Multi-scale Evolutionary Characteristics and Influencing Factors of the Spatial Layout of Logistics Enterprises in Xinjiang (Postprint)

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Abstract

The National Development and Reform Commission' s "14th Five-Year Plan for Modern Distribution System Construction" emphasizes "improving the regional logistics service network," while the State Council' s "Overall Plan for the China (Xinjiang) Pilot Free Trade Zone" proposes "building a comprehensive logistics hub connecting Europe and Asia." Therefore, investigating the spatial layout of logistics enterprises in Xinjiang holds significant strategic importance for enhancing the regional logistics service network and constructing the Xinjiang Pilot Free Trade Zone. Based on geographic coordinate data of Xinjiang logistics enterprises from 1992 to 2022, this study analyzes the evolution characteristics of logistics enterprise spatial distribution across different scales and conducts an in-depth examination of the formation mechanisms underlying logistics enterprise spatial layout and the spatial heterogeneity of influencing factors at both county and grid scales. The results indicate: (1) Xinjiang logistics enterprises exhibit an agglomerated development pattern, evolving into a "single axis, single main core, multiple sub-cores" spatial configuration at the macro level, and a "one main core, multiple sub-cores" spatial configuration at the local level. (2) At the county scale, hotspot and sub-hotspot areas of Xinjiang logistics enterprise spatial distribution remain consistently concentrated in northern Xinjiang, constrained by the geographical barrier of the northern Tianshan slope; however, at finer grid scales, sub-hotspot areas ultimately overcome this geographical constraint. (3) E-commerce parks, comprehensive bonded zones, and population density constitute important factors influencing logistics enterprise spatial layout across different scales; natural environmental factors can generate nonlinear enhancement interactions with other influencing factors, warranting particular attention. (4) Xinjiang should prioritize logistics park development, improve port functional construction and economic development, and formulate location-specific logistics plans tailored to local influencing factors such as e-commerce, industrial parks, ports, and comprehensive bonded zones. This

study advances enterprise location theory and provides theoretical support and practical guidance for Xinjiang’ s development as a Eurasian logistics hub and core area of the Silk Road Economic Belt.

Full Text

Preamble

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Multi-scale Evolution Characteristics and Influencing Factors of Spatial Layout of Logistics Enterprises in Xinjiang

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Abstract: The National Development and Reform Commission’ s *14th Five-Year Plan for Modern Circulation System Construction* emphasizes “improving the regional logistics service network,” while the State Council’ s *Overall Plan for the China (Xinjiang) Pilot Free Trade Zone* proposes “building a comprehensive logistics hub connecting Europe and Asia.” Therefore, studying the spatial layout of Xinjiang’ s logistics enterprises holds significant strategic importance for improving regional logistics service networks and constructing the Xinjiang Pilot Free Trade Zone. Based on geographic coordinate data of Xinjiang logistics enterprises from 1992 to 2022, this study analyzes the evolution characteristics of logistics enterprise spatial distribution across different scales and deeply examines the formation mechanisms and spatial heterogeneity of influencing factors at county and grid scales. The results indicate: (1) Xinjiang’ s logistics enterprises exhibit agglomeration development, forming an overall spatial pattern of “single axis, single main core, and multiple sub-cores,” while locally developing into a “one main core, multiple sub-cores” pattern. (2) At the county scale, hotspots and sub-hotspots of logistics enterprise spatial distribution remain in northern Xinjiang, constrained by the northern slope of the Tianshan Mountains, whereas at smaller grid scales, sub-hotspots ultimately break through this geographical constraint. (3) E-commerce parks, comprehensive bonded zones, and population density are important factors affecting logistics enterprise spatial layout across different scales, with natural environmental factors generating nonlinear enhancement interactions with other factors that require attention. (4) Xinjiang should prioritize logistics park construction, improve port functional development, and promote economic growth. Targeting local influencing factors such as e-commerce, industrial parks, ports, and comprehensive bonded zones, logistics planning should be formulated according to

local conditions. This research deepens enterprise location theory and provides theoretical support and practical guidance for constructing Xinjiang' s Eurasian logistics hub and the core area of the Silk Road Economic Belt.

Keywords: logistics enterprises; multi-scale; spatial layout; evolutionary characteristics; influencing factors; Xinjiang

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1 Data and Methods

1.1 Study Area Overview

Under the Belt and Road Initiative, Xinjiang' s geographical location advantage has become more prominent, and the construction of the China (Xinjiang) Pilot Free Trade Zone has further elevated Xinjiang' s strategic position. Xinjiang' s logistics industry has thus entered a historically rare period of opportunity. Xinjiang covers a total area of 166.49$\times 10^{4}$ km^2, accounting for approximately one-sixth of China' s territory, and comprises 14 prefecture-level administrative regions, 96 county-level administrative units, and 12 division-level cities of the Xinjiang Production and Construction Corps. Xinjiang' s complex geographical environment features interwoven mountains and basins, forming a unique "three mountains sandwiching two basins" pattern, with the Tianshan Mountains traversing central Xinjiang, the Tarim Basin and Kunlun Mountains to the south, and the Junggar Basin and Altai Mountains to the north. Under these complex geographical conditions, the number of logistics enterprises in Xinjiang has grown from over 2,000 to more than 20,000, with 107 logistics parks, 6 comprehensive bonded zones, and 20 Class-I ports providing favorable conditions for logistics enterprise development. Xinjiang has basically formed a "one axis, two rings" comprehensive transportation network centered on the New Eurasian Land Bridge, with Urumqi as the national comprehensive transportation hub and the Tarim and Junggar Basins as the two wings, enhancing transportation convenience and helping reduce logistics costs.

1.2 Data Sources

This study focuses on logistics enterprises, with data sourced from enterprise registration information on the Tianyancha website. Using the Gaode Map API, enterprise registration addresses were converted to geographic coordinates, excluding samples with incomplete or erroneous information. Administrative boundary data were obtained from the National Basic Geographic Information Center. Road network vector datasets for 1992–2022, annual nighttime light data, land use data, and geomorphological type spatial data were sourced from the Chinese Academy of Sciences' Resource and Environmental Science Data Center. Population density spatial data for 1992–2022 were obtained from the WorldPop data website. Annual freezing days datasets for 1992–2022 were sourced from the National Science and Technology Infrastructure Platform—National Earth System Science Data Center (http://www.geodata.cn). Geographic data for airports, parks, railway stations, and ports were obtained through web scraping of the Gaode Map platform.

1.3 Research Methods

This study employs the average nearest neighbor and kernel density methods to analyze the overall evolution characteristics of Xinjiang logistics enterprise spatial distribution, spatial autocorrelation and hotspot analysis to examine evolution characteristics across different scales, geodetector to study formation mechanisms of spatial distribution, and multiscale geographically weighted regression (MGWR) to investigate heterogeneity of important influencing factors. Specific methods are as follows:

1.3.1 Geodetector Geodetector's factor detection can identify spatial stratification heterogeneity of dependent variables and measure the explanatory power of independent variables on spatial differentiation of dependent variables using q-values. Interaction detection can identify interactions between independent variables, assessing whether the combined effect of two variables increases or decreases explanatory power for the dependent variable. This study uses geodetector to analyze formation mechanisms of logistics enterprise spatial layout and employs multiscale geographically weighted regression to analyze how important influencing factors affect logistics enterprise spatial layout across different scales, further exploring spatial heterogeneity of influencing factors to provide support and guidance for optimizing logistics enterprise spatial layout in Xinjiang.

1.3.2 Multiscale Geographically Weighted Regression Model (MGWR) The MGWR model improves upon the GWR model by allowing parameters to vary spatially, with bandwidth specificity. The model is expressed as:

$$y_i = \sum_{j=1}^{k} \beta_{bwj}(u_i, v_i) x_{ij} + \varepsilon_i$$

where y_i is the dependent variable value for region i; $\beta_{bwj}(u_i, v_i)$ is the local regression coefficient for the jth independent variable in region i; bwj is the geographic bandwidth for the jth independent variable; x_{ij} is the value of the jth independent variable in region i; and ε_i is the error term. Bandwidth is a key indicator for studying spatial heterogeneity of independent variables. The MGWR model uses different bandwidth divisions for different variables. This study employs a Gaussian kernel function with adaptive bandwidth, determines bandwidth through golden section search, considers regression results converged when iterative changes in regression coefficients are less than 0.00001, and optimizes the model based on the corrected Akaike Information Criterion (AICc).

2 Results

2.1 Overall Evolution Characteristics of Xinjiang Logistics Enterprise Spatial Distribution

2.1.1 Overall Distribution Pattern The average nearest neighbor index for Xinjiang logistics enterprises from 1992 to 2022 consistently remains below 1 and passes significance tests at the 99% confidence level, indicating that Xinjiang logistics enterprises exhibit significant agglomeration distribution characteristics and regional patterns. Combined with kernel density analysis to examine specific agglomeration area distributions, larger-scale analysis clearly reflects overall distribution trends, while smaller-scale analysis better reveals local evolution characteristics. Selecting 1992, 2006, 2015, and 2022 as time nodes and calculating kernel density values at 200 km, 100 km, and 50 km search radii generates kernel density distribution maps for Xinjiang logistics enterprises [Figure 1: see original paper]. The results show that Xinjiang logistics enterprises exhibit obvious spatial agglomeration, primarily concentrated in the northern Tianshan slope region, evolving from a "single axis, single main core, single sub-core" pattern to a "single core" and then to a "single axis, single main core, multiple sub-cores" spatial distribution pattern. This evolution indicates coordinated development among prefecture-level cities in Xinjiang' s logistics industry, with logistics agglomeration areas gradually forming in Aksu and Kashgar regions in southern Xinjiang. Figure 1 better reflects local evolution characteristics of logistics enterprise spatial distribution, with Urumqi consistently showing the highest agglomeration as Xinjiang' s logistics center. Meanwhile, sub-core areas with relatively high agglomeration are gradually forming in cities such as Kashgar and Aksu, becoming regional logistics centers. In summary, Xinjiang logistics enterprises mainly agglomerate in the northern Tianshan slope region, maintaining Urumqi as the main core while gradually forming multiple sub-core areas with high agglomeration that serve as regional logistics enterprise distribution centers.

2.1.2 County-Scale Evolution Characteristics Global Spatial Autocorrelation Analysis: To explore evolution characteristics of Xinjiang logistics enterprise spatial distribution at the county scale, ArcGIS 10.8 software was used to calculate global Moran' s I for logistics enterprise quantities in 96 counties (cities) from 1992 to 2022 . Results show Moran' s I ranges from 0.122 to 0.268, all passing significance tests with Z-values greater than 1.96, indicating significant positive spatial autocorrelation in county-scale logistics enterprise distribution—counties with high logistics enterprise quantities consistently show spatial clustering. Temporally, the strength of positive spatial autocorrelation exhibits cyclical changes, generally following a pattern of first rising, then falling, then rising again. It can be inferred that positive spatial autocorrelation at the county scale will gradually strengthen, with logistics enterprises further clustering around counties with high enterprise quantities.

Intra-regional Hotspot Analysis: Since global Moran's I only reflects overall spatial association and may mask local instability, ArcGIS 10.8 hotspot analysis tools were further employed to analyze clustering locations of logistics enterprises at the county scale from 1992 to 2022. Using the natural breaks classification method, hotspots were divided into five categories for visualization [Figure 2: see original paper]. Results show that hotspot areas consistently remain in Toutunhe, Shayibake, Xinshi, and Shuimogou districts of Urumqi, with Tianshan District gradually shifting from hotspot to sub-hotspot. Sub-hotspot areas show a pattern of first decreasing then increasing, with Midong District, Urumqi County, and Changji City consistently serving as sub-hotspots, but always located in northern Xinjiang without breaking through the northern Tianshan slope constraint. Transition zones show a pattern of first increasing then decreasing, with a trend toward southeast expansion. Most counties (cities) in Tacheng, Kashgar, Altay, and Kizilsu Kirghiz Autonomous Prefecture consistently remain sub-coldspot and coldspot areas, where logistics development is relatively weak and enterprises struggle to form effective agglomerations.

2.1.3 Grid-Scale (70 km$\times$70 km) Evolution Characteristics Global Spatial Autocorrelation Analysis: Research exploring spatial distribution evolution characteristics across different scales can clarify scale dependence of evolution processes and break free from county-level administrative unit constraints. To further examine evolution characteristics at smaller scales, ArcGIS 10.8 was used to calculate global Moran' s I for grid-scale logistics enterprise quantities from 1992 to 2022 . Results show Moran' s I ranges from 0.127 to 0.167, all passing significance tests at the 99% level with Z-values greater than 2.58, indicating consistently significant positive spatial autocorrelation at the grid scale. Temporally, Moran' s I shows little variation at the grid scale, suggesting relatively stable positive spatial autocorrelation strength.

Intra-regional Hotspot Analysis: To further reveal local instability in logistics enterprise spatial distribution, hotspot analysis was used to identify clustering locations at the grid scale [Figure 3: see original paper]. Hotspot areas show a pattern of first decreasing then increasing, with a northward shift in Xinjiang, but consistently remain in Urumqi and surrounding counties (cities) without breaking through the northern Tianshan slope constraint. Sub-hotspot areas show a pattern of first contracting then expanding. In 1992 and 2006, sub-hotspots remained constrained within the northern Tianshan slope; by 2015, Huocheng County and Yining City in northern Xinjiang developed into sub-hotspots, breaking through the northern Tianshan slope constraint; by 2022, Kashgar City and Shufu County in southern Xinjiang also developed into sub-hotspots, becoming regional logistics development centers. Transition zones show a pattern of first increasing then decreasing. In 2006, Bole City and Karamay District in northern Xinjiang shifted from sub-hotspot to transition zone, while Aksu City and Korla City in southern Xinjiang shifted from sub-coldspot to transition zone; by 2022, extensive transition zones became the breakthrough point for logistics enterprises to overcome the northern Tianshan slope constraint, with counties directly under Ili Kazakh Autonomous Prefecture shifting from sub-coldspot to transition zone. Sub-coldspot and coldspot areas continue to decrease, but most areas in Bayingolin Mongol Autonomous Prefecture (Bayingolin), Hotan, and Altay remain sub-coldspot and coldspot areas, indicating long-term obstacles to logistics development. In summary, hotspot areas consistently distribute in Urumqi and its surroundings without breaking through the northern Tianshan slope constraint; sub-hotspot areas first decrease then increase, with Bayingolin and other areas consistently remaining sub-coldspot and coldspot areas.

Comparing evolution processes across different scales reveals that in overall spatial association evolution, logistics enterprise spatial layouts show significant positive spatial autocorrelation across scales. However, at the county scale, the strength of positive autocorrelation shows cyclical changes, while remaining relatively stable at the grid scale. In clustering location evolution, hotspot and sub-hotspot areas initially concentrate in the northern Tianshan slope across scales. At the county scale, they struggle to break through the northern Tianshan slope constraint, but the finer grid scale successfully overcomes this geographical barrier.

2.2 Formation Mechanism Analysis of Logistics Enterprise Spatial Layout

2.2.1 Variable Selection Given that long time spans have limited impact on logistics enterprise spatial layout and kernel density values effectively display spatial differentiation and evolution processes, kernel density values of newly established logistics enterprises in different spatial scales for 1992, 2006, 2015, and 2022 were selected as the dependent variable Y. Following principles of scientificity and feasibility in indicator selection and drawing on existing research, five primary indicators and 13 secondary indicators were selected from agglomeration factors, economic factors, transportation factors, policy factors, and natural environmental factors .

2.2.2 County-Scale Formation Mechanism Analysis **Factor Detection Analysis:** Factor detection reveals that agglomeration factors, economic factors, transportation factors, and policy factors all significantly influence logistics enterprise spatial layout, but with varying explanatory power. Among natural environmental factors, desert and Gobi area proportion (X_{11}) shows significant influence but with relatively weak explanatory power. Population density (X_1), economic development level (X_2), and comprehensive bonded zone distance (X_9) are the three strongest indicators, each maintaining explanatory power above 0.2, indicating these are important factors influencing spatial layout at the county scale.

Interaction Detection Analysis: Factor detection only analyzes single-factor effects on spatial differentiation, not the combined effects of two factors. Interaction detection shows 11 scenarios producing nonlinear enhancement interactions at the county scale, where the combined explanatory power exceeds the sum of individual factors. Natural environmental factors' mountain area proportion (X_{10}) and annual freezing time proportion (X_{12}) produce nonlinear enhancement interactions with numerous factors. Although natural environmental factors have weak individual explanatory power, their nonlinear enhancement interactions with other indicators make them unavoidable considerations in logistics enterprise spatial layout.

2.2.3 Grid-Scale Formation Mechanism Analysis **Factor Detection Analysis:** Grid-scale analysis reveals that economic, policy, and agglomeration factors significantly influence logistics enterprise spatial layout. E-commerce park distance (X_5) and industrial park distance (X_6) are the strongest indicators, each maintaining explanatory power above 0.2, indicating these are important factors at the grid scale.

Interaction Detection Analysis: At the grid scale, 41 scenarios produce nonlinear enhancement interactions, accounting for 34.17% of all interaction scenarios. Transportation accessibility (X_8) and natural environmental factors produce nonlinear enhancement interactions with numerous indicators. Although these factors have weak individual explanatory power, they become unavoidable considerations. X_8 and natural environmental factors produce nonlinear enhancement interactions with all important influencing factors, indicating these are key considerations for logistics enterprise spatial layout at the grid scale.

2.2.4 Summary of Formation Mechanism Analysis Theoretical mechanisms: (1) Across scales, population density, e-commerce park distance, and comprehensive bonded zone distance significantly influence logistics enterprise spatial layout. At the county scale, economic development level and port distance have greater impact, while at finer grid scales, logistics park distance and industrial park distance have greater impact. (2) Regardless of scale, natural environmental factors show weak individual explanatory power but produce nonlinear enhancement interactions with other factors, making them essential considerations.

Practical mechanisms: (1) Across scales, population density and distances to e-commerce parks and comprehensive bonded zones are important considerations. At larger scales, economic development level and port distance matter more; at smaller scales, logistics park and industrial park distances matter more. (2) At any scale, the combined impact of natural environmental factors and important factors must be considered.

2.3 MGWR-Based Influencing Factor Analysis

Geodetector' s factor detection analyzed formation mechanisms and identified important influencing factors but cannot explain what kind of impact these factors have. Therefore, MGWR was further employed to analyze important influencing factors at different scales.

2.3.1 County-Scale Influencing Factor Analysis County-scale formation mechanism analysis identified population density, economic development level, and distances to comprehensive bonded zones, e-commerce parks, and ports as the five most important factors. Correlation analysis shows variance inflation factors (VIF) are all below 7.5, indicating no multicollinearity. MGWR model R^2 and adjusted R^2 are significantly higher than OLS and GWR models, with AICc values significantly lower, indicating MGWR better reflects reality.

Global Variable Analysis: E-commerce park distance, economic development level, and population density are global variables (lacking spatial heterogeneity), with regression coefficients showing little spatial variation. E-commerce park distance has a mean regression coefficient of -0.003, indicating weak promotion of logistics enterprise agglomeration, as Xinjiang' s e-commerce parks currently mainly handle commerce flow, information flow, and capital flow, with logistics separated from commerce flow, resulting in low direct demand for logistics services. Economic development level and population density have mean regression coefficients of 0.011 and 0.010 respectively, indicating logistics enterprises tend to locate in counties (cities) with higher economic development and population density, as economic development' s social division of labor and market advantages effectively promote logistics enterprise agglomeration.

Local Variable Analysis: The constant term, port distance, and comprehensive bonded zone distance are local variables (with spatial heterogeneity), showing large spatial variation in regression coefficients. Natural breaks classification was used to categorize coefficients for visualization [Figure 4: see original paper].

The constant term coefficient shows a stepwise decreasing trend from east to west [Figure 4a: see original paper], indicating locational advantages for logistics enterprise spatial layout gradually decrease from east to west at the county scale. The area east of the "Tacheng City-Qiemo County" line has locational conditions conducive to logistics enterprise agglomeration, while areas to the west inhibit development, due to relatively developed transportation infrastructure, proximity to inland markets, less desert and Gobi terrain, and higher land development utilization in eastern regions.

Port distance regression coefficients are all positive, indicating insufficient promotion of logistics enterprise agglomeration. Xinjiang' s ports primarily serve as import-export channel nodes with limited capacity to drive regional logistics development. The distribution shows a "high in the middle, low in both ends" pattern [Figure 4b: see original paper], with eastern ports having stronger driving effects than central and western regions. The "Tacheng City-Qiemo County" line represents counties with the highest driving capacity.

Comprehensive bonded zone distance coefficients are all negative, showing a " " shaped distribution decreasing from both east and west toward the center [Figure 4c: see original paper], indicating that shortening distance to comprehensive bonded zones effectively promotes logistics enterprise agglomeration, as bonded zones' functions in bonded warehousing, export processing, and entrepôt trade help reduce land costs, access markets, and save expenses.

2.3.2 Grid-Scale Influencing Factor Analysis Grid-scale formation mechanism analysis identified e-commerce park distance, comprehensive bonded zone distance, population density, logistics park distance, and industrial park distance as the five most important factors. All VIF values are below 7.5, indicating no multicollinearity. MGWR model R^2 and adjusted R^2 are significantly higher than OLS and GWR models, with AICc values significantly lower, indicating MGWR better reflects reality. All variables at the grid scale have bandwidth ratios below 0.5, making them all local variables with spatial heterogeneity requiring spatially specific analysis [Figure 5: see original paper].

Constant term coefficients are all negative [Figure 5a: see original paper], indicating Xinjiang' s locational conditions have not effectively promoted logistics enterprise agglomeration at the grid scale. Coefficients show a north-south distribution pattern of low in the north and high in the south, suggesting southern Xinjiang has better locational conditions than northern Xinjiang, as southern routes better connect with the New International Land-Sea Trade Corridor and the China-Pakistan Economic Corridor provides greater impetus for southern Xinjiang' s logistics development.

Industrial park distance coefficients are negative in Altay, Urumqi, and Aksu regions [Figure 5b: see original paper], indicating proximity to industrial parks promotes logistics enterprise agglomeration in these areas due to better upstream-downstream industry integration and locational advantages near borders, ports, and comprehensive bonded zones.

E-commerce park distance coefficients are overall negative [Figure 5c: see original paper], indicating most regions show agglomeration tendencies near e-commerce parks, but positive coefficients in Hotan, southern Bayingolin, and northern border areas indicate logistics enterprises struggle to agglomerate near e-commerce parks in these regions due to poor transportation, harsh natural environments, and the fact that logistics shipping locations for e-commerce park products are not in the parks themselves.

Population density coefficients are positive along the "Kashgar City-Urumqi City" line [Figure 5d: see original paper], indicating population effectively promotes logistics enterprise agglomeration in these areas through increased market demand. Other regions show insufficient road infrastructure, large desert/Gobi areas, or excessive freezing periods that prevent population from effectively promoting agglomeration.

Logistics park distance coefficients are overall negative [Figure 5e: see original paper], indicating logistics park construction helps enterprise agglomeration, with smaller coefficients in Aksu, Turpan, northern Altay, and Urumqi regions showing stronger promotional effects.

Comprehensive bonded zone distance coefficients are overall negative [Figure 5f: see original paper], indicating bonded zones promote logistics enterprise agglomeration, but positive coefficients in Hotan and southern Bayingolin suggest bonded zones struggle to promote local logistics development there. Coefficients show a "low in the north, high in the south" pattern, indicating northern Xinjiang's comprehensive bonded zones more effectively promote logistics enterprise agglomeration.

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3 Discussion

The formation and evolution of research object spatial patterns are scale-dependent. Exploring spatial distribution evolution characteristics across different scales can clarify scale dependence of evolution processes and provide reference for more precise policy formulation. Focusing on mechanisms and spatial heterogeneity of influencing factors across scales facilitates tailored regulation and guidance. This study' s contributions include: (1) Highlighting the importance of multi-scale analysis. Unlike previous single-scale provincial studies, this research finds that at relatively smaller scales, spatial hotspot distribution more easily breaks through certain geographical constraints. (2) Emphasizing the importance of nonlinear interactions of natural environmental factors. While most scholars assume homogeneous geographical environments when studying logistics enterprise spatial layout, this study introduces natural environmental factors into formation mechanism analysis and finds that although they have weak explanatory power across scales, they produce nonlinear enhancement interactions with other factors that cannot be ignored. (3) Clarifying regional differences in logistics enterprise spatial layout mechanisms. Population density and economic development level are important influencing factors in Xinjiang, but their effects are not significant in the Beijing-Tianjin-Hebei region due to smaller population density gaps between county-level administrative districts and the fact that smaller county areas allow economic advantages to better radiate to surrounding areas.

Future research plans: (1) Different types of logistics enterprises should be distinguished, as spatial layout must consider synergies between different enterprise types. Future research could classify logistics enterprises and study spatial layout from a collaborative development perspective. (2) This study only analyzed which influencing factors produce nonlinear enhancement interactions without further regression analysis of these interactions. Future research could conduct further analysis to better clarify how natural environmental factors affect logistics enterprise spatial layout.

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4 Conclusions and Recommendations

4.1 Conclusions

(1) Logistics enterprises overall show a spatial distribution pattern evolving from "single axis, single main core, single sub-core" to "single core" and then to "single axis, single main core, multiple sub-cores." Locally, a "one main core, multiple sub-cores" pattern has gradually formed with Urumqi as the main core and Kashgar, Korla, Aksu, and other cities as sub-cores.

(2) At the county scale, hotspots and sub-hotspots of Xinjiang logistics enterprise spatial distribution remain in northern Xinjiang, constrained by the northern Tianshan slope. At the grid scale, although hotspots and sub-hotspots initially concentrate in northern Xinjiang, sub-hotspots ultimately break through this geographical constraint, with Kashgar City, Shufu County, and Korla City and surrounding counties (cities) in southern Xinjiang developing into sub-hotspots that will become focal points for regional logistics industry development.

(3) E-commerce park distance, population density, and comprehensive bonded zone distance are important factors affecting logistics enterprise spatial layout across scales. Economic development level and port distance have greater impact at the county scale, while logistics park distance and industrial park distance have greater impact at the grid scale. Although natural environmental factors have weak explanatory power across scales, their nonlinear enhancement interactions with other factors make them unavoidable issues in spatial layout.

(4) At the county scale, e-commerce park distance, economic development level, and population density are global variables, with economic development level and population density promoting logistics enterprise agglomeration overall, but e-commerce parks showing weak promotion. Port distance and comprehensive bonded zone distance are local variables, with the former showing weak promotion and the latter showing strong promotion. At the grid scale, industrial park distance, e-commerce park distance, population density, logistics park distance, and comprehensive bonded zone distance are all local variables, requiring spatially specific consideration of their impacts on logistics enterprise spatial layout.

4.2 Recommendations

(1) **Coordinate overall planning with tailored local strategies.** Xinjiang should coordinate logistics park construction with economic development to attract logistics enterprises and form agglomeration effects that enhance specialization and service quality. For southern Xinjiang, accelerating industrial development and population concentration is urgent, as this will directly generate strong demand for logistics services and drive local logistics enterprise growth. Kashgar, Altay, Urumqi, and Hami cities

and their surrounding areas should leverage their advantages to boost e-commerce industry development through specialized industrial parks, cultivating and expanding the logistics demand market to promote specialization and scaling of logistics enterprises.

(2) **Optimize overall and regional logistics center layout.** To build Xinjiang into a comprehensive logistics hub connecting Europe and Asia, we must optimize spatial layout strategies. Specifically, Urumqi should be positioned as Xinjiang' s logistics center, leveraging its superior geographical location and transportation network to radiate and drive logistics industry development across the region. Meanwhile, Khorgos, Yining, Kashgar, Korla, Aksu, and Yizhou districts should be cultivated as regional logistics centers. These areas not only have large-scale logistics enterprises but also possess strong development potential that can effectively drive surrounding regions. Particularly, Kashgar and Korla are gradually breaking through the northern Tianshan slope constraint and should be prioritized for support to optimize logistics enterprise spatial layout.

(3) **Strengthen functional development of comprehensive bonded zones and ports.** Kashgar Comprehensive Bonded Zone shows weak promotion of logistics enterprise development and should learn from Urumqi Comprehensive Bonded Zone' s construction experience to improve functions, enhance infrastructure investment, and upgrade cargo handling capacity, warehousing and distribution efficiency, and information service levels to make it an important node connecting domestic and international markets. Ports should improve functional development—not just as import-export channels but as international cargo hubs and economic development engines—to drive local and surrounding logistics enterprise development.

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Note: Figure translations are in progress. See original paper for figures.