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Impact of urban built environment on urban short-distance taxi travel: the case of Shanghai

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Abstract. The excessive individual motorized transport is the main cause of urban congestion and generates negative consequences on urban environmental quality, energy consumption, infrastructure supply and urban security. Bicycle can compete effectively with automobile for short-distance travels within 3km. If we take action to encourage the rider to shift from automobile to bike for the short-distance travels, it leaves us a great chance to reduce the modal share of individual motorized mode. This paper focus on the spatial impact of built environment on short-distance taxi riders' travel behaviour. The data sources include taxi trajectory data for a week, demographic data of the Sixth National Census, POI data. In this paper, we figure out the volumes and spatial distribution of short-distance taxi travel in the central city of Shanghai. We build a multiple regression model to quantitative analyze the impact of urban built environment on urban short-distance taxi travel. The findings explain the spatial distribution short-distance taxi travel. In the conclusion, some advice are provided on how planners change the spatial settings to discourage short-distance individual motorized travel.

1.Introduction

Motorized transport shortens the temporal distance of urban travel. The great superiority made urban motorized transport one of the main focus of urban development in the past decades. However, it has been a general consensus that urban individual motorized transport brought a great burden on economics, environment and society. Over-development of urban individual motorized transport crowded out slow mode traffic. But in contrast, non-motorized transport seems to be a low carbon substitutes to short-distance individual motorized transport. The main competition between non-motorized transport and motorized transport is within 3km. Thus, we define short-distance motorized travel in this paper as urban motorized travel within 3km.

Existing literatures considered short-distance individual motorized travel should be discouraged and it could help if we designed slow area in city (Liu T et al.,2008). But few literatures put forward scientific and accurate methods to identify the exact problem location. Smart city has now become an important realm of urban planning. With the help of big data, we have a powerful tool to explore urban planning and urban transport. This paper tries filling the blank from a smart city perspective. To protect personal privacy, this paper concentrates on short-distance taxi travel which is still a blind spot of existing research.

There are already abundant prior studies about urban taxi travel from a smart city perspective. In these researches variables relating to the urban taxi travel mainly comprise three aspects: demographic, land use, traffic environment (Xinwu Q et al., 2015). Urban built environment variables including employment density, residence density, metro station density and road density are significantly related to the taxi travel (Li Q et al., 2016).

The data sources of this paper include taxi trajectory data, POI data and demographic data of the Sixth National Census. The taxi trajectory data recorded the information on paths of taxis from March 1, 2016 to March 5, 2016 including 3 working days and 2 rest days. Consider error of analysis conclusion of single day, we use the adjacent working days and rest days as a control group to check the results. The taxi trajectory data format is shown in Table 1.

Table 1. Data format of taxi trajectory data

Name	Type	Sample
Vehicle ID	Char	12143
time	Date	20160301070139
statues	Int	0
Longitude	Float	120.1283
Latitude	Float	31.1463
Velocity	Float	21.1
Direction	Float	272.3

The POI data was crawled by the author with Baidu map. The POI data has location information on facilities in Shanghai. The facilities selected for this study contain educational facilities, medical facilities, metro stations, bus stops and community public service facilities. The data cleaning work in this study mainly includes coordinate, correction, deduplication, deletion of erroneous data and incomplete information, and screening of interference information.

The demographic data is based on the Sixth National Census. The data takes the sub-district as the basic statistical unit. The data carries information on the densities of permanent residents, the floating population and employees.

2. Travel characteristics of short-distance taxi travels

Taxis are one of the urban public transport resources, and taxis are more flexible than other types of public transport. The operation of taxis is not only limited by the command of taxi dispatch companies, but also directly affected by taxi drivers' personal attributes, subjective judgments and other factors. Compared with other modes of public transport, taxis are more self-organized. To some extent, travel characteristics of taxis are close to individual motorized travel. It has obvious peak and trough period.

The results show that the peak hours of taxi travels are at 10, 18 and 21. In addition, the trough periods of taxi travels are at 12, 17and midnight, which coincided with the taxi drivers' meal time and rest time.

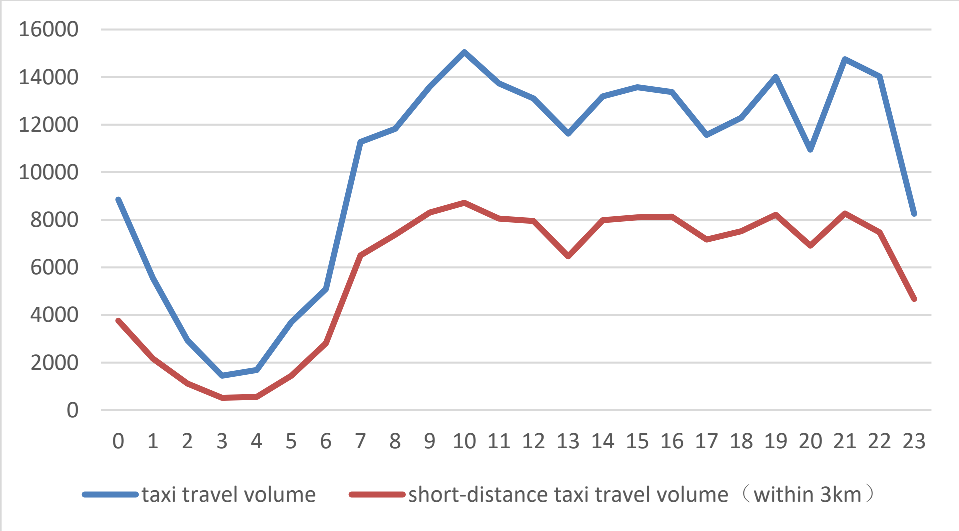

Figure1.One-day taxi travel volume changes

The travel distance distributions also change over time. For contrast analysis, this paper selected three study groups which respectively include the working day morning group (March 2, 2016 & March 3, 07: 00 ~ 09: 00), working day night group (March 2 and March 3, 2016 from 22:00 to 24:00) and rest day morning group (March 5 and March 6, 2016 07:00 to 09:00, 00). To simplify the calculate process, we use the straight distance between the departure place and the destination to replace the real travel distance. We use travel non-linear coefficient (1.3) to correct the error.

the sum of taxi travels of the working day morning group was 41327. The result shows that 24949 taxi travels were within 3km, which accounted for 60.36% of the sum. That is to say, during the morning peak, short-distance taxi travels occupied the main part of urban taxi travels.

By contrast, for working day night group, there were 48023 taxi travels, which exceed the working day morning group. The average taxi travel distance was 5.99km, which was longer than the working day morning group. The volumes of taxi travels within 5 to10 kilometers obviously increased, and the longest travel reached 77.85km. There was a larger demand for taxis at working day night than in the morning and the average travel distance was longer than it was in the day. The costs of metro transport were much cheaper than taxis and public transport was very attractive to travelers, especially to long-distance travellers. After 22:00, however, urban metro transport systems and most of the ordinary bus lines ceased, resulting in a large number of urban transport needs being forced to switch to other transport, such as taxis, which not only increased the total demand for taxis, but also changed taxi travel distance distribution.

In the three group, the sum of taxi travels of the rest day morning group was the fewest, with only 38997.

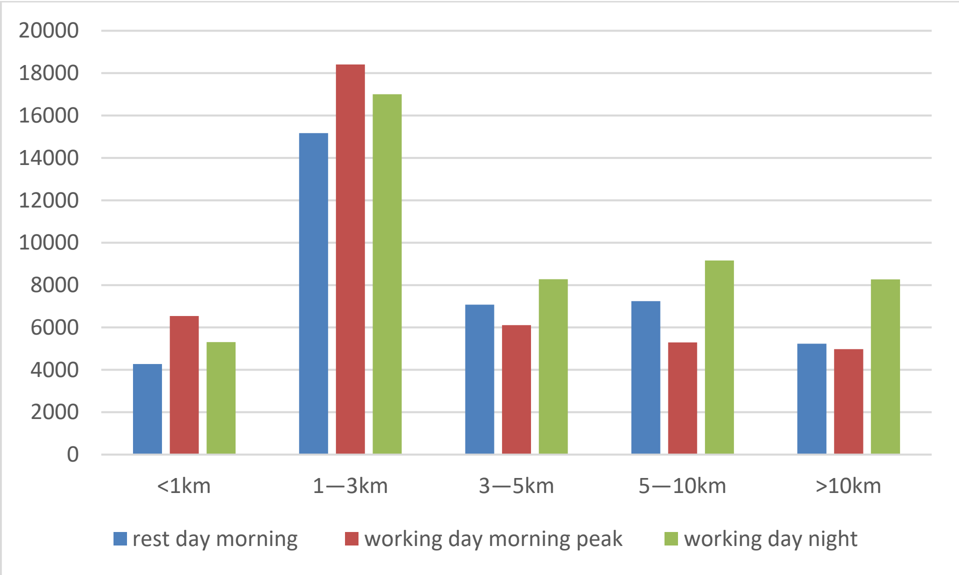

Figure.2 Comparison of taxi travel distance distribution

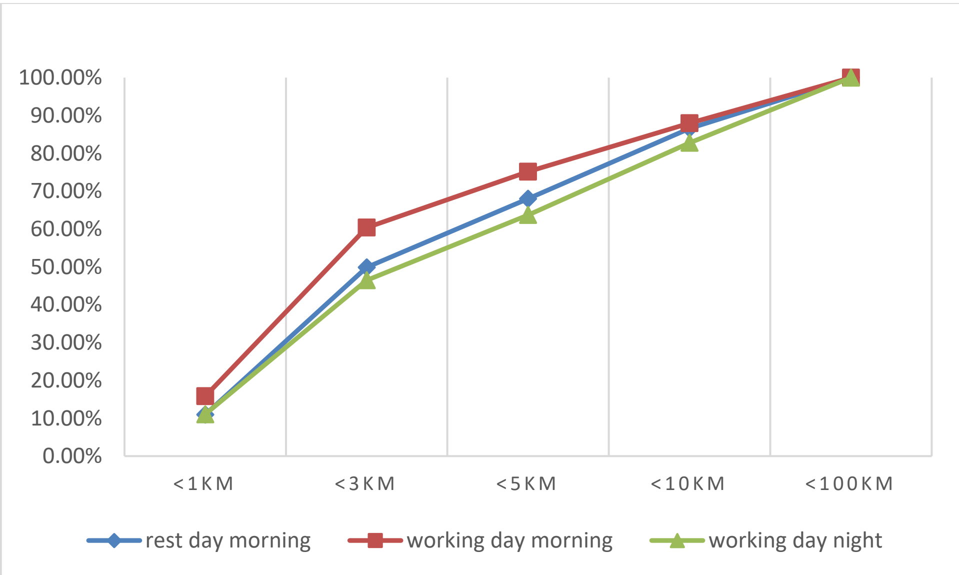

Figure.3 Taxi travel distance distribution of the research time periods

3. Spatial distribution of short-distance taxi travels

According to the analysis result of the working day morning group, short-distance taxi travels which occurred in Shanghai central city (within the Outer Ring Road in Shanghai) accounted for 80.79% of the city's total. Still in Shanghai central city, we observed a clear spatial aggregation phenomenon. Close to 50% of the city's short-distance taxi travels occurred in five districes (Huangpu District, Luwan District, Jing'an District, Hongkou District, Changning District). But their grounds only accounte for 25.4% of the grounds of Shanghai central city. Short-distance taxi travel density of Luwan District, Huangpu District and Jing'an District was significantly higher than the average, which reached 56.09 / km², 53.34 / km² and 49.30 / km², respectively. The average of short-distance taxi travel density of downtown was only 15.91 / km².

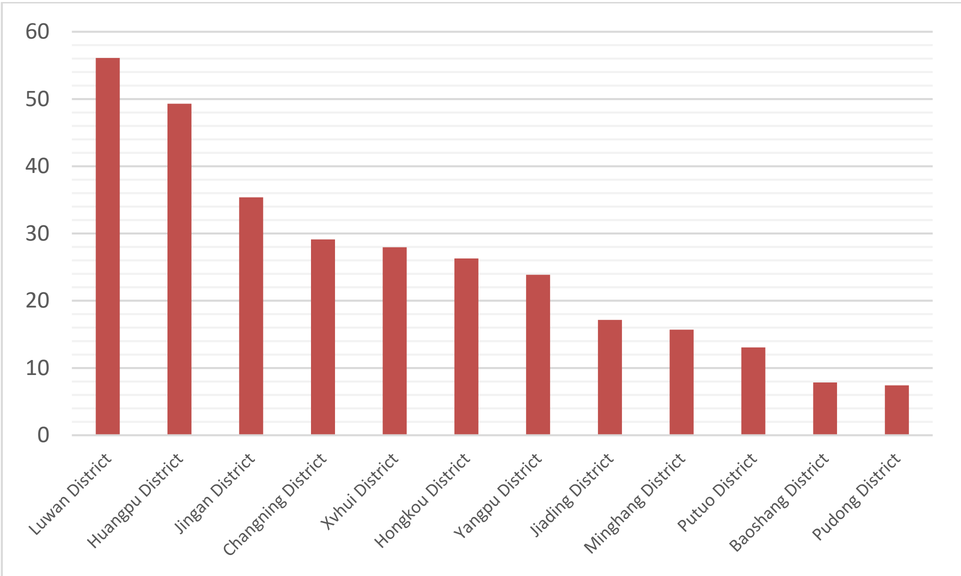

Figure.4 Short-distance taxi travel density of each district in Shanghai central city

To further study the agglomeration of short-distance taxi travels in the city and the changes of it at different time periods, the research started with the following two aspects. First, we selected three groups including morning rush hour, working day night and rest day morning, and identified the hot spots of origin of short-distance taxi travels. In the hope of reducing the proportion of short-distance motorized travel in urban areas and increasing the attractiveness of non-motorized transport, we should start with the demand side to enhance the accessibility of slow mode transport such as public bicycles. Identify the hot points of origins would make sense. Secondly, we identified the hot spots of the travel paths of the short-distance taxi. The shortcoming of this study was that we used OD lines to instead of the real travel paths. Repeating the method of this study within a small spatial scale might lead to errors.We used the data of adjacent days as control groups in case of the error.

Hot spots of the origin of the working day morning group included transportation hub (people square, for example) and employment concentrate area ((Lujiazui area, for example). Because during the commuter rush hour, a large number of short-distance commuter travels took place.The hot spots of short-distance taxi travels centralized in employment concentrate areas and densely populated areas. Similar results were found in the identification of hot spots of short-distance taxi travel paths.

At the working day night, the hot spots were not obviously centralized in several districts. The origins and travel paths were more dispersed. In other words, compared with the working day morning group, the degree of differentiation of short-distance taxi travel density decreased. Hot spots were mainly concentrated in the Puxi area along inner ring road. The travel density of Pudong district was relatively low. Compared with the morning peak travellers, at night, there were many changes in their travel purposes, travel time budget and travel economic budget. Large numbers of non-essential travels (Such as entertainment travels, shopping travels, etc.) took place. Due to the differentiation of travel purposes, the aggregation degree of short-distance taxi travels declined. At night, travellers were consumers but not commuters, and they might be willing to pay higher costs in traffic in exchange for more comfortable transport services. In addition, urban metro systems and most of the ordinary bus lines ceased, which also directly affected the transportation options of the travellers. This may explain that the degree of aggregation of short-distance taxi travel density fell but the total increased. We discovered that the night Puxi, Riverside Expressway is a hot spot. If we could improve the carrying capacity of the public transport run south-north at night, it might be improved.

On rest day, travel purpose might focus on non-essential travel and recreate travel. large numbers of tourists would also change the gathering situation of short-distance taxi travels. External transportation hubs (Shanghai railway station, Shanghai long distance bus station) and important tourist attractions

(East Nanjing road, People Square, The bund, Expo park) became hot spots of short-distance taxi travels. It was clear that tourist travels take up an important proportion of urban traffic on rest days, especially for taxis. By the way, it was discovered that along Puxi Riverside and Shanghai Railway Station to Jing'an Temple road section are short-distance taxis track gathering area.

Urban traffic management department could consider adding the tourist bus line or slow mode traffic guidance on these road sections.

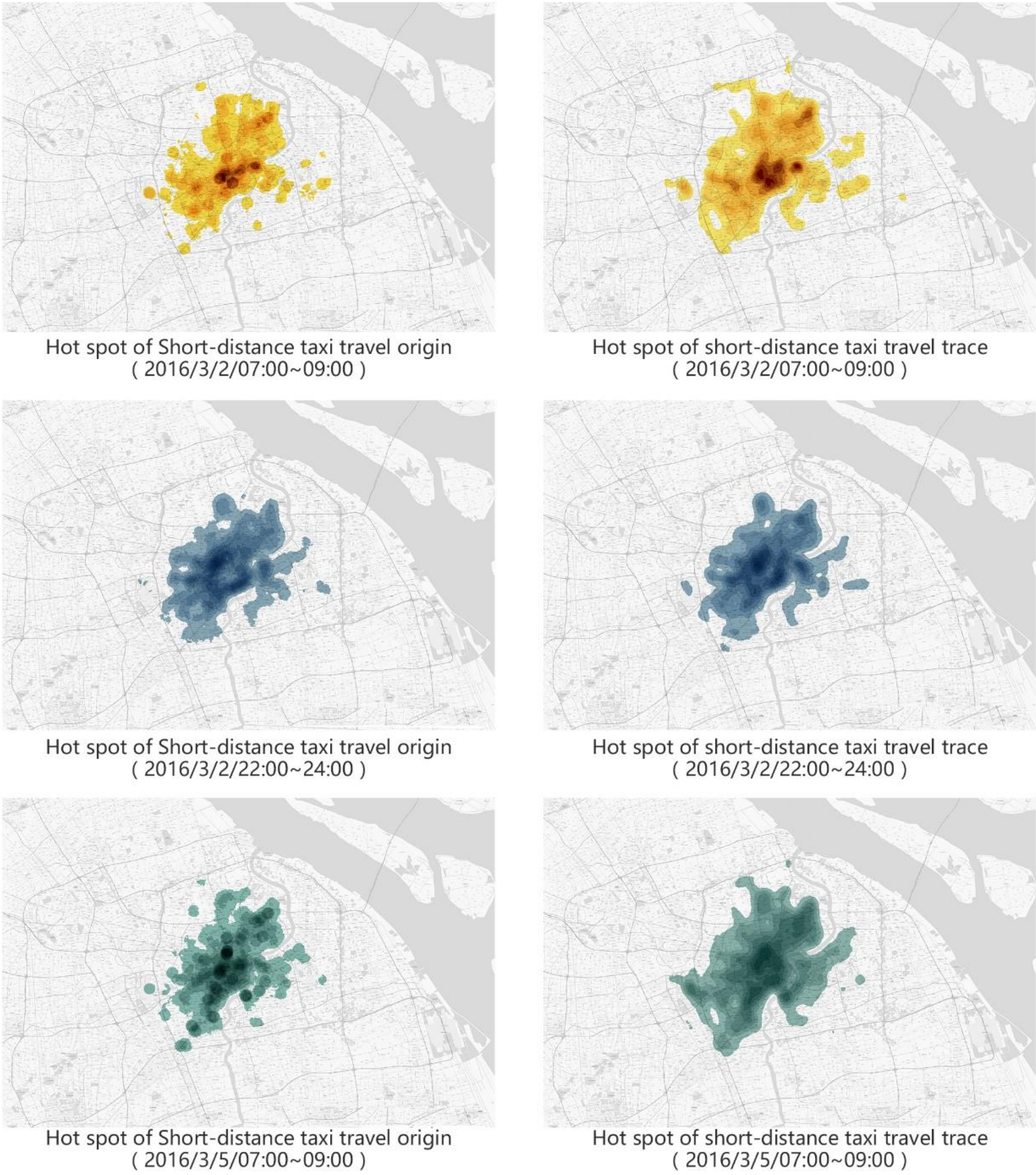

Figure.5 identification of hot spots of short-distance taxi travel

4.Impact of urban built environment on urban short-distance taxi travel

The research scope included 209 sub-districts within the municipal boundaries of Shanghai. After properly processing the taxi trajectory data and removing abnormal data, we screened and obtained geographical information on all origins of short-distance taxi travels from 7:00 to 9:00 on March 3, 2016. To measure the spatial distribution of short-distance taxi travel, we selected the short-distance taxi travel intensity of short-distance taxi travel of each sub-district for dependent variables. Refer to the existing literature on the selection of explanatory variables (Taylor B D et al., 2003, Xinwu Q et al., 2015, Li Q et al., 2016), 10 explanatory variables of urban built environment were selected. The selection of explanatory variables is shown in Table 2. Household population density and the Occupied population density are commonly considered for urban travel research, for they have direct influence on total traffic demand. There are a large number of floating population in Shanghai, most of which are unable to bear the cost of private car travels. They may become an important part of the taxi users. On the basis of the classification of the travel purpose, we also selected four urban facility variables. Selected facilities included entertainment facilities (covers park, theaters, stadiums), medical facilities (tertiary hospital), public service facilities, education facilities. In the traffic environment, because the quality and the accessibility of taxi services are directly restricted by the urban road network density, we needed to take it into account. Considering the competitive relationship between city buses, subways and taxis on short-distance travel, both were also taken as explanatory variables.

Table 2 Candidate list of explanatory variables

Variable	Data source	Description
Household population density	data of the Sixth Population Census	The number of household population per km^2 in each sub-district
Floating population density	data of the Sixth Population Census	The number of floating population per km^2 in each sub-district
Occupied population density	data of the Sixth Population Census	The number of occupied population per km^2 in each sub-district
Entertainment facility density	POI data from Baidu map	The number of entertainment facilities (include park, theaters, stadiums) per km^2 in each sub-district
public service facility density	POI data from Baidu map	The number of public service facilities (including retail facilities and social welfare facilities) per km^2 in each sub-district
Medical facility density	POI data from Baidu map	The number of medical facilities per km^2 in each sub-district
Educational facility density	POI data from Baidu map	The number of education facilities per km^2 in each sub-district
Road network density	Road network data	The length of road per km^2 in each sub-district
Bus service level	POI data from Baidu map	The number of bus stations per km^2 in each sub-district
Metro service level	POI data from Baidu map	The number of metro stations per km^2 in each sub-district

This article used a linear regression model to fit the explanatory variables with the short-distance taxi travel density.The model fitting results are shown in Table 3 and Table 4.

Table 3. Estimation results for linear regression model

Explanatory variable	Unstandardized Coefficients		t	Sig.
	B	standard error		
Constant quantity	-12.463	3.293	-3.784	.000
Bus service level	.146	.780	.188	.851
Educational facility density	.361	.083	4.370	.000
Entertainment facility density	-1.205	.534	-2.259	.025
Floating population density	-.002	.001	-1.796	.074
Household population density	-.001	.000	-2.888	.004
Living service facility density	.282	.213	1.322	.188
Medical facility density	.732	.138	5.324	.000
Metro service level	-16.803	5.492	-3.060	.003
Occupied population density	.000	.000	2.001	.047
Road network density	5355.988	1261.697	4.245	.000

Table 4. Estimation of the fitting model

Model type	R	R square	Adjust the R square	standard estimate Error.
Multi factor linear regression model	0.877a	0.769	0.757	19.509

In the demographic variables, only household population density was significantly related to the dependent variable. Floating population density and occupied population density, were weakly related to short-distance taxi travel density, and couldn't be included in the regression model.

Urban road network density was significantly related to dependent variables. One of the greatest advantages of taxis in urban transport systems is the flexibility. With the emergence of online taxi platforms, the accessibility of taxi services is increasing. On the one hand, the urban road network density directly affects the accessibility and flexibility of taxi services. On the other hand, the urban road network density also reflects the regional demand for motorized transportation, and the two have a positive impact relationship.

In the regression analysis, the competition relationship between metro systems and taxis was identified. The urban metro service level had a significant negative impact on the urban short-distance taxi travel density. That is to say, in areas with higher metro service levels, more short-distance travellers may prefer to choose metro systems rather than taxis. There is possibility of reducing short-distance taxi travel by improving service levels of urban rapid public transport.

In urban facility variables, medical facility density and educational facility density were significantly related to short-distance taxi travel density. We could also further speculate on the individual characteristic of short-distance taxi riders from urban facilities variables. For short-distance taxi travels that take place around medical facilities, it is likely that the traveller is a patient seeking medical treatment or even a disadvantaged person with mobility problems. We should improve accessible design and shorten the walking distance for travellers. The educational facilities were mainly elementary schools. Results also show that some parents choose to pick up children by taxi.

We are very clear that the relationship between urban facility variables and the spatial distribution of urban short-distance taxi travel is most active. For example, on rest days, the short-distance taxi travel density around entertainment facilities may increase.

5.Discussion

With the concept of sharing economy and smart city gradually develop from concept to practice, urban management and urban study are also facing unprecedented opportunities and changes. In the context of smart city, using big data to Identify city issues and optimize city space is more reliable and accurate. This is a hot research field for urban scholars. This paper is just one of numerous attempts. The research findings reveal the impact of urban built environment on short-distance taxi travel. This study and in-depth study may have suggestions for urban management in the following aspects. First of all, it helps to identify short-distance taxi travel hotspots. Second, some short-distance taxi riders are exactly potential users of shared bicycles. Understanding their travel preferences and guiding them to use low-carbon travel will also make a significant contribution to the improvement to the urban environment. Third, the optimization of the model will also provide some reference to predict the future spatial distribution of short-distance taxi passengers.

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