Journal of Social Sciences and Economics
Vol. 3(1), 2024, 48-54
ISSN (Online) 2958-1532
https://finessepublishing.com/jsse

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 constraint factors of self-driving tourists within a geographical range using GPS trajectory data. This exploration aids in the planning and designing 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 "Fooooooot" 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 [1]. The dominant role of emotional attitudes also indicates that car travel behavior is highly refined and suitable for most people [2]. The freedom and comfort of self-driving travel are the main goals pursued by tourists [3], making self-driving travel gradually become 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 large span from east to west, tourism resources in the region are distributed in a dispersed manner. 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 the tourism transportation methods, demonstrating the huge potential of the self-driving tourism market in Inner Mongolia. This study utilizes a large amount of self-driving trajectory data and geotagged photos provided by online platforms such as "Fort" These data can accurately reflect the activity range, travel paths, points of interest, and mobility patterns of tourists [4], and can also reveal the activity patterns, behavior modes, and underlying constraint factors behind these behaviors of tourists. Existing studies mostly focus on utilizing "tourism digital footprints" [5] to study the spatial structure, organization of tourism routes, and tourism flow characteristics of self-driving tourism, while research on deeper spatio-temporal behavior characteristics such as activity rhythms and behavior patterns of tourists is relatively lacking.

This study aims to explore the spatiotemporal behavior characteristics of self-driving tourists within a geographical range and the temporal constraint factors using GPS trajectory data, taking 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.

[Received] 19 Feb 2024; Accepted 21 Apr 2024; Published (online) 24 Apr 2024]
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DOI: 10.61363/j884n740

2. Literature Review

In recent years, research on tourist behavior has been introduced into the field of self-driving tourism and has received widespread attention. The characteristics of private car travel are mainly influenced by two factors: the attributes of travelers and the characteristics of cities [6]. Domestic and foreign scholars have mainly focused on the relationship between the social attribute characteristics of behavioral individuals and self-driving behavior, decision-making models for self-driving behavior, the development of the self-driving tourism market, quantitative research on self-driving routes, and other aspects [7-13]. For example, Lew et al. analyzed the characteristics of tourists' choice of destination and the factors influencing tourists' decisions by establishing a spatial movement model for tourists [14]. Mishina, Yoshinori, and others researched how to reduce carbon dioxide (CO2) emissions related to car travel [15]. Lu Song and other domestic scholars analyzed the source market structure and spatial behavior patterns of self-driving tourists in Huangshan City using tourism flow spatial usage curves [16]. Zhao Wei et al., based on the mining of online travelogues, comprehensively used social network analysis methods, GIS, and mathematical statistics techniques to reveal the characteristics of the self-driving tourist market and network structure in Fujian Province [17]. Li Feng et al. used GIS technology to analyze the spatial distribution characteristics of 380 self-driving campsites nationwide and found that self-driving campsites are mainly concentrated in economically developed and resource-rich areas, and their development relies on the market, resources, transportation, and policy drivers [18]. Gu Yijiang, Sun Gennian, and others used data such as self-driving trajectories shared by relevant users and conducted a spatial analysis using GIS to explore the spatial distance and destination selection of urban self-driving travel [19]. However, relatively little research has been conducted on the spatiotemporal behavior of self-driving tourists. This is because tourists control their vehicles independently, and their activities have high flexibility and variability. The spatiotemporal data of tourist behavior are difficult to collect in real-time, which may lead to insufficient timeliness, coverage, and representativeness of data [20].

This study, based on the theory of time geography and focusing on self-driving tourists in Inner Mongolia, analyzes the spatiotemporal behavior of self-driving tourism to obtain the temporal and spatial characteristics of self-driving tourism at a macroscopic level.

3. Methodology

Traditional methods for studying tourist spatial behavior characteristics mainly include surveys, behavioral observations, and cognitive mapping tests, which are time-consuming labor-intensive, and prone to large errors in research results [21]. The analysis in this paper mainly focuses on two aspects: spatial behavior and temporal behavior. In terms of space, the connection between self-driving tourists and roads and attractions is the most prominent. By analyzing the spatial distribution relationship between tourists' points of interest and roads/attractions, we explore the spatial movement and aggregation characteristics of tourists. In terms of time, the analysis is divided into two dimensions: intra-annual and quarterly, to analyze the evolution of tourist behavior in different seasons and explore the temporal constraints of self-driving tourists [4]."Foot" is an online platform that specifically provides functions for self-driving tourists to share and record travel trajectories. GPS has obvious advantages over traditional questionnaire surveys in revealing tourist behavior characteristics, including the precision and reliability of spatiotemporal behavior [22]. 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 coupled with the spatial patterns of location photos and stay times posted by tourists [23]. This platform provides a valuable data source for in-depth research on the spatiotemporal behavior characteristics of self-driving tourists.

Data collection is a key step in this study. We wrote data collection scripts using the Python programming language to obtain GPS data from self-driving tourists in Inner Mongolia from the "Fort" platform for the years 2017 to 2022. Through API interfaces, we obtained detailed information such as tourists' travel trajectories, travel times, and points of stay. During the data collection process, we followed relevant laws, regulations, and ethical guidelines to protect the privacy and personal information security of tourists. We only collected anonymized data and strictly ensured the confidentiality and storage of the data to ensure its security and sensitivity.

4. Research Object

Official Website Analysis and news reportThe official websites of the PSCs are visited to collect data, on their objectives, research areas, publications, collaborations, and historical development. News reports by authentic media are adopted for references when some of the official websites are not functioning properly.

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 [24]. 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 [25]. Inner Mongolia is rich in natural scenery and ethnic cultural resources. When the characteristic resources of the tourist source area are highly compatible with the interests of tourists, potential tourists in the source area are usually attracted by the characteristic resources of the destination city [26].

Among the many factors influencing self-driving tourism, the climate environment is a direct factor affecting the seasonality of tourism in China [27]. Tourists are mainly influenced by temperature and holidays when choosing the timing and type of tourist attractions [28], and adverse weather conditions can have a certain impact on tourist travel [29]. Considering that Inner Mongolia has significant annual and seasonal climate changes, it is conducive to understanding the spatiotemporal behavior characteristics of self-driving tourists in Inner Mongolia over the years and seasons.

On the other hand, when choosing self-driving tourism destinations, tourists mainly consider three aspects: the attributes, images, and personal experiences of the destination [30]. Due to the long span from east to west in Inner Mongolia, the distances between attractions are relatively long, and some scenic spots are located in remote areas. The choice of transportation is of great significance for tourist travel. Between the same starting and ending points, the average travel time of auxiliary buses is almost twice that of ordinary cars, and their travel time standard deviation is four times that of car travel standard deviation [31]. Compared with taking public transportation, car travel shows a significant spatiotemporal compression effect [32], and choosing self-driving travel has obvious advantages over other travel modes. Transportation is one of the most important factors affecting the spatial structure of tourist flows [33], and transportation infrastructure such as highways and service areas has a significant impact on the development and utilization of the tourism industry [34]. With the development of the self-driving tourism market, Inner Mongolia has continuously improved its self-driving tourism infrastructure, providing convenience and security for self-driving tourists.

In terms of the research period, there were significant differences in social conditions between 2017 to 2019 and 2020 to 2022. Under the influence of the epidemic, the higher the risk perception of self-driving tourists, the lower their willingness to travel and recommend [35]. At the same time, tourist travel shows a significant "holiday effect" and a "brake effect" caused by major events, and tourists are highly sensitive to the "holiday effect" and "brake effect" of major events, with a long lag time for these effects [36]. For these reasons, the Inner Mongolia Autonomous Region was chosen as the hotspot area for this study. By analyzing the GPS data of self-driving tourists in this area, we can gain in-depth insights into the spatiotemporal behavior characteristics of self-driving tourists in the region and the constraints of self-driving tourism, thereby providing scientific basis and decision support for the development of self-driving tourism in Inner Mongolia Autonomous Region and other 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 have longer stays. Besides the allure of unique attractions, factors such as special 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 impact of the pandemic on the tourism industry, with many tourists opting for short trips, 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 occurring during the tourism peak seasons of June and October. 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 fluctuation in self-driving

tourist numbers throughout the year 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 dependence on long holiday periods for travel, and the heightened promotion of self-driving tourism by governments and through social media.

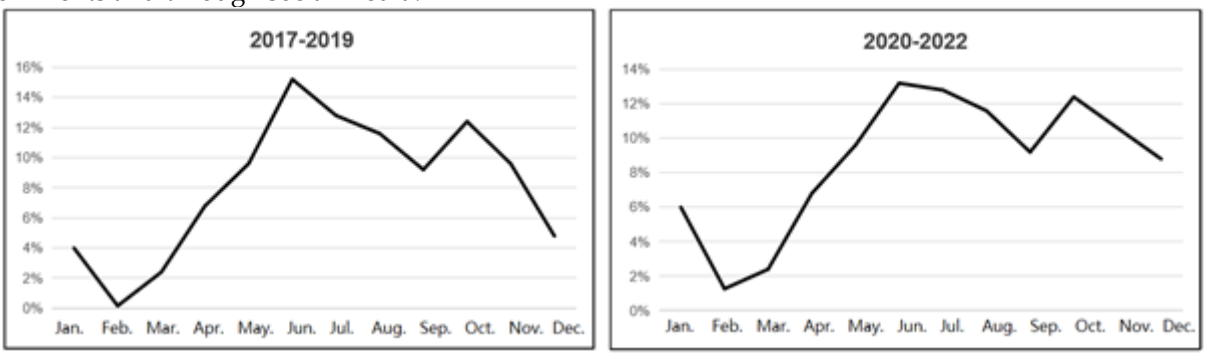

Figure 1. Annual variation of self-driving tourists in Inner Mongolia
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

5.1.3 Seasonal Differences

From 2017 to 2019, there were significant seasonal differences in self-driving tourism in Inner Mongolia, with peaks occurring during summer and autumn and fewer tourists during 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 due to the pandemic, heightened enthusiasm for winter sports tourism following discussions about the 2022 Winter Olympics, and the development of travel platforms facilitating self-driving trips.

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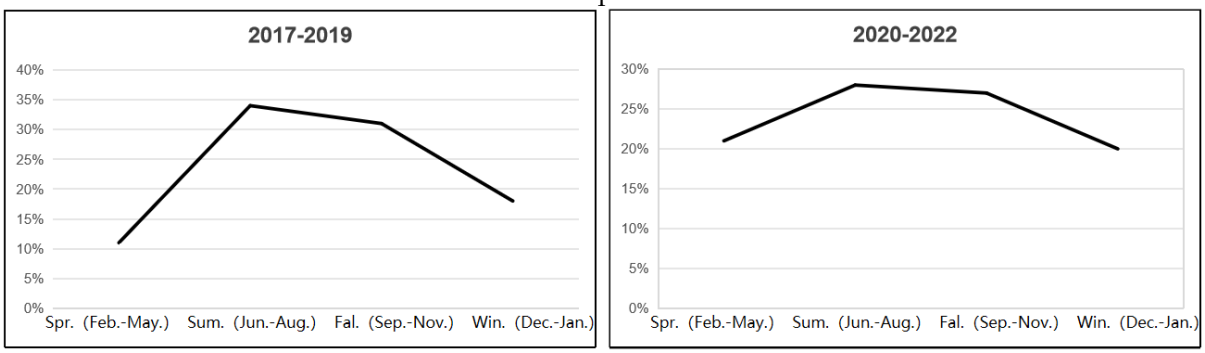

(Feb-May) Sum(Jun-Aug) Aut(Sep-Nov) Win(Dec-Jan)
Figure 2. Seasonal difference distribution of self-driving tourists in Inner Mongolia

5.2 Spatial Characteristics

5.2.1 Spatial Distribution

The self-driving tourism activity trajectory in Inner Mongolia exhibits a trend 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 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.

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5.2.2 Density Spatial Distribution of Self-Driving Tourists

Before the outbreak of 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 largely 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.

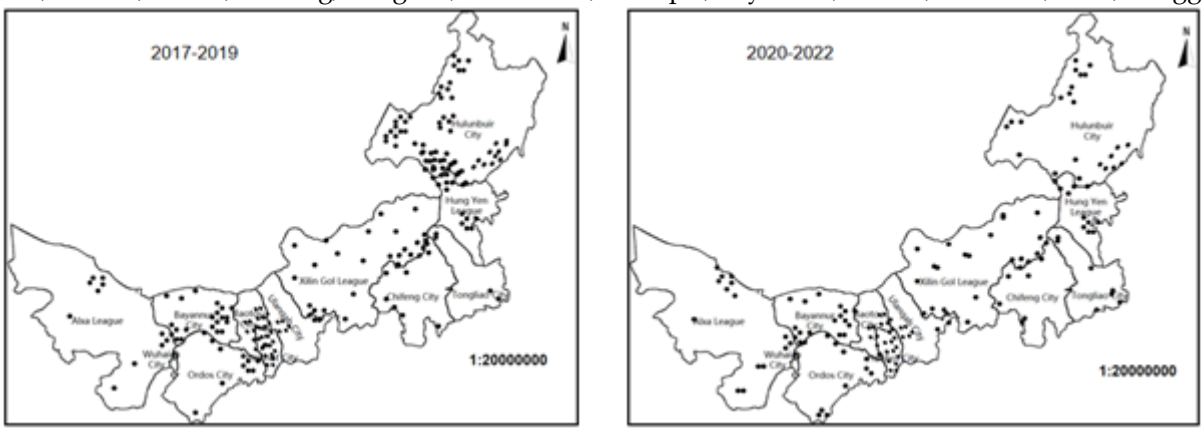

Figure 3. Spatial distribution of self-driving tourist density in Inner Mongolia

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, with a relatively low proportion of visitors from neighboring provinces. Different regions' self-driving tourists showed some preferences in destination selection. For example, visitors from Bei-jing 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 sea-sons, characterized by a significant increase in the number of tourists during non-traditional tourist seasons. This shift suggests that self-driving tourism is breaking through seasonal limitations and gradually transitioning to year-round tourism activities. Further analysis of data from 2020 to 2022 revealed a shorter overall travel time, reduced stay duration, and faster tourism pace, with self-driving activities mainly concentrated in autumn. This phenomenon is closely related to increased attention to tourism safety and hygiene during the pandemic, reflecting self-driving tourists' rapid adaptation to changes in tourism patterns under global events.

In the spatial dimension, self-driving routes became shorter in later periods, with tourists preferring closer destinations, and a higher concentration of interest point distribution. Additionally, the travel pattern shifted from circular routes to linear routes, with paths becoming more singular. Furthermore, there was a decrease in the number of tourists from neighboring provinces and cities, with provincial tourists becoming the main force of 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 transitioned from previous multi-point stays and circular routes to fixed-point stays and linear routes, with tourism pace evolving from a slow pace to a

more compact and faster pace. This transformation is primarily to meet the demand for short-distance travel and reduce potential risks during travel.

This study is supported by: 1. Inner Mongolia culture and tourism development research project in 2023, grant number 2023-WL0037.2. The Fundamental Research Funds for the Inner Mongolia Normal University, grant number:2022JBXC007. 3. Graduate students research & Innovation Fund of Inner Mongolia Normal University, grant number: CXJJS22040.

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