

Article

Spatial Differentiation and Driving Mechanisms of County-Level Tourism Accessibility in Gansu Based on Multi-Dimensional Travel Cost Perspective

Ruhu Gao ¹ , Wenkai Shi ¹, Yuwei Wang ², Zhennan Qi ¹ and Liangzhi Li ^{3,*} 

¹ School of Traffic and Transportation, Lanzhou Jiaotong University, Lanzhou 730070, China; grh@mail.lzjtu.cn (R.G.); 11250029@stu.lzjtu.edu.cn (W.S.); 20220302227@stu.lzjtu.edu.cn (Z.Q.)

² School of Low-Altitude Management and Digital Economy, Xihang University, Xi'an 710077, China; 202106003@xaau.edu.cn

³ School of Land Engineering, Chang'an University, Xi'an 710064, China

* Correspondence: liliangzhi@chd.edu.cn

Abstract

Tourism accessibility is an important indicator for assessing the coordinated development of transport and tourism. Using counties and districts in Gansu Province as the units of analysis, this study developed a three-dimensional evaluation framework comprising temporal accessibility, economic accessibility, and balanced accessibility, based on real-world travel data between county and district centres and China's A-rated tourist attractions obtained from the Amap API. Spatial autocorrelation analysis, the Geographical Detector, the Spatial Durbin Model (SDM), and Multiscale Geographically Weighted Regression (MGWR) were employed to systematically investigate the spatial patterns and driving mechanisms of tourism accessibility in Gansu Province. The results indicate that: (1) tourism accessibility exhibits significant spatial clustering, with high-value areas primarily concentrated in the Hexi Corridor and low-value areas mainly distributed in the mountainous regions of central and southern Gansu; (2) distance to the provincial capital, elevation, and the number of adjacent counties constitute the core determinants of tourism accessibility, while interactions among factors generally exhibit bi-factor enhancement or nonlinear enhancement effects; and (3) tourism accessibility exhibits significant spatial spillover effects and spatial heterogeneity, with the effects of different driving factors varying considerably across space. The findings provide a theoretical basis for optimising tourism transport and promoting balanced regional tourism development in Gansu Province.

Keywords: tourism accessibility; spatial spillover effects; spatial heterogeneity; Gansu Province



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1. Introduction

With the continued advancement of China's Western Development Strategy, the improvement in transport infrastructure, and the rapid growth of the tourism industry, the coordinated development of transport and tourism has become an important pathway for promoting high-quality regional economic development. National policy frameworks, including the Belt and Road Initiative, ecological protection and high-quality development of the Yellow River Basin, and the rural revitalisation strategy, have created new opportunities for the transformation and upgrading of the cultural and tourism industries in western China.

Gansu Province, located along the ancient Silk Road and in the upper reaches of the Yellow River, represents an important strategic region for national development. The

province possesses abundant tourism resources, particularly China's officially rated A-grade tourist attractions, which exhibit substantial differences in type, scale, and spatial distribution [1]. In recent years, continuous improvements in transport infrastructure and the integration of culture and tourism have contributed to the rapid development of the regional tourism economy. However, owing to the province's elongated geographical configuration, complex terrain conditions, and uneven regional development, substantial disparities remain in transport service capacity and tourism spatial connectivity across different areas. Consequently, the accessibility of tourist attractions exhibits pronounced spatial differentiation.

From the perspective of travel behaviour theory, tourism activities are constrained by multiple factors, particularly temporal and economic constraints. Travel behaviour theory suggests that destination choice results from a comprehensive evaluation of travel benefits and travel costs, among which travel time and monetary expenditure are the primary determinants of tourists' travel decisions [2,3]. Consequently, tourism accessibility not only reflects the temporal convenience of reaching a destination but also represents tourists' ability to access tourism opportunities after incurring the corresponding economic costs. Accordingly, tourism accessibility should be evaluated from the dual perspectives of temporal and economic constraints in order to better reflect tourists' actual travel processes. Against this background, tourism accessibility, as a key indicator of the spatial accessibility of tourist destinations, not only directly influences the efficiency of tourism resource utilisation but also reflects, to a certain extent, the level of coordination between transportation and tourism development. Therefore, a systematic assessment of the spatial patterns and driving mechanisms of tourism accessibility to A-rated tourist attractions in Gansu Province from a multidimensional perspective is of considerable practical significance for optimising the regional tourism spatial structure, enhancing transport–tourism coordination, and promoting balanced regional tourism development.

Accordingly, this study takes counties and districts in Gansu Province as the basic units of analysis. Based on real-world travel data from counties and districts to A-grade tourist attractions obtained through the Amap API, a three-dimensional evaluation framework comprising temporal accessibility, economic accessibility, and balanced accessibility is constructed. Furthermore, spatial econometric and geographic analytical methods are employed to identify the spatial differentiation patterns, spatial spillover effects, and spatial heterogeneity of tourism accessibility and to investigate the mechanisms through which different factors influence tourism accessibility. The findings contribute to a deeper understanding of the underlying mechanisms and regional disparities of tourism accessibility in Gansu Province.

The remainder of this paper is organised as follows. Section 2 reviews the relevant literature. Section 3 introduces the data sources and research methods. Section 4 presents the empirical results. Finally, Section 5 discusses the findings and draws the conclusions.

2. Literature Review

Accessibility, as a fundamental concept in spatial science and regional studies, has evolved from a single physical measure into a multidimensional analytical framework. Early studies primarily conceptualised accessibility in terms of spatial interaction and distance-decay effects [4]. Subsequently, the concept was extended beyond purely geometric measurements to incorporate temporal costs, economic constraints, and individual travel demands, thereby shifting from simple spatial distance measurement to the comprehensive characterisation of travel impedance [5]. As accessibility theory continued to develop, its application gradually expanded across multiple disciplines, including transport engineering, urban geography, regional economics, public administration, and environmental studies. In

transport geography, accessibility has been widely employed to evaluate transport network efficiency and infrastructure allocation [6]. In urban studies, it has been used to analyse urban spatial structure, land-use patterns, and residents' travel behaviour [7]. In public administration, accessibility has served as an important indicator for assessing the spatial equity of public services such as healthcare and education [8]. In regional economics, it has been utilised to reveal the impacts of transport infrastructure on factor mobility, industrial distribution, and regional economic growth [9].

With the rapid expansion of the global cultural and tourism industry, accessibility theory has been increasingly incorporated into tourism research. Previous studies have suggested that tourism accessibility inherently embodies the principle of barrier-free access [10], thereby establishing a close conceptual relationship between tourism accessibility and accessible tourism [11]. Tourism accessibility primarily concerns the ease with which spatial impedance between tourist origins and destinations can be overcome and has become an important analytical tool for examining tourism spatial patterns, evaluating destination development potential, and optimising tourism transport networks [12]. As travel behaviour theory has evolved, research on tourism accessibility has increasingly focused on the multiple constraints underlying tourists' actual decision-making processes. Existing studies have demonstrated that tourists' travel choices are jointly constrained by time and financial budgets [13,14], indicating that single-dimensional indicators based solely on travel time or travel distance are insufficient to comprehensively capture the ability to access tourism opportunities. Consequently, destination attractiveness [15], tourists' travel preferences [16], and multimodal transport choices [17] have gradually been incorporated into accessibility assessment frameworks, enabling tourism accessibility to evolve from a simple measure of transport costs into a comprehensive evaluation approach integrating both tourism supply and demand [18].

To date, tourism accessibility research has achieved considerable progress in terms of research content, spatial scale, and methodological approaches. Existing studies have mainly focused on evaluating the accessibility of tourist attractions and related destinations [19], including park accessibility [20], rural tourism accessibility [21,22], heritage destination accessibility [23], and hotel accessibility [24]. Research scales have ranged from national [25], urban agglomeration [26], and provincial levels [27] to specific tourism destinations such as mountainous scenic areas [28], cultural heritage sites [29,30], and well-known tourist cities [31–33] and other specific tourist destinations [14,34,35]. Methodologically, tourism accessibility studies have adopted a variety of analytical approaches, including spatial analysis [36] network analysis [37,38], the cost–distance method [39,40], Ordinary Least Squares (OLS) regression [41], Data Envelopment Analysis (DEA) [42] Data Envelopment Analysis (DEA) [43], Multiscale Geographically Weighted Regression (MGWR) [44], and the Spatial Durbin Model (SDM) [45]. Among these approaches, MGWR and SDM have been widely recognised as effective tools for capturing spatial heterogeneity and spatial spillover effects, respectively.

Nevertheless, most existing studies continue to focus primarily on either travel time or spatial distance, making it difficult to fully capture the combined influence of temporal and economic constraints experienced by tourists during actual travel. According to travel behaviour theory, tourism decision-making involves balancing travel benefits against travel costs under limited time and financial resources. Consequently, tourism accessibility should account for the combined effects of multiple forms of spatial impedance. However, relatively few studies have simultaneously quantified both travel time and monetary costs from the perspective of tourists' actual travel behaviour, or further developed integrated accessibility indicators capable of reflecting these dual constraints. Furthermore, previous studies have mainly focused on eastern plains or urban agglomerations, whereas systematic

investigations of elongated corridor-type regions with complex terrain, such as Gansu Province, remain relatively limited. To address these research gaps, this study adopts a tourist-oriented perspective and utilises travel time and travel cost data obtained from the Amap API to construct a three-dimensional accessibility framework comprising temporal accessibility, economic accessibility, and balanced accessibility. Geographical Detector is subsequently employed to identify the principal driving factors, while the Spatial Durbin Model (SDM) and Multiscale Geographically Weighted Regression (MGWR) are applied to investigate spatial spillover effects and spatial heterogeneity. Ultimately, this study systematically reveals the spatial differentiation characteristics and formation mechanisms of tourism accessibility in Gansu Province.

3. Materials and Methods

3.1. Study Area

Gansu Province is located in north-western inland China and in the upper reaches of the Yellow River. As a core corridor of the ancient Silk Road and an important transport hub in north-western China, the province represents a key strategic region for the implementation of multiple national development initiatives, including the Belt and Road Initiative and the ecological protection and high-quality development strategy of the Yellow River Basin. The province covers an area of approximately 425,800 km² and comprises 12 prefecture-level cities, two autonomous prefectures, and the Lanzhou New Area. Counties and districts were selected as the basic units of analysis in this study.

Gansu Province possesses abundant tourism resources characterised by substantial diversity and extensive spatial distribution. The region integrates rich historical and cultural heritage with distinctive natural landscapes and has developed a relatively comprehensive system of China's officially rated A-grade tourist attractions. Owing to its elongated geographical configuration, complex topography, and uneven regional development, the province exhibits pronounced differences in transport connectivity and tourism spatial organisation, thereby providing an appropriate empirical setting for investigating the spatial differentiation and driving mechanisms of tourism accessibility.

3.2. Research Framework

To investigate the spatial differentiation characteristics and formation mechanisms of tourism accessibility to A-rated tourist attractions in Gansu Province, this study develops a theory-driven analytical framework comprising four interconnected components: theoretical foundation–formation mechanism analysis–spatial pattern identification–driving mechanism interpretation (Figure 1). Centred on the formation process of tourism accessibility, the framework integrates accessibility theory, travel behaviour theory, spatial interaction theory, and spatial heterogeneity theory as its theoretical foundations. The formation logic of tourism accessibility is interpreted from three complementary perspectives, namely travel impedance, regional carrying capacity, and spatial interactions. These theoretical perspectives are subsequently integrated with spatial analytical approaches to reveal the spatial differentiation patterns and their underlying mechanisms.

Based on accessibility theory and travel behaviour theory, tourism accessibility essentially reflects tourists' ability to access tourism opportunities after overcoming various forms of spatial impedance, including geographical distance, travel time, and monetary costs. During the travel process, both temporal and economic costs directly influence destination choice and travel behaviour, thereby determining the level of tourism opportunity accessibility across different regions. Accordingly, this study employs the 86 county-level administrative units of Gansu Province as the basic spatial units of analysis. Using actual multimodal travel information obtained from the Amap API for journeys between county

administrative centres and 556 A-rated tourist attractions, a three-dimensional accessibility assessment framework consisting of temporal accessibility, economic accessibility, and balanced accessibility is established from the perspective of tourists to comprehensively evaluate regional accessibility to tourism opportunities.

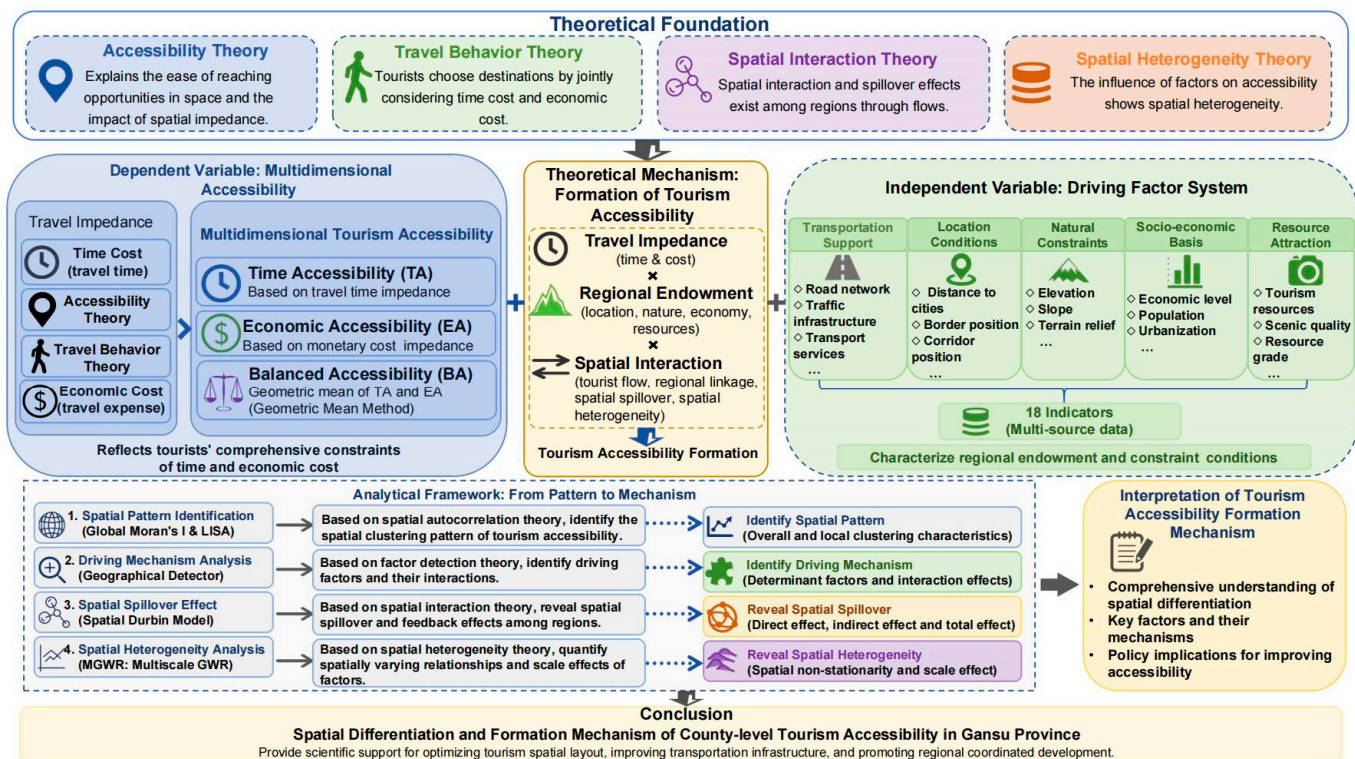


Figure 1. Research framework diagram.

However, tourism accessibility is not determined solely by travel distance and travel costs; its spatial variation is also shaped by regional development conditions and resource–environmental endowments [46,47]. According to regional development theory and spatial differentiation theory, well-developed transport infrastructure reduces spatial impedance and enhances regional connectivity [48]; higher levels of economic development strengthen transport investment capacity and tourism service provision [49]; natural topographical conditions may increase transport construction difficulty and travel costs, thereby acting as physical barriers [50]; and tourism resource endowments further influence accessibility by shaping destination attractiveness and tourist movement patterns [51,52]. Accordingly, this study develops a driving-factor framework encompassing five dimensions—transport infrastructure, locational conditions, natural environment, socioeconomic development, and tourism resources—to identify the key determinants of tourism accessibility.

Furthermore, according to spatial interaction theory, tourism accessibility exhibits pronounced regional interdependence. Interregional transport connections, economic interactions, and tourist mobility may generate spatial spillover effects, whereby the development conditions of one region influence the level of tourism accessibility in neighbouring regions. Accordingly, this study first employs both global and local spatial autocorrelation analyses to identify the spatial clustering characteristics of tourism accessibility and reveal its spatial organisational patterns. Subsequently, the Spatial Durbin Model (SDM) is introduced to estimate both the direct effects and spatial spillover effects of different influencing factors, thereby revealing the spatial transmission mechanisms operating across regions.

Meanwhile, given the substantial differences among regions in terms of natural conditions, stages of economic development, and locational characteristics, the influence of the

same factor on tourism accessibility may vary considerably in both spatial scale and effect magnitude [48]. Based on spatial heterogeneity theory, this study applies the Multiscale Geographically Weighted Regression (MGWR) model to further identify the spatial non-stationarity of the relationships between driving factors and tourism accessibility, thereby revealing regional variations in the formation mechanisms of tourism accessibility.

Overall, this study establishes a progressive analytical framework comprising spatial impedance measurement–spatial pattern identification–driving factor detection–spatial mechanism analysis–spatial heterogeneity interpretation. Accessibility measurement is employed to quantify tourists' ability to access tourism opportunities, spatial analytical methods are used to identify spatial distribution patterns, spatial econometric models reveal regional interactions and spillover mechanisms, and the MGWR model explains the spatial heterogeneity underlying the effects of different driving factors. By integrating theoretical mechanisms with spatial analytical approaches, this framework advances the analysis from identifying the spatial distribution characteristics of tourism accessibility to systematically explaining its underlying formation mechanisms.

3.3. Research Methods

3.3.1. Spatial Autocorrelation Analysis

Global Moran's I was employed to evaluate the overall spatial autocorrelation of balanced accessibility across Gansu Province and to determine whether the spatial distribution exhibited clustering, dispersion, or randomness. The model is expressed as follows:

$$I = \frac{n \sum_{i=1}^n \sum_{j=1}^n W_{ij} (y_i - \bar{y})(y_j - \bar{y})}{\sum_{i=1}^n \sum_{j=1}^n W_{ij} \sum_{i=1}^n (y_i - \bar{y})^2} \quad (1)$$

where n denotes the number of county-level samples; y_i and y_j represent the balanced accessibility indices of counties i and j , respectively; $\bar{y}$ is the mean accessibility equity value of the study area; and W_{ij} denotes the spatial weight matrix constructed based on the Rook contiguity criterion. Moran's I ranges from $[-1, 1]$. Positive values indicate positive spatial autocorrelation, negative values indicate negative spatial autocorrelation, and values approaching 0 indicate a random spatial distribution.

Local spatial autocorrelation was analysed using Anselin's Local Moran's I to identify local spatial association patterns of tourism accessibility. The results were classified into four categories: high–high (H–H) clusters, low–low (L–L) clusters, high–low (H–L) outliers, and low–high (L–H) outliers, corresponding to local hot spots, cold spots, and spatial anomalies [53,54].

3.3.2. Geographical Detector

The Geographical Detector was employed to quantify the explanatory power of different driving factors with respect to the spatial differentiation of balanced accessibility. The factor detector is expressed as follows:

$$q = 1 - \frac{1}{n\delta^2} \sum_{i=1}^n n_i \delta_i^2 \quad (2)$$

where n and δ^2 denote the sample size and variance of the entire study area, respectively, while n_i and δ_i^2 represent the sample size and variance of subregion i . The value of q ranges from 0 to 1, with larger values indicating stronger explanatory power of the corresponding factor.

The interaction detector was further applied to compare the explanatory power of individual factors and pairwise interactions. According to the changes in q statistics, the

interaction relationships were classified as linear enhancement, nonlinear enhancement, mutual independence, or antagonistic effects [55,56].

3.3.3. Spatial Durbin Model

Tourism accessibility is affected not only by local socioeconomic and geographical characteristics, but also by spatial spillover effects across neighbouring regions. The Spatial Durbin Model (SDM) was employed to estimate both local effects and spatial spillover effects. The model is specified as follows:

$$y_i = \rho W y_i + \sum_{k=1}^m \beta_k x_{ik} + \sum_{k=1}^m \theta_k W x_{ik} + \mu_i + \varepsilon_i \quad (3)$$

where W denotes the spatial weight matrix; ρ is the spatial autoregressive coefficient; $W y_i$ represents the spatial lag term of the dependent variable; $W x_{ik}$ denotes the spatial lag term of the independent variable; β_k and θ_k represent the local effect coefficient and spatial spillover coefficient of the explanatory variable, respectively; μ_i denotes the fixed effect; and ε_i is the random error term [57].

3.3.4. Multiscale Geographically Weighted Regression Model

Spatial non-stationarity is a common characteristic of geographical phenomena, indicating that the effects of the same influencing factor may vary across locations. The Multiscale Geographically Weighted Regression (MGWR) model was employed to estimate the spatial heterogeneity and scale effects of the core driving factors influencing tourism accessibility. The model is expressed as follows:

$$y_i = \sum_{j=1}^k \beta_{bwj}(u_i, v_i) x_{ij} + \varepsilon_i \quad (4)$$

where (u_i, v_i) denote the geographical coordinates of sample i ; $\beta_{bwj}(u_i, v_i)$ represents the local regression coefficient of variable j at location i ; and bwj denotes the variable-specific bandwidth parameter [58].

3.4. Construction of the Indicator System

Building upon accessibility theory, tourism geography, transport economics, and spatial interaction theory, this study constructs a driving-factor framework for tourism accessibility following the principles of systematicity, scientific rigour, operational feasibility, and regional applicability. The multidimensional accessibility of A-rated tourist attractions at the county level in Gansu Province is adopted as the core dependent variable. Tourism accessibility represents the comprehensive ability of a region to overcome spatial impedance and access tourism opportunities, and its formation is jointly influenced by transport conditions, locational characteristics, natural environmental conditions, socioeconomic development, and tourism resource endowments [59,60]. Accordingly, a driving-factor framework is established from five dimensions: transport infrastructure, locational conditions, natural constraints, economic foundations, and tourism resource attractiveness.

The transport infrastructure dimension comprises road network density and expressway mileage. Road network density reflects the coverage of the regional road system and is used to measure the level of basic transport provision [61], whereas expressway mileage represents the development level of high-speed transport infrastructure and characterises the capacity for rapid connections with external tourism markets [62].

The locational conditions dimension includes the distance to the nearest passenger transport station, the distance to the nearest airport, the distance to the provincial capital,

and the number of adjacent counties. Specifically, the distance to the nearest passenger transport station measures the accessibility of the public transport network [63]; the distance to the nearest airport reflects regional air transport connectivity [64]; the distance to the provincial capital captures the radiating influence of the regional growth centre on tourism development [65]; and the number of adjacent counties characterises the extent of regional spatial connectivity and neighbouring interaction opportunities [66].

The topographical conditions dimension consists of elevation, slope, the proportion of mountainous terrain, and river systems. Elevation represents the basic topographical characteristics of a region [67]; slope measures terrain ruggedness and its influence on transport construction and tourist mobility [68]; the proportion of mountainous terrain reflects the constraints imposed by complex landforms on regional connectivity [69]; and river systems indicate the potential influence of physical geographical conditions on transport route configuration and spatial connectivity [69].

The socioeconomic dimension includes GDP per capita, urbanisation rate, and tourism revenue. GDP per capita is used to measure the level of regional economic development and supporting capacity [70]; the urbanisation rate reflects population agglomeration and the provision of public services [71]; and tourism revenue represents the scale of tourism industry development and the market foundation of the destination [72].

The tourism resource dimension comprises resource openness, attraction density, the number of cultural heritage resources, and tourist arrivals. Resource openness measures the availability of exploitable tourism resources [73]; attraction density reflects the spatial concentration of tourism resources [74]; the number of cultural heritage resources characterises the endowment of distinctive tourism assets [75]; and tourist arrivals indicate actual tourism demand and destination attractiveness [76].

Unlike the theoretical framework, which conceptually explains the mechanisms underlying tourism accessibility, the indicator system translates these mechanisms into quantifiable variables. Considering the elongated corridor-type geographical characteristics of Gansu Province and the availability of county-level data, seventeen indicators were ultimately selected to analyse the mechanisms underlying the spatial differentiation of tourism accessibility. The resulting indicator system encompasses the complete causal pathway from natural environmental constraints, transport infrastructure provision, and regional development foundations to tourism resource attractiveness, thereby providing a comprehensive representation of the multidimensional drivers of county-level tourism accessibility. To ensure the robustness of subsequent model estimation, all explanatory variables passed significance tests, and no significant multicollinearity was detected (Table 1). Furthermore, Pearson correlation analysis was conducted to examine potential correlations among the explanatory variables. As shown in Table 2, all correlation coefficients remained below the threshold that would compromise model stability.

Table 1. Indicator system of factors influencing county-level tourism accessibility in Gansu Province.

Dimension	Indicator	Definition	VIF
Transport infrastructure	Road network density	Total length of roads of different grades divided by county area, reflecting regional road network coverage	2.999
	Expressway mileage	Total operational mileage of expressways within the county, reflecting the supply capacity of high-grade roads	2.235
	Distance to the nearest passenger station	Shortest distance from the county centroid to the nearest road passenger transport station	1.652
	Distance to the nearest airport	Shortest distance from the county centroid to the nearest civil transport airport	1.796

Table 1. *Cont.*

Dimension	Indicator	Definition	VIF
Locational conditions	Distance to the provincial capital	Shortest network distance from the county centroid to Lanzhou, reflecting the radiation effect of the provincial hub city	2.788
	Number of adjacent counties	Number of county-level administrative units bordering the county, reflecting regional spatial linkage conditions	1.466
Topographical characteristics	Elevation	Mean elevation of the county, reflecting fundamental topographical conditions	1.999
	Slope	Mean terrain slope of the county, reflecting topographical constraints on transport construction and travel activities	3.486
	Mountainous area ratio	Proportion of mountainous area relative to total county area	2.647
	Water area ratio	Proportion of water area within the county, reflecting hydrological constraints on transport layout	2.767
Socio-economic development	GDP per capita	Gross domestic product per capita of the county, reflecting the level of regional economic development	1.480
	Urbanisation rate	Proportion of the resident population living in urban areas, reflecting the level of urban development	2.742
	Tourism revenue	Annual tourism revenue of the county, reflecting the scale of regional tourism development	4.418
	Tourism resource openness	Number of free-entry A-grade tourist attractions within the county, reflecting the accessibility threshold of tourism resources	3.991
Tourism resources	Scenic spot density	Number of A-grade tourist attractions divided by county area, reflecting the spatial abundance of tourism resources	2.776
	Number of cultural heritage resources	Number of cultural heritage protection units at all administrative levels within the county, reflecting the endowment of cultural tourism resources	3.176
	Tourist arrivals	Annual number of tourist visits received by the county, reflecting tourism market demand and destination popularity	3.722

Table 2. Correlation coefficient matrix.

Variable	Tourism Revenue	Tourist Arrivals	Scenic Spot Density	Cultural Heritage	Balanced Accessibility
Tourism revenue	1.000	0.725	0.358	0.174	−0.023
Tourist arrivals	0.725	1.000	0.325	0.229	−0.018
Scenic spot density	0.358	0.325	1.000	0.522	−0.015
Cultural heritage	0.174	0.229	0.522	1.000	−0.008
Balanced accessibility	−0.023	−0.018	−0.015	−0.008	1.000

3.5. Measurement of Multidimensional Accessibility

Tourism accessibility was measured using actual travel route data obtained from the Amap API. For each origin–destination (OD) pair linking a county administrative centre with an A-rated tourist attraction, the Amap API returned multiple feasible multimodal travel itineraries, including direct private-car travel as well as combinations of public transport, walking, and taxi services. Unlike conventional accessibility assessments based on a single transport mode, this study does not predefine tourists' travel mode. Instead, all feasible multimodal travel routes generated by different transport mode combinations are treated as candidate travel alternatives.

Based on these candidate routes, the optimal travel option was identified separately for the temporal and economic dimensions. For temporal accessibility, the total travel time of each multimodal itinerary was compared, and the shortest travel time was selected as

the temporal impedance associated with reaching the destination attraction. For economic accessibility, the total monetary expenditure of each itinerary was evaluated, and the lowest travel cost was adopted as the economic impedance. Economic costs include fuel expenses and road tolls associated with private-car travel, together with fares or service charges incurred through public transport, taxi services, and other transport modes. Based on the resulting temporal and economic costs, temporal accessibility and economic accessibility indicators were constructed, respectively. Subsequently, balanced accessibility was calculated using the geometric mean of the two indicators to comprehensively represent tourists' ability to access tourism opportunities under multimodal transport conditions. It should be noted that temporal accessibility, economic accessibility, and balanced accessibility developed in this study are essentially travel impedance indicators. Lower indicator values represent lower temporal and monetary costs required to access tourism opportunities and therefore correspond to higher levels of tourism accessibility.

(1) Temporal accessibility

Temporal accessibility reflects the travel time required for tourists to reach tourist attractions from a county or district. The mean minimum travel time from each county to all A-grade tourist attractions was first calculated and subsequently standardised using the range normalisation method. The model is expressed as follows:

$$T_i = \frac{1}{n} \sum_{j=1}^n t_{ij} \quad (5)$$

where T_i denotes the temporal accessibility of county i ; t_{ij} represents the minimum travel time from county i to tourist attraction j ; and n is the total number of A-grade tourist attractions. Lower values indicate better temporal accessibility.

(2) Economic accessibility

Economic accessibility measures the monetary cost incurred by tourists when travelling to tourist attractions. The mean minimum travel cost from each county to all A-grade tourist attractions was calculated and then standardised. The model is expressed as follows:

$$C_i = \frac{1}{n} \sum_{j=1}^n c_{ij} \quad (6)$$

where C_i denotes the economic accessibility of county i , and c_{ij} represents the minimum monetary travel cost from county i to tourist attraction j . Lower values indicate better economic accessibility.

(3) Balanced accessibility

According to travel behaviour theory, tourists' destination choice represents a decision-making process in which travel benefits are balanced against travel costs under the joint constraints of temporal and financial budgets. Among these constraints, travel time and monetary expenditure constitute the two principal factors influencing tourists' travel decisions. Consequently, tourism accessibility not only reflects the temporal convenience of reaching a destination but also represents tourists' ability to access tourism opportunities after incurring the associated economic costs.

Because temporal and economic costs jointly constrain tourists' actual travel behaviour, a single-dimensional indicator cannot comprehensively capture the level of accessibility to tourism opportunities. Given that both temporal and economic costs constitute fundamental constraints on destination choice, this study assigns equal weights to temporal accessibility and economic accessibility when constructing the composite accessibility indicator. Compared with the arithmetic mean, the geometric mean reduces the compensatory effect of a dominant dimension over a weaker one. Consequently, a relatively poor per-

formance in either temporal or economic accessibility proportionally lowers the overall accessibility score, making the geometric mean more appropriate for representing balanced accessibility under multidimensional travel constraints. The calculation is expressed as follows:

$$B_{balance} = \sqrt{T_{norm} \times C_{norm}} \quad (7)$$

where B_i denotes the balanced accessibility index, while T_{norm} and C_{norm} represent the normalised temporal accessibility and economic accessibility, respectively. Lower values indicate that tourism opportunities can be accessed at relatively lower and more balanced comprehensive costs, corresponding to a higher level of tourism accessibility.

3.6. Data Sources

The administrative boundary data of Gansu Province were obtained from the official platform of the Gansu Provincial Department of Natural Resources (<http://zrzy.gansu.gov.cn/>). Data on A-grade tourist attractions were derived from the official list of A-grade tourist attractions. Precise geographical coordinates (latitude and longitude) of tourist attractions were collected through the Amap API (<https://lbs.amap.com/>) to construct the spatial dataset of tourist attractions. Socioeconomic indicators, including GDP per capita, population density, and urbanisation rate, were obtained from the Gansu Statistical Yearbook 2025. Data on tourism revenue and tourist arrivals were derived from the 2024 statistical bulletin issued by the Gansu Provincial Department of Culture and Tourism. Elevation, mountainous area ratio, and water-area data were obtained from the National Cryosphere Desert Data Centre (<https://www.ncdc.ac.cn/portal/>). Road network density and transport-node data, including passenger stations, railway stations, and airports, were obtained from OpenStreetMap (<https://www.openstreetmap.net.cn/>).

4. Result

4.1. Spatial Differentiation and Spatial Association Patterns of Accessibility

4.1.1. Global Spatial Autocorrelation Analysis

The results of the global spatial autocorrelation analysis (Table 3) indicate that the Moran's I values for temporal accessibility, economic accessibility, and balanced accessibility are 0.851, 0.783, and 0.827, respectively, all of which are significant at the 1% significance level. These results demonstrate that the spatial distribution of county-level tourism accessibility in Gansu Province is far from random and exhibits significant positive spatial autocorrelation. To examine the robustness of the identified clustering patterns with respect to the specification of the spatial weight matrix, additional analyses were conducted using both the Queen contiguity matrix and the K-nearest neighbour matrix ($K = 4$). As shown in Table 4, taking balanced accessibility as an example, Moran's I remains significantly positive under both alternative spatial weight matrices, with highly consistent clustering patterns and significance levels. These findings confirm that the spatial clustering characteristics of tourism accessibility are robust and are not sensitive to the choice of spatial weight matrix.

Table 3. Results of global spatial autocorrelation (Moran's I) for tourism accessibility in Gansu Province.

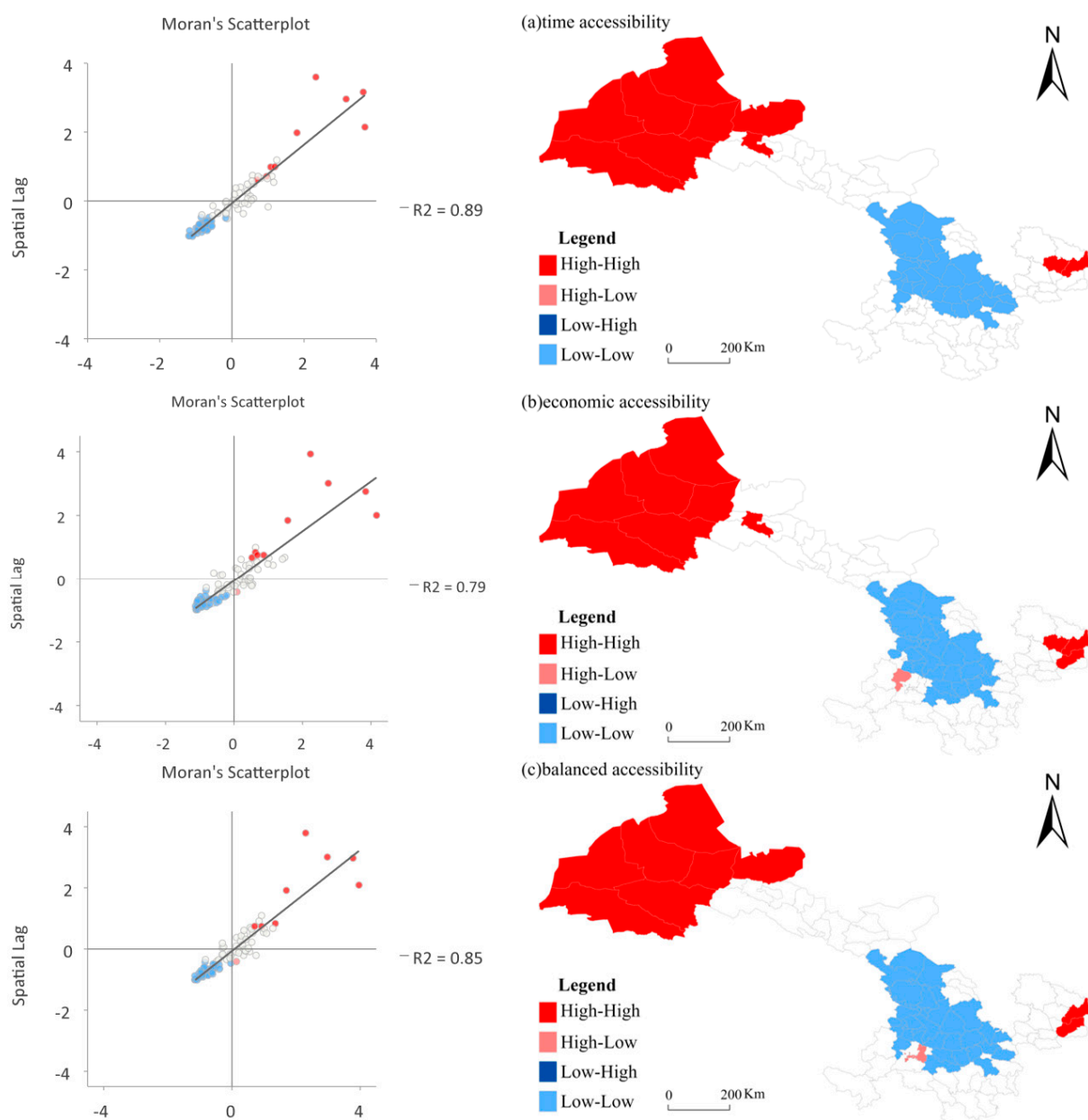
Accessibility Dimension	Moran's I	z-Score	p-Value	Spatial Pattern
Temporal accessibility	0.851	14.183	0.000	Significant clustering
Economic accessibility	0.783	13.163	0.000	Significant clustering
Balanced accessibility	0.827	13.850	0.000	Significant clustering

Table 4. Robustness test of spatial weight matrix.

Spatial Weight Matrix	Moran's I	z-Score	p-Value	Spatial Pattern
Rook contiguity matrix	0.862	13.518	0.000	Significant spatial clustering
Queen contiguity matrix	0.862	13.518	0.000	Significant spatial clustering
KNN (k = 4) matrix	0.848	12.537	0.000	Significant spatial clustering

4.1.2. Local Spatial Autocorrelation Analysis

Local spatial autocorrelation analysis indicates that all three dimensions of accessibility for A-level tourist attractions in Gansu Province exhibit prominent spatial clustering; however, their local spatial association patterns vary to some extent (Figure 2).

**Figure 2.** Moran's scatterplots and LISA cluster maps of tourism accessibility in Gansu Province.

The high-high (H-H) clusters are primarily distributed across the Hexi Corridor in north-western Gansu Province, forming a relatively continuous pattern of high travel impedance. Among the three accessibility indicators, the H-H clusters of temporal acces-

sibility cover the largest geographical extent, forming an almost continuous high-value belt throughout the Hexi Corridor, indicating comparatively poor transport efficiency across this region. The H–H clusters of balanced accessibility largely coincide with those of temporal accessibility but occupy a slightly smaller spatial extent. In contrast, the H–H clusters of economic accessibility are mainly concentrated in the western Hexi Corridor, exhibiting weaker spatial continuity and a more fragmented distribution pattern.

The low–low (L–L) clusters are mainly concentrated within the transitional zone of central Gansu Province, forming relatively stable clusters characterised by low travel impedance. This pattern indicates that, benefiting from well-developed transport corridors and favourable locational conditions, tourists require relatively little travel time to reach A-rated tourist attractions in this region, thereby creating a clear temporal accessibility advantage. The L–L clusters of balanced accessibility generally correspond to those of temporal accessibility but exhibit a slightly reduced spatial extent, suggesting that incorporating both temporal and economic costs moderately alters the overall accessibility advantage in some areas. By comparison, the L–L clusters of economic accessibility are primarily located in the western Hexi Corridor, indicating comparatively lower fuel costs, road tolls, and overall travel expenditure in this region.

In addition, high–low (H–L) outlier clusters are observed only for economic accessibility and balanced accessibility, mainly occurring in several counties of the Gannan Tibetan Autonomous Prefecture, reflecting pronounced local spatial heterogeneity. The H–L pattern is particularly evident for economic accessibility, suggesting that although some high-altitude peripheral areas exhibit relatively unfavourable locational conditions overall, specific tourism nodes nevertheless maintain comparatively high levels of economic accessibility. By contrast, no significant H–L clusters are identified for temporal accessibility, indicating a more stable spatial structure in terms of temporal travel costs. Furthermore, no statistically significant low–high (L–H) clusters are detected for any of the three accessibility indicators, implying that areas characterised by low travel impedance exhibit strong spatial continuity and clustering stability.

4.2. Identification of Core Impact Factors

By employing the Jenks natural breaks method to stratify the 17 driving factors and discretise the continuous variables, the Geodetector model was applied to identify the dominant driving factors for the temporal, economic, and balanced accessibility of county-level A-level tourist attractions in Gansu Province, respectively; the results are compiled in Table 5.

The results demonstrate that the significant driving factors across the three accessibility dimensions exhibit high consistency overall. Distance to the nearest provincial capital, elevation, and the number of adjacent counties all passed the significance test at the 0.05 level, while slope and road network density achieved a significance level of 0.1 in certain models. This indicates that the spatial differentiation of tourism accessibility in Gansu Province is primarily shaped by the combined influence of locational conditions, topographical features, and transport infrastructure, whereas the explanatory capacities of the socio-economic and tourism resource dimensions are relatively constrained.

Specifically, the distance to the nearest provincial capital exhibits the highest explanatory power across all three dimensions of accessibility, with *q*-values exceeding 0.83—markedly higher than those of other factors. This confirms that the hub radiation effect of the provincial capital, Lanzhou, serves as the core driving force shaping the spatial configuration of tourism accessibility in Gansu Province. By comparison, topographical factors such as elevation and slope possess the second highest explanatory power, reflecting the pronounced restrictive role of complex landforms on transport organisation efficiency and regional connectivity strength. Additionally, the number of adjacent counties

reflects a certain spatial linkage effect, indicating that the degree of inter-regional boundary connectivity influences tourism travel efficiency.

Table 5. Factor detector results of the Geodetector model for accessibility measures in Gansu Province.

Indicator Classification	Impact Factors	Temporal Accessibility q-Value	p-Value	Rank	Economic Accessibility q-Value	p-Value	Rank	Balanced Accessibility q-Value	p-Value	Rank
Transport infrastructure	Road network density	0.221	0.053	4	0.180	0.101	—	0.201	0.074	4
	Expressway mileage	0.154	—	—	0.118	0.989	—	0.136	—	—
	Distance to the nearest passenger station	0.132	—	—	0.178	0.875	—	0.155	—	—
	Distance to the nearest airport	0.179	—	—	0.229	0.977	—	0.206	—	—
Locational conditions	Distance to the nearest provincial capital	0.859	0.000	1	0.832	0.000	1	0.857	0.000	1
	Number of adjacent counties	0.173	0.026	5	0.170	0.025	4	0.173	0.025	5
Topographical conditions	Elevation	0.237	0.047	3	0.258	0.022	2	0.252	0.030	2
	Slope	0.252	0.051	2	0.199	0.098	3	0.226	0.071	3
	Proportion of mountainous area	0.038	—	—	0.045	0.786	—	0.042	—	—
	Water systems	0.206	0.136	—	0.174	0.176	—	0.191	—	—
Socio-economics	GDP per capita	0.161	—	—	0.163	0.418	—	0.164	—	—
	Urbanisation rate	0.099	—	—	0.074	0.482	—	0.086	—	—
	Tourist attraction density	0.015	—	—	0.017	0.999	—	0.016	—	—
	Tourism revenue	0.147	—	—	0.113	0.922	—	0.130	—	—
Tourism resources	Cultural heritage	0.018	—	—	0.016	0.969	—	0.017	—	—
	Tourist arrivals	0.051	—	—	0.047	0.936	—	0.048	—	—
	Resource openness	0.036	—	—	0.037	0.987	—	0.036	—	—

Note: $p > 0.10$ indicates a failure to pass the significance test.

The driving mechanisms differ to some extent among the three accessibility indicators. The significant explanatory variables for temporal accessibility and balanced accessibility are broadly consistent, both being jointly influenced by locational conditions, topographical characteristics, and road network provision. This finding suggests that transport network conditions play a crucial role in reducing travel impedance and improving overall travel accessibility. In contrast, road network density does not exert a statistically significant influence on economic accessibility, indicating that monetary travel costs are less sensitive to the scale of transport infrastructure and depend more strongly on locational advantages and topographical constraints. Overall, the spatial variation in tourism accessibility exhibits a clear pattern characterised by location-dominated, terrain-constrained, and transport-regulated effects, with the monocentric provincial capital structure playing a decisive role in organising the provincial tourism spatial system.

To further evaluate the robustness of the Geographical Detector results with respect to the discretisation method, taking balanced accessibility as an example, additional sensitivity analyses were conducted using both the equal-interval classification and quantile classification approaches. As reported in Table 6, although the q-statistics of individual factors vary slightly under different discretisation methods, the identification of the core driving factors remains highly consistent, confirming the robustness of the analytical results.

Table 6. Ranking of q-statistics under different discretization methods.

Variable	Jenks Natural Breaks q-Value (Rank)	Equal Interval q-Value (Rank)	Quantile q-Value (Rank)
Distance to the nearest provincial capital	0.857 (1)	0.806 (1)	0.646 (1)
Elevation	0.252 (2)	0.242 (2)	0.295 (3)
Slope	0.226 (3)	0.175 (3)	0.090 (6)
Road network density	0.201 (4)	0.064 (7)	0.388 (2)
Number of adjacent counties	0.173 (5)	0.143 (4)	0.132 (4)

4.3. Spatial Spillover Effects

4.3.1. Model Comparison and Selection

To identify the spatial dependence characteristics of accessibility for A-level tourist attractions in Gansu Province and determine the optimal spatial econometric model, this study employed the Lagrange Multiplier (LM) test to distinguish between spatial lag and spatial error effects (Table 7). The results reveal that the LM-Error, Robust LM-Error, Robust LM-Lag, and LM-SARMA tests all passed the significance test at the 1% level, whereas the LM-Lag test failed to reach statistical significance. This indicates that the research object not only exhibits significant spatial error correlation but is also accompanied by a certain degree of spatial lag effects, signifying that its spatial dependence structure possesses composite characteristics.

Table 7. Results of the Lagrange Multiplier (LM) tests.

Test	Statistic	p-Value
LM-Error	49.748	0.000
LM-Lag	0.626	0.429
Robust LM-Error	63.149	0.000
Robust LM-Lag	14.027	0.000
LM-SARMA	63.775	0.000

According to the spatial econometric model selection criteria proposed by Anselin, when the robust LM tests are simultaneously significant, a single spatial lag model or SEM is insufficient to fully account for the spatial association structure between variables. In comparison, the SDM can concurrently incorporate the spatial lag terms of both the dependent and independent variables. It not only effectively characterises the spatial transmission mechanisms of tourism accessibility across regions but also identifies the spatial spillover effects of driving factors, thereby preventing estimation distortions arising from model misspecification. Consequently, this paper ultimately selects the SDM as the optimal model for analysing the spatial effects of accessibility for A-level tourist attractions in Gansu Province.

4.3.2. SDM Spatial Effect Decomposition

Based on the Spatial Durbin Model (SDM), this study decomposes the effects of individual driving factors on balanced accessibility, temporal accessibility, and economic accessibility across county-level administrative units in Gansu Province into direct, indirect, and total effects, thereby identifying the spatial mechanisms underlying tourism accessibility (Table 8). Regression coefficients are reported outside the parentheses, while t-statistics are presented within parentheses. The results indicate that the directions and magnitudes of the effects vary across the three accessibility indicators, reflecting spatial heterogeneity in the responses of temporal costs, economic costs, and their integrated accessibility measure.

Table 8. Spatial effect decomposition results from the SDM.

Variable	Effect Type	Temporal Accessibility	Economic Accessibility	Balanced Accessibility
Road network density	Direct effect	0.001 (0.10)	0.001 (0.15)	−0.001 (−0.13)
	Indirect effect	0.003 (0.06)	0.077 (0.38)	−0.024 (−0.32)
	Total effect	0.004 (0.10)	0.078 (0.39)	−0.024 (−0.33)
Distance to the nearest provincial capital	Direct effect	0.001 *** (7.65)	0.001 *** (5.87)	−0.001 *** (−7.16)
	Indirect effect	−0.001 *** (−3.44)	−0.001 *** (−2.94)	−0.001 *** (−3.37)
	Total effect	0.001 (0.89)	0.000 (0.75)	−0.001 (−0.89)
Number of adjacent counties	Direct effect	−0.007 *** (−2.92)	−0.004 (−1.42)	−0.006 ** (−2.24)
	Indirect effect	0.017 (0.08)	−0.080 (−0.21)	−0.034 (−0.11)
	Total effect	−0.024 *** (−2.15)	−0.084 (−1.06)	−0.040 ** (−2.15)
Elevation	Direct effect	0.001 *** (3.28)	0.000 *** (5.13)	−0.001 *** (−4.69)
	Indirect effect	−0.000 * (−1.92)	−0.000 *** (−4.01)	−0.000 *** (−3.38)
	Total effect	0.000 (0.02)	−0.000 (−0.01)	−0.000 (−0.02)
Slope	Direct effect	0.002 (1.08)	−0.000 (−0.03)	−0.001 (−0.44)
	Indirect effect	−0.002 (−0.86)	0.001 (0.01)	−0.001 (−0.36)
	Total effect	0.000 (0.21)	−0.001 (−0.02)	−0.000 (−0.21)

Note: *, ** and *** represent significance at the 10%, 5%, and 1% levels, respectively; values within parentheses indicate Z-statistics.

The distance to the provincial capital constitutes the most influential locational determinant of tourism accessibility. Its direct effects are statistically significant for all three accessibility indicators. Specifically, the variable exerts positive effects on temporal accessibility and economic accessibility, indicating that greater distances from the provincial capital are associated with higher travel time and monetary costs. In contrast, its direct effect on balanced accessibility is significantly negative, suggesting that, when temporal and economic constraints are considered jointly, locational conditions influence overall accessibility through a different mechanism. The estimated spatial spillover effects are significantly negative for both temporal and economic accessibility, implying that the locational advantages of the provincial centre extend to neighbouring areas through spatial transmission processes. However, because the direct and indirect effects operate in opposite directions, the corresponding total effects are not statistically significant.

Elevation exerts significant effects on all three accessibility indicators. It is positively associated with both temporal and economic accessibility, indicating that more challenging topographical conditions increase tourists' travel time and monetary expenditure. By contrast, elevation exhibits a significantly negative effect on balanced accessibility, suggesting that the influence of natural environmental conditions differs when accessibility is evaluated as an integrated measure of temporal and economic costs. Moreover, the indirect effects of elevation are generally negative, indicating that topographical constraints exhibit spatial diffusion characteristics across neighbouring regions.

The number of adjacent counties primarily exhibits localised effects. It has significant negative effects on both temporal accessibility and balanced accessibility, indicating that stronger regional connectivity contributes to reducing overall travel impedance. However, its influence on economic accessibility is not statistically significant. In comparison, neither road network density nor slope exerts statistically significant effects on any of the three accessibility indicators, suggesting that, after controlling for locational and natural environmental conditions, the marginal contributions of transport infrastructure scale and terrain ruggedness are relatively limited.

Overall, the spatial differentiation of tourism accessibility in Gansu Province is jointly shaped by locational conditions and natural environmental factors. Among these, the distance to the provincial capital represents the strongest spatial constraint, elevation reflects the influence of physical geographical conditions on tourism connectivity, and regional adjacency captures the importance of interregional network connectivity. The

varying directions of spatial spillover effects jointly contribute to the observed spatial configuration of tourism accessibility.

4.4. Spatial Heterogeneity Analysis

4.4.1. Model Comparison

To determine the functional relationship between tourism accessibility and its driving factors, this study first compares the performance of linear and non-linear modelling approaches. Considering that machine learning algorithms are capable of capturing complex non-linear interactions, XGBoost and Geographical Weighted Random Forest (GWRF) models are employed to examine potential non-linear relationships and are compared with the benchmark Ordinary Least Squares (OLS) model.

The results indicate that the XGBoost model achieves coefficients of determination (R^2) below 0.85 for all three accessibility indicators, performing less effectively than the linear OLS model, whose goodness-of-fit exceeds 0.90. Although the GWRF model attains exceptionally high goodness-of-fit ($R^2 > 0.98$), it exhibits clear signs of overfitting and does not demonstrate superior generalisation performance. These findings suggest that the relationships between tourism accessibility and its driving factors in county-level Gansu Province are predominantly linear.

Having established the suitability of linear modelling, the performances of the OLS, Geographically Weighted Regression (GWR), and Multiscale Geographically Weighted Regression (MGWR) models are further compared. As shown in Table 9, the MGWR model achieves adjusted R^2 values exceeding 0.90 for all three accessibility indicators, while its corrected Akaike Information Criterion (AICc) is substantially lower than those of both OLS and GWR. These results indicate that the MGWR model provides superior model fit and parameter estimation efficiency by accounting for spatial scale heterogeneity. Accordingly, the MGWR model is ultimately adopted to investigate the spatial heterogeneity of the driving mechanisms.

Table 9. Diagnostic statistics of the OLS, GWR, and MGWR models.

Diagnostic Indicator	Accessibility Classification	OLS Model	GWR Model	MGWR Model
R-squared (R^2)	Balanced accessibility	0.930	0.944	0.947
	Temporal accessibility	0.927	0.950	0.957
	Economic accessibility	0.919	0.919	0.926
Adjusted R^2	Balanced accessibility	0.909	0.917	0.935
	Temporal accessibility	0.904	0.926	0.945
	Economic accessibility	0.894	0.887	0.908
AICc	Balanced accessibility	−257.600	61.472	34.968
	Temporal accessibility	530.300	51.411	25.220
	Economic accessibility	498.900	82.349	65.882

Note: OLS denotes Ordinary Least Squares regression; GWR denotes Geographically Weighted Regression; MGWR denotes Multiscale Geographically Weighted Regression. AICc represents the corrected Akaike Information Criterion, where a smaller value indicates a superior model fit.

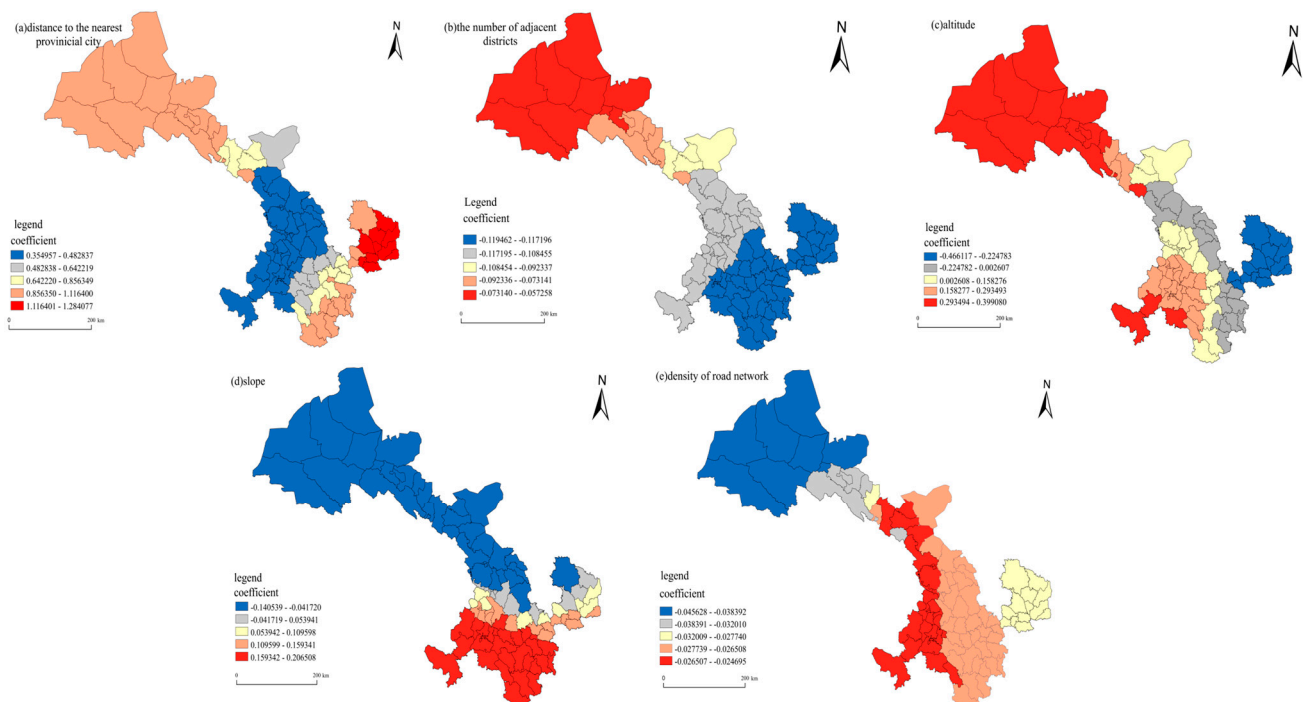
To further verify the robustness of the modelling results, an additional robustness analysis was conducted by replacing potentially correlated explanatory variables. As presented in Table 10, after progressively removing correlated variables and re-estimating the balanced accessibility model, the estimated effects of the core explanatory variables remain directionally consistent, and the overall model performance changes only marginally, confirming the robustness of the empirical results.

Table 10. Robustness test results of variable substitution.

Model Specification	R ²	Stability of Core Variable Coefficients
Baseline model (full variables)	0.8959	Baseline
Excluding “Tourist arrivals”	0.8847	Stable (consistent direction, $p < 0.01$)
Excluding “Tourism revenue”	0.8945	Stable (consistent direction, $p < 0.01$)
Excluding “Cultural heritage”	0.8949	Stable (consistent direction, $p < 0.01$)
Excluding “Scenic spot density”	0.8954	Stable (consistent direction, $p < 0.01$)

4.4.2. Spatial Heterogeneity Characteristics

The effects of the driving factors on temporal accessibility exhibit pronounced spatial heterogeneity, with distinct spatial distributions and effect magnitudes (Figure 3).

**Figure 3.** Spatial distribution of MGWR coefficients for core factors (temporal accessibility).

The distance to the provincial capital exerts an overall positive influence, indicating that travel time increases and temporal accessibility decreases as the distance from the provincial capital becomes greater. The largest coefficients are observed in the western Hexi Corridor and several peripheral areas, suggesting that greater separation from the provincial transport hub substantially increases temporal impedance between these regions and the core transport network. By contrast, relatively smaller coefficients are observed in central Gansu and the areas surrounding Lanzhou, reflecting the strong radiating effect of the provincial centre in reducing travel time.

The number of adjacent counties exhibits an overall negative effect, indicating that stronger regional connectivity reduces temporal travel impedance. Relatively small coefficients are observed in the western Hexi Corridor, suggesting that the elongated geographical configuration constrains interregional transport connectivity. In contrast, larger coefficients occur in south-eastern Gansu, where denser regional transport networks help alleviate spatial barriers.

Elevation displays an overall positive effect, indicating that higher-altitude regions are generally associated with longer travel times. Larger coefficients are concentrated in the western Hexi Corridor and the Qilian Mountains, where topographical conditions

substantially constrain transport efficiency. Conversely, lower coefficients are observed in the south-eastern river-valley regions, where topographical barriers are comparatively weaker.

Although slope exhibits an overall negative relationship with temporal accessibility, its effects vary considerably across space. Larger coefficients occur in the Gannan Plateau and the mountainous areas of southern Gansu, where complex terrain increases road construction difficulty and reduces vehicle operating efficiency, thereby increasing temporal impedance. In contrast, coefficients become negative across the plains of the Hexi Corridor, indicating that slope has only a limited influence on travel time in relatively flat terrain.

Road network density exerts an overall negative effect, suggesting that more developed transport networks reduce travel time and improve temporal accessibility. Its strongest effects are observed in Longnan, eastern Gansu, the eastern Hexi Corridor, and northern Gansu Province, whereas relatively weaker effects occur in the western Hexi Corridor and the Gannan region, reflecting regional differences in the marginal benefits of transport infrastructure improvements under varying natural environmental conditions.

The spatial heterogeneity of the driving factors influencing economic accessibility is illustrated in Figure 4.

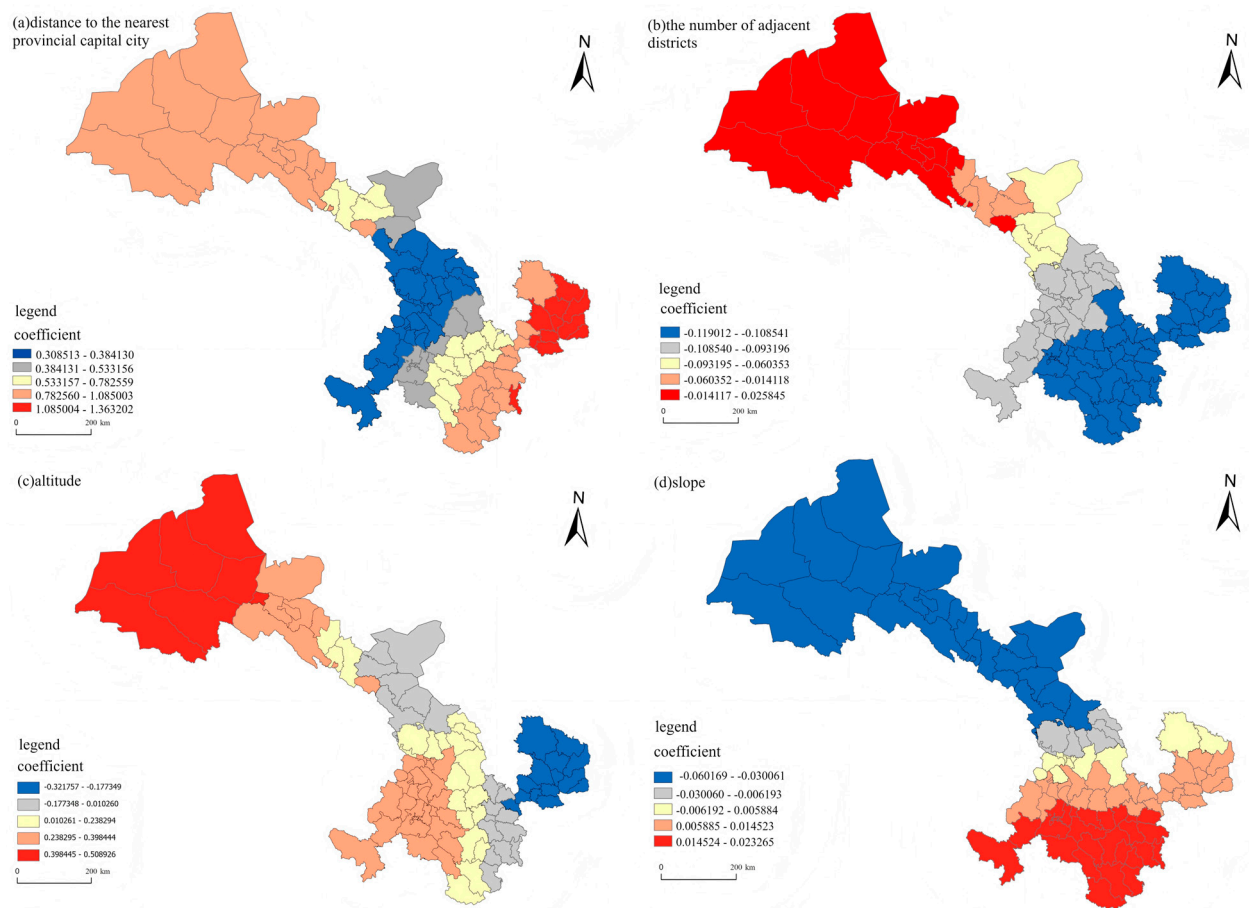


Figure 4. Spatial distribution of MGWR coefficients for core factors (economic accessibility).

The distance to the provincial capital exhibits an overall positive effect with considerable spatial variation. Larger coefficients are concentrated in the western Hexi Corridor and south-eastern Gansu, indicating that greater distances from the provincial centre substantially increase interregional travel distances, thereby raising fuel consumption, road tolls, and other travel expenditures, ultimately imposing stronger constraints on economic accessibility. In contrast, relatively smaller coefficients are observed in central Gansu, where

regional transport hubs and stronger interregional connectivity help moderate the increase in travel costs associated with distance.

The number of adjacent counties generally exerts a negative effect. Smaller coefficients are found in parts of the Hexi Corridor, indicating that the elongated geographical configuration limits inter-county connectivity and weakens the contribution of adjacency to reducing travel costs. Conversely, larger coefficients occur in south-eastern Gansu, where stronger internal transport connectivity and more diversified route options reduce economic travel impedance and improve economic accessibility.

Elevation exhibits a pronounced west-to-east spatial differentiation pattern, with positive effects in the western Hexi Corridor and negative effects in eastern regions. Larger positive coefficients in the western counties indicate that higher elevations contribute to increased travel expenditure. Although the terrain is relatively gentle in these areas, their remoteness and dependence on long-distance transport links strengthen the association between elevation and economic impedance. By contrast, negative coefficients in south-eastern Gansu and several river-valley regions suggest that improvements in local transport infrastructure mitigate the influence of topographical conditions on travel costs.

Slope generally exerts a negative effect, although its spatial variation remains evident. Relatively small coefficients occur across the Hexi Corridor and northern Gansu, indicating that increased slope has only a limited influence on travel expenditure in these areas. Conversely, larger coefficients are observed in parts of the Gannan Plateau and the mountainous regions of Longnan, where complex terrain increases vehicle operating resistance and energy consumption, thereby raising tourists' travel costs.

As a comprehensive indicator integrating both time and economic accessibility, balanced accessibility exhibits the key spatial characteristics of its two constituent dimensions while revealing a distinct location-driven pattern. It therefore provides a more comprehensive representation of the spatial variation in the combined temporal and monetary costs of tourist travel (Figure 5).

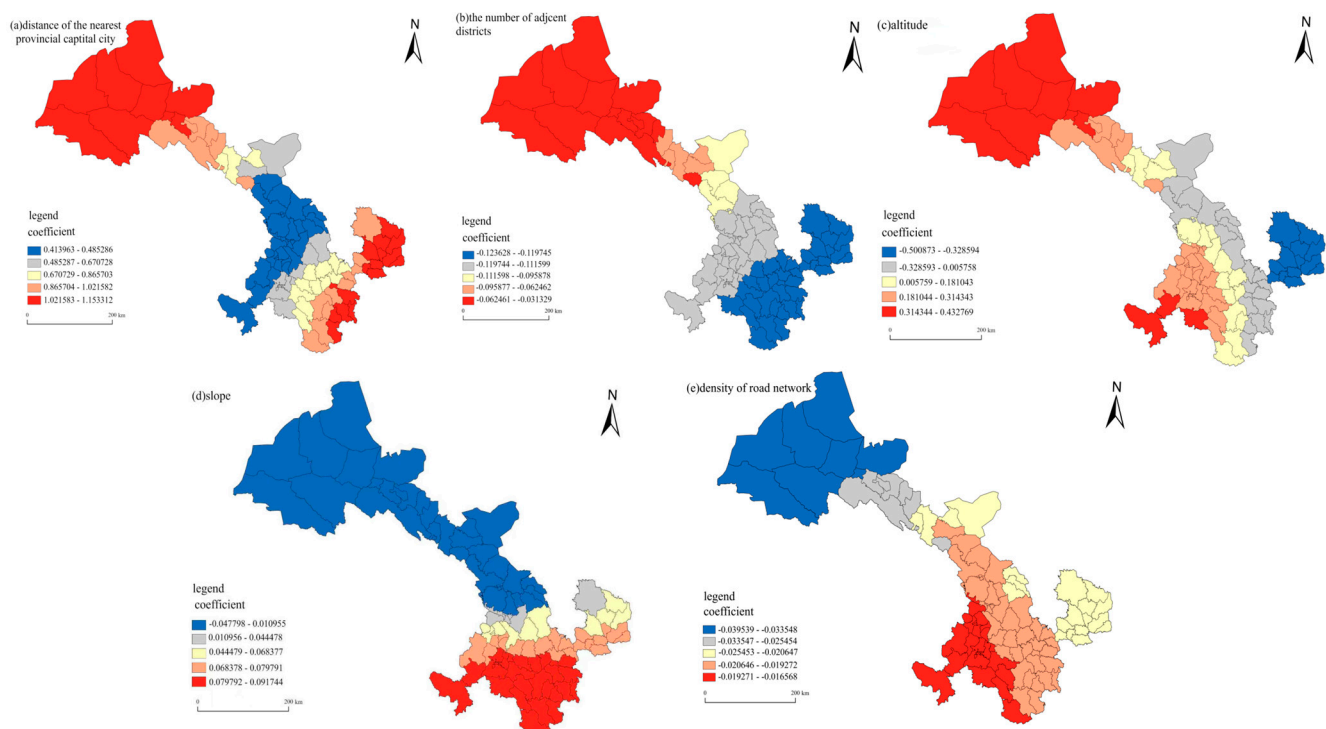


Figure 5. Spatial distribution of MGWR coefficients for core factors (Balanced Accessibility).

The distance to the nearest provincial capital exerts an overall positive influence on balanced accessibility, with pronounced spatial heterogeneity. Larger coefficients are concentrated in the western and northern parts of the Hexi Corridor, indicating that greater distances from the provincial capital increase the demand for long-distance travel, thereby raising both travel time and monetary costs and imposing stronger constraints on balanced accessibility. By contrast, the central region of Gansu exhibits relatively smaller coefficients, reflecting that regional transport hubs and a more interconnected transport system help alleviate the overall travel cost associated with geographical distance.

The number of adjacent counties shows an overall negative effect, indicating that stronger regional connectivity contributes to lower overall travel costs. Owing to its elongated geographical configuration, the Hexi Corridor has relatively limited inter-county transport connections, reducing the contribution of spatial adjacency to improvements in overall accessibility. In contrast, counties in southeastern Gansu possess denser regional transport networks and multiple route options, enabling tourists to reduce both travel time and monetary expenditure.

Elevation demonstrates pronounced spatial heterogeneity. Higher coefficients are mainly observed in the western and northern Hexi Corridor, suggesting that high-elevation environments increase the overall cost of tourist travel. Although some areas are characterised by relatively open terrain, high-altitude conditions may still increase road construction costs and vehicle operating expenses, thereby raising both travel time and monetary expenditure and constraining balanced accessibility. Conversely, negative coefficients are identified in parts of southeastern Gansu, where valley landforms combined with existing transport infrastructure mitigate the influence of elevation on travel costs, reduce overall travel impedance, and improve balanced accessibility.

The influence of slope exhibits a clear north-to-south increasing pattern. Coefficients remain relatively low across the Hexi Corridor and the central-northern regions, where relatively flat terrain limits the effect of slope on overall travel costs. In contrast, larger coefficients are observed across the Gannan Plateau and the mountainous areas of Longnan, where rugged terrain increases vehicle operating costs and detour requirements, substantially raising the overall cost of travel and reducing balanced accessibility.

The influence of road network density on balanced accessibility generally decreases from the northwest to the southeast. Higher coefficients occur in the western Hexi Corridor, where a well-developed road network effectively reduces both travel time and monetary costs, thereby improving overall accessibility. By comparison, coefficients are lower in central and southeastern Gansu, suggesting that the contribution of road network expansion to balanced accessibility is relatively constrained by topographic conditions and the difficulty of transport infrastructure development.

Overall, the spatial heterogeneity of balanced accessibility reflects the combined influence of locational conditions, the natural environment, and transport networks. The Hexi Corridor benefits from favourable transport infrastructure and strong regional connectivity, resulting in relatively high levels of overall accessibility. In contrast, the mountainous regions of Longnan and Gannan continue to experience dual constraints imposed by complex topography and insufficient transport infrastructure. Rather than operating independently, these factors jointly shape the spatial pattern of tourism accessibility through their interactions with regional transport conditions and spatial connectivity.

4.5. Interaction and Coupling Effects of Accessibility Driving Factors

A Geographical Detector was employed to examine the interaction effects among the principal driving factors influencing the three dimensions of county-level tourism accessibility in Gansu Province. The results (Figure 6) indicate that the driving factors

do not operate independently. Instead, all pairwise interactions exhibit either bivariate enhancement or nonlinear enhancement, with no evidence of independent or weakening effects. This finding suggests that the spatial differentiation of tourism accessibility results from the combined influence of the natural environment, locational conditions, and transport infrastructure.

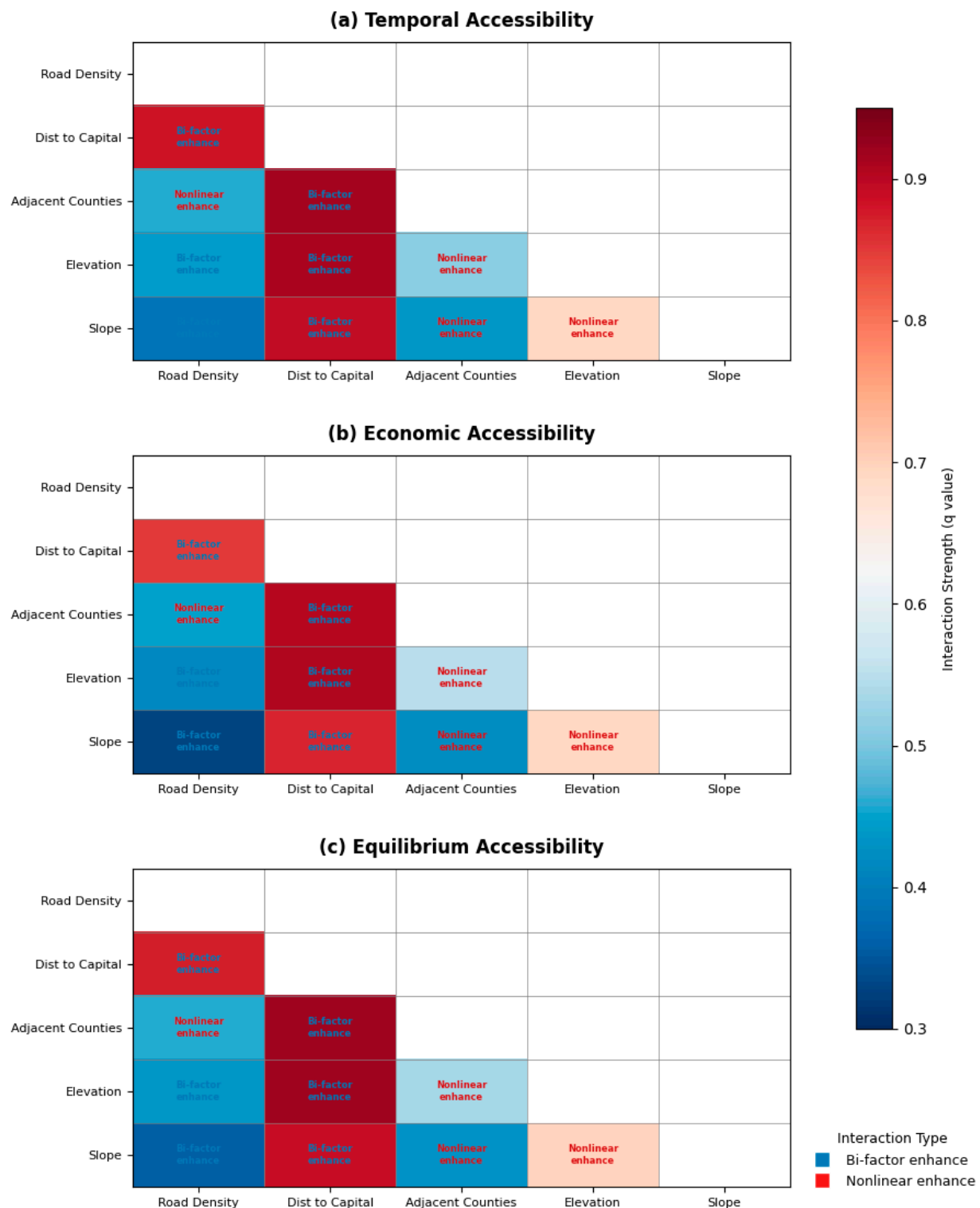


Figure 6. Interaction detector results of driving factors for the three dimensions of accessibility.

Among the interaction effects, the distance to the nearest provincial capital exhibits consistently high explanatory power when interacting with other factors, highlighting

the dominant role of locational conditions in shaping tourism accessibility. Interactions between the topographic variables (elevation and slope) and between the distance to the nearest provincial capital and road network density also display strong explanatory power, substantially exceeding that of individual factors. In particular, the interactions between the distance to the nearest provincial capital and elevation, as well as between the distance to the nearest provincial capital and the number of adjacent counties, rank among the most influential combinations.

Disparities exist in the interactive characteristics among the three accessibility dimensions. The interactive explanatory power of core factors for temporal accessibility is the highest overall, followed by economic accessibility, while balanced accessibility falls between the two. Nevertheless, the core dominant interactive factor combinations across all three dimensions exhibit a high degree of consistency. Overall, multi-factor synergistic enhancement serves as the pivotal mechanism driving the spatial differentiation of county-level accessibility in Gansu Province, with locational conditions relative to the provincial capital playing a dominant role in this synergy.

4.6. Analysis of Driving Mechanisms

The preceding analyses demonstrate that the spatial differentiation of county-level tourism accessibility in Gansu Province is not driven by any single factor but instead reflects the long-term interaction among physical geography, the regional centre system, and the transport network. In terms of the underlying mechanism, the natural environment first constrains regional spatial connectivity by influencing the cost of transport infrastructure construction and route alignment. The regional centre system subsequently reinforces spatial polarisation through the concentration of population, economic activities, and transport resources, while the transport network moderates both topographic constraints and locational disparities, collectively shaping the spatial pattern of tourism accessibility (Figure 7).

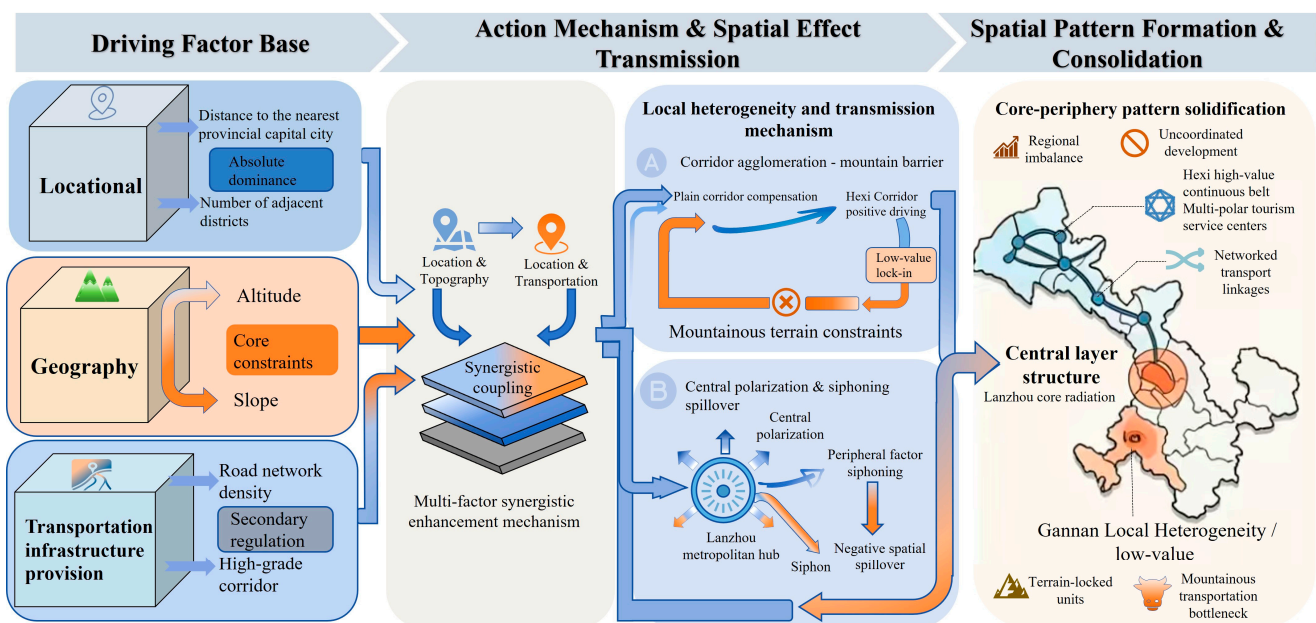


Figure 7. Driving mechanisms of tourism accessibility in Gansu Province.

Owing to its elongated geographical configuration, the transport network in Gansu Province exhibits a pronounced corridor-based structure rather than a balanced network configuration. The Hexi Corridor, characterised by relatively flat terrain and favourable construction conditions, facilitates the continuous development of high-grade transport infrastructure. The resulting scale and connectivity effects reduce both temporal and

monetary travel impedance, strengthen spatial interactions among tourist attractions, and generate clusters of relatively high accessibility. By contrast, the Gannan Plateau, the mountainous areas of Longnan, and the Qilian Mountains are characterised by high elevations, steep slopes, and complex terrain, resulting in higher construction and maintenance costs and lower road network density and continuity. Consequently, tourism linkages in these regions remain relatively weak. These findings suggest that topography does not directly determine tourism accessibility; rather, it indirectly shapes regional tourism spatial interactions by influencing the formation and development of transport networks.

Meanwhile, the regional centre system influences tourism accessibility through the dynamic interplay between resource concentration and spatial diffusion. As the provincial transport hub and primary growth pole, Lanzhou possesses clear advantages in transport interchange, tourism services, and resource allocation. Its central functions extend to surrounding regions through the transport network, improving tourism connectivity in neighbouring areas. However, because Gansu Province remains characterised by a single-core spatial structure, the concentration of high-level transport resources and service functions within the provincial capital outweighs their diffusion to peripheral regions, limiting the ability of distant areas to benefit from central advantages. The SDM results further reveal significant spatial spillover effects associated with locational factors, indicating that tourism accessibility depends not only on local conditions but also on spatial interactions with neighbouring regions and major transport hubs, ultimately producing a core-periphery spatial structure.

Furthermore, transport networks play an important moderating role between environmental constraints and locational disparities. The Geographical Detector analysis reveals significant enhancement effects among multiple interacting factors, demonstrating that tourism accessibility is jointly determined by multiple dimensions rather than by any single determinant. Transport infrastructure can mitigate some of the constraints imposed by the natural environment through reducing spatial impedance, although its effectiveness varies spatially. In regions such as the Hexi Corridor, where transport infrastructure is relatively well developed, further investment primarily reinforces existing locational advantages and resource concentration. In contrast, in mountainous and plateau regions with limited transport provision, infrastructure development primarily functions to overcome topographic barriers and strengthen regional connectivity. Consequently, future transport planning in Gansu should shift from expanding infrastructure scale towards improving network efficiency, strengthening interregional transport integration, and addressing transport deficiencies in mountainous areas, thereby facilitating the transition from corridor-based connectivity to network-based coordination and alleviating the current spatial imbalance in tourism accessibility.

5. Discussion

The findings further corroborate previous studies demonstrating that spatial variations in tourism accessibility are primarily determined by locational conditions and regional transport connectivity [14,59]. Existing research has shown that tourism accessibility generally exhibits pronounced spatial heterogeneity and is jointly shaped by transport networks, economic development, and regional spatial structure [47,77]. However, previous studies have mainly focused on urban agglomerations, national-scale analyses, or regions with well-developed transport systems [25,27], while tourism accessibility has typically been evaluated using either travel time or spatial distance alone [14,77]. Consequently, relatively limited attention has been paid to the joint constraints imposed by temporal and monetary travel costs in geographically complex regions.

Focusing on Gansu Province as a typical corridor-shaped region, this study develops a multidimensional tourism accessibility evaluation framework from the perspective of actual tourist travel behaviour. The results indicate that the Hexi Corridor and the Lanzhou metropolitan area benefit from transport corridors and favourable locational conditions, forming relatively low-impedance regions. In contrast, the mountainous areas of Gannan and Longnan experience substantially higher travel impedance because of complex topography. These findings are consistent with previous studies demonstrating that transport infrastructure and physical geography jointly shape regional tourism spatial structures [47,51]. Furthermore, the results reveal that the spatial differentiation of tourism accessibility is jointly influenced by transport conditions, locational characteristics, topographic constraints, and regional connectivity. This study therefore extends current understanding of the mechanisms underlying tourism accessibility in geographically complex regions and provides useful evidence for transport optimisation and coordinated regional tourism development in corridor-type areas.

Despite these contributions, several limitations should be acknowledged. First, the Gaode Map API data were collected during a specific period in 2026 and therefore do not capture the long-term spatiotemporal evolution of tourism accessibility. Future research will continuously collect navigation data to construct a longitudinal database for analysing temporal changes in tourism accessibility. Second, balanced accessibility was calculated using the geometric mean, implicitly assuming equal importance for travel time and monetary cost. However, different tourist groups may exhibit heterogeneous preferences, meaning that accessibility assessments could vary according to behavioural characteristics. Finally, although the MGWR model and the SDM effectively reveal spatial associations among variables, they do not establish causal relationships. Accordingly, the findings should be interpreted primarily as providing a spatial explanation of the mechanisms underlying tourism accessibility rather than strict causal inference.

Future research can be extended in several directions. First, continuous collection of multi-period navigation data will enable the construction of a longitudinal tourism accessibility database, facilitating analyses of the long-term effects of transport infrastructure development, tourism resource exploitation, and regional policy changes on tourism accessibility. Second, questionnaire surveys and tourist mobility trajectory data could be integrated to identify heterogeneous preferences regarding travel time and monetary costs among different tourist groups, thereby developing behaviourally informed tourism accessibility models with stronger explanatory power. Finally, future studies may combine panel data, quasi-natural experiments, or causal inference methods to identify causal relationships between tourism accessibility and its determinants, extending current spatial association analyses towards rigorous causal explanations and providing stronger theoretical support for regional tourism transport planning and high-quality tourism development.

6. Conclusions and Policy Implications

6.1. Conclusions

Using the counties of Gansu Province as the primary research units, this study acquired empirical travel data from counties to A-level tourist attractions via the Amap API to construct a three-dimensional measurement framework encompassing temporal, economic, and balanced accessibility. By integrating spatial autocorrelation, Geodetector, the Spatial Durbin Model SDM, and MGWR, we systematically elucidated the spatial patterns, spatial spillover effects, and driving mechanisms of tourism accessibility across the province. The primary conclusions are outlined below:

Tourism accessibility to A-level tourist attractions in Gansu Province exhibits pronounced spatial differentiation across all three dimensions, namely time accessibility,

economic accessibility, and balanced accessibility. Clear regional disparities are observed, with relatively high accessibility concentrated in the Hexi Corridor, whereas the Gannan Plateau, the mountainous areas of Longnan, and several counties in central Gansu display comparatively low accessibility. Overall, tourism accessibility follows a declining spatial pattern extending from the northwest towards the central and southern parts of the province. Compared with economic accessibility, the spatial distribution of balanced accessibility more closely resembles that of time accessibility.

Locational conditions and topographic conditions constitute the principal determinants of tourism accessibility in Gansu Province, among which the distance to the provincial capital exhibits the greatest explanatory power. The Geographical Detector results indicate that the distance to the provincial capital, elevation, and the number of adjacent counties significantly influence all three dimensions of tourism accessibility. Moreover, interactions among these factors consistently exhibit either bivariate enhancement or nonlinear enhancement, indicating that the spatial differentiation of tourism accessibility arises from the synergistic effects of multiple driving factors.

Tourism accessibility to A-level tourist attractions in Gansu Province exhibits significant spatial spillover effects and spatial heterogeneity. The Spatial Durbin Model (SDM) results reveal that the principal driving factors generate both local effects and spatial spillover effects on neighbouring areas. Furthermore, the Multiscale Geographically Weighted Regression (MGWR) analysis demonstrates substantial spatial variation in the strength of individual driving factors. Specifically, the Hexi Corridor primarily benefits from favourable locational conditions and well-developed transport infrastructure, whereas the mountainous regions of Gannan and Longnan remain constrained by complex topographic conditions. These findings are consistent with the growing body of tourism spatial econometric research emphasising the joint importance of spatial spillovers and spatial heterogeneity in shaping regional tourism development.

Overall, the formation of tourism accessibility in Gansu Province follows a mechanism characterised by “location-led development, topographic constraints, and transport regulation.” The central radiating role of Lanzhou, the provincial capital, fundamentally shapes the province-wide spatial pattern of tourism accessibility, while complex terrain and insufficient transport connectivity further exacerbate regional disparities. Future policy should prioritise transport infrastructure development in the mountainous areas of central and southern Gansu and in peripheral counties, with the aim of improving regional connectivity and promoting a more balanced distribution of tourism accessibility across the province. These recommendations are broadly consistent with recent studies highlighting that coordinated transport investment and enhanced regional connectivity are essential for mitigating spatial inequalities in tourism accessibility and regional tourism development.

6.2. Policy Implications

Grounded in the spatial pattern characteristics and underlying driving mechanisms of tourism accessibility for A-level attractions in Gansu Province, future policy interventions should systematically advance the development of the tourism transport system across three strategic dimensions: transport network optimization, regional collaborative linkage, and differentiated spatial governance.

First, transport infrastructure should be further improved in the mountainous areas of central and southern Gansu and in peripheral counties through the development of a multi-level tourism transport network. Particular priority should be given to low-accessibility regions such as the Gannan Plateau and the mountainous areas of Longnan by strengthening expressway construction, dedicated tourist transport routes, and scenic-area shuttle systems. These measures would improve transport connectivity between mountainous

counties and major transport hubs, thereby mitigating the adverse effects of complex topography on tourism mobility. At the same time, greater emphasis should be placed on enhancing the integration between high-speed railway stations, airports, and A-level tourist attractions to further improve the overall connectivity and integration of the regional tourism transport system.

Second, the radiation and spillover effects of Lanzhou, as the primary core hub, should be fortified to catalyze regional collaborative tourism development. Empirical evidence demonstrates that while the provincial capital exerts a dominant influence on the spatial configuration of provincial tourism accessibility, a pronounced “core–periphery” structure persists. Consequently, future initiatives should leverage Lanzhou’s comparative advantages as a comprehensive transport hub to foster multi-directional transport linkages among the Hexi Corridor, the central transitional zone, and the southern mountainous areas. This will facilitate the spatial diffusion of tourist flows, transport resources, and public services toward peripheral regions, progressively alleviating regional disparities in tourism development.

Finally, differentiated tourism spatial governance strategies should be implemented according to regional resource endowments and spatial constraints. The Hexi Corridor should further improve the integration efficiency between transport infrastructure and tourism resources while strengthening the tourism service functions of major transport corridors. Central Gansu should focus on enhancing inter-county transport connectivity and improving regional internal accessibility. In contrast, the mountainous areas of Gannan and Longnan should place greater emphasis on balancing basic transport provision with ecological conservation. Collectively, these differentiated measures will rectify spatial mismatches and propel the tourism transport system of Gansu Province toward balanced, high-quality development.

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