



Study on Spatiotemporal Behavior of Self-driving Tourists in Inner Mongolia

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Abstract: Against the backdrop of normalized tourism and upgraded consumption, self-driving tours have become one of the main choices for tourists. Faced with the booming self-driving tour market, it is of great significance to explore the spatial behavior characteristics and temporal constraints of self-driving tourists within a given geographical area using GPS trajectory data. This exploration aids in the planning and design of self-driving tour routes and tourism products, and promotes the healthy and sustainable development of the self-driving tour industry. This paper selects the Inner Mongolia Autonomous Region as the self-driving tour hotspot area, collects GPS data of self-driving tourists from 2017 to 2022 on the online platform "Foooooot" using Python, and conducts in-depth exploration and comparative analysis of the spatiotemporal behavior trajectories of self-driving tourists, aiming to explore the spatiotemporal behavior characteristics of self-driving tourists and their constraining factors.

Keywords: GPS trajectory data; self-driving tourists; spatiotemporal behavior; tourist behavior characteristics; tourism demand

1. Introduction:

Nowadays, with the continuous increase in residents' travel demand and private car ownership, travelers' travel behaviors are influenced when accompanied by their children, leading them to prefer self-driving travel (Ye et al., 2018). The dominant role of emotional attitudes also indicates that car travel behavior is highly refined and suitable for most people (Fu, 2023). The freedom and comfort of self-driving travel are the main goals pursued by tourists (Shi et al., 2014), making it gradually one of the main ways of mass tourism. Inner Mongolia Autonomous Region is famous for its unique historical culture and grassland natural landscape. With a vast territory and a wide east-west span, the region's tourism resources are dispersed.

These characteristics make self-driving travel the preferred way of tourism in this region. According to the "Statistical Analysis Brief of Tourism in Inner Mongolia Autonomous Region 2020-2021," self-driving tourism accounts for more than 50% of tourism transportation methods, underscoring the significant potential of the self-driving tourism market in Inner Mongolia. This study uses a large amount of self-driving trajectory data and geotagged photos from online platforms such as "Fort."

These data can accurately reflect tourists' activity range, travel paths, points of interest, and mobility patterns, and can also reveal tourists' activity patterns, behavioral modes, and underlying constraints. Existing studies mainly focus on using "tourism digital footprints" to examine the spatial structure, organization of tourism routes, and characteristics of tourism flows in self-driving tourism, while research on deeper spatio-temporal behavioral characteristics, such as tourists' activity rhythms and patterns, is relatively lacking (Li & Wang, 2020).

This study aims to explore the spatiotemporal behavior characteristics of self-driving tourists within a geographic range and the temporal constraints, using GPS trajectory data from the Inner Mongolia Autonomous Region as an example. The conclusions of this study not only provide decision support for tourism operators, helping them better understand the needs and preferences of self-driving tourists, but also have significant implications for optimizing the development and utilization of tourism resources.

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2. Literature Review

In recent years, research on tourist behavior has been introduced into the field of self-driving tourism, attracting widespread attention. The characteristics of private car travel are mainly influenced by two factors: traveler attributes and urban characteristics (Feng, 2009). Domestic and international research has primarily focused on the relationship between individuals' social attributes and self-driving behavior, decision-making models for self-driving travel, the development of the self-driving tourism market, quantitative studies of self-driving routes, and related topics (Chen, 2004; Yang & Chen, 2017). Studies have analyzed tourists' destination choices and the factors influencing their decisions by constructing spatial movement models (Lew & McKercher, 2006) and by developing approaches to reduce carbon dioxide (CO₂) emissions associated with car travel (Mishina & Muromachi, 2012). Other research has examined the source market structure and spatial behavior patterns of self-driving tourists using tourism flow spatial usage curves (Wang & Cao, 2019). At the same time, additional studies have employed online travelogue data, combined with social network analysis, GIS, and statistical methods, to reveal the characteristics and network structure of self-driving tourist markets in specific regions (Luo & Liang, 2016).

GIS technology has been used to analyze the spatial distribution of self-driving campsites nationwide, revealing that they are mainly concentrated in economically developed, resource-rich areas, with their development driven by market demand, resource endowment, transportation conditions, and policy support (Xue & Bai, 2023). Spatial analyses based on shared self-driving trajectory data have explored travel distances and destination selection patterns of urban self-driving tourists (Zhou et al., 2015). However, relatively little research has focused on the spatiotemporal behavior of self-driving tourists. This is mainly because tourists control their own vehicles, resulting in highly flexible, variable activity patterns. Consequently, spatiotemporal behavioral data are challenging to collect in real time, which may result in insufficient timeliness, coverage, and representativeness (Zhang et al., 2018). Based on time geography theory and focusing on self-driving tourists in Inner Mongolia, this study analyzes the spatiotemporal behavior of self-driving tourism to identify its macroscopic temporal and spatial characteristics.

3. Methodology

Traditional methods for studying tourists' spatial behavior mainly include surveys, behavioral observations, and cognitive mapping tests, which are time-consuming, labor-intensive, and prone to significant errors in research results (Bursa et al., 2022). The analysis in this paper focuses on two main aspects: spatial behavior and temporal behavior. From a spatial perspective, the relationship between self-driving tourists and roads and attractions is the most prominent. By analyzing the spatial relationships among tourists' points of interest, roads, and attractions, this study explores tourists' movement paths and spatial aggregation characteristics. From a temporal perspective, the analysis is divided into two dimensions – interannual and seasonal (quarterly) – to examine the evolution of tourist behavior across different seasons and to explore the temporal constraints faced by self-driving tourists (Liu et al., 2019).

“Foot” is an online platform that provides specialized functions for self-driving tourists to share and record travel trajectories. Compared with traditional questionnaire surveys, GPS data offer clear advantages for revealing characteristics of tourist behavior, particularly in terms of the accuracy and reliability of spatiotemporal information (Shuai, 2022). GPS trajectories can represent the spatial distribution patterns of different types of tourist behavior at multiple spatiotemporal scales. At the same time, they are well aligned with the spatial patterns of location-based photographs and the posted stay durations by tourists (Akciek et al., 2024).

Therefore, this platform provides a valuable data source for in-depth research on the spatiotemporal behavior of self-driving tourists. Data collection is a key step in this study. Data collection scripts were developed in Python to obtain GPS data from self-driving tourists in Inner Mongolia via the “Foot” platform for the period from 2017 to 2022. Through application programming interfaces (APIs), detailed information was collected, including tourists' travel trajectories, travel times, and points of stay. During the data collection process, relevant laws, regulations, and ethical guidelines were strictly followed to protect tourists' privacy and personal information security. Only anonymized data were collected, and strict measures were implemented to ensure data confidentiality and secure storage.



4. Research Object

The official websites of the PSCs are visited to collect data on their objectives, research areas, publications, collaborations, and historical development. News reports from authentic media sources are used as references when some official websites are not functioning correctly. Previous studies have shown that self-driving tourism flows in urban clusters are influenced by factors such as tourism resources, transportation conditions, economic factors, and the tourism industry, and these factors interact with each other ([Wang et al., 2015](#)). The spatial behavior patterns are closely related to the population base of the tourist source and the resource level and scale of the tourist destination ([Chen et al., 2020](#)). Inner Mongolia is rich in natural scenery and ethnic cultural resources. When the source area's characteristic resources are highly compatible with tourists' interests, potential tourists in the source area are often attracted to the destination city's characteristic resources.

Among the many factors influencing self-driving tourism, climate is a direct driver of tourism seasonality in China ([Feng & Liu, 2023](#)). Tourists are mainly influenced by temperature and holidays when choosing the timing and types of tourist attractions, and adverse weather conditions can negatively affect travel behavior ([Wu et al., 2016](#)). Given that Inner Mongolia experiences pronounced annual and seasonal climatic variations, it provides a suitable context for examining the spatiotemporal behavior characteristics of self-driving tourists across different years and seasons.

In addition, when selecting self-driving tourism destinations, tourists primarily consider three aspects: destination attributes, destination image, and personal experience. Due to Inner Mongolia's extensive east-west span, distances between attractions are considerable, and some scenic sites are located in remote areas. Consequently, transportation choice plays a crucial role in tourist travel. For the exact origin-destination pair, the average travel time of auxiliary buses is nearly twice that of private cars, and the standard deviation of travel time is approximately four times greater. Compared with public transportation, car travel exhibits a significant spatiotemporal compression effect, making self-driving travel clearly advantageous. Transportation is one of the most important factors shaping the spatial structure of tourist flows, and transportation infrastructure—such as highways and service areas—significantly influences the development and utilization of tourism resources ([Wang et al., 2015](#)). With the continued growth of the self-driving tourism market, Inner Mongolia has steadily improved its transportation infrastructure, providing greater convenience and safety for self-driving tourists.

Regarding the research period, notable differences in social conditions existed between 2017–2019 and 2020–2022. Under the influence of the epidemic, higher risk perception among self-driving tourists is associated with lower travel and recommendation intentions ([Shuai, 2022](#)). At the same time, tourist travel behavior exhibits a pronounced “holiday effect” as well as a “brake effect” caused by significant events. Tourists are susceptible to both effects, which are characterized by a long lag period ([Liu et al., 2019](#)). For these reasons, the Inner Mongolia Autonomous Region was selected as the study area. By analyzing GPS data from self-driving tourists in this region, this study aims to gain deeper insights into their spatiotemporal behavior characteristics and the constraints affecting self-driving tourism. The findings are expected to provide a scientific basis and decision support for the development of self-driving tourism in the Inner Mongolia Autonomous Region and other comparable regions.

5. Spatiotemporal Characteristics of Self-Driving Tourists

5.1 Temporal Characteristics

5.1.1 Visiting Duration

During the period from 2017 to 2019, self-driving tourists in Inner Mongolia tended to stay longer. Besides the allure of unique attractions, factors such as exceptional experiences and diverse cultural activities contributed to extended visitor stays. Visitor durations ranged from 1 to 20 days, with the majority opting for 3-day stays, mainly comprising leisure travelers seeking to experience the region's unique scenery and culture within a limited time. A significant proportion also stayed for 4 to 9 days, allowing for more flexible itinerary planning and deeper exploration of the region. However, from 2020 to 2022, most visitors' durations decreased to 1 to 2 days, indicating a significant reduction in travel time. This shift can be attributed to the pandemic's impact on the tourism industry, with many tourists opting for short trips and emphasizing the safety and hygiene conditions of their destinations.

5.1.2 Annual Variation

From 2017 to 2019, self-driving tourist traffic in Inner Mongolia showed significant annual fluctuations, with peaks during the June and October tourism seasons. This can be attributed to several factors, including favorable weather conditions during June and October and the availability of various activities and programs at tourist attractions during these months. However, from 2020 to 2022, the year-round fluctuations in self-driving tourist numbers decreased. Statistically, there was a noticeable increase in self-driving tourists from October to December compared to pre-pandemic levels. This trend can be attributed to various factors, including the gradual control of the pandemic, increasing travel desires and demands, reduced reliance on long holiday periods for travel, and heightened government and social media promotion of self-driving tourism.

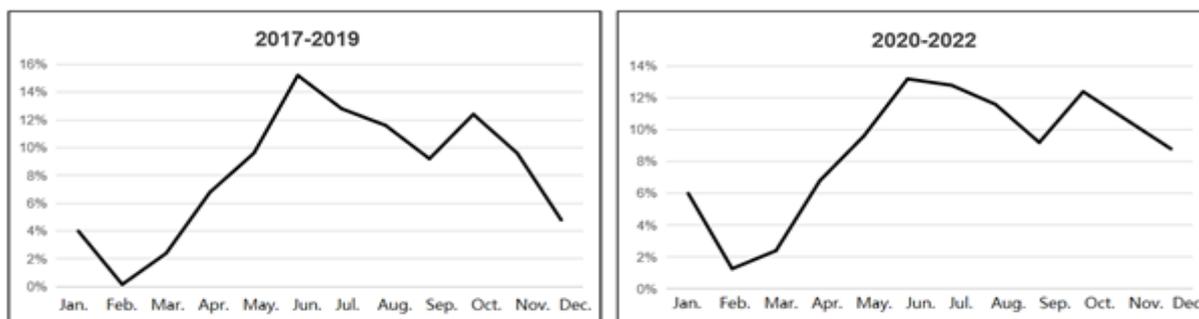
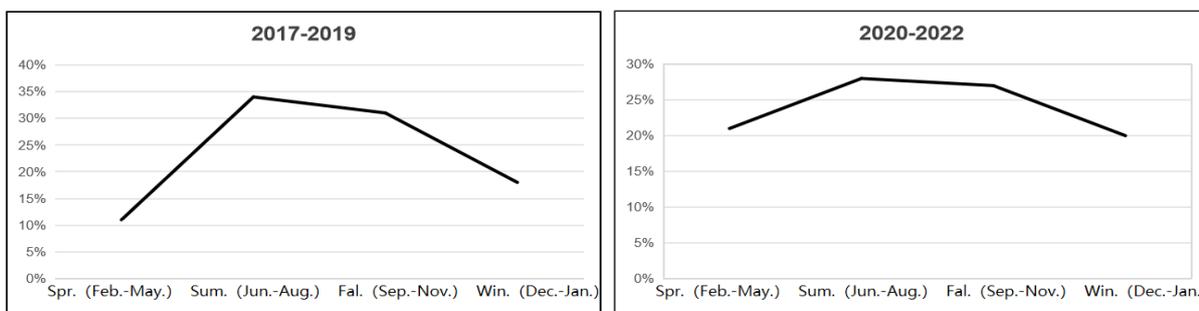


Figure 1: Annual variation of self-driving tourists in Inner Mongolia (Jan to Dec)

5.1.3 Seasonal Differences

From 2017 to 2019, there were significant seasonal differences in self-driving tourism in Inner Mongolia, with peaks in summer and autumn and fewer tourists in winter and spring. Summer and autumn, with their pleasant weather and various activities, attracted a large number of self-driving tourists. Conversely, winter's cold weather and potential road hazards deterred many tourists, leading to fewer self-driving tourists during this season. However, from 2020 to 2022, the seasonal variation in self-driving tourists decreased. This change can be attributed to factors such as increased interest in self-driving tourism amid the pandemic, heightened enthusiasm for winter sports tourism following discussions about the 2022 Winter Olympics, and the development of travel platforms that facilitate self-driving trips.



Spr(Feb-May) Sum(Jun-Aug) Aut(Sep-Nov) Win(Dec-Jan)

Figure 2: Seasonal difference distribution of self-driving tourists in Inner Mongolia

5.2 Spatial Characteristics

5.2.1 Spatial Distribution

The trajectory of self-driving tourism activity in Inner Mongolia shows a pattern of multiple core nodes radiating from polygonal areas. Overall, it can be divided into three main routes attracting tourists from surrounding and neighboring provinces. The first route runs from Hulunbuir to Tongliao through Xing'an League, forming the eastern route of self-driving tourism. The second route passes through Hohhot, Baotou, to Ordos and Ulanqab, representing the central route of self-driving tourism. The third route focuses on the Alxa League and Bayannur, constituting the western route of self-driving tourism. Additionally, the eastern area of Inner Mongolia shows higher node connectivity density than the central and western areas.



5.2.2 Density Spatial Distribution of Self-Driving Tourists

Before the pandemic (2017-2019), there were spatial differences in the distribution of self-driving tourists in Inner Mongolia. The eastern region had higher self-driving tourist numbers and density throughout the year compared to the central and western regions. This can be attributed to the rich natural landscapes and convenient transportation networks in the eastern region. However, since the outbreak of the pandemic (2020-2022), a downward trend in self-driving tourist density, especially in the segment from Hulunbuir to Manzhouli, has been observed in the eastern region. This change is primarily influenced by the pandemic's impact on the tourism industry and travel restrictions.

Hohhot, Baotou, Ordos, Chifeng, Tongliao, Hulunbuir, Ulanqab, Bayannur, Wuhai, Xilin Gol, Alxa, Hinggan.

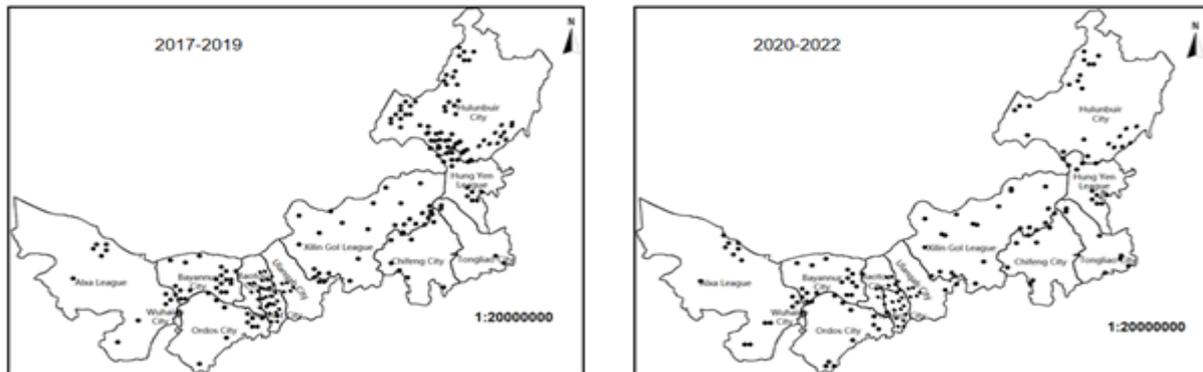


Figure 3: Spatial distribution of self-driving tourist density in Inner Mongolia

5.2.3 Destination Selection of Self-Driving Tourists

Before the pandemic (2017-2019), self-driving tourists in Inner Mongolia mainly came from economically developed areas, with Beijing and Tianjin being the main source markets. The potential local market for self-driving tourism in Inner Mongolia is significant, yet the proportion of visitors from neighboring provinces is relatively low. Self-driving tourists from different regions showed preferences in destination selection. For example, visitors from Beijing preferred destinations such as Chifeng and Xilinhot, while those from Heilongjiang and Jilin provinces preferred the northern city of Hulunbuir. Additionally, tourists from Gansu and Ningxia Hui Autonomous Region preferred Alxa League for self-driving tours.

6. Conclusion

This study compared and analyzed the spatiotemporal behavior patterns of self-driving tourists in the Inner Mongolia Autonomous Region during two periods: 2017 to 2019 and 2020 to 2022, aiming to explore the evolving trends and influencing factors of self-driving tourist behavior. The results indicate significant changes in behavior patterns in both temporal and spatial dimensions.

In terms of temporal dimension, there was an expansion of self-driving tourism activity seasons, characterized by a significant increase in the number of tourists during non-traditional tourist seasons. This shift suggests that self-driving tourism is overcoming seasonal limitations and gradually transitioning to year-round activities. Further analysis of data from 2020 to 2022 revealed shorter overall travel time, shorter stay duration, and a faster tourism pace, with self-driving activities mainly concentrated in autumn. This phenomenon is closely related to heightened attention to tourism safety and hygiene during the pandemic, reflecting self-driving tourists' rapid adaptation to changes in tourism patterns driven by global events.

In the spatial dimension, self-driving routes became shorter over time, with tourists preferring closer destinations and a higher concentration of points of interest. Additionally, the travel pattern shifted from circular routes to linear routes, with paths becoming more singular. Furthermore, the number of tourists from neighboring provinces and cities decreased, with provincial tourists becoming the main force in self-driving tourism. This change led to adjustments in the focus of tourism routes. These changes in spatial behavior reflect new tendencies of self-driving tourists in destination selection and itinerary planning, prioritizing distance and safety.

Overall, the mode of self-driving tourism in Inner Mongolia has shifted from multi-point stays and circular routes to fixed-point stays and linear routes, with the pace of tourism evolving from slow to more compact and faster. This transformation is primarily to meet the demand for short-distance travel and reduce potential risks during travel.

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Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with ethical guidelines, and all necessary approvals were obtained.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

References

- Akcicek, C., Misra, A., Shirgaokar, M., & Marshall, W. (2024). How time-inefficient and uncertain are paratransit trips compared to car trips? *Transportation Research Record*, 2678(1), 272-285.
- Bursa, B., Mailer, M., & Axhausen, K. W. (2022). Travel behavior on vacation: tourists' transport mode choice at destinations. *Transportation Research Part A: Policy and Practice*, 166, 234-261.
- Chen, Q. (2004). Research on the development of the self-driving tourism market. *Tourism Tribune*(03), 66-71.
- Chen, S., Xi, J., & Liu, M. (2020). Analysis of complex transportation network and its tourism utilization potential: A case study of Guizhou expressways. *Complexity*, 2020, 1-22.
- Feng, C. X. H. L. (2009). Private car travel characteristics and influencing factors in Chinese cities: A case study of Guangzhou in Guangdong, China. *Chinese Geographical Science*(004), 325-332.
- Feng, J., & Liu, X. (2023). Analysis of the influence of risk perception of self-driving tourists to Xinjiang on travel intentions: Based on the moderated mediation model. *Xinjiang Social Science Forum*(02), 102-112.
- Fu, X. (2023). Identifying the nature of travel by different transport modes as consummatory or instrumental. *Transportation Research Record*.
- Lew, A., & McKercher, B. (2006). Modeling tourist movements: A local destination analysis. *Annals of Tourism Research*, 33(2), 403-423.
- Li, W., & Wang, K. (2020). Research on the spatiotemporal characteristics and development of rural self-driving tourism in Henan Province based on digital footprints. *Journal of Social Sciences of Yunnan Agricultural University*, 14(03), 79-85.
- Liu, Y., Bao, J., & Huang, Y. (2019). A study on the spatiotemporal behavior of self-driving tourists based on GPS data: A case study of Tibet. *World Regional Studies*, 28(01), 149-160.
- Luo, Q., & Liang, S. (2016). Research on the spatiotemporal characteristics of self-driving tourist flow based on digital footprints: A case study of Yunnan Province. *Tourism Tribune*, 31(12), 41-50.
- Mishina, Y., & Muromachi, Y. (2012). Revisiting decomposition analysis for carbon dioxide emissions from car travel: Introduction of the modified Laspeyres index method. *Transportation Research Record*, 2270(1).
- Shi, C., Sun, Y., & Zhang, H. (2014). A study on the satisfaction of self-driving tourists based on a structural equation model. *Geographical Research*, 33(04), 751-761.
- Shuai, L. (2022). Exploration of the driving factors in destination selection for self-driving tourists. *Chinese Collective Economy*(06), 140-141.



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- Wang, D., Chen, T., & Lu, L. (2015). The high-speed rail effect and mechanism of regional tourism flow spatial structure: A case study of China's Beijing-Shanghai high-speed rail. *Acta Geographica Sinica*, 70(02), 214-233.
- Wang, L., & Cao. (2019). Accessibility comparison and spatial differentiation of Xi'an scenic spots across different modes based on Baidu real-time travel data. *Chinese Geographical Science*, 29(05), 126-138.
- Wu, J., Zhang, X., & Ye, L. (2016). Study on the fluctuation characteristics of tourism passenger flow at different time scales: A case study of Nyingchi City, Tibet. *Geographical Research*, 35(12), 2347-2362.
- Xue, C. H., & Bai, Y. P. (2023). Spatiotemporal characteristics and factors influencing urban tourism market network in Western China: Taking Chengdu as an example. *Sustainability*, 15(10), 8135.
- Yang, B., & Chen, X. (2017). Study on spatiotemporal behavior of self-driving tourism based on network log content analysis: A case study of Hanzhong City, Shaanxi Province. *Journal of Western Human Settlements*, 32(05), 76-82.
- Ye, N., Gao, L., & Juan, Z. (2018). Are people from households with children more likely to travel by car? An empirical investigation of individual travel mode choices in Shanghai, China. *Sustainability*, 10(12).
- Zhang, X., Li, J., & Zuo, Y. (2018). Analysis of spatiotemporal behavior characteristics of tourists based on digital footprints: A case study of Nanjing. *Economic Geography*, 38(12), 226-233.
- Zhou, C., Feng, X., & Jin, C. (2015). Analysis of seasonality and potential enhancement of tourism in China based on climate comfort. *Resource Development & Market*, 31(12), 1529-1533.