Analysis of Taxi Trip Distribution Characteristics Based on GPS Data

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Abstract: Taxi, as one of the important passenger transportation modes in cities, has always had the problem of imbalance between supply and demand. Analyzing the characteristics of taxi travel distribution can effectively help relevant departments realize scientific taxi dispatch, thereby solving the contradiction between supply and demand between taxis and passengers. To achieve the above goals, this article takes Beijing as an example, and analyzes the temporal and spatial distribution characteristics of taxi travel based on the GPS data of taxis in Beijing from January 1 to January 14, 2019. The research results show that: in terms of time, the total number of taxi trips on weekdays is higher than that on weekdays. The peak average total number of trips on weekdays is 14,000 passengers/h, and on weekends it is 10,000 passengers/h. Spatially, the distribution of taxi trips is consistent, mainly in core areas such as essential transportation hubs.

Keywords: Taxi, Time distribution, Spatial distribution, Traffic Planning

1. Introduction

The "door-to-door" and "point-to-point" convenience of taxis make it popular among urban residents. The average daily empty rate of cruising taxis is between 35% and 50%, while the waiting time for bus rides in large cities can be up to half an hour, resulting in a severe imbalance of supply and demand between taxis and passengers[1]. To solve the above problems, in recent years, relevant researchers at home and abroad have analyzed the distribution of taxis in the city, hoping to scientifically optimize the scheduling of taxis, to achieve the balance of supply and demand between taxis and passengers[2]. Related research mainly studies the temporal and spatial distribution of taxi travel, reflecting the residents' travel law and the main flow of urban traffic from the perspective of time and space, and provides important guidance for the management and layout of urban taxis[3-4]. However, related researchers also have corresponding research deficiencies[5]. For example, the data set analyzed in the completed research is earlier and the amount of data is small[6], which leads to inconsistent with the current traffic development law[7]. Therefore, based on the above research deficiencies, this article uses the GPS data of taxis in Beijing from January 1 to January 14, 2019, and accurately divides the travel data into working days, weekends, and peak hours in terms of space. Python's Geopandas module performs gridding for division. In the end, we can accurately analyze the travel distribution characteristics of Beijing taxis in time and space.

2. Analysis of the Characteristics of the Temporal and Spatial Distribution of Taxi Travel

2.1. Analysis of Travel Time Characteristics

By collecting the taxi pick-up and drop-off points each hour, the residents' pick-up and drop-off amounts in each hour are obtained, and the time series comparison analysis is made on the 14-day pick-up and drop-off amounts. As shown in Figure 1, the amount of getting on and off the taxi on January 1 (New Year's Day) is lower than that of daily workdays and weekends. Except for January 1, the amount of getting on and off shows a cyclical change over time. The specific manifestation is that the daily changes in the amount of getting on and off the taxi on weekdays are similar, and the amount of getting on and off the taxi on weekends drops sharply, and Saturday is slightly higher than that on Sunday.
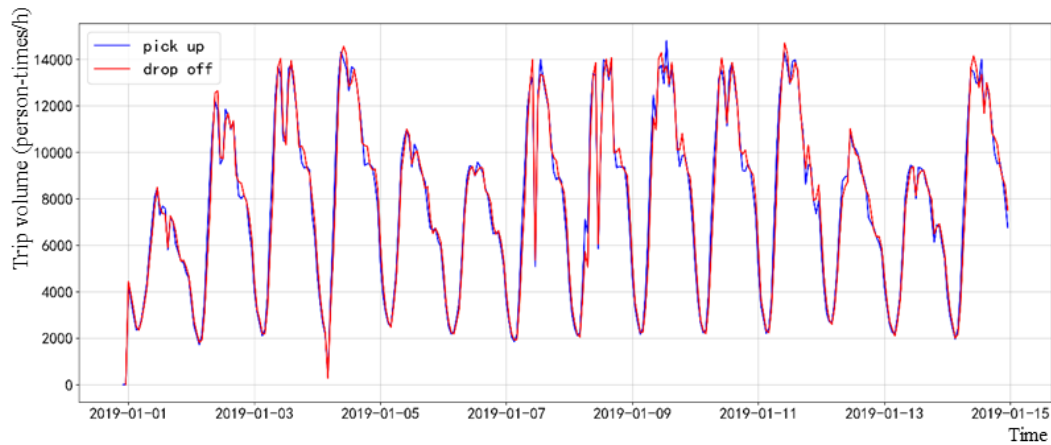
Figure 1: Time series comparison of the amount of getting on and off the bus from January 1st to January 14th.

Since the number of taxis boarding and alighting are basically the same, to fully describe the law of taxi travel distribution over time, the total number of trips is defined as the average number of taxis boarding and alighting. From the above analysis, we can see that the time distribution characteristics of taxis on working days and weekends are different. Thus, the total number of trips on working days and weekends is analyzed separately.
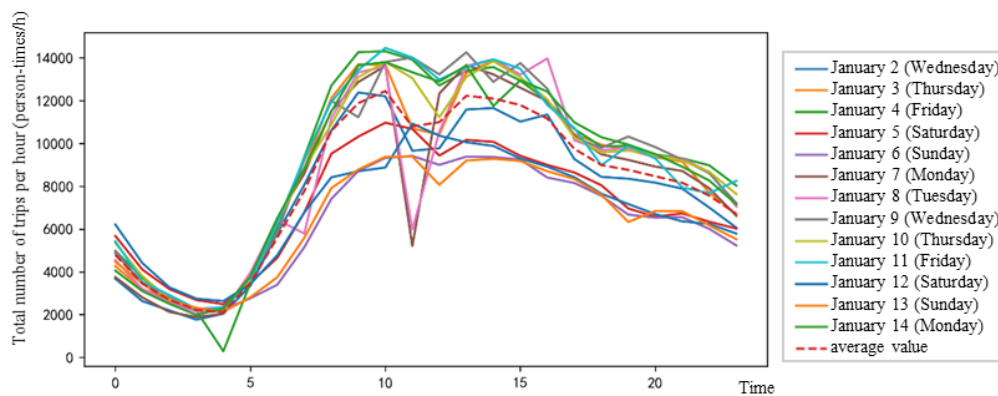

Figure 2: Taxi trip volume analysis.

It can be seen from Figure 2 that the morning and evening peak hours of weekend taxis are 9:00-11:00 and 19:00-21:00 respectively, lagging behind 8:00-10:00 and 18:00-20:00 on weekdays. The afternoon peak hours on weekdays and weekends are consistent, and the total number of trips reached their peak between 14:00 and 16:00. Comparing the total amount of trips between the two, it can be seen that the peak average total number of trips on weekdays is 14,000 person-times/h, which is much higher than the peak average total number of trips on weekends of 10,000 person-times/h. The reason is that most people take a break on weekends, and residents have less travel demand, so the total amount of travel is much lower than that of working days. There are also specific differences in the time distribution characteristics of Saturday and Sunday during the weekend. It can be seen that the total number of trips on Sunday is lower than the total number of trips on Saturday.

2.2. Analysis of Travel Space Characteristics

By gridding the administrative divisions of Beijing, using Python's Geopandas module to plot the spatial distribution of trips, due to the significant difference in the amount of trips between weekdays and weekends in the time characteristics, the data of pick-up and drop-off points are divided into weekdays and weekends.

2.2.1. Spatial Distribution of Travel in Various Periods of the Working Day

According to the time characteristics of taxi travel in Beijing, the time is divided into 8:00-10:00, 14:00-16:00, and 18:00-20:00, and the distribution of travel space on weekdays is analyzed respectively. The three time periods correspond to the morning peak, noon peak, and evening peak of
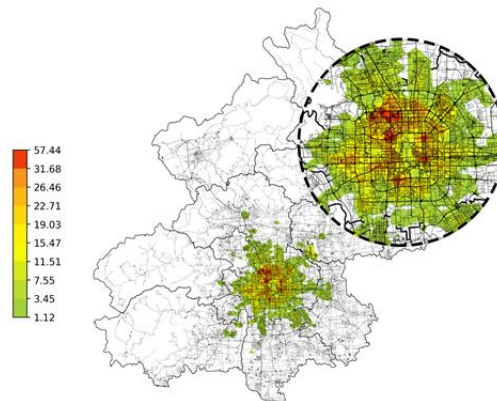
taxi travel. The heat map of travel distribution at each time of the working day is shown in Figure 3. The density is divided into 10 levels, from green to red indicating that the density gradually increases, so as to analyze the travel distribution law of taxis during peak hours on working days.
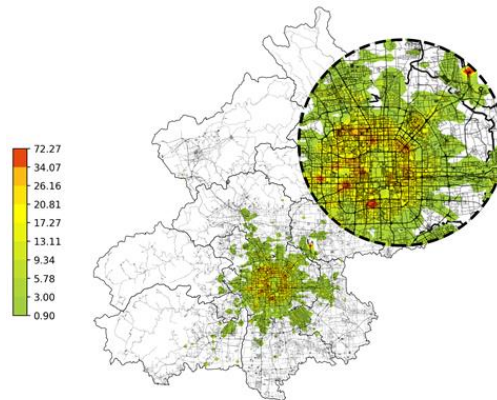
(a) Travel distribution from 8:00 to 10:00.
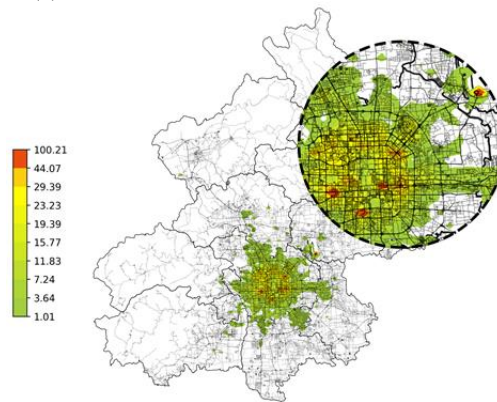
(b) Travel distribution from 14:00 to 16:00.

(c) Travel distribution from 18:00 to 20:00.

Figure 3: Taxi travel heat map at various times of the working day.

As shown in Figure 3(a), 8:00-10:00 is the morning rush hour during working hours, and the travel demand is relatively great, which is mainly reflected in commuting travel needs such as going to work and school, and connecting to the city's external transportation hub. At this time, taxi trips are concentrated in large urban transportation hubs and large residential areas, such as Beijing South Railway Station, Capital Airport T2 Terminal, Xizhimen and other areas within the Fourth Ring Road.

It can be seen from Figure 3(b) that 14:00-16:00 is the afternoon peak time for taxi trips. At this time, taxis are mainly distributed in large urban business districts, sizeable urban transportation hubs, and industrial technology parks, such as Beijing West Railway Station, In Wangfujing business district, Zhongguancun and other places, there is relatively little travel demand inside the third ring road at this time, and travel is concentrated on the third ring road and its periphery.

Figure 3(c) shows the evening peak time of taxi travel between 18:00-20:00. The travel distribution is relatively concentrated, mainly in science and technology industrial parks, office areas, and large-scale urban transportation hubs, such as Zhongguancun, Wangjing, Beijing Railway Station, etc. It is in the peak period of off-get off work, so a large number of travel needs are generated in locations where there are more off-duty people, such as technology industrial parks and office areas.

2.2.2. Spatial Distribution of Trips in Various Periods on Weekends.

In the same way, the weekend travel period is divided into three periods of 9:00-11:00, 14:00-16:00, and 19:00-21:00, and the travel space distribution is analyzed. 9:00-11:00 is the morning rush hour for weekend trips. Many taxi trips are distributed in Changchun Bridge, Xuezhi Bridge, Sitong Bridge and other surrounding university clusters, as well as transfer connections and transportation hub areas such as Beijing West Railway Station. From 14:00 to 16:00, a large number of trips are still distributed in urban transportation hubs such as Beijing West Railway Station and the airport, and the remaining trips are mainly distributed in large commercial areas such as Wangfujing. The evening rush hour (19:00-21:00) for weekend trips is mainly concentrated in large residential communities, commercial districts, and transportation hubs, such as Peony Garden, Wangfujing, and Beijing West Railway Station.

In general, the distribution of trips during different peak hours on weekdays and weekends is mainly concentrated in urban large-scale transportation hubs, residential, commercial, and interchange stations, and transportation hubs have the largest amount of trips at almost every time. Comparing the distribution of total trips on weekdays and weekends, it can be seen that weekend trips are less and more scattered. This is because most of the trips of residents on weekends are entertainment and life-oriented, and travel demand is low. On weekdays, due to commuting trips to work and school, the number of trips increases sharply, and peak trips are concentrated in the morning and evening.

3. Conclusions

Based on the GPS data of taxis in Beijing from January 1 to January 14, 2019, this article analyzes the time and spatial distribution characteristics of taxi travel in Beijing. The main conclusions obtained are as follows:

(1) In terms of time, the number of taxi trips on weekdays is higher than that on weekends, and the number of trips on Saturdays is slightly higher than that on Sundays. The morning and evening peak hours of taxis on weekends are 9:00-11:00 and 19:00-21:00 respectively, lagging behind 8:00-10:00 and 18:00-20:00 on weekdays. The afternoon peak hours on weekdays and weekends are consistent, and both of them peaked at 14:00-16:00.

(2) In terms of space, regardless of the period, the transportation hub is the main area for taxi travel. In addition, the distribution of trips on weekdays is concentrated in the surrounding regions of technology industrial parks and large residential areas. The distribution of trips on weekends is more scattered.

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