Spatiotemporal Variation of Domestic Tourists' Emotional Experience in Xi'an Based on Big Data (Postprint)

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Abstract

In the era of Big Data, the widespread application of social media provides a novel data source for studying tourist sentiment experiences and exploring their spatiotemporal variations. This study collects Weibo check-in data from domestic tourists in Xi' an over a 3-year period, and employs hotspot grid mapping, the Getis-Ord Gi* method, and X-means clustering to examine the spatiotemporal variations and evolutionary patterns of domestic tourist sentiment experiences in Xi' an from two dimensions: positive sentiment and negative sentiment. The results indicate: (1) Tourist sentiment is relatively high and stable in the city center, along the main urban axis, in major commercial districts, and near scenic spots, with high-sentiment-experience areas primarily distributed in Qujiang New District and the Xi' an Ancient City Tourist Area. (2) Negative sentiment experiences account for a high proportion of space in Xi' an' s transportation hubs and urban fringe, with transportation hubs mainly comprising stations and city entrances/exits. (3) Overall, tourist sentiment in Xi' an remained relatively stable during the 3-year period, with positive sentiment exhibiting a 'center-periphery' spatial pattern. The manifestation of negative sentiment shows similarity to that of positive sentiment, primarily consisting of three types: stable, relatively stable, and sharply fluctuating. Among these three types, the stable type is mainly concentrated near the city center, commercial districts, major traffic arteries, and scenic spots; the relatively stable type occupies a large area of Xi' an; and the sharply fluctuating type is located on the fringe far from the city center.

Full Text

Spatial-temporal Variation of Emotional Experience of Domestic Tourists in Xi' an City Based on Big Data

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Abstract

In the era of big data, the extensive application of social media provides a new data source for studying tourist emotional experiences and exploring their spatiotemporal variations. This study collected Weibo check-in data of domestic tourists in Xi' an from July 2013 to June 2016, using hot grid map method, Getis-Ord Gi* method, and X-means clustering method to investigate the spatiotemporal changes and evolution patterns of tourist emotional experiences in Xi' an from the dimensions of positive and negative emotion. The results show that: (1) Tourist emotions are relatively high and stable near the city center, main urban axis, major business districts, and scenic spots, with high emotional experience areas mainly distributed in Qujiang New Area and the ancient city tourism area of Xi' an. (2) Negative emotional experiences occupy a high proportion in Xi' an' s transportation hubs and urban fringe areas, with transportation hubs mainly consisting of stations and city entrances/exits. (3) Overall, tourist emotions in Xi' an during the study period were relatively stable, with positive emotions showing a "center-periphery" spatial pattern, and negative emotions showing similarities to positive emotions. (4) The spatiotemporal clustering results mainly present three types: stable type, relatively stable type, and violently fluctuating type. Among these three types, the stable type is mainly concentrated near the city center, business districts, transportation trunk lines, and scenic spots; the relatively stable type occupies a large area of Xi' an; and the violently fluctuating type is located at the urban fringe far from the city center.

Keywords: emotional experience; spatiotemporal variation; X-means clustering; Weibo check-in data

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Emotion studies originated in Western philosophy but remained neglected for a long time. It was not until the mid-to-late 20th century that scholars began paying attention to "emotionality." Emotion, as a human instinct, runs throughout human development. With rapid social development, people have gradually satisfied basic physiological needs such as food and clothing, leading to higher-level emotional needs for safety, love, and belonging. Consequently, emotion research has gained continuous attention across various disciplines. From

an interdisciplinary perspective, current emotion research primarily focuses on emotion and philosophy, psychology, sociology, and geography. In today' s increasingly developed social transportation networks, modern people often use tourism to express inner anxiety and frustration and to break away from conventional lifestyles. Western tourism emotion research started earlier and exhibits diverse characteristics, while domestic research remains relatively weak, mainly relying on interviews and questionnaires for data collection, which has certain limitations. In contrast, using social media big data for emotion research offers significant advantages.

This study examines tourist emotional experiences in Xi' an using Weibo check-in data, primarily employing hot grid map method to explore the temporal and spatial evolution patterns of tourist emotions, providing a new perspective and method for tourism emotion research. Under the long-term influence of Western rational thinking, emotion as a subjective perception has been ignored, and 感性思维 (affective thinking) has not received attention, causing people to rely mainly on rational thinking for judgment and consider problems too narrowly without comprehensive analysis. Emotion first entered the research scope of geography, and with the progress of scholars' research and the convening of geography academic seminars with emotion as the theme, emotional geography emerged, and geography gradually achieved an "emotional turn." Foreign emotional geography research mainly involves human psychological and physical health, place perception, place attachment, emotional phenomena under migration, emotion distribution and characteristics in tourism, and emotions under different political backgrounds. Domestic research results are relatively few, mainly focusing on reviews and studies on place and sense of place by social and cultural geographers.

With the widespread use of social media, tourists' behavior and experiences are influenced and even changed. In tourism, people interact through subjective cognition and experience, gain new cognition and experience, further construct experiences, and express experiences and perceptions in written forms such as sentences, making them more valuable for research. Emotion is embedded throughout the entire tourism process and is also reflected in the interaction of stakeholder communities. Incorporating emotion research into tourism studies can more systematically understand the specific factors affecting tourists at destinations and compensate for the previous over-rational research. The emotional turn has been realized in social and cultural studies, and geography research related to feminism has also been involved. It is believed that emotion research in the tourism field should also be valued, recognizing the urgency of studying emotion for improving tourism content. Current tourism emotion research mainly focuses on specific emotional experiences during tourism and special forms of tourism emotional experiences, such as specific emotions like loss and hope; tourist behavior under emotional influence, such as impact on destination choice and satisfaction; spatiotemporal distribution of tourist emotional experiences; and influencing factors of tourist emotional experiences.

Emotional maps are an important research tool in emotional geography. Through emotional maps, we can explore the environmental conditions of the surrounding area and understand specific locations and spatial distributions. Emotional maps use detailed and comprehensive data to present actual, personally characteristic emotions generated based on surrounding environmental stimuli in space. In 2009, scholars conducted research on emotional maps, using biomapping devices to measure participants' skin conductance responses during walking and reflecting their emotional changes through GPS-acquired locations. Currently, there are three main types of emotional map data collection methods: (1) obtaining people' s physiological responses to the environment through related psychology experiments; (2) using questionnaires or interviews to invite participants to submit emotion-centered questionnaires and interview content, integrating and analyzing the collected materials; and (3) crawling social media big data to explore people' s emotional changes.

Existing studies show that emotion research in urban studies is increasing, mainly including identifying different urban places, dividing urban functions, designing transportation facilities, and planning urban landscapes. CRANSHAW et al. used data with geographic tags to analyze urban functional area division. ASHKEZARI-TOUSSI used photos with geographic tags from Flickr and facial expression recognition technology to explore and compare the emotional distribution of cities such as Beijing and Athens. GAO Ziyi et al. used POI data to explore urban retail patterns. WANG Lucang et al. used Baidu heat map data to analyze the city' s job-housing relationship. GOLDER et al. used social media big data for emotion research. Domestic scholars used Weibo, review data, travel notes, and photos to study tourist satisfaction with tourism destinations and scenic spots, destination branding and marketing, tourist spatiotemporal behavior, and tourist emotional experiences. Currently, research on tourist emotions based on social media data has become a new hotspot, mainly focusing on tourist emotion calculation and comparison of emotional experiences.

Overall, foreign research is relatively comprehensive and systematic, while domestic research focuses on emotion classification and measurement, with relatively insufficient research on emotion generation, spatiotemporal distribution, and influencing factors. Domestic research on emotional maps is limited, and the detailed mining of emotional data is insufficient. Social media data has injected new momentum into tourism research. Existing studies show that research on tourist emotions using social media as a data source is limited, and research content mainly focuses on exploring the patterns of tourist emotions, lacking solutions to the influencing mechanisms of tourist emotional experiences. This study examines the characteristics and spatiotemporal patterns of tourist emotional changes in Xi' an from a spatiotemporal perspective, aiming to enrich the content and methods of emotional geography.

1 Research Area and Data Processing

1.1 Research Area

This study takes the built-up area within Xi' an' s Third Ring Road as the research area. Xi' an is a city with over 3,000 years of history. As a world-famous historical and cultural city, the Bell Tower, Drum Tower, Big Wild Goose Pagoda, Small Wild Goose Pagoda, and City Wall within Xi' an are the soul of this ancient capital. A large number of tourist attractions are located within the Third Ring Road, and most tourist activities are concentrated in this area. Through effective social media promotion, Xi' an tourism has received widespread attention online and become an important check-in destination for tourists. The rapid development of tourism has made many attractions in Xi' an hotspots of tourist attention. Various characteristic foods and activities (such as "bowl-smashing wine" and "unwavering doll") have attracted countless domestic and foreign tourists to this ancient city.

1.2 Data Collection

The research area is a circular region centered on Xi' an Bell Tower with a radius of 11,132 meters, covering an area of approximately 390 km^2. The area includes scenic spots such as Big Wild Goose Pagoda and Tang Paradise, commercial centers such as Bell Tower and Xiaozhai, and important transportation hubs such as North Railway Station and Railway Station. The rapid development of high-speed railways has transformed Xi' an' s external transportation, enhancing city accessibility. The completion and operation of Metro Lines 1 and 2 have continuously improved internal urban transportation. Meanwhile, with steady economic development in Xi' an, comprehensive tourism has been continuously promoted, and Xi' an has transformed from a city tourism model to a tourism city model, with urban infrastructure and tourism service facilities constantly improving. Due to restrictions on obtaining Weibo check-in data, after comprehensive consideration, data from July 2013 to June 2016 were crawled for analysis.

Using web crawler software, Weibo check-in data were collected. Users registered outside "Shaanxi Xi' an" were selected, ultimately obtaining 11,132 data entries. The data mainly consisted of username, user ID, specific time of Weibo posting, latitude and longitude coordinates of check-in locations, and Weibo content.

1.3 Data Denoising

Data organization revealed a large number of Weibo users registered outside Xi' an. People studying or working in Xi' an were excluded. Existing research shows that in Weibo big data, if a user' s posting time interval is less than 30 days, this Weibo user will not be included in the tourist group. Meanwhile, based on existing criteria for screening groups and combined with personal experience, keywords with promotional meanings such as "purchasing agent" and "agency"

were filtered to exclude non-tourist Weibo accounts with business nature. Finally, it was decided to retain 10,000+ Weibo check-in data entries.

1.4 Weibo Sentiment Value Calculation

The study adopted the ROST EA software developed by Zhang Weishu from Beihang University. Compared with MBEWC, the calculation accuracy improved by 22.72%. For tourists in non-habitual environments, the dictionaries constituting the software were updated to better meet research needs and further improve accuracy.

Most tourist sentiment values ranged between [-0.5, 0.5], accounting for 99.63% of the data. Considering that a small number of extreme sentiment values would significantly impact the calculation of average sentiment values, the data were standardized, with final tourist Weibo sentiment values distributed within the [-1, 1] range. These were divided into positive emotion (>0), neutral emotion (=0), and negative emotion (<0). The specific results are shown in Table 1, where neutral emotion accounts for the largest proportion, and positive emotion accounts for a relatively large proportion (38.55%).

2 Spatiotemporal Variation Analysis of Tourist Emotional Experience

A 0.5 km × 0.5 km grid was used to grid the research area. Based on the quantified positive and negative emotion values above, each Weibo' s sentiment value and latitude and longitude coordinates were accurately mapped onto each grid. The spatiotemporal distribution patterns of tourist emotions from 2013 to 2016 were deeply explored, and the hot and cold spots of tourist sentiment spatial distribution in different time periods were obtained using the Getis-Ord Gi* method.

2.1 Spatiotemporal Variation of Tourist Positive Emotion

Based on yearly divisions, positive emotion values were processed using grid mapping, with the average positive emotion value in each 0.5 km × 0.5 km grid serving as the grid weight to detect the spatiotemporal distribution patterns of tourist positive emotion. The quantified Weibo sentiment values were divided into three time periods for spatial visualization (Figure 1). Based on sentiment value magnitude, they were divided into five levels, with darker colors indicating higher positive emotion values in the grid and lighter colors indicating lower positive emotion values.

Analysis of tourist positive emotion from July 2013 to June 2014 found that positive emotion was mainly concentrated in the (0, 0.5] interval, with extremely high positive emotion values mainly appearing in major urban business districts and tourist attractions. Compared with the July 2014-June 2015 period, the July 2015-June 2016 period showed an increase in the number of high positive

emotion value areas, while low positive emotion value areas also increased substantially, reaching the highest value among the three time periods, with more dispersed distribution.

From the spatial perspective, low-value and high-value clustering areas with different confidence interval levels (90%, 95%, 99%) in the three time periods can be identified based on the G* index constructed from sentiment values in the divided grids, using z-score and p-value indicators—namely, the Getis-Ord Gi* method mentioned above. Using this method, the hot and cold spots of tourist positive emotion spatial distribution from 2013 to 2016 can be detected (Figure 2).

From July 2013 to June 2014, tourist positive emotion hot spots (high-value areas) were concentrated in two typical tourism functional areas: Bell and Drum Tower area and Qujiang New Area. The Bell and Drum Tower area is located in Xi' an' s city center, including a series of scenic spots such as Bell Tower, Drum Tower, and Muslim Quarter, with more complete dining, accommodation, and entertainment facilities than other areas. The other hot spot area is Qujiang New Area, a national-level cultural industry demonstration zone and national 5A-level scenic area, considered a typical leisure and recreation area in Xi' an, with complete tourism services and public infrastructure, mainly featuring open scenic spots such as Big Wild Goose Pagoda North Square, Tang Paradise, and South Lake. In addition to hot spot areas, cold spot areas (low-value areas) of tourist positive emotion were mainly concentrated in transportation hub areas such as stations and highway entrances/exits, as well as urban fringe areas.

From July 2014 to June 2015, the number of tourist positive emotion hot spot areas decreased compared with the previous period. In contrast to the concentrated distribution of hot spot areas in the previous two periods, the July 2015-June 2016 period showed low aggregation of tourist positive emotion hot spot areas. Except for Qujiang New Area, aggregation was not obvious in other areas of Xi' an, and even within the Qujiang area itself, emotional heat showed a downward trend. In recent years, the rapid development of Xi' an tourism has prompted Xi' an to gradually break away from its inherent image as a tourist city and enter a new stage of urban tourism. Scenic spots are no longer the only factor affecting tourist emotion; every tree and blade of grass in the city has become a tourism attraction affecting tourist emotion. The rapid expansion of positive emotion hot spot areas in this period also reflects the high-speed development of regional tourism in Xi' an. Secondly, the distribution of tourist positive emotion cold spot areas in this period was more dispersed than in the previous two periods, with no obvious aggregation points. As can be seen from Figure 2, cold spot areas were widely distributed along the West Third Ring Road, including not only important transportation nodes such as Epang Palace Interchange and Hechizhai Interchange but also urban villages such as Xixinzhuang and Yuhuazhai, which basically matches the conclusion from the previous two periods that tourist positive emotion cold spots were mainly concentrated in urban fringe areas and transportation hubs.

2.2 Spatiotemporal Variation of Tourist Negative Emotion

Similar to positive emotion, tourist negative emotion from 2013 to 2016 was processed using grid mapping. Based on sentiment value magnitude, they were divided into five levels, with darker colors indicating lower negative emotion values in the grid and lighter colors indicating higher negative emotion values. As can be seen from Figure 3, tourist negative emotion was concentrated in the (-0.5, 0] range, with extremely high and extremely low negative emotion value areas being few and mainly scattered in urban fringe areas.

From July 2013 to June 2014, there were many cold spots (high-value areas) of tourist negative emotion space, meaning tourists' negative emotion was weak in this period, and negative emotion hot spot areas were scattered without forming obvious negative emotion aggregation areas. This is consistent with tourists' conventional psychology of having more positive emotions and fewer extreme negative emotions during tourism. Secondly, cold spots (high-value areas) of negative emotion space were mainly concentrated in transportation hubs and nearby areas and urban fringe areas, which has certain similarity to the distribution pattern of cold spots (low-value areas) of tourist positive emotion, both being due to tourists' reluctance to leave Xi' an, which drives negative emotion fluctuations.

From July 2014 to June 2015, the number of tourist negative emotion hot spot areas and cold spot areas increased compared with the previous period, with more obvious aggregation, mainly distributed in areas with relatively backward development and poorer environment such as Xiying Road, Yuhuazhai, and East Third Ring Road 沿线. Cold spot areas remained the same as the previous period, mainly distributed in urban fringe areas and transportation hub areas such as stations and city entrances/exits. As can be seen from Figure 4, compared with the previous period, cold spot areas of tourist negative emotion in this period were mainly distributed in the Han City Lake scenic area and its surrounding areas. In July 2015-June 2016, park development was slightly weak, tourism facilities and activities were still scarce, environmental quality had not been significantly improved, and negative emotion was easily bred. Another cold spot area was located in the West High-tech Interchange area, the junction of Taibai South Road and South Third Ring Road. As a relatively important city entrance/exit in Xi' an, this area has relatively large traffic and pedestrian flow, and tourist negative emotion is relatively stronger.

From July 2015 to June 2016, tourist negative emotion distribution was relatively scattered. Negative emotion hot spot areas were only formed in Yuhuazhai and its surrounding areas, which include several large-scale urban villages within Xi' an urban area, gathering many migrant workers with poor public infrastructure. Compared with the previous two periods, the aggregation degree of tourist negative emotion cold spot areas decreased significantly but still distributed around city entrances/exits and urban fringe areas. This is consistent with the reasons for the aggregation of tourist positive emotion hot spot areas in this

period as elaborated above—both are accompanied by the continuous development of Xi' an tourism, rapid improvement of infrastructure and services, and changes in tourists' thinking patterns about traveling to Xi' an. The tourism scope has expanded from scenic spot tours to sightseeing across the entire Xi' an area.

3 Spatiotemporal Clustering Analysis of Tourist Emotional Experience

Before studying the spatiotemporal variation of tourist emotional experiences, sentiment values were first standardized using grids as the basic unit. Equation (1) shows the standardization process of tourist sentiment values:

$E = \{S_1, S_2, S_3\}$ (1)

where E represents the set of grid sentiment values from 2013 to 2016. As above, S_1 represents the grid sentiment value for the July 2013-June 2014 period, S_2 represents the grid sentiment value for the July 2014-June 2015 period, and S_3 represents the grid sentiment value for the July 2015-June 2016 period.

$N\_E = |\max(E)|$ (2)

where N_E represents the standardized value of grid sentiment, using the absolute value of the maximum sentiment value from 2013 to 2016 to divide the sentiment value of the same grid.

$n = \{n_1, n_2, n_3\}$ (3)

where n is the set of standardized sentiment values. Among them, n_1 represents the standardized sentiment value for the July 2013-June 2014 period, n_2 represents the standardized sentiment value for the July 2014-June 2015 period, and n_3 represents the standardized sentiment value for the July 2015-June 2016 period.

Finally, after standardizing the grid sentiment values, X-means clustering analysis was used for clustering.

3.1 Spatiotemporal Clustering of Tourist Positive Emotional Experience

The clustering results of tourist positive emotion are shown in Table 2. It can be found that tourist positive emotion ultimately presents three clustering results in space, and the overall change of positive emotion is not significant. Based on the clustering results, sentiment values in the [0.33, 1] interval in the three time periods are summarized as relatively high emotion, sentiment values in the [-0.33, 0.33] interval are summarized as relatively medium emotion, and sentiment values below -0.33 in the three time periods are summarized as relatively low emotion. Based on the magnitude of sentiment values, it can be found that

the overall tourist positive emotion did not change much across the three time periods.

Spatial visualization of the tourist positive emotion clustering results reveals that the "center-periphery" structure conforms to the spatial variation of tourist positive emotion. The city center area is dominated by a certain type and gradually diffuses to the surroundings, mixing with other types. Furthermore, the three clustering results of tourist positive emotion can be summarized as three types of positive emotion evolution phenomena: stable type, relatively stable type, and violently fluctuating type. Specifically, Type 1 belongs to positive emotion stable type, occupying the largest area, mainly distributed in the city center and around scenic spots; Type 2 belongs to positive emotion relatively stable type, with relatively concentrated distribution, mainly distributed in most areas of the city except Type 1; Type 3 belongs to positive emotion violently fluctuating type, with relatively small spatial proportion, mainly distributed in urban fringe areas.

3.2 Spatiotemporal Clustering of Tourist Negative Emotional Experience

The clustering results of tourist negative emotion are shown in Table 3. It can be found that tourist negative emotion ultimately presents three clustering results in space, and the overall fluctuation of negative emotion is not significant.

Spatial visualization of the tourist negative emotion clustering results reveals that the "center-periphery" structure also conforms to the spatial variation of tourist negative emotion. The city center and main axis areas are dominated by a single type and gradually diffuse to the surroundings, mixing with other types. Furthermore, the three clustering results of tourist negative emotion can be summarized as three types of negative emotion evolution phenomena: stable type, relatively stable type, and violently fluctuating type. Specifically, Type 1 belongs to negative emotion stable type, occupying the largest area, mainly distributed in the city center, urban business circles, transportation trunk lines, and near scenic spots; Type 2 belongs to negative emotion relatively stable type, with scattered distribution, mainly occupying most areas of the city; Type 3 belongs to negative emotion violently fluctuating type, with relatively small spatial proportion, mainly distributed in urban fringe areas, showing similar distribution characteristics to the violently fluctuating type of positive emotion.

4 Conclusions

This study is based on emotional geography, taking tourist emotion as the research object, relying on Xi'an Weibo data from 2013 to 2016, using visualization method and X-means clustering method to study and analyze the spatiotemporal variation of tourist emotions. The specific conclusions are as follows: (1) From a spatial perspective, tourist positive emotion values are high in the city' s main tourism functional areas. High emotional experience areas include the

ancient city tourism area and Qujiang New Area of Xi' an. Tourist emotions near the city center, main urban axis, major business circles, and scenic spots are relatively high and stable. Tourist negative emotion is mainly concentrated in transportation hubs dominated by stations and city entrances/exits, as well as urban fringe areas. (2) From a spatiotemporal perspective, tourist positive emotion hot spot areas show a significant pattern of diffusion from the city center and scenic spots to the surrounding areas. Cold spot areas of tourist positive emotion show a dispersion trend centered on urban fringe areas and transportation hubs. Cold spot areas of tourist negative emotion are similar to those of tourist positive emotion, both concentrated in urban fringe areas and transportation hubs dominated by city entrances/exits. Hot spot areas of tourist negative emotion have low aggregation and appear alongside cold spot areas. With the development of Xi' an' s urban tourism and improvement of the overall environment, and with tourists shifting from scenic spot tourism to city-wide tourism, the spatiotemporal aggregation effect of tourist emotional experiences has decreased. (3) In terms of spatiotemporal clustering effects, tourist emotional experiences showed little change from 2013 to 2016, and the spatiotemporal clustering results of positive and negative emotions also show certain similarities, mainly presenting three types: stable type, relatively stable type, and violently fluctuating type. The stable type is mainly concentrated in typical urban business circles, city center, around scenic spots, and near transportation trunk lines; the relatively stable type occupies a large area of Xi' an, with medium tourist emotion values; the violently fluctuating type forms aggregation areas in urban fringe areas.

Compared with previous studies, this research enriches the content of tourism emotion research, opens up new perspectives, and expands new research fields. Currently, research on tourism emotional experiences from the perspective of social media has just begun, and research combining emotion with urban zoning is almost blank. This study combines tourist emotional experiences, spatiotemporal changes, and urban environment to analyze the laws of tourist emotional changes in cities, hoping to provide theoretical basis for urban tourism development and urban infrastructure construction. In addition, compared with previous studies such as YU Jing' s use of nuclear density analysis to study emotion distribution, this study comprehensively uses grid map method, Getis-Ord Gi* method, and X-means clustering method to study emotion changes and analyze emotion patterns, which has certain methodological innovation.

5 Limitations and Prospects

(1) The accuracy of emotion calculation results needs improvement. Based on existing research, this study used the ROST EA Weibo emotion calculation software and updated the emoticon dictionary with re-assignment, which improved the accuracy of emotion value calculation results to a certain extent. However, tourist emotion is complex and changeable. How to understand and calculate tourist emotion more accurately will be an

important issue for future research.

(2) Data substitution issues. Due to the decline in Weibo usage popularity and API restrictions on Sina Weibo, the availability of Weibo data has become an important issue. Under such circumstances, future research may need to find new data sources based on Weibo data and use multiple data sources for collaborative complementarity.

(3) Enhance the role of tourist emotion in urban tourism planning. Give full play to the important role of tourist emotion in urban planning, and provide certain reference value and guidance for urban tourism development, urban environment creation, and urban road traffic construction.

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