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Spatial differentiation characteristics of regional self-driving tourism flow: A case study of central Yunnan urban agglomeration

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ABSTRACT

The aim of this study was investigate the spatial effects of A-class scenic spots and the spatial distribution of highway networks on the influence of self-driving tour behavioral patterns in China at the urban agglomeration scale, based on big data of road traffic during three holidays. A spatial analysis method and a geographically weighted regression model were used to analyze the spatial distribution differences and influencing factors of self-driving tourism flows in the central Yunnan urban agglomeration. The results showed that holiday self-driving tourism in the central Yunnan urban agglomeration presented a typical core-edge spatial pattern. The mean value of the spatial autocorrelation coefficient was 0.54, indicating significant spatial autocorrelation. The influence of tourism resources and traffic conditions on self-driving tourism flow showed a decreasing trend from the center of the high positive value to the periphery of the main urban area of Kunming. This study reveals the spatial differentiation characteristics of self-driving tourism flows in urban agglomerations and lays a theoretical foundation for understanding flow pattern.

1. Introduction

In the context of accelerating and implementing the new urbanization process in China, urban agglomerations have gradually become the main regional body on which the tourism industry develops and forms a type of tourist place on a specific scale [1]. Urban agglomeration tourism flow is an essential means of adjusting and optimizing the structure and layout of the tourism industry in urban agglomerations; its spatial form and layout directly affect the overall image of urban agglomerations and the degree of tourism cooperation, which significantly promotes the integrated development of tourism in urban agglomerations [2,3]. Driven by the market and policy, Chinese cities have focused on tourism development in recent years, and tourism competition has become increasingly intense within urban agglomerations [4]. Therefore, a detailed clarification of the spatial characteristics of tourism flows in urban agglomerations and their related influencing factors is critical to promoting tourism development in urban agglomerations.

In recent years, scholars have analyzed the influencing factors of tourism flows in urban agglomerations based on questionnaires or statistical data. For example, the travel purpose and travel mode of residents in four major urban agglomerations in Ghana are mainly influenced by transportation costs, convenience, service quality, and safety, and residents have a strong will and demand to reduce

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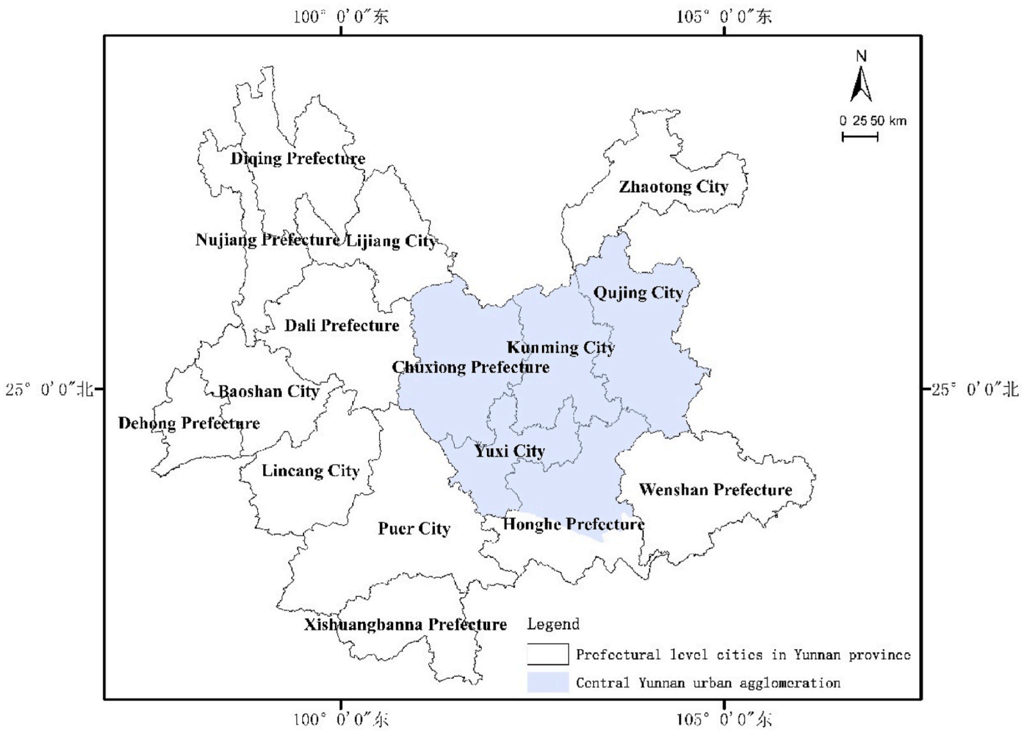
transportation costs [5]. However, with the accelerating urbanization and development of tourism in China, an increasing number of researchers are focusing on the mechanism of interaction between tourism sites and cities on the development of tourism at the regional and national macro levels. Liu et al. [6] investigated the stage characteristics and spatial differentiation of tourism development in the central Yunnan urban agglomeration. They found that the quality of tourism development at the county level was closely related to the strength of the tourism economy, tourism resources, and tourism service facilities. Traffic flow can describe and reflect the traffic conditions and essence, and effective road planning, design, and operation management programs have been proposed [7–9]. In addition, researchers have analyzed their network structures based on theoretical models to reveal the variations in the structure and spatial patterns of tourism flow networks in urban agglomerations. For example, the spatial distribution pattern and structural characteristics of tourism trips in China have been analyzed based on tourism travel big data [10]. Huang combined a consumption utility theory with a travel probability model to establish a competitive gravity model with multiple destinations and sources. The author also used geographic information system (GIS) spatial econometrics to empirically analyze the influence of these two factors on the tourism flow structure of the Yangtze River Delta urban agglomeration in China before and after the opening of the Ning-Hang high-speed railway [11]. Liu investigated the spatial pattern evolution of tourism flows in the middle reaches of the Yangtze River urban agglomeration by combining the data mining of web travelogues and GIS spatial analysis using social network analysis [12]. Ruan examined the relationship between tourism information flow and regional tourism economic linkages from a macro perspective, using the Yangtze River Delta urban agglomeration in China [13]. Most previous studies focused on the network structure of tourism flows within urban agglomerations, variations in spatial patterns, and tourism service facilities. Relatively few quantitative studies have been conducted on regional differences in self-driving tourism flows and their influencing factors at the urban agglomeration scale.

As the main mode of tourism travel in recent years, self-driving tourism has a certain degree of “urban cluster trip range”, a trip radius limited to 300 km, and trip time of less than three days of short- and medium-distance trips. Therefore, the spatial associations and interactions between them should be clarified. Therefore, the aim of this study was to accurately determine the spatial differentiation characteristics of self-driving tourism flows in urban clusters. The self-driving tourism flows in urban clusters in central Yunnan on New Year’s Day, Tomb Sweeping Day, and May Day were adapted as the research objects, and spatial analysis and a geographically weighted regression (GWR) model were used to analyze the differences in the spatial distribution of self-driving tourism flows in urban clusters in central Yunnan and its influencing factors. This study lays a theoretical foundation for revealing



Note: This map was drawn with the standard map number GS (2020) 4619 downloaded from the standard map service website of the National Bureau of Surveying, Mapping, and Geographic Information; the base map has not changed.

Fig. 1. Location of central Yunnan urban agglomeration.

the patterns of self-driving tourism flow in urban clusters.

2. Overview of study area and data sources

2.1. Study area

The central Yunnan urban agglomeration is located in the core of the Yunnan plat-eau, bordering Guizhou Province to the east, Dali Prefecture, Pu'er City, Honghe and Wenshan Prefecture to the west and south, and Sichuan Province to the north. The area has an annual average temperature of 15–18 °C and four seasons. The central Yunnan urban agglomeration has a transportation network, with Kunming as the center. Road transportation is the main traffic source, and railroad transportation is a supplementary source of traffic. The central Yunnan urban agglomeration is rich in tourism resources, forming unique natural tourism resources, and rich ethnic and cultural tourism resources. Tourism is an essential factor for the integrated development of the central Yunnan urban agglomerations. In summary, Yunnan Province is one of the provinces with the richest tourism resources and the largest tourism flow in China, while the urban agglomeration of central Yunnan Province, as the central region of Yunnan Province, has rich tourism resources and a more developed highway network. Therefore, it is a representative of the central Yunnan urban agglomeration as a research unit for self-driving tourism flow in urban agglomerations. Data were selected for New Year's Day, the Tomb Sweeping Day Festival, and May Day. The data were initially processed using the Navicat software. Forty-nine counties (cities and districts) were selected from the central Yunnan urban agglomeration, including Kunming City, Chuxiong Yi Autonomous Prefecture, Yuxi City, and Qujing City, and seven counties (cities)were selected from the northern part of Honghe Hani and Yi Autonomous Prefecture (Fig. 1).

2.2. Data sources

This study adapted the self-driving tourism node traffic at the toll stations of the central Yunnan urban agglomeration on holidays as the research object. The traffic data was obtained from the toll system, and the initial data was processed to eliminate the data irrelevant to the topic and abnormal data. The self-driving tourism flow data with complete field information was extracted as the sample data, and a total of 256 toll stations, nearly 11 million sample data, and 18 total data fields were counted. Table 1 presents an overview of the data fields.

The node traffic of each region in the central Yunnan urban agglomeration was calculated. The node traffic of self-driving tourism flow in the central Yunnan urban agglomeration showed an increasing trend for the three holidays of New Year's Day, Tomb Sweeping Day, and May Day. Kunming, which is the traffic distribution center of Yunnan Province, topped the node traffic among prefecture-level cities. An overview of the daily variations in node traffic of the self-driving tourism flow during the three holidays is shown in Fig. 2. The daily changes that the daily changes of node traffic of the self-driving tourism flow on the same holiday were somewhat similar.

The A-level scenic spots in the central Yunnan urban agglomeration were obtained from data counted by the Yunnan Provincial Department of Tourism and Culture as of November 2020. The number of A-level scenic spots and their distributions in each state and city of the central Yunnan urban agglomeration is shown in Fig. 3.

3. Methods

Tourism flow data based on big data of road traffic flow have easy access, complete content, and timeliness, which can characterize the mobility and macro-aggregation characteristics of self-driving cars better. Therefore, the differences in the spatial distribution of self-driving tourism flow and the intensity of its influencing factors in the central Yunnan urban agglomeration on holidays were investigated, based on road traffic flow big data. First, a weighted average travel-time accessibility model was used to evaluate the average minimum time of access to each A-level tourist attraction in each county (city or district) of the Central Yunnan urban agglomeration (called "the county unit"). Second, the spatial autocorrelation method is applied to analyze the spatial clustering degree and status of self-driving tourism flows and examine the differences in their spatial distribution. Finally, the GWR model was used to analyze the clustering characteristics of self-driving tourism flow on holidays and its spatial differentiation characteristics in the county units of the central Yunnan urban agglomeration. In the GWR model, the self-driving tourism flow network was adopted as the dependent variable, and the factors influencing the self-driving tourism flow fundamentally shaped the relationship pattern of the self-

Table 1
Data fields of road self-driving tourism flow.

Field Name	Field Description	Example
VEHPLATE	License plate number	Cloud A2**U3
VEHCLASS	Billing model code	1 (Type I bus)
ENTOLLSTATIONID/EXTOLLSTATIONID	Toll Station Number	G0056530060020 (Yunnan Taiping Station)
LONGITUDE	Longitude	102.584790
LATITUDE	Latitude	24.965185
CITY	Prefecture-level city	Kunming
DISTRICT	County (City, District)	Xishan District

Note: The middle two digits of the license plate number have been replaced by * to protect passenger privacy.

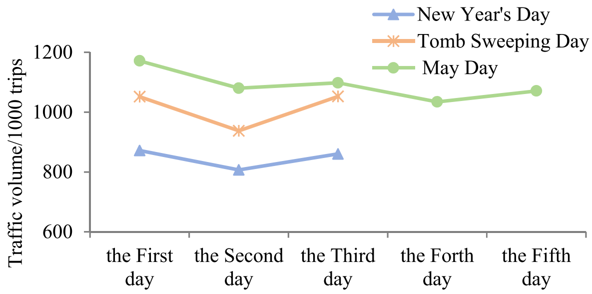


Fig. 2. Overview of daily variations in different holidays.

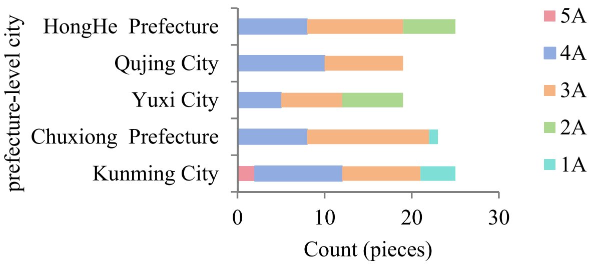


Fig. 3. Overview of number of A-class scenic spots in central Yunnan urban agglomeration.

driving tourism flow network. Based on this approach, the spatial differences in factors influencing self-driving tourism flow were measured, with the traffic conditions, tourism resources, tourism industry, and economy as independent variables, (Table 2).

3.1. *Weighted average travel time*

The degree of accessibility of each county unit to each A-class scenic spot was analyzed using the weighted average travel time, which reflects the importance of the source and can improve the time measurement analysis of each source to reach the scenic spot [14–16]. The equation is expressed as follows:

$$A_i = \frac{\sum_{j=1}^{n} (T_{ij}.M_j)}{\sum_{j=1}^{n} M_j} \tag{1}$$

where A_i is the accessibility of each county unit i, T_{ij} is the time-cost required for study unit i to reach scenic spot j along the shortest travel time route in the transportation network, M_j is the tourism revenue of study unit i in which scenic spot j is located. The tourism revenue of scenic spot j is used as the M_j calculation index. The lower the A_i score, the better the accessibility of the study unit. In the weighted average travel time equation, the highway opening time is calculated by dividing the distance by the speed. The distance data were obtained from the Baidu map, where a highway driving speed of 100 km/h was used.

3.2. *Spatial autocorrelation*

The global spatial autocorrelation index Moran's I was used to analyze the increasing or decreasing trend of the correlation of the overall self-driving tourism flow in the study area. The local spatial autocorrelation index reveals the degree of connection and difference between local neighboring spaces, and the Getis-Ord Gi* index is used to analyze the cold- and hot-spot areas of self-driving tourism flows [17].

Table 2
Indicator system construction.

Indicator System	Secondary Indicators	Variable Agent Symbol	Unit
Transportation conditions	Highway Accessibility	D_{FA}	min
Tourism resources	Number of scenic spots above A level	D_{TA}	individual
Tourism industry	Number of star-rated hotels	D_{SH}	unit
Economic factors	Total gross domestic product (GDP)	D_{GDP}	billion RMB

Global Moran's I statistic:

$$I = \frac{\sum_{a=1}^{m}\sum_{b=1}^{m} w_{ab}(Y_a - \overline{Y})(Y_b - \overline{Y})}{mS^2} \tag{2}$$

Getis-Ord Gi* index formula

$$G_a^* = \frac{\sum_{b=1}^{m} W_{ab}(d) Y_b}{\sum_{b=1}^{m} Y_b} \tag{3}$$

In Equations (2) and (3), S^2 is the sample variance,¯ Y is the sample mean, Y_a and Y_b are the attribute values of the a and b spatial cells of the highway stations (called "stations"), and w_{ab} is the spatial weight matrix. When the observed variable is the number of self-driving vehicles at holiday toll stations in the Central Yunnan urban agglomeration, m is the number of high-speed toll stations, Y_a is the number of self-driving vehicles at station a, Y_b is the number of self-driving vehicles in the neighboring stations centered on station b, and w_{ab} is a neighboring matrix that has been column standardized. The value of Moran's I ranges from [-1,1]. When $I > 0$, the space is positively correlated, and the distribution is aggregated in space; when $I < 0$, the space is negatively correlated, and the distribution is discrete in space; when $I = 0$, the space is not correlated, and the distribution is random in space. If the value of Z (Gi*) is significantly positive (negative), the value at station a is higher (lower) than the mean value and belongs to the hot (cold) spot area.

3.3. GWR model

The GWR model is a spatially variable parameter model proposed by Fotheringham et al. [18], that extends the ordinary least squares regression model in space [19]. The GWR model simulates the spatial non-stationarity of spatial parameters in space and time, and the variation in spatial location. These results are consistent with the objective reality [20,21]. The model is expressed by Equation (4):

$$y_i = \beta_0(u_i, v_i) + \sum_{k=1}^{n} \beta_k(u_i, v_i) x_{ik} + \varepsilon_i \tag{4}$$

Table 3
Weighted average travel time of each county unit in central Yunnan urban agglomeration (unit: min).

Serial Number	Region Name	Weighted Average Travel time	Serial Number	Region Name	Weighted Average Travel time	Serial Number	Region Name	Weighted Average Travel time
1	Shilin County	111.20	18	Tonghai County	131.33	35	Mouding County	201.27
2	Guandu District	97.55	19	Huaning County	137.92	36	Nanhua County	194.46
3	Chenggong District	99.23	20	Yimen County	148.99	37	Yao'an County	237.80
4	Songming County	118.44	21	Eshan County	135.93	38	Dayao County	237.76
5	Panlong District	103.86	22	Xinping County	169.29	39	Yongren County	238.15
6	Xishan District	101.52	23	Yuanjiang County	199.97	40	Yuanmou County	209.99
7	Anning City	115.48	24	Qilin District	154.31	41	Wuding County	145.73
8	Fumin County	121.03	25	Zhanyi District	161.37	42	Lufeng City	165.35
9	Xundian County	139.80	26	Malong District	143.73	43	Mengzi City	193.89
10	Yiliang County	107.21	27	Luliang County	142.96	44	Jianshui County	159.74
11	Jinning District	110.01	28	Shizong County	158.22	45	Gejiu City	198.83
12	Wuhua District	105.41	29	Luoping County	199.55	46	Kaiyuan City	168.51
13	Dongchuan District	169.98	30	Fuyuan County	202.01	47	Mile City	137.89
14	Luquan County	148.37	31	Huize County	222.89	48	Luxi County	151.10
15	Hongta District	120.20	32	Xuanwei City	246.41	49	Shiping County	193.22
16	Jiangchuan District	124.45	33	Chuxiong City	179.05	50	Average value	159
17	Chengjiang City	100.35	34	Shuangbai County	230.05			

where y_i is the self-driving traffic in the i study unit, and x_{ik} is the value of the k independent variable in the i study unit; that is, k is an independent variable. n is the number of explanatory variables, (u_i, v_i) is the spatial coordinate of the i study unit, ε_i is the random error term, and $\beta_k(u_i, v_i)$ is the regression coefficient of the kth explanatory variable. Because the Akaike information criterion (AIC) method can effectively solve the problem of differences in degrees of freedom in different models, the Gaussian function was used to determine the weights, and the AIC method was used to determine the optimal bandwidth [22–24]. The GWR model of the influencing factors of self-driving tourism flow in the county units of the central Yunnan urban agglomeration on holidays is expressed by Equation (5):

$$y_i = \beta_0(u_i, v_i) + \sum_{j=1}^{k} \beta_1(u_i, v_i) x_{ij}(D_{FA}) + \sum_{j=1}^{k} \beta_2(u_i, v_i) x_{ij}(D_{TA}) + \sum_{j=1}^{k} \beta_3(u_i, v_i) x_{ij}(D_{SH}) + \sum_{j=1}^{k} \beta_4(u_i, v_i) x_{ij}(D_{GDP}) + \varepsilon_i \quad (5)$$

4. Results

4.1. Spatial pattern of accessibility of self-driving tourism flow

The average accessibility level of each county unit in the Central Yunnan urban agglomeration to reach 123 A-class scenic spots was calculated using Equation (1), and its weighted average travel time is listed in Table 3.

The weighted average travel time required for each county unit in the Central Yunnan urban agglomeration to reach the 123 A-class scenic spots was between 97 and 240 min, with an average value of 159 min. The county unit with the best accessibility was Guandu District (97.55 min), located southeast of the main city of Kunming with good location advantages. The county unit with the worst accessibility was Xuanwei City (246.41min), located in the northeast of the central Yunnan urban agglomeration and has a poorly connected transportation network and low-accessibility level. Based on the tourism accessibility coefficient, 22 counties (45 %) had accessibility levels lower than the average value of the central Yunnan urban agglomeration, and 27 counties (55 %) had levels higher than the average of the Central Yunnan Urban Agglomeration. The accessibility of tourism transportation in most county units was higher than the average level of the central Yunnan urban agglomeration. The overall accessibility pattern of county units in the central Yunnan urban agglomeration is shown in Fig. 4.

4.2. Spatial autocorrelation analysis of self-driving tourism flow

Based on the spatial correlation analysis method, the spatial autocorrelation degree of the self-driving tourism flow at each toll station in the central Yunnan urban agglomeration was analyzed using global statistics (global spatial autocorrelation), where the local spatial autocorrelation was calculated to identify the spatial location of high- and low-value clusters. The local spatial autocorrelation was then used to identify the spatial location of high- and low-value clusters and recognize the spatial distribution of self-driving tourism hot and cold spots in the central Yunnan urban agglomeration. The results of the region-wide Moran's I calculation obtained using Equation (2) are listed in Table 4.

The spatial autocorrelation coefficient of self-driving tourism flow in the central Yunnan urban agglomeration was positive for all

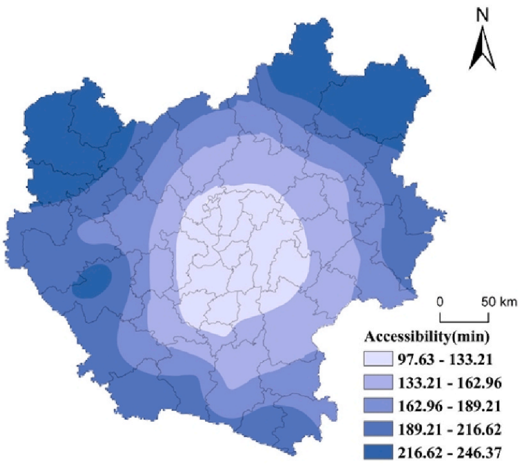


Fig. 4. Overall pattern of accessibility of county units in central Yunnan urban agglomeration.

three holidays, with a mean value of 0.54. This indicates that a significant spatial autocorrelation in the degree of self-driving tourism agglomeration was observed. That is, the spatial distribution of self-driving tourism flow is neither homogeneous nor random and exhibits significant spatial agglomeration distribution characteristics.

The local spatial autocorrelation Getis-Ord Gi* index of the self-driving tourism flow for the three holidays in the central Yunnan urban agglomeration was derived from Equations (2) and (3) using ArcGIS 10.8 to analyze the spatial characteristics of its cold- and hot-spots. This was conducted to further investigate the degree of contribution of each county unit to the self-driving tourism flow and examine the spatial pattern characteristics of the self-driving tourism flow in the central Yunnan urban agglomeration.

Fig. 5 shows the spatially divergent characteristics of "concentrated hotspots and decentralized layout". A few critical nodes collected many self-driving tourism flows, and this property is observed for different holidays. The spatial distribution of self-driving tourism traffic was characterized by high values at toll stations in the main urban area of Kunming, forming contiguous high-traffic areas, particularly on May 1. This significantly influences the travel satisfaction of self-driving tourism in central Yunnan urban agglomeration if congestion occurs at these nodes. Within a confidence interval of 90%–95 %, a point-like low-value area was formed, with Luxi and Shizong Counties as the main areas.

4.3. Analysis of factors influencing spatial heterogeneity

The self-driving tourism flows in the central Yunnan urban agglomeration on holidays showed evident spatial clustering characteristics and were not spatially independent of each other. As shown in Fig. 6, tourism resources, traffic conditions, economic factors and tourism industry have spatial heterogeneity and different characteristics.

(1) Tourism resources in Xishan and Guandu Districts had a strong positive driving effect on self-driving tourism flow, but there were as many as 19 county units with a negative correlation. The most abundant tourism resource, that is, the highest number of scenic spots above the A-class, was located in Maitreya City, but its self-driving tourism flow showed a strong negative correlation. The action mechanism of tourism resources on self-driving tourism flows was relatively complex, with different degrees and directions of influence. From the perspective of the three holidays and based on the scale of the urban agglomeration, self-driving tourism flow was more inclined to occur in the central area of the urban agglomeration with rich tourism resources, that is, the main urban area of Kunming. This phenomenon indicated that, with an increase in regional tourism resources during the holidays, the central area of urban agglomerations experienced significant demand for self-driving tourists, thus increasing the flow of self-driving tourism. (2) Traffic conditions positively influenced the overall self-driving tourism flow in urban agglomerations. Specifically, the main urban area of Kunming was the core area, and the trend gradually increased from southwest to northeast. Traffic conditions in some northeastern regions had a stronger driving effect on the self-driving tourism flow of urban agglomerations. This pattern might be because the traffic conditions in some regions near neighboring provinces in the northeast show a less positive driving force on the self-driving tourism flow of urban agglomerations than the pressure induced by other factors. Improvements in transport accessibility are beneficial for self-driving tourism flows. This is because the improvement in the transportation network creates conditions for accessibility of scenic spots, reduces the spatial distance between scenic spots, and promotes the circulation of tourism flows among various regions of urban agglomerations. (3) Economic factors have a significant positive driving effect on self-driving tourism flows. In terms of the intensity of economic factors, Chenggong, Guandu, and Xishan Districts of Kunming were the strongest, whereas Wuhua District was the weakest. The economic factors of the urban agglomerations are conducive for the construction of self-driving tour infrastructures and service systems, thus promoting the development of self-driving tours in the region. Being one of the central regions in Kunming, Wuhua District has always been at the forefront in terms of good economic factors. However, because it focuses more on the construction of producer services, it has a minimal effect in facilitating self-driving tourism flows. (4) Generally, an increase in the tourism industry promotes self-driving tourism flow. The three holidays all show spatial characteristics in that the main urban area of Kunming is at high-value area, and Chuxiong City and Luliang County are the lowest-value areas. The development of the tourism industry in Chuxiong City and Luliang County is more significant than those of regions far from the urban agglomeration center, but its beneficial influence on self-driving tourism flow is lower than those of other regions. A possible reason is that owing to the difference in the degree of development of the tourism industry in urban agglomerations, the development level of regions far from the center of urban agglomerations has a stronger promoting effect on self-driving tourism flow than those of regions near the center of urban agglomerations. High-quality development of the tourism industry in urban agglomerations can lead to the provision of more services, products, and infrastructure-related supplies for self-driving tourism to satisfy the diverse needs of self-driving tourists. The tourism industry involves a collection of services, such as travel, accommodation, food, shopping, and entertainment, with extroversion or externality. Thus, the tourism industry can improve its service quality, increase publicity, and apply other measures to promote the high-quality development of the tourism industry.

Overall, the influence of tourism resources and traffic conditions on self-driving tourism flow shows that the main urban area of Kunming is at highly positive center, and this influence decreases in the surrounding areas. Tourism resources and traffic conditions

Table 4
Spatial autocorrelation statistics.

Holiday	Moran's I value	Z-value	P-value
New Year's Day	0.705392	4.051392	0.000051
Tomb Sweeping Day	0.564927	3.253737	0.001139
May Day	0.347106	1.944156	0.051877

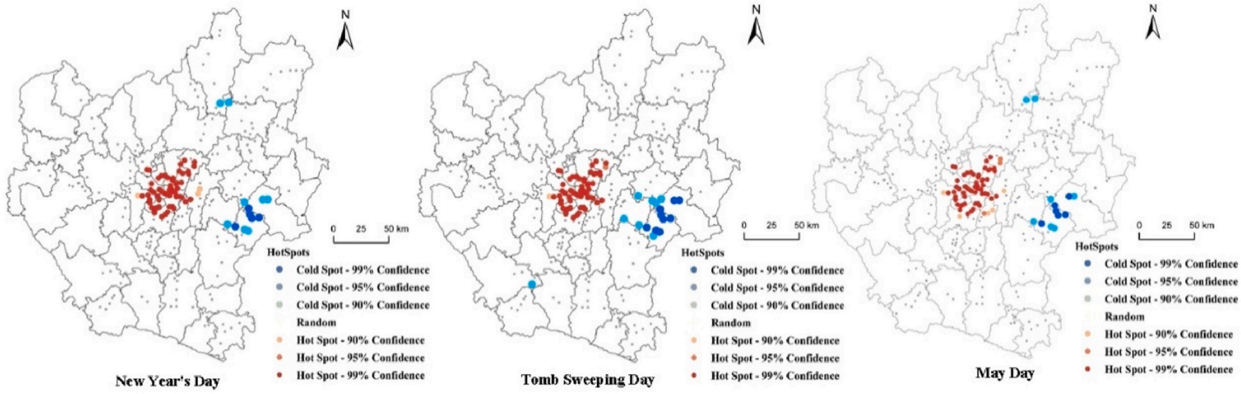


Fig. 5. Distribution of cold and hot spots.

are basic factors that create conditions for self-driving travel in urban agglomerations. Economic factors and the tourism industry are macro factors that play a moderate driving role, resulting in the regional stratification of self-driving tourism flow in urban agglomerations. However, self-driving tourism flow is not cause by a single factor. The spatial structural characteristics of self-driving tourism flow in urban agglomerations are the result of the comprehensive effects of tourism resources, traffic conditions, economic factors, the tourism industry, and other factors. The superposition of the positive effects strengthened the positive driving effect, and the superposition of the negative effects strengthened the negative driving effect. If the positive effect exceeds the negative effect, a positive driving effect is induced on the self-driving tourism flow.

5. Conclusions and discussion

Based on the big data of road traffic flow, the spatial differences of self-driving tourism flow in the central Yunnan urban agglomeration on holidays were analyzed in this study. Four major factors (traffic conditions, tourism resources, tourism industry, and economic factors) were selected, and the driving mechanism of self-driving tourism flow were investigated using the GWR model. The following conclusions are drawn. (1) The spatial distribution of the driving tourism flow in the central Yunnan urban agglomeration showed positive spatial autocorrelation in the three holidays (New Year's Day, Tomb Sweeping Day, and May Day), with a mean value of 0.54, indicating a significant spatial clustering distribution. The spatial distribution of the driving tourism flow in the central Yunnan urban agglomeration showed a continuous hot spot area in the main city of Kunming and a point-like cold-spot areas in Luxi County and Qujing City. The spatial distribution of driving tourism flow in the central Yunnan urban agglomeration was characterized by the main urban area of Kunming as a contiguous hot spot area, and Luxi County and Qujing City as point-like cold spot areas. (2) The spatially different factors influencing holiday self-driving tourism flows showed different correlations in the central Yunnan urban agglomeration, with spatially divergent characteristics. The strengths of the influencing factors differed for each county unit within the different regions. In contrast to previous studies on the influencing factors of the tourism flow [25–27], the order of influence intensity of the influencing factors on holiday self-driving tourism flow in the central Yunnan urban agglomeration in this study is as follows: economic factors > tourism industry > traffic conditions > tourism resources. Control variables such as the tourism industry, economic factors, and traffic conditions promote autonomous driving tourism flow in urban agglomerations, whereas tourism resources have no apparent promoting effects on autonomous driving tourism flow in urban agglomerations. (3) In terms of comprehensive resource endowment and various location conditions, all influencing factors in the study showed a strong positive correlation with self-driving tourism flow in Xishan and Guandu Districts during the three holidays. The positive driving effect of the tourism industry, economic factors, traffic conditions, tourism resources, and other influencing factors on the self-driving tourism flow of urban agglomerations decreased with distance.

As the development center of Yunnan Province, the unique geographical distribution and natural resource endowment of the central Yunnan urban agglomeration provides continuous support for the development of this region. Therefore, high-quality development of tourism in the central Yunnan urban agglomeration must be based on reasonable planning and management. Optimizing the relevant configuration of self-driving tourism, and improving the management level of holiday self-driving tourism flow will promote the self-driving tourism flow in urban agglomerations and improve the travel experience of self-driving tourists. Based on the spatial heterogeneity analysis results of the tourism industry, the economic factors, traffic conditions, tourism resources, and other influencing factors influence on self-driving tourism flow in urban agglomerations. It is necessary to strengthen the linkage role of tourism resources. In contrast to travel by other means of public transportation, tourism-related industries and resources play a vital role in self-driving tourism. Therefore, all districts and counties in urban agglomerations should strengthen linkage development with surrounding cities, strengthen the construction of transportation infrastructure, promote tourism-related resources on the roads of self-driving tourism, improve the visibility of tourism resources and the tourism industry, and promote the development of self-driving travel. The positive and negative drivers of self-driving tourism flow in urban agglomerations should be further optimized. Various social and economic factors influence affect changes in the flow changes in the flow of self-driving tourism in urban agglomerations.

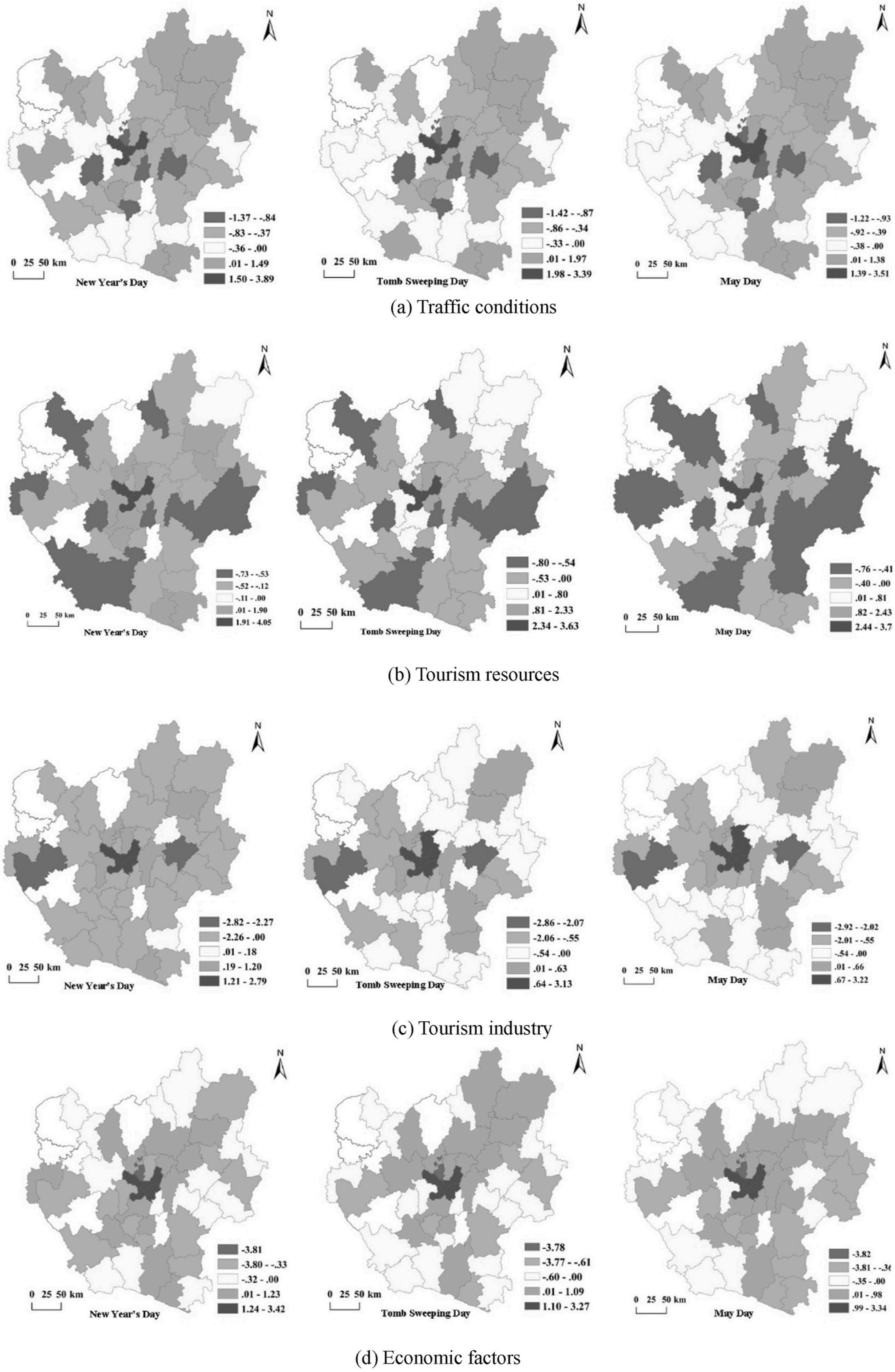


Fig. 6. Correlation coefficients of influencing factors.

Strengthening the beneficial effect of positive driving and reducing the inhibiting effect of negative driving are methods for maintaining the sustainable development of self-driving in urban agglomerations.

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Ethics declaration

Informed consent was not required for this study because this study analyzed the overall spatial characteristics of self-driving tourism flow based on the big data of highway traffic flow provided by the Road Network Center. The study does not involve the detailed privacy information of each person, nor does it involve their biomedical research.

Data availability

Data will be made available on request.

CRediT authorship contribution statement

Xiaofeng Ji: Conceptualization, Funding acquisition, Project administration, Supervision. **Haiqin Huang:** Data curation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing. **Fang Chen:** Conceptualization, Funding acquisition, Project administration, Supervision, Validation. **Mingjun Li:** Data curation, Software, Validation, Visualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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