realize the computational simulation of the correlation between ports and hinterland for the past 15 years from the perspective of tourism spatial optimization, and reveal its driving mechanism; (2) this study attempts to construct an evaluation index system for cross-border tourism in port–hinterland systems, expanding the basic unit of analysis of hinterland from the county to the province, and enriching the research on the relationship between macro-scale provincial units and border ports.

2. Materials and Methods

2.1. Study Area and Data Sources

2.1.1. Mohan Port

Mohan Port is located in the southwest of Mengla County, Xishuangbanna Prefecture, Yunnan Province, China. It is the only national land port connected to Laos [23]. The geographical coordinates of Mohan Port are 21°18′32″ N, 101°68′40″ E, 181 km south of Jinghong, the capital of Xishuangbanna Prefecture, 701 km southwest of Kunming, the capital of the province; 382 km northwest of Vientiane, the capital of Laos, 958 km northeast of Bangkok, the capital of Thailand; and 500 km west of Hanoi, the capital of Vietnam. Mohan Port is an important point of export from mainland China to the southeast peninsula, and it is also the main window for economic and trade exchanges between China and Southeast Asian countries. Mohan port and Boten, Laos, have become land-based links between the two economic sectors of Indochina and China. In May 2022, the Yunnan Provincial Party Committee and the government decided that the Kunming City Trust would go to the town of Mohan, and they jointly built an international port city, which will be conducive to the high-quality development of Mohan Port.

2.1.2. Yunnan's Economic Hinterland

Yunnan's economic hinterland is located in the southwest of China, between latitude 21°8′ N and 29°15′ N, longitude 97°31′ E and 106°11′ E. It is adjacent to Guizhou and Guangxi to the east, is connected to Sichuan to the north, borders Myanmar to the west, and borders Laos and Vietnam to the south. Yunnan Province is an important part of the Yangtze River economic belt, and it has an important strategic economic position in the country as the intersection of China, Southeast Asia and South Asia [24]. The total area of Yunnan Province is about 39.41×10^4 km^2, accounting for 4.1% of the total land area of the country, with a population of about 47.22 million. The topography of Yunnan Province slopes from northwest to southeast, and the mountainous area accounts for 88.64% of the total area of the province. The climate is mainly subtropical and tropical with monsoons. It has a rich and unique biodiversity and is known as the "Kingdom of Plants". By 2021, Yunnan Province had achieved a regional GDP of CNY 2,714,676 billion, an annual increase of 7.3% from 2020, with an increasingly reasonable industrial structure. The per capita GDP of the province reached CNY 57,686, an increase of 7.5% from the previous year, and a foreign trade import and export value of CNY 314,380 million, an increase of 16.8%. In recent years, Yunnan's economic hinterland has shown an economic agglomeration effect with the central Yunnan city cluster as the core, with industrial development gradually accumulating in the transportation economic belt and economic spatial differences gradually reducing. The location of Mohan port and Yunnan's economic hinterland are shown in Figure 1.

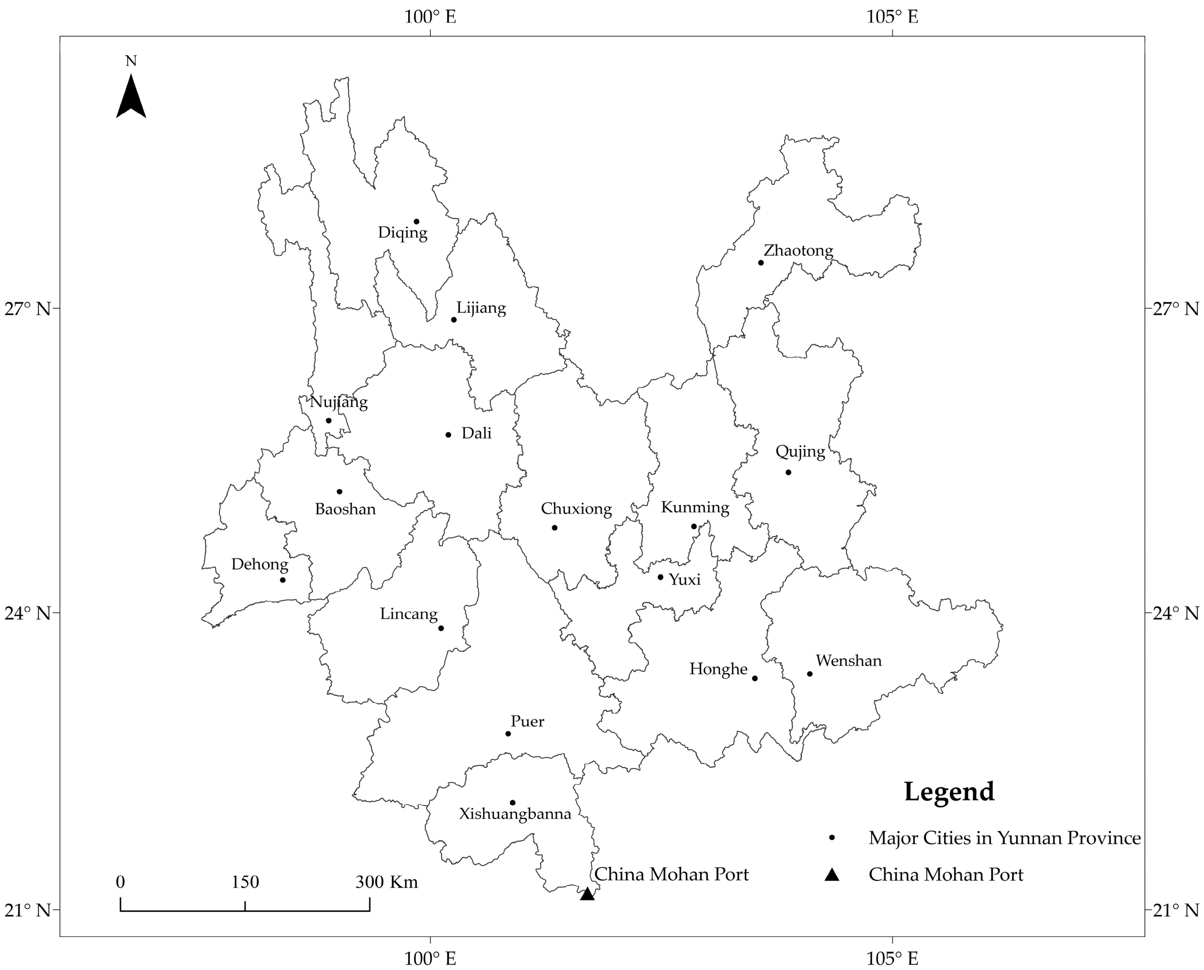

Figure 1. Overview of the study area.

2.1.3. Data Sources

This study focuses on the accessibility of evaluation index data and fully considers the actual situation of the research object. The data in the port index system came from the China Port Database, the statistical yearbook of Xishuangbanna Prefecture, and the statistical data of Mohan Port from 2007 to 2021. The data in the Yunnan economic hinterland index system mainly came from the China city statistical yearbook for 2007–2021, the Yunnan Provincial Statistical Yearbook, and the statistical yearbooks and statistical bulletins of each city and state in Yunnan Province. To fully reflect the comprehensive strength of Mohan Port, three indicators with strong representativeness were selected to characterize its cargo throughput, foreign trade throughput, and total tourism income.

2.2. Research Methodology

2.2.1. Indicator System Construction

Considering the economy, geographic space, population, social culture, material energy, and other aspects of the connection between the port and the hinterland, it can be regarded as an open and complex system. In this complex system, the flow of production factors must be placed in a socioeconomic context, and it is due to the orderly flow of production factors that the port and the hinterland can be closely integrated. The connection between the subsystems within the port–hinterland system concerning cross-border tourism strengthens over time and can be perturbed by various external factors. Promoting the integration of port–hinterland systems concerning cross-border tourism will enhance their stability (Figure 2). Under the specific socioeconomic context, the correlation between the port and the hinterland shows a different behavior, which has a certain ambiguity. Therefore, to investigate the correlation effect between ports and hinterland, the research object should be placed in a specific socioeconomic context, and the computational simulation based on gray correlation degree will have good applicability.

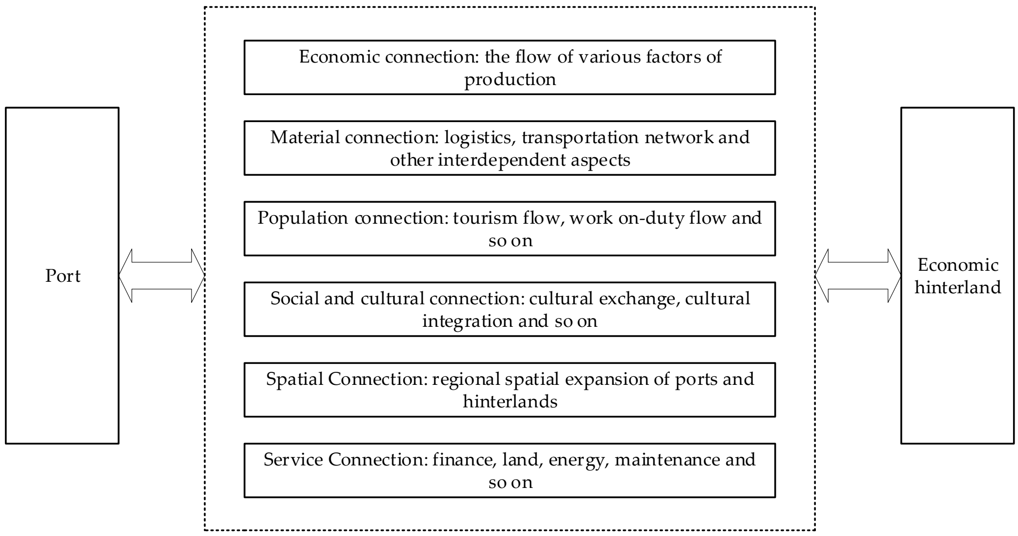

Figure 2. Typical model of cross-border tourism in a port–hinterland system.

Based on the results of previous research [25], to objectively analyze the degree of connection between Mohan Port and the Yunnan hinterland, evaluation indicators were selected according to the two subsystems (port and hinterland), and a quantitative index system was then constructed (Table 1). In this evaluation index system, X_1 to X_4 reflect the economic connections; X_5 to X_7 reflect the material connections; X_8 to X_9 reflect the population connections; X_{10} to X_{12} reflect the service connections between the port and the hinterland concerning cross-border tourism; and X_{13} to X_{15} reflect the scale of the port, which can have some influence on the development of the hinterland in terms of its economic and service connections.

Table 1. Evaluation index system of port–hinterland systems concerning cross-border tourism.

Evaluation Object	Indicator Variables	Indicator Content
Hinterland	X_1	GDP per capita
	X_2	Hinterland fixed asset investment
	X_3	Ratio of the output value of the tertiary and secondary industries
	X_4	Foreign exchange earnings from tourism
	X_5	Total passenger traffic in the hinterland
	X_6	Total freight volume in the hinterland
	X_7	Road network density
	X_8	Urbanization rate
	X_9	Number of overseas visitors
	X_{10}	Tourism resource endowment
	X_{11}	Total retail sales of consumer goods
	X_{12}	Share of tertiary sector in GDP
Port	X_{13}	Foreign trade throughput at ports
	X_{14}	Cargo throughput at ports
	X_{15}	Total tourism revenue at ports

2.2.2. Computer Simulation of Gray Correlation

A port–hinterland system has different correlations and paths of action at different stages of development. It is an open and complex system where the relationship between the internal elements is gray. The data contained in the evaluation indexes of the port–hinterland system concerning cross-border tourism could not be completely duplicated, and they were not independent of each other. Therefore, the correlation coefficient could therefore not be used to accurately measure the degree of correlation. In the fuzzy calculation of the relationship between unknown variables, gray correlation theory was introduced to calculate the degree of correlation within the port–hinterland system concerning cross-border tourism. This study adopts the gray correlation method for computer simulation [26] to quantitatively measure the degree of correlation between border crossing and the economic hinterland of Yunnan based on the construction of a correlation analysis model that objectively reflects the interaction between their factors.

$$\xi_{ij}(t) = \frac{\Delta_{\min} + k\Delta_{\max}}{\Delta_{jj}(t) + k\Delta_{\max}} (t = 1, 2, \cdots, m) \quad (1)$$

In the formula, $\xi_{ij}(t)$ denotes the correlation coefficient of hinterland (port) indicator X_i to port (hinterland) indicator X_j at time t, $\Delta_{ij}(t) = |X_i(t) - X_j(t)|$, $\Delta_{\max} = \max\limits_i \max\limits_j \Delta_{ij}(t) \Delta_{\min} = \min\limits_i \min\limits_j \Delta_{ij}(t)$, $X_i(t)$ and $X_j(t)$ denote the standardized values of the hinterland and port indicators, respectively. k is the discrimination coefficient, with a value range of 0–1, usually 0.5.

Based on Equation (1), the mean correlation is calculated based on Equation (2) to systematically characterize the degree of correlation between the Mohan Port and the economic hinterland of Yunnan at a certain point in time.

$$r(t) = \frac{1}{m \times n} \sum_{i=1}^{m} \sum_{j=1}^{n} \xi_{ij}(t) (m = 3, n = 11) \quad (2)$$

In the formula, $r(t)$ indicates the mean correlation of the port–hinterland system of cross-border tourism, and m and n indicate the number of secondary indicators of the development level of the port and hinterland subsystems, respectively, $0 < r(t) \leq 1$. When $r(t)$ is the maximum value of 1, it indicates that the correlation between the two subsystems of the port and hinterland is the largest, and the change trend between the two subsystems is consistent; when $0 < r(t) < 1$, it indicates that there is a certain correlation between the two subsystems of the port and the hinterland; when $r(t)$ tends to 1, it indicates that the correlation effect between the port and hinterland system is gradually increasing; and when $r(t)$ tends to 0, it indicates that the correlation effect between the port and hinterland system is gradually weakening. In this study, based on previous research, the change in $r(t)$ is further subdivided: when $0 < r(t) \leq 0.30$, the correlation effect between the port–hinterland system is weak; when $0.30 < r(t) \leq 0.60$, the association effect between the port–hinterland system is medium; when $0.60 < r(t) \leq 0.90$, the correlation effect between the port–hinterland system is strong; and when $0.90 < r(t) \leq 1$, the correlation effect between the port–hinterland system is extremely strong.

3. Results

3.1. Spatial Evolution Analysis of Correlation Properties Based on Computer Simulation

Based on an evaluation index system constructed for a port–hinterland system concerning cross-border tourism and combined with an evaluation index database, the mean correlation degree of the Mohan Port–Yunnan economic hinterland system was calculated using computer simulation software; the results are shown in Table 2.

Table 2. The computational simulation results of the mean degree of correlation for the Mohan Port–Yunnan economic region.

Hinterland	Mean Correlation Degree										
	2006	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Yunnan	0.7103	0.7211	0.7319	0.7135	0.7528	0.7657	0.7844	0.7736	0.7416	0.7365	0.7278
Kunming	0.7021	0.7326	0.7354	0.7495	0.7487	0.7771	0.7635	0.7898	0.7622	0.7210	0.7315
Qujing	0.6312	0.6388	0.6428	0.6899	0.7124	0.7225	0.7148	0.7326	0.7451	0.7302	0.7219
Yuxi	0.7089	0.7189	0.7195	0.7258	0.7396	0.7500	0.7724	0.7385	0.7436	0.7521	0.7215
Zhaotong	0.7652	0.7742	0.7852	0.7769	0.7634	0.7882	0.7963	0.7650	0.7552	0.7464	0.7457
Baoshan	0.6868	0.6964	0.7076	0.7125	0.7169	0.7245	0.7354	0.7522	0.7624	0.7210	0.7314
Lijiang	0.7458	0.7487	0.7568	0.7635	0.7695	0.7705	0.7932	0.7852	0.7661	0.7604	0.7433
Pu'er	0.7001	0.7012	0.7125	0.7258	0.7364	0.7452	0.7551	0.7487	0.7620	0.7375	0.7431
Lincang	0.6734	0.6979	0.6994	0.7122	0.7029	0.7189	0.7255	0.7366	0.7251	0.7167	0.7088
Dehong	0.7016	0.7173	0.7253	0.7353	0.7496	0.7851	0.8034	0.7722	0.7666	0.7521	0.7230
Nujiang	0.6523	0.6754	0.6899	0.6941	0.7195	0.7436	0.7324	0.7558	0.7651	0.7409	0.7218
Diqing	0.7365	0.7456	0.7521	0.7553	0.7852	0.7689	0.8012	0.7899	0.7852	0.7456	0.7401
Dali	0.6855	0.6986	0.7222	0.7421	0.6936	0.7522	0.6853	0.7011	0.7469	0.6855	0.6784
Chuxiong	0.7129	0.7253	0.7125	0.7555	0.7542	0.7662	0.7881	0.8025	0.7634	0.7885	0.7255
Honghe	0.6950	0.7001	0.7214	0.7103	0.7544	0.7667	0.7992	0.7666	0.7587	0.7910	0.7422
Wenshan	0.7028	0.7173	0.7151	0.7421	0.7368	0.7355	0.7589	0.7877	0.7544	0.7663	0.7237
Xishuangbanna	0.7567	0.7724	0.7949	0.8063	0.8211	0.8344	0.8010	0.7552	0.7646	0.7421	0.7224

Over the past ten years, the correlation between Mohan Port and the Yunnan hinterland showed the following main characteristics (Table 2):

(1) The degree of correlation rose slightly from 0.7103 in 2006 to 0.7844 in 2016 and then fell to 0.7278 in 2020, with fluctuations throughout.

Since 2006, the correlation between Mohan Port and Xishuangbanna Prefecture has changed considerably, with its mean correlation degree increasing from 0.7567 in 2006 to 0.8344 in 2015, showing an increasing trend year by year, which indicates a general strengthening of the association between Mohan Port and Xishuangbanna Prefecture from 2006 to 2015. Simultaneously, except for a rise in 2018, the association between Mohan Port and Xishuangbanna Prefecture gradually decreased from 2016 to 2020, and its mean degree of correlation decreased from 0.8010 in 2016 to 0.7224 in 2020. This represents a more significant decrease that indicated a weakening trend between Mohan Port and Xishuangbanna Prefecture from 2016 to 2020. In general, the relationship between Mohan Port and Xishuangbanna Prefecture showed an increase, followed by a decrease, with some level of variation.

Statistics show that the total volume of foreign trade freight through Mohan Port increased from 697,000 tons to 5,026,000 tons during this period, with an average annual growth of 28.9%. The number of domestic and foreign tourists increased by 15.3%, and the total business income increased by 19.35% on average. During this period, the port–city relationship entered the development stage, relying on the incremental increase in total tourism revenue brought by Mohan Port, which, to a certain extent, promoted the economic prosperity of Xishuangbanna Prefecture. In turn, the rapid development of cities in Xishuangbanna Prefecture also provided a more-than-adequate source of goods for the high-quality development of Mohan Port. However, with the novel coronavirus pandemic in 2020, the cargo throughput, foreign trade throughput, and cross-border tourism revenue of Mohan Port were adversely affected. Simultaneously, as time progressed, the Mohan Port–Xishuangbanna Prefecture area had its own development orientation and needs, and the original port–city development relationship evolved into a competitive state, especially in terms of demand for construction land, channel construction, ecological environments, and so on.

(2) The correlation between Mohan Port and the Yunnan hinterland continues to advance as a result of their originally strong association, but there has been a significant weakening trend.

With the rapid development of urbanization and tourism, the relationships within the port–hinterland system concerning cross-border tourism showed a dynamic evolutionary process, weakening and then gradually strengthening. As can be seen from Table 2, from 2006 to 2020, the mean correlation degree between Mohan Port and the Yunnan hinterland was between 0.7103 and 0.7844, indicating a strong correlation. Except for a fluctuating decline in 2013, the mean degree of correlation between Mohan Port and the Yunnan hinterland increased year by year from 2006 to 2016, while it decreased year by year from 2017 to 2020, with a significant weakening trend. According to the statistical data, the total imports and exports of Yunnan's ports increased more from 2006 to 2020, and about 85% of the cargo sources of Mohan Port came from the economic hinterland of Yunnan. In recent years, Yunnan Province has focused on transportation conditions, information construction, hinterland–port channel construction, and so on. It has constantly strengthened the economic and trade exchanges between the port and the provincial economic hinterland, focusing on the integrated construction level of the port–hinterland system, promoting a strong correlation phase in the Mohan Port–Yunnan hinterland area. However, the Mohan Port–Yunnan hinterland area has an open and complex economic system, restricted by multiple factors such as the development of the port itself, the comprehensive strength of the economic hinterland, the capacity of the port–hinterland channel, and competition from neighboring ports and their administrative interventions, resulting in fluctuations in the degree of correlation and a weakened correlation in 2020, from 0.7736 in 2017 to 0.7278. Furthermore, there is also no circular structure between Mohan Port and Yunnan's economic hinterland, which may be due to the shared hinterland between Mohan Port and its neighboring ports, interference to the port–hinterland area's access capacity due to the "distance decay rate", and regional differences in the economic hinterland.

(3) The degree of spatial correlation in the Mohan Port–Yunnan hinterland system has a "north–south–central–south" dynamic evolutionary pattern, with significant regional differences.

Figure 3 indicates that the degree of spatial correlation between Mohan Port and the Yunnan hinterland system evolved in stages from 2006 to 2020, showing a concentration pattern from the north–south to the central region and then diffusion into the south, with significant regional differences. In 2006, 2011, and 2014, the areas of high correlation between Mohan Port and the Yunnan hinterland were mainly distributed in the southern and northern regions; the southern region was mainly distributed in Xishuangbanna Prefecture, while the northern region was mainly distributed in Zhaotong City, Lijiang City, and Diqing Prefecture. Mohan Port's geographical and spatial proximity to Xishuangbanna Prefecture, where the majority of the state's industrial and agricultural products depend on the outbound transportation of the port, coupled with the driving force of cross-border tourism, contributed to the high degree of correlation. With the second largest lignite field and one of the five major sulfur and iron mining areas in southern China, Zhaotong City relies on Mohan Port for the outward transportation of the abundant coal, ore, and non-ferrous metal resources in the region. The areas with a high degree of correlation with Mohan Port in this period were mainly distributed in resource-intensive cities, which showed that the degree of resource intensity was the dominant factor affecting the degree of correlation. Lijiang City and Diqing Prefecture are tourist towns with rich tourism resources and convenient and accessible transportation capacities. They are typical representatives of cross-border tourism, which, along the border with Mohan Port, form a tourism "golden triangle". As such, the correlation Mohan Port has with Lijiang City and Diqing Prefecture in northern Yunnan has strengthened. In 2017, the degree of correlation in the Mohan Port–Yunnan hinterland area was concentrated in the central region, mainly in Kunming City and Chuxiong Prefecture. This is because, in recent years, Yunnan Province as a whole has overtaken the central city of Yunnan as the power engine of future economic development, focusing on attracting investments, urban construction, modern industry, and other fields. The province has gradually built itself into the core of China's trade connections to South and Southeast Asia. The region's relatively developed economy and high level of infrastructure further drive the correlation between the two concentrations in the central region. In 2020, the degree of correlation in the Mohan Port–Yunnan hinterland area gradually spread to the southern region, mainly Pu'er City and Honghe Prefecture. In recent years, with the national emphasis on the gradual development of border port cities and cross-border tourism, Honghe Prefecture and Pu'er City, as regions with ports in southern Yunnan, have ushered in favorable conditions for high-quality development. Yunnan Province overtook the border ports as important windows to the outside world by developing an outward-oriented economy, providing a key policy orientation that will lead to higher correlations within the southern region. The policy orientation at this stage is the key factor influencing the evolution of correlations in the port–hinterland system.

(4) The change in the degree of correlation in the Mohan Port–Yunnan hinterland system is characterized by a "border zone–eastern region–central region–northern region" distribution, which was influenced by the cross-border tourism, industrial status, and the hinterland's economic development level.

Figure 4 illustrates the change in the degree of correlation in the Mohan Port–Yunnan hinterland system from 2006 to 2020. Compared with 2006, in 2017, most of the cities and states in the Yunnan hinterland exhibited an increased degree of correlation with Mohan Port. However, by 2020, except for Lincang, Yuxi, and Zhaotong, the degree of correlation between the rest of the cities and states and the Mohan port had declined. From 2006 to 2011, the areas where the degree of correlation in the port–hinterland system concerning cross-border tourism increased were mainly along the border zone of Yunnan Province, specifically, in Lincang City, Xishuangbanna Prefecture, and Dehong Prefecture. From 2011 to 2014, the areas with an increasing correlation between the two moved to the eastern part of Yunnan Province. From 2014 to 2017, areas of increasing correlation were concentrated in the inland hinterland, mainly in the central part of Yunnan Province, and from 2017 to 2020, it pushed northward (except for Yuxi City) and was distributed into Zhaotong City and Lijiang City. From 2006 to 2011, with the increase in cross-border tourism flow, the economic exchanges between Mohan Port and the main port cities along the border zone of Yunnan Province were frequent, strongly promoting the increase in income and the rapid development of the border port cities, as well as a significant increase in the correlation between Mohan Port and the cities and states along the border zone. From 2011 to 2014, driven by multiple factors such as traffic conditions, industrial structure, and cross-border tourism, the frequency of economic activities and the degree of traffic linkage between Mohan Port and eastern Yunnan strengthened, and the coupling effect between the port–passage–hinterland system increased, leading to the migration of the highly correlated region to the eastern part of Yunnan. From 2014 to 2017, Yunnan as a whole gradually overtook the central city of Yunnan, the provincial capital of Kunming, as the economic development engine of the province; with a high level of industrial development, transportation facilities, and economic integration, the economic communication between Mohan Port and the cities of central Yunnan was strengthened. Therefore, the degree of correlation between Mohan Port and the cities and states in central Yunnan increased. From 2017 to 2020, the spatial change in the degree of correlation between the port and hinterland concerning cross-border tourism moved northward, closely related to the distribution of Zhaotong's coal industry and Lijiang's tourism industry. However, compared with 2006–2017, the degree of correlation decreased.

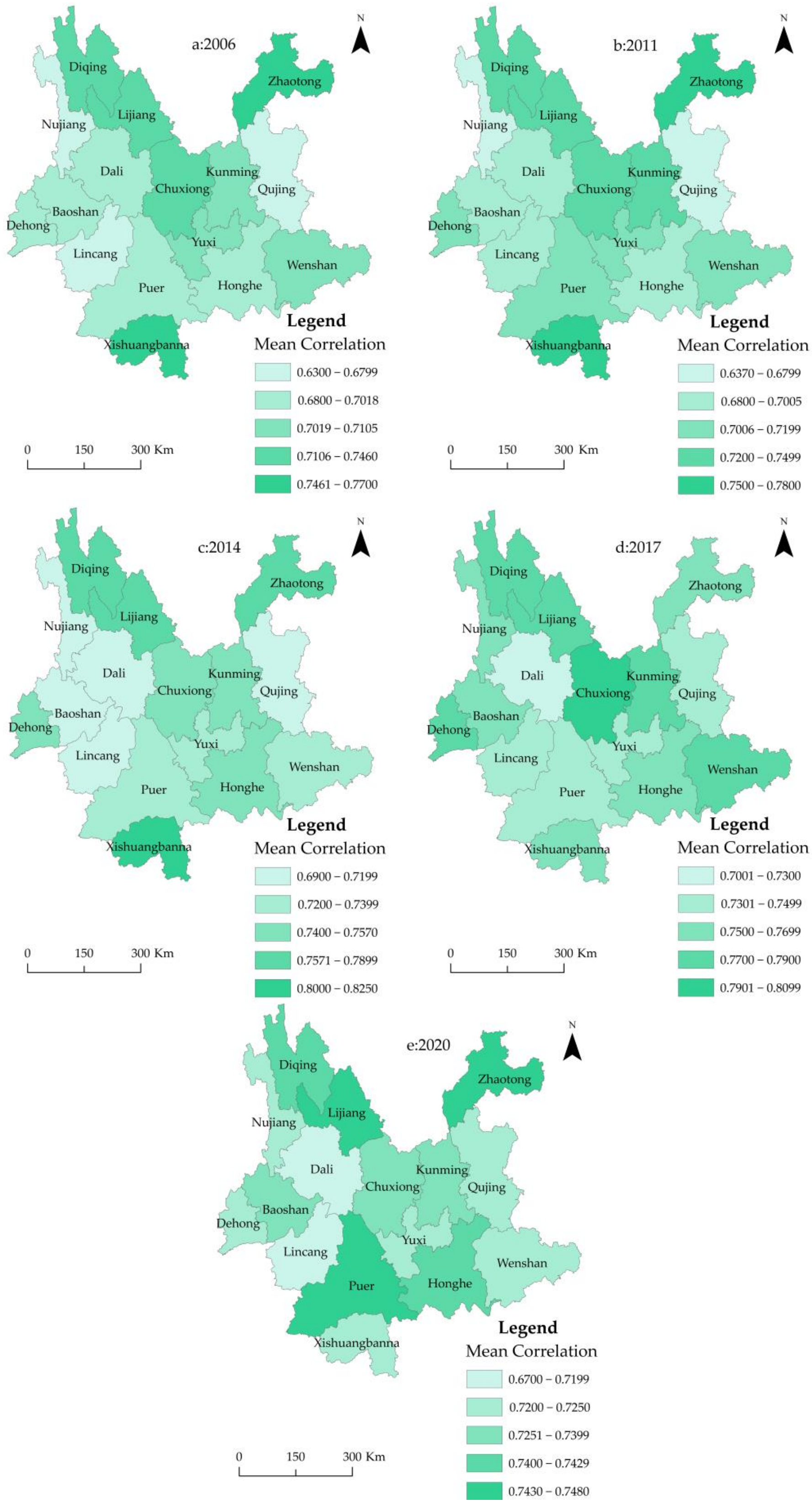

Figure 3. Spatial distribution characteristics of Mohan Port–Yunnan hinterland correlations based on a computer simulation.

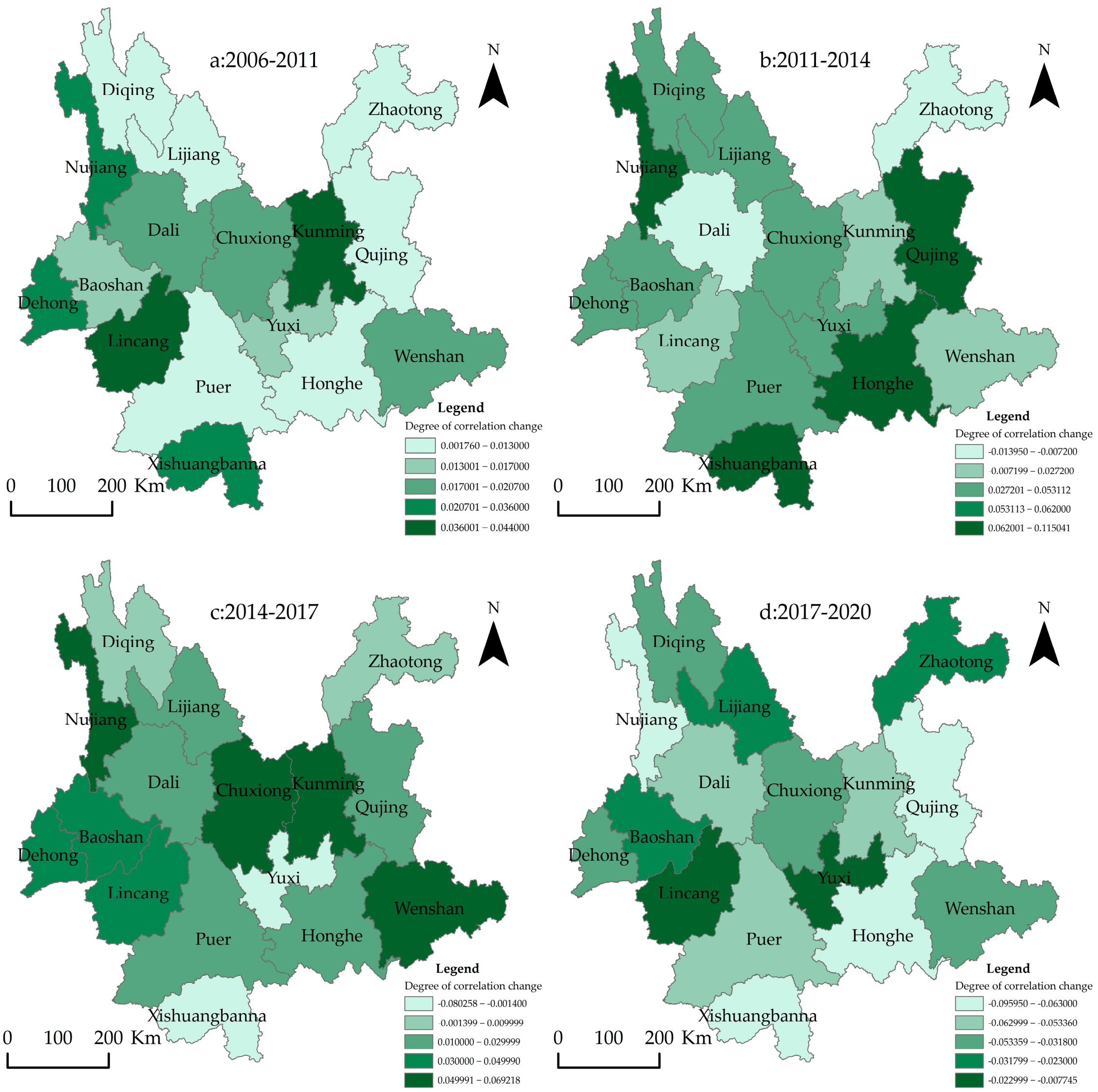

Figure 4. Computer spatial simulation analysis of the evolving degree of correlation in the Mohan Port–Yunnan hinterland system from 2006 to 2020.

3.2. Driving Mechanism Analysis of the Correlation Development from the Perspective of Tourism Spatial Optimization

Many factors affect correlations in port–hinterland systems concerning cross-border tourism, mainly natural conditions, resource endowments, national policies, the development status of the port itself, the level of economic integration in the hinterland, capacity building in the port–hinterland channel, the economic strength of the hinterland, and competition from its neighboring ports. Combined with the actual situation of the Mohan Port–Yunnan hinterland area's development, the mechanism driving this development correlation can be divided into five aspects.

(1) Natural conditions of the location and tourism resources endowments

Natural conditions and tourism resource endowment are the direct factors that directly affect the evolution of the correlation in port–hinterland systems. Unfavorable natural conditions will inevitably affect the scope, scale and development process of port–hinterland systems concerning cross-border tourism; to a certain extent, this also influences the development orientation, economic structure and regional structures of port–hinterland systems in the cross-border tourism [27]. Tourism resource endowments have an impact on the survival and development of border ports. Rich tourism resources undoubtedly have an effect on the breadth, depth, and intensity of the connection between the port and hinterland, as well as other economic regional systems, thus affecting the degree of correlation in the port–hinterland system concerning cross-border tourism. Mohan Port is the central hub of the Kunming–Bangkok international corridor, at the central node of the three major cities of Kunming, Vientiane, and Bangkok. It is an important open port in Yunnan Province, and Yunnan Province is an important part of China's Yangtze River Economic Belt, with a unique endowment of tourism resources. Relying on Mohan Port can effectively broaden the cross-border tourism market. The superior natural conditions, rich tourism resources, and substantial location advantages strongly encourage correlation in the development of the Mohan Port–Yunnan economic hinterland system.

(2) Infrastructure and traffic conditions

Infrastructure comprises the basic elements required to build a port–hinterland system, and it can provide strong guarantees for the flow of various production factors and the smooth development of economic activities. It is also necessary for strengthening the connection within the port–hinterland system [28]. Transportation is an important link between the port and the hinterland system, and a high level of capacity in the construction of port–hinterland channels can effectively guarantee the efficiency of cargo distribution and save transportation costs, which is conducive to the expansion and enhancement of the trade capacity of the port. The opening of the China–Laos Railway and Kunman Highway brought huge freight volume to Mohan Port, which then provided convenient conditions for the import and export of goods in Yunnan Province, effectively creating economic links in the port–hinterland system. Yunnan Province has formed a more complete transportation network system, allowing for the convenient transportation of goods, commodity circulation, and foreign trade with neighboring countries and regions. However, due to the infrastructure construction and Mohan Port's limited capacity for collection and distribution, meeting the needs of the Yunnan hinterland is difficult, resulting in a weakened correlation between Mohan Port and some cities in the Yunnan hinterland from 2016 to 2020.

(3) Economic strength and integration level of the hinterland

The economic strength and integration level of a hinterland is crucial to the specialization, production, socialization, and modernization of a port, and to a certain extent, this will affect the spatial connection of the port–hinterland system [29]. The port usually depends on the hinterland to provide various supporting factors, and when the scale and strength of the port reach a certain level, it can attract a large number of goods from the hinterland, increasing the economic income of the port. Similarly, a hinterland with strong economic strength and a high level of integration can provide sufficient sources of goods to the port, which is conducive to promoting its development. Yunnan Province is an important window to South and Southeast Asia, with convenient transportation, rich natural resources, and developed economic strength, especially driven by the strategy of building the China–ASEAN Free Trade Area and China–ASEAN Community of shared futures. The total volume of foreign trade and import and export goods has also achieved rapidly grown. These factors may have an impact on the quality of the development in the Mohan Port. However, due to the differences in the level of economic and social development among the cities and states in Yunnan's hinterland, there are still administrative, trade and economic barriers, meaning the combination effect between the various factors has not been optimized, and the level of economic integration needs to be further improved.

(4) Policy orientation

National policies, international and domestic situations, and other such factors can affect the degree of correlation in a port–hinterland system. Preferential policies introduced by the state can guide the high-quality development of port–hinterland systems, which is conducive to encouraging the port to enhance its competitiveness and extending the space of port distribution and trade, thus enhancing the correlation in the port–hinterland system. The rapid development of many ports locally and abroad can be attributed to the implementing of active foreign trade and opening policies; breaking administrative, economic and tariff barriers; and attracting many freight enterprises to join and cooperate. In recent years, the state has attached great importance to the development of foreign trade in Yunnan Province, and it has clarified the important position of Yunnan as China's link to South and Southeast Asia. Furthermore, Kunming's trusteeship for Mohan Port promotes the construction of infrastructure and rapid economic development. The strong support of national policies and the effective implementation of national strategies will be conducive to accelerating the level of economic integration between the Mohan Port and the Yunnan hinterland, promoting the free flow of factors within the port–hinterland system and effectively promoting the gradual optimization of the industrial structure, regional structure and industrial layout of the Yunnan hinterland. To a certain extent, this will also avoid the adverse effects of local protection policies and administrative interventions.

(5) Competition from neighboring ports

Driven by the mechanism of regional marketization and economic integration mechanisms, there will undoubtedly be competition among the neighboring ports within the same economic hinterland, and this may change the attraction scope and attraction capacity of the hinterland, which will have certain influences on the spatial pattern evolution, correlation and function type of the port–hinterland system. In Yunnan's border area, there are 10 national ports and 12 provincial ports of different scales, such as Wanding, Ruili, Mohan, Daluo, Hekou, Jinshuihe and Houqiao. Some of these ports are close to one another and share a large hinterland. Cooperation and the division of labor among these ports are not clear, and a more reasonable port layout has not yet been formed, manifesting in the overloaded operation of some national ports. Some of the provincial ports are not sufficient sources of goods, leading to an unreasonable allocation of resources. In recent years, with the effective implementation of the national foreign trade policy, some ports in Yunnan Province have developed rapidly in terms of infrastructure, transportation conditions, and port functions. With the increasing demand for goods in the hinterland of Yunnan hinterland, the competition between ports for resources has become more and more prominent; therefore, the correlation between Mohan Port and some border port cities appeared to exhibits a significantly decreasing trend from 2016 to 2020.

In summary, under the combined effect of the external push from the natural conditions of the location and tourism resource endowments, national policies, competition factors from nearby ports and the internal push from infrastructure and traffic conditions, economic strength, and the integration level of the hinterland, the port–hinterland system degree of correlation is alters, driving the evolution of the port–hinterland system's correlations, as shown in Figure 5.

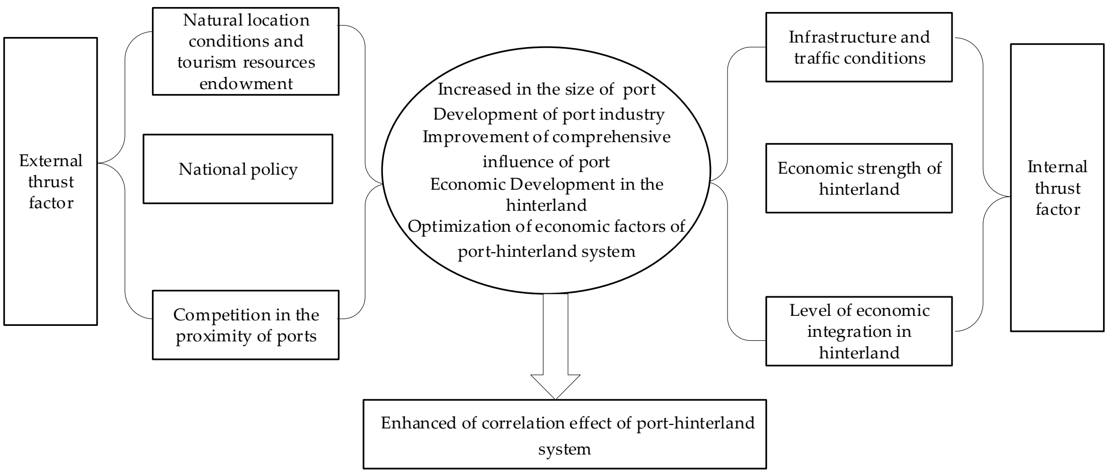

Figure 5. The mechanisms driving the development of the port–hinterland system's association with cross-border tourism from the perspective of tourism spatial optimization.

4. Discussion

By analyzing the gray correlation degree using a computer simulation, this study explored the correlation effects and driving mechanisms of the port–hinterland system concerning cross-border tourism, it is helpful to clarify the spatial and temporal evolution characteristic of port–hinterland system, which can provide a theoretical basis for the high-quality development of regional economy. This study focuses on analysis of the correlation in the port–economic hinterland system over the past 15 years. Unlike previous studies, this study attempted to reveal the driving mechanism of the correlation development on the port–hinterland system from the perspective of internal and external factors. From 2006 to 2020, the degree of spatial correlation of the Mohan port–Yunnan hinterland system showed a dynamic evolution law of "north–south–central–south". The results are consistent with the actual development of the port–hinterland system in the region, which further proves the scientificity and effectiveness of the results. Meanwhile, the correlation between the Mohan port and the Yunnan hinterland from 2006 to 2020 increased on the basis of the original strong association, but there was a marked decline in volatility, which is more consistent with the research results of the spatial function of Dalian port–Northeast hinterland system by Dong Xiaofei and others [18]. From the perspective of the change trend of the correlation degree between Mohan port and Yunnan economic hinterland, the results of this study are basically consistent with the research results of the Lianyungang port by Zhu Chuangeng and others. However, this study performs an innovative analysis of the typical model of the port–hinterland system association [22]. In addition, from the perspective of the driving mechanism of the correlation between Mohan port and Yunnan economic hinterland, the results of this study are different from the research results of the Qingdao port by Yao Taotao and others [26]. This study believes that national policies and competition in the proximity of ports are key factors that should be considered.

5. Conclusions

By constructing an index system for a port–hinterland system concerning cross-border tourism from a tourism spatial optimization perspective, this study quantitatively measured correlations in the Mohan port–Yunnan economic hinterland system from 2006 to 2020 using a computational simulation to analyze the gray correlation degree. The analysis revealed the spatial evolution characteristics of the correlation degree and the mechanisms driving the Mohan port–Yunnan economic hinterland's development correlation. This study found the following: (1) Due to the influence of administrative interventions and the competition of the neighboring ports, the correlation between the Mohan port and the Yunnan hinterland from 2006 to 2020 showed a rising–falling trend. (2) The correlation between the Mohan port and Xishuangbanna prefecture showed an obvious fluctuating trend, and the original port–city development relationship evolved to a competitive status. (3) From 2006 to 2020, the degree of spatial correlation of the Mohan port–Yunnan hinterland system evolved in the north–east–south–central–southern direction, with "border zone–central region–northern region" distribution characteristics. (4) The natural conditions of the location, national policies, competition of nearby ports, infrastructure and traffic conditions, and economic strength are the main driving factors affecting the correlation change between Mohan port and the Yunnan hinterland.

However, due to the difficulty of obtaining data and information, correlations in port–hinterland systems concerning cross-border tourism are limited to analysis from the perspective of a single port. Analyzing correlations in a port–hinterland system comprising a port group and a hinterland will be more reflective and representative of the real situation. A comprehensive analysis using computerized dynamic spatial simulation technology of the spatial mechanisms and evolutionary laws of a port group-hinterland system concerning cross-border tourism is the direction future efforts should take. Meanwhile, the concept of hinterland systems should be further clarified, and the representativeness and comprehensiveness of the indicators should be emphasized in their selection. In addition, this study focused on prefecture-level cities (states) and quantitatively measured the association effect in a port–hinterland system concerning cross-border tourism on a macroscopic scale, but it did not make this analysis on a microscopic scale, and this should be the focus of future research.

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