

Analysis of the Spatial and Temporal Distribution Characteristics and Influencing Factors of Urban Taxi Empty Load Rate: A Case Study of the Central Urban Area of Chengdu City

Lu Lu, Yongping Bai *

Northwest Normal University, Lanzhou Gansu, 730070, China

* Corresponding author: (Email: baiyp@nwnu.edu.cn)

Abstract: This paper analyzes the spatial and temporal relationships between cab driver behavioral factors and external environmental factors and cab unoccupancy rate based on the GPS trajectory data and POI data of cabs in Chengdu, using a geographically weighted regression (GWR) model. The results show that: (1) The average empty rate of Chengdu cabs on weekdays and non-weekdays is 53.9% and 56.7% respectively, and its empty rate on weekdays and non-weekdays as a whole shows the spatial distribution characteristics of clustering towards the city center. (2) The low empty rate of urban cabs is mainly dominated by the morning and evening peaks on weekdays and non-workdays. The external environmental factors can significantly reduce the cab idling time in most areas.

Keywords: Cab empty rate; Factors affecting idling rate; Geographically weighted regression; Spatio-temporal relationship.

1. Introduction

According to statistics from the Ministry of Transportation and Communications (MOTC), the passenger volume of urban cruising taxis nationwide was about 3,584,081,000 from January to December 2024, a year-on-year increase of 7.1% [1]. However, due to the imbalance between cab supply and passenger demand in time and space, the problem of high cab idling rate is still faced in many cities, which reduces the efficiency of cab operation.

In recent years, many scholars have done a lot of research based on cab trajectory data, Lu et al. used geographically weighted regression (GWR) to analyze the spatial and temporal relationship between cab driver behavioral factors and external environmental factors and cab idling rate based on cab GPS trajectory data, POI data and census data in Shanghai [2]. Jiang et al. explored the idling of cabs in various streets of Shenzhen based on Shenzhen OSM data [3]. Jia et al. analyzed the cab idling rate from multiple temporal and spatial scales [4]. Ma et al. found that the overall time utilization rate of online taxis is slightly higher than that of traditional cruising cabs by comparing the time utilization rates of online taxis and traditional cruising cabs at different time scales in Shanghai, but it is mainly driven by part-time online taxis, and the time utilization rate of full-time online taxi drivers is similar to that of traditional cruising cab drivers, which is about 50% [5]. Ju et al. analyzed the effects of the number and distribution of passengers and cabs, drivers' regional preferences, drivers' route preferences, changes in travel supply and demand, and the degree of matching on the cab idling rate [6].

To sum up, there are still some limitations in the existing analysis of the driving mechanism of taxi no-load rate during peak hours. On the one hand, most of the current research focuses on macroscopic statistical analysis, and lacks in-depth description of micro behavior. On the other hand, there is a lack of systematic quantification of the combined effect of

external environment and driver behavior factors. This paper uses the GPS trajectory data, POI data and census data of taxis in Chengdu to analyze the spatio-temporal variation characteristics of taxi no-load rate during weekday and non-weekday peak periods in the central urban area of Chengdu. Secondly, the main taxi driver behavior factors and external environmental factors were selected, and the factors that had a greater impact on the taxi no-load rate were screened out through collinearity analysis and global Moran index test. Finally, the geographically weighted regression (GWR) model is used to analyze the spatio-temporal relationship between taxi driver behavior factors and external environmental factors and taxi no-load rate.

2. Research Methodology and Analysis of Influencing Factors

2.1. Overview of the Study Area

Chengdu is the provincial capital of Sichuan Province, the deputy provincial city of large cities. The downtown area of Chengdu is the core area for business and finance as well as politics and military. Therefore, the study area of this paper mainly includes the five central urban areas of Jinjiang District, Qingyang District, Jinniu District, Wuhou District and Chenghua District, and is located between 103° and 104° east longitude and 30° and 31° north latitude (see Fig.1). By the end of 2014, the total number of cabs in the central city of Chengdu was 14,898.

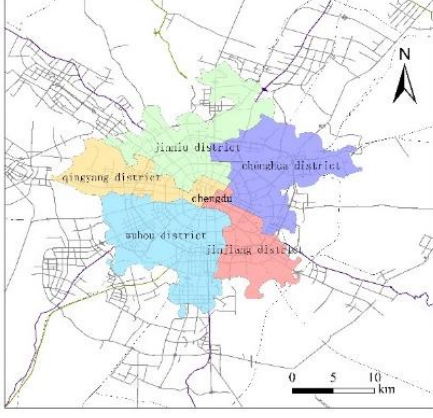


Figure 1. Chengdu city center area

2.2. Data Sources

In this paper, the trajectory data of more than 14,000 cabs collected in Chengdu for a total of one week from August 4, 2014 (Monday) to August 10, 2014 (Sunday), including five days of working day data and two days of non-working day data, with basically good weather conditions, are selected. Cab GPS track data comes from the “Wisdom China Cup” competition data, including vehicle number, GPS time, passenger status (0 is empty, 1 is passenger), longitude, latitude and other valid field data. By analyzing the original GPS data, it is found that there are a lot of redundancy and bias, this paper preprocesses the abnormal data with the help of python [7]

2.3. Research Methodology

2.3.1. Taxi Empty Rate

Cab idling rate is categorized into time idling rate and distance idling rate. The time-idle rate is the ratio of the total cab idling time to the total cab operating time; the distance-idle rate is the ratio of the total cab idling distance to the total cab operating distance. Since cabs are more concerned about the length of their empty trips than the distance in the operation process, the time-empty rate is chosen as a measurement index in this paper. The calculation formula is as follows [6]:

$$ELR_k = \frac{\sum_{i=1}^n T_{vi}^K}{\sum_{i=1}^n T_{vi}^K + \sum_{j=1}^m T_{pj}^K}$$

Where: k is the number of the square; i is the ith GPS point in the square K; n denotes the number of all unloaded GPS points in the square K; $\sum_{i=1}^n T_{vi}^K$ denotes the sum of unloaded time of all GPS points in the square K; j denotes the jth GPS point in the square K; m denotes the number of all passenger-carrying GPS points in the square K; $\sum_{j=1}^m T_{pj}^K$ denotes the sum of passenger-carrying time of all GPS points in the square grid K.

2.3.2. Geographically Weighted Regression

The GWR model is a local spatial statistical method, which can take into account the spatial autocorrelation and spatial heterogeneity of the observations by assuming that the influence of nearby observations on variables is greater than that of distant observers and establishing local regression equations at each location in the study area [8-10].

2.4. Analysis of Influencing Factors

Based on the discussion of taxi operation efficiency evaluation and its influencing factors [11-13], this paper identifies five taxi driver behavior factors and 13 external

environmental factors that affect taxi empty load rate (Table 1). Taxi driver behavior factors include pick-up probability, search time, search distance, passenger search strategy, pick-up and drop-off speed. Among them, passenger search strategies include waiting strategy, cruising strategy and long-distance strategy. External environmental factors include catering density, scenic spots, shopping density, company density, transportation facilities density, science, education and culture density, finance and insurance density, residential density, hotel density, government agencies and social groups density, health care density, sports and leisure density, and life service density.

The calculation method of taxi driver behavior factors is as follows [4]:

(1) Probability of receiving customers. The probability of receiving customers in the central urban area grid r refers to the ratio of the number of pick-up events in grid r to the sum of the number of empty vehicles passing through grid r and the number of pick-up events in grid r, and the calculation formula is as follows:

$$P_r = \frac{N_r}{N_r + N_{r,c}}$$

Where P_r represents the probability of receiving customers in grid r; N_r represents the number of passing through grid r from 0 to 1, that is, the number of customer pick-up events in grid r; $N_{r,c}$ represents the number of empty cars passing through grid r.

(2) Search time. The search time of grid r refers to the average of the time between the empty trajectory of all taxis that receive passengers in grid r from the last passenger drop-off point to the passenger boarding point in grid r, and the time of empty trajectory is obtained by adding the time between two adjacent GPS trajectory points. The calculation formula for the time of empty trajectory e and the search time of grid r is as follows:

$$T_e = \sum_{a=1}^A t(p_a, p_{a+1})$$

$$T_{r,s} = \frac{1}{M_r} \sum_{m=1}^{M_r} T_{e,r}$$

Where T_e represents the time of empty trajectory e; $t(p_a, p_{a+1})$ represents the time between the p_a of two adjacent GPS track points and p_{a+1} of the empty driving track; A represents the number of trajectory points of empty driving trajectory e; $T_{r,s}$ indicates the search time of grid r; $T_{e,r}$ represents the time when the passenger's empty trajectory e is received in the grid r; M_r represents the number of empty trajectories received by passengers in zone r.

(3) Search distance. The driving trajectory of a taxi is composed of a series of continuous trajectory points, which can be divided into no-load travel and passenger driving trip according to its empty state, and a single trip can be obtained by accumulating the spherical distance between two adjacent GPS trajectory points. Assuming that the two adjacent GPS track points of a taxi are p_h and p_{h+1} , the distance D of a single trip of the taxi is calculated as follows:

$$D = \sum_{h=1}^H d(p_h, p_{h+1})$$

Where $d(p_h, p_{h+1})$ represents the distance between two adjacent GPS track points p_h and p_{h+1} ; h for a, b; H stands for A, B. The spherical distance between two adjacent

GPS trajectory points is calculated by the Haversine formula [14-15]. The Haversine calculation formula is as follows:

$$d(p_h, p_{h+1}) = 2R \cdot \arcsin \left(\sqrt{\sin^2 \left(\frac{\varphi_{h+1} - \varphi_h}{2} \right) + \cos(\varphi_h) \cos(\varphi_{h+1}) \sin^2 \left(\frac{\lambda_{h+1} - \lambda_h}{2} \right)} \right)$$

Where: R represents the radius of the earth (length 6371km); φ_h and φ_{h+1} represent the latitude of the trajectory point p_h and p_{h+1} , respectively; λ_h and λ_{h+1} represent the longitude of the trajectory point p_h and p_{h+1} , respectively. The search distance of grid r is the average distance of all taxis that receive passengers in grid r from the last passenger drop-off point to the empty driving trajectory between the grid r passenger boarding point, calculated as follows:

$$D_{r,s} = \frac{1}{M_r} \sum_{m=1}^{M_r} D_{e,r}$$

Where $D_{r,s}$ represents the search distance of grid r; $D_{e,r}$ indicates the distance within the grid r to the passenger's empty trajectory e.

(4) Passenger search strategy. The passenger search strategy refers to determining whether the distance between the last drop-off point and the next boarding point is greater than the distance threshold τ_d , and if it is greater than the distance threshold τ_d , the taxi chooses a relatively far area to find passengers; Otherwise, further determine whether the time between the last drop-off point and the next boarding point is greater than the time threshold τ_t , if it is greater than the time threshold τ_t , the taxi chooses to wait to find passengers, otherwise, the taxi chooses to cruise to find passengers. A taxi passenger search strategy can be represented as follows:

$$D_e \begin{cases} \leq \tau_d & \begin{cases} T_e > \tau_t & \text{wait} \\ T_e \leq \tau_t & \text{cruise} \end{cases} \\ > \tau_d & \text{Long distance} \end{cases}$$

Where D_e and T_e represent the distance and time of the empty trajectory e, respectively; τ_d and τ_t represent distance and time thresholds, set to 1.5 km and 5 minutes [16], respectively. Waiting, cruising, and long-distance passenger search strategies for Grid R are the proportion of the number of waiting, cruising, and long-distance passenger search strategies selected by taxis in the grid to the number of all policies in the area.

(5) Pick-up and drop-off speed. The pick-up and drop-off speed of grid r refers to the average of the speed of all pick-up events in grid r, and the calculation formula for the speed of pick-up event o and grid r is as follows:

$$V_o = \frac{1}{B} \sum_{b=1}^B \frac{d(p_b, p_{b+1})}{t(p_b, p_{b+1})}$$

$$V_{r,d} = \frac{1}{N} \sum_{n=1}^{N_r} V_{o,r}$$

Where V_o represents the speed of the customer pick-up event o; $d(p_b, p_{b+1})$ represents the distance between two GPS track points adjacent to p_b p_{b+1} ; $t(p_b, p_{b+1})$ represents the time between the p_b of two adjacent GPS track points and p_{b+1} ; B represents the number of trajectory points of the pick-up event o; $V_{r,d}$ indicates the pick-up and drop-off speed of the grid r; $V_{o,r}$ represents the speed of pick-up event o within the grid r.

Table 1. Variable description and statistics

Variable categories	Variable name	Variable description	weekday		Non-working days	
			average	variance	average	variance
Taxi driver behavior	Probability of customer service	—	0.387	0.095	0.383	0.094
	Search time (h)	—	0.148	0.051	0.161	0.055
	Search distance (km)	—	1.342	1.636	1.597	2.189
	Wait for the strategy	—	0.259	0.065	0.276	0.066
	Cruising strategy	—	0.659	0.00037	0.625	0.00038
	Long-range strategy	—	0.081	0.374	0.098	0.378
	Pick-up and drop-off speed (km/h)	—	28.51	242.128	29.013	244.426
External environmental factors	Catering density (units/km2)	Number of restaurants, pastry shops, cold drink shops, etc	124.6	3071.98	124.66	3071.98
	Density of scenic spots (units/km2)	Number of parks, squares, attractions, memorials, etc	2.52	1.86	2.52	1.86
	Company enterprise density (units/km2)	Number of companies, enterprises, factories, etc	75.22	2137.48	75.22	2137.48
	Density of shopping services (units/km2)	The number of home building materials markets, shopping malls, fruit markets, etc	244.6	9185.59	244.68	9185.59
	Transportation Facilities Service Density (units/km2)	Number of bus stops, metro stations, parking lots, etc	58.62	836.98	58.62	836.98
	Density of financial and insurance services (units/km2)	Number of banks, ATMs, insurance companies, etc	15.17	68.63	15.17	68.63
	Residential density (units/km2)	The number of residential complexes, villas, office buildings, etc	34.42	244.15	34.42	244.15
	Hotel service density (units/km2)	Number of guesthouses, hotels, hostels, etc	19.97	72.08	19.97	72.08
	Density of science, education and cultural services (units/km2)	The number of schools, scientific research institutions, training institutions, etc	32.33	254.13	32.33	254.13
	Density of sports and leisure services (units/km2)	The number of chess and card rooms, billiard halls, picking gardens, etc	18.39	86.67	18.39	86.67
	Density of government agencies and social organizations (units/km2)	Number of government agencies, charities, industry associations, etc	20.17	59.05	20.17	59.05
	Healthcare service density (units/km2)	Number of hospitals, clinics, health centers, etc	31.65	156.65	31.65	156.65
	Density of living services (units/km2)	The number of post offices, logistics express delivery, etc	125.33	2496.74	125.33	2496.74

3. Analysis of Results

3.1. Spatio-temporal Distribution

Characteristics of Taxi No-Load Rate

3.1.1. Spatio-temporal Distribution Characteristics of Daily No-Load Rate

The taxi empty load rate is relatively low in the five days of weekdays, with an average empty load rate of 53.9%, and the average empty load rate is high on non-working days, with an average empty load rate of 56.7%. During the weekday, the empty load rate is highest on Monday and the lowest on Friday. (See Figure 2)

The spatial distribution of taxi no-load rate on weekdays and non-working days is shown in Fig. 3. The low unoccupied rate is mainly concentrated in the southeast of Qingyang District, the northeast of Wuhou District and the northwest of Jinjiang District, and the high no-load rate of taxis is mainly distributed in the periphery of the central urban area. on non-working days, the distribution of taxi empty load rate in the city center is more scattered, and the higher taxi no-load rate is still mainly in the periphery of the central urban area, due to the decrease in people's commuting demand on non-working days and the increase in the randomness of travel

plans.

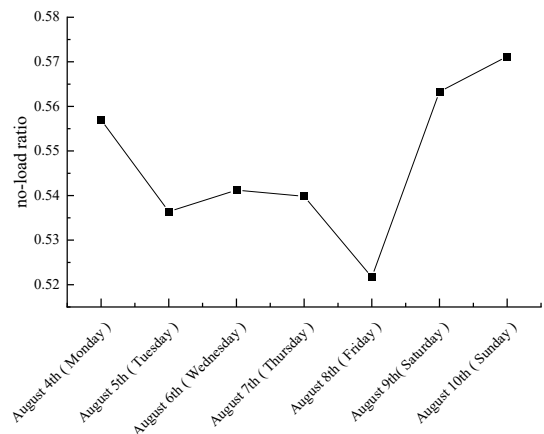


Figure 2. The daily trend of taxi empty load rate

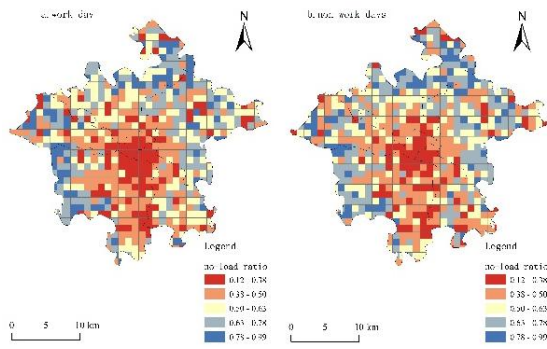


Figure 3. Spatial distribution of taxi empty load rate on weekdays and non-working days

3.1.2. Spatio-temporal Distribution Characteristics of Peak Empty Load Rate in The Morning, Noon and Evening

Observing the shape of the change curve of the empty load rate in a week, it can be seen that the empty load rate gradually decreases between T 7:00-8:00 and T 8:00-9:00 during the morning rush hour, and a large number of travel demand leads to a shortage of taxis. During the noon peak period, the no-load rate from T 12: 00-13: 00 to T 13: 00-14: 00 increased. During the evening rush hour, a large number of office workers, students and citizens need to take taxis to their destinations, such as going home, having dinner or doing other activities. At this time, the number of private cars on the road will also increase, further exacerbating traffic congestion and making more people choose to take taxis to save time and energy. During the night rush hour, some companies' "996" policy makes employees' commuting from get off work concentrated between T 21:00 and 23:00, and the unloaded

level is low during this period.

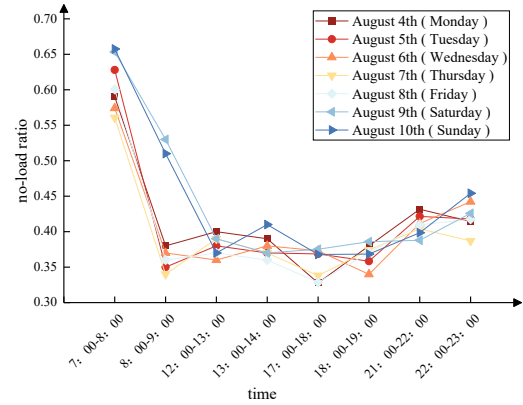


Figure 4. Trend of empty load rate of taxis during peak hours in the morning, noon, evening and evening

From the spatial scale, whether it is weekdays or weekends, the no-load rate of the morning peak T 7:00-8:00 time period is high and dispersed. During the working day, the low unloaded load rate of T 8:00-9:00 was densely distributed in Wuhou District. The travel hotspots during the afternoon rush hour are mainly distributed in the central area of the city, especially the commercial and financial district, and the eastern part of Qingyang District and Wuhou District are more concentrated. The low load rate during the evening peak period is mainly distributed in the eastern part of Wuhou District, the southeast of Qingyang District and the northwest of Jinjiang District, and the distribution range of the no-load rate will expand significantly during the period from 18:00 to 19:00 T. During the night rush hour, passenger demand is more diverse.

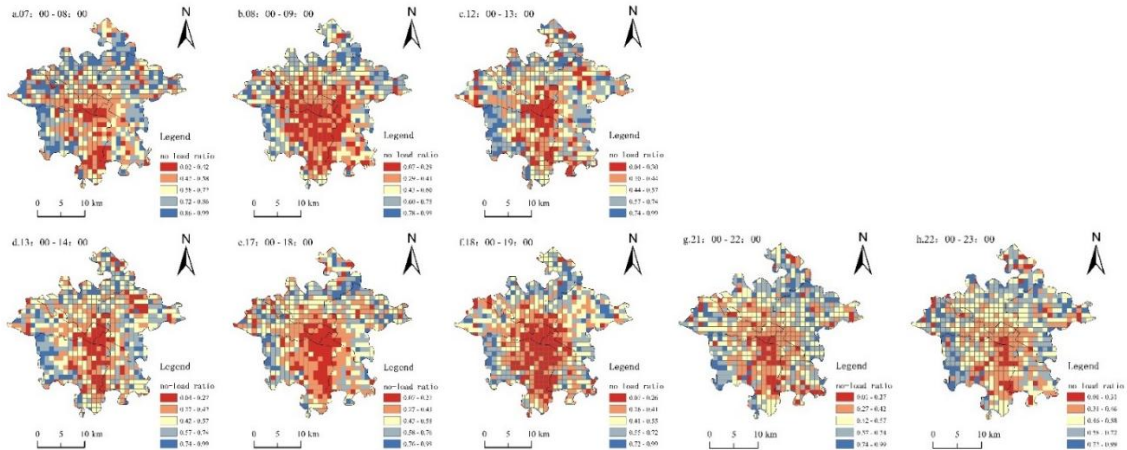


Figure 5. Spatial distribution of no-load rate of taxis in the morning, noon and evening peak hours on weekdays

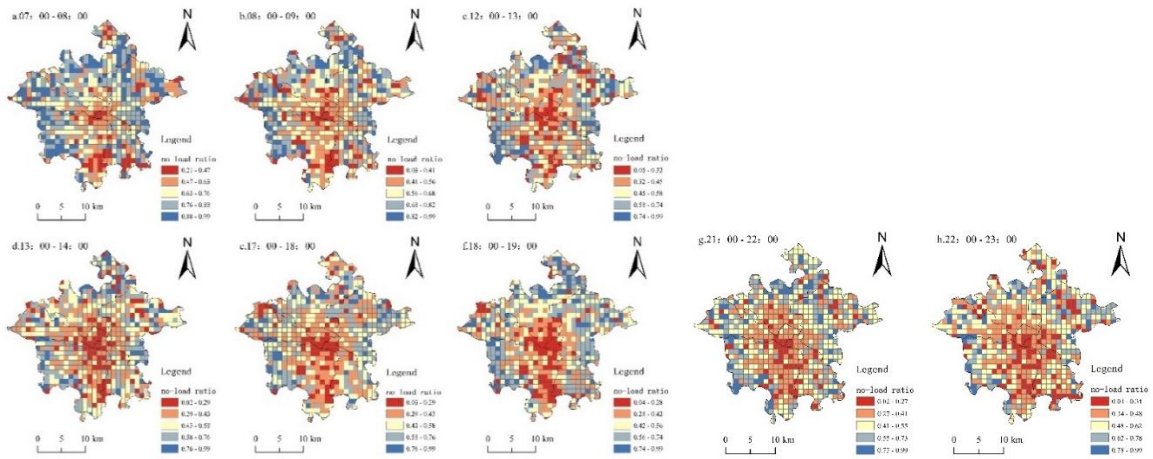


Figure 6. Spatial distribution of no-load rate of non-working day taxis during morning, noon and evening peak hours

3.2. Analysis of Influencing Factors of Taxi No-Load Rate

3.2.1. Influencing Factor Selection and Data Testing

Before modeling the taxi no-load rate, collinearity analysis and Moran index test were first carried out on the taxi no-load rate and its influencing factors. Collinearity analysis and Moran exponential test were analyzed using SPSS and ArcGIS10.6, respectively. In order to ensure the accuracy of the data, the influencing factors of variance expansion factor (VIF) greater than 5 were filtered out. The results of the Moran index test of taxi empty load rate and its influencing factors showed that there was a significant spatial autocorrelation between taxi empty load rate and its influencing factors at the 95% confidence level, and showed a spatial positive correlation.

3.2.2. Analysis of Influencing Factors

During the morning rush hour on weekdays (Table 3 and Fig. 7), the probability of picking up passengers and the empty load rate were mainly positively correlated in the southeast of Qingyang District, the southern part of Jinniu District, the eastern part of Chenghua District, the north and south of Jinjiang District, and the western and northeastern parts of Wuhou District.

During non-working days, the probability of picking up passengers was negatively correlated with the taxi empty load rate in the central part of Qingyang District, the eastern and southern parts of Jinniu District, the central and eastern parts of Chenghua District, the southern part of Jinjiang District, and the western and eastern parts of Wuhou District. Science, education and cultural services form a positive correlation with the taxi no-load rate.

Table 2. Regression results of the morning peak GWR model

variable	weekday			Non-working days		
	max	average	min	max	average	min
Probability of customer service	3.8600	0.0108	-3.1360	2.2617	-0.0080	-3.2085
Search distance (km)	2.8496	0.0008	-3.0927	2.2225	0.0011	-3.3118
Pick-up and drop-off speed (km/h)	3.2398	0.0067	-2.9246	2.3019	0.0005	-3.2707
Cruising strategy	2.8815	0.0039	-2.8944	2.1562	0.0055	-3.2569
Density of scenic spots (units/km ²)	3.1256	-0.0002	-3.0024	2.1459	0.0002	-3.2713
Company enterprise density (units/km ²)	2.9844	-0.0007	-2.8427	2.1653	0.0016	-3.2825
Density of shopping services (units/km ²)	2.8754	0.0075	-2.9034	2.1660	0.0050	-3.2614
Hotel service density (units/km ²)	3.0411	0.0048	-2.9110	2.1295	-0.0003	-3.2998
Density of science, education and cultural services (units/km ²)	2.9898	-0.0056	-2.8978	2.4820	0.0026	-3.7794
Density of government agencies and social organizations (units/km ²)	2.9688	0.0059	-2.9187	2.1403	0.0018	-3.2941
Healthcare service density (units/km ²)	3.0195	0.0089	-2.9086	2.1702	0.0043	-3.2817

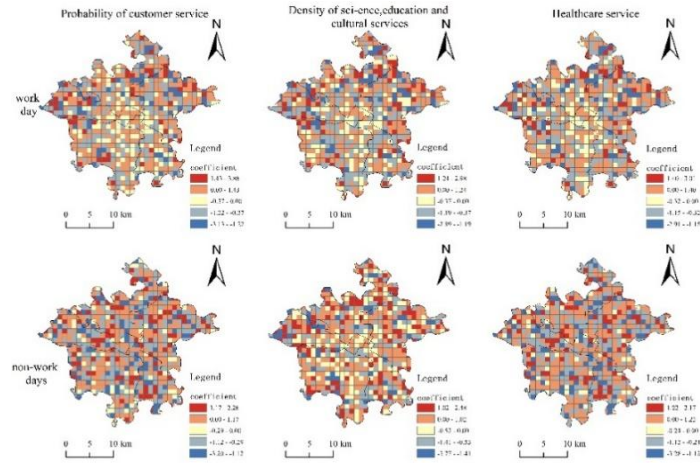


Figure 7. Spatial distribution of influencing factors of morning peak

During the peak afternoon period on weekdays (see Table 4 and Fig. 8), the search distance was mainly positively correlated with the taxi empty load rate in the western part of Qingyang District, the northern and central parts of Jinniu District, the central and southern parts of Chenghua District,

the southern part of Jinjiang District, and the southern and northern parts of Wuhou District. During non-working days, the search distance and the unloaded rate were negatively correlated in Jinjiang District and Wuhou District.

Table 3. Regression results of the noon peak GWR model

variable	weekday			Non-working days		
	max	average	min	max	average	min
Probability of customer service	3.3709	-0.0032	-3.4960	2.6449	-0.0002	-2.6448
Search distanc (km)	3.3692	0.0052	-3.2490	2.6939	-0.0048	-2.7093
Pick-up and drop-of speed (km/h)	3.2141	0.0025	-3.2437	2.6937	0.0019	-2.7120
Cruising strategy	2.9603	-0.0002	-3.2104	2.6219	-0.0001	-2.6414
Density of scenic spots (units/km2)	3.0074	-0.0035	-3.2235	2.6589	0.0015	-2.6586
Company enterprise density (units/km2)	3.3422	-0.0041	-3.2640	2.6676	-0.0023	-2.6615
Density of shopping services (units/km2)	3.1440	0.0043	-3.2340	2.6895	0.0008	-2.6378
Hotel service density (units/km2)	3.0665	-0.0026	-3.2350	2.6932	-0.0013	-2.6757
Density of science, education and cultural services (units/km2)	3.2245	-0.0027	-3.5468	2.6705	-0.0023	-2.6532
Density of government agencies and social organizations (units/km2)	2.9699	-0.0006	-3.4455	2.6713	-0.0018	-2.6572
Healthcare service density (units/km2)	3.1330	0.0060	-3.2933	2.6754	-0.0010	-2.7215

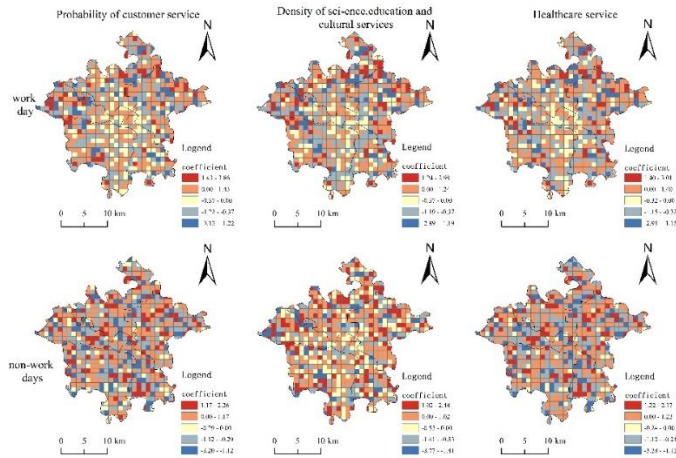


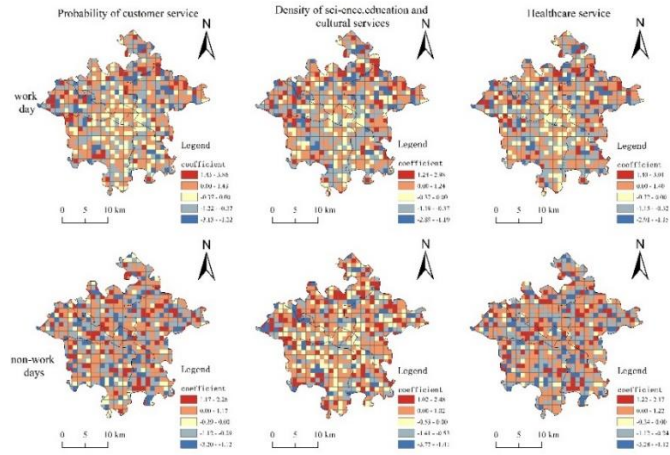
Figure 8. Spatial distribution of influencing factors of noon peak

During the evening peak period on weekdays (see Table 5 and Figure 9), the search distance is mainly positively correlated with the taxi empty load rate, because the novice load rate is low due to the concentration of passenger demand and the short search distance of taxis. Scenic spots, government agencies and social organization services in the

southeast of Jinniu District, Qingyang District and the south of Wuhou District are mainly negatively correlated with taxi empty load rates. During non-working days, people's behavior patterns are more scattered, and search distance is mainly negatively correlated with no-load rate.

Table 4. Regression results of the evening peak GWR model

variable	weekday			Non-working days		
	max	average	min	max	average	min
Probability of customer service	3.8610	0.0070	-2.9912	2.5507	-0.0039	-2.2296
Search distanc (km)	3.2892	0.0212	-2.9599	2.5382	-0.0013	-2.2433
Pick-up and drop-of speed (km/h)	3.1636	0.0049	-3.3327	2.5541	0.0017	-2.2372
Cruising strategy	3.3895	-0.0002	-2.8605	2.5452	0.0011	-2.2668
Density of scenic spots (units/km2)	3.5968	-0.0055	-2.9743	2.5561	0.0061	-2.2312
Company enterprise density (units/km2)	3.3652	-0.0029	-3.1010	2.5617	-0.0003	-2.2391
Density of shopping services (units/km2)	3.3865	0.0025	-2.8349	2.5633	-0.0017	-2.3031
Hotel service density (units/km2)	3.4552	0.0086	-2.8177	2.5472	-0.0029	-2.2594
Density of science, education and cultural services (units/km2)	3.3650	-0.0068	-2.8264	2.5532	-0.0026	-2.3965
Density of government agencies and social organizations (units/km2)	3.5056	-0.0032	-2.8947	2.5684	0.0027	-2.2699
Healthcare service density (units/km2)	3.4260	0.0042	-2.8791	2.5711	0.0018	-2.2878

**Figure 9.** Spatial distribution of influencing factor coefficients of evening peak

During the peak hours of working days and nights (see Table 6, Figure 10), the cruise strategy is mainly positively correlated with the taxi no-load rate. Hotel services are mainly negatively correlated with taxi unloaded rates in urban centers and positively correlated in urban peripheral areas.

During working days and non-working days, the company's corporate services are mainly negatively correlated in the eastern part of Wuhou District, Jinjiang District, and the northeastern part of Chenghua District.

Table 5. Regression results of the night peak GWR model

variable	weekday			Non-working days		
	max	average	min	max	average	min
Probability of customer service	3.6998	0.0032	-3.6313	2.7944	0.0010	-2.7979
Search distanc (km)	3.6256	0.0143	-3.4691	2.7822	-0.0005	-2.7969
Pick-up and drop-of speed(km/h)	3.3195	0.0064	-3.8364	2.9046	0.0018	-2.7640
Cruising strategy	3.4989	0.0095	-3.3757	2.7572	-0.0017	-2.7541
Density of scenic spots (units/km2)	3.4378	0.0028	-3.4763	2.7838	-0.0038	-2.7731
Company enterprise density (units/km2)	3.4794	-0.0068	-3.3287	2.7520	-0.0048	-2.7409
Density of shopping services (units/km2)	3.5048	0.0090	-3.2957	2.7907	0.0034	-2.7849
Hotel service density (units/km2)	3.5270	0.0043	-3.2810	2.7677	-0.0076	-2.7455
Density of science, education and cultural services (units/km2)	3.5095	-0.0011	-3.4634	2.7713	-0.0053	-2.7356
Density of government agencies and social organizations (units/km2)	3.5755	0.0056	-3.6673	2.8565	-0.0054	-2.8023
Healthcare service density (units/km2)	3.5697	0.0139	-3.3947	2.7960	-0.0023	-2.7724

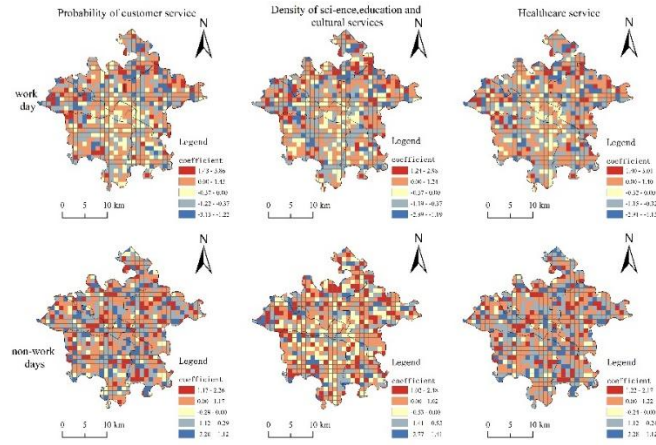


Figure 10. Spatial distribution of influencing factors of night peak

4. Conclusion and Discussion

Based on the GPS trajectory data and POI data of taxis in the central urban area of Chengdu, this paper analyzes the spatial distribution characteristics of taxi empty load rate during weekday and non-working day peak periods, and establishes a GWR model to analyze the spatial influence of these factors on taxi no-load rate during weekday and non-working day peak periods, and draws the following research conclusions:

The unloaded rates of taxis in Chengdu on weekdays and non-working days were 53.9% and 56.7%, respectively, and the spatial differences in the no-load rates were significant, which was manifested in the low empty load rate in the city center and high in the suburbs, and the spatial distribution characteristics were similar on weekdays and non-working days.

The GWR results showed that different influencing factors had different influences on the taxi empty load rate, among which the pick-up probability, pick-up speed, search distance, cruising strategy, health care service density, and service density of government agencies and social groups had a greater impact on the taxi unloaded rate.

Future research can be started from the perspective of multi-scale coupling: in terms of vertical expansion, a cross-city comparative analysis framework can be constructed, and the moderating effect of urban physical parameters such as terrain complexity, road network structure and economic level can be analyzed through Moran's I index and geographic detector. In terms of horizontal extension, it is necessary to integrate the festival migration map of LBS sign-in data to develop a three-level spatio-temporal regression model of "peak-peak-festival", so as to realize the time-varying parameter analysis of the formation mechanism of no-load rate. This extension can not only verify the parameter sensitivity of the DECM model, but also promote the transformation of urban traffic resilience research from static correlation to dynamic adaptability paradigm.

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