

Private Car Travel Characteristics and Influencing Factors in Chinese Cities —A Case Study of Guangzhou in Guangdong, China

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Abstract: Taking Guangzhou as a case, this paper adopted a questionnaire survey to gather first-hand data and analyzed the characteristics and influencing factors of private car travel in Chinese cities. As the research indicated, trip purposes of private car travel are mainly commute and business affairs with a more flexible trip in the urban core area. And trip intensities are concentrated in a certain extent, with trip frequency being lower in the urban core area than the peripheral area. In addition, the trip time has two significant peaks occurring in the morning and afternoon, and one trough in the midday. And trip spatial distribution is mainly within commute with both residence and employment in urban area and inward commute with residence in suburban area while employment in urban area. Both kinds of commutes direct to the urban area. The study also shows that the characteristics of private car travel are principally influenced by two aspects: travelers' attributes and urban characteristics. The main travelers' social and economic attributes influenced it include the gender, education attainment, age, driving experience and per capita monthly household income. The urban characteristics influenced it mainly cover the land use pattern, public traffic facilities and spatial attributes of residential environment.

Keywords: car travel; travel characteristics; private car; Chinese cities; Guangzhou

1 Introduction

As urban economy develops and living standard improves in China since the 1990s, private car is brought into families dramatically. Thus, traffic maneuverability is accelerating obviously and the percentage of car travel in all travel modes is rising. By the end of 2007, the amount of Chinese private vehicle had reached 28,762,200, among which the passenger vehicle number was 23,169,100. From 1985 to 2000, the sixteen years witnessed the private vehicle ownership increasing from 280,000 to 6,250,000, and the number grew even faster since 2000, finally amounting to 28,762,200 in the late eight years (2000–2007). And the national vehicle number per thousand persons in China was 21.8, among which the number passenger vehicle per thousand persons was 17.5 (National Bureau of Statistics of China, 2008). So the private vehicles in China have been gone through a surprisingly rapid development.

Western literature about car travel mainly focused on exploring the influence of some factors on the car ownership and car usage level. Most studies showed that the expansion of urban scale would probably result in the travel mode choice being automobile especially car travel dominant (Schwanen et al., 2001). They also found that the car travel would be controlled by increasing the urban density, balancing the distribution of dwelling and employment, combining the land use with transportation planning and designing traditional neighborhoods (Frank, 1994; Levinson, 1998; Sim et al., 2001; Handy et al., 2005; Khattak and Rodriguez, 2005; Giuliano and Dargay, 2006; Cao et al., 2006). By contrast, some other scholars figured out that these factors are not as important as the regional difference and economic factors on car travel (Crane, 2000; Schimek, 1996a; 1996b; Miller and Ibrahim, 1998; Crane and Crepeau, 1998). The domestic researches on car travel mainly concentrated on the car purchase reason, trip

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purpose and trip characteristics (He et al., 2005). Some scholars also analyzed the car trip characteristics of clustered cities in China based on urban residents' travel survey data in seventeen cities (Wan et al., 2007). These studies definitely included some cars of corporates, institutes, schools and governments besides private cars. Some studies about private car had been done (Li and Du, 2007). They analyzed the influence of private car on residential space based on inhabitants' commute behavior, and found out that the private car can improve the commute convenience and the number of private cars would increase as residential space spreads.

Regardless of the official car revolution implemented in some cities, one significant issue still exists due to Chinese special condition, which is how to exclude the different travel behavior of corporates, institutes, schools and governments' cars from that of real private car. Meanwhile, by focusing on the car travel characteristics and their influencing factors from the perspective of personal travel behavior, we can determine the substance and scope of the urban transportation problems, furthermore get both empirical basis and theory guide for the private car development.

2 Study Area and Data Source

This research chose Guangzhou as the study area which includes ten districts after administration division ad-

justment in 2005, involving Liwan, Yuexiu, Haizhu, Tianhe, Baiyun, Huangpu, Panyu, Huadu, Nansha, and Luogang (Fig. 1). For the need of analysis and statistics, we define the four districts of Liwan, Yuexiu, Tianhe and Haizhu as the urban area, all of which are with high development level and powerful economy, while the other six districts—Baiyun, Huangpu, Panyu, Huadu, Nansha and Luogang as the suburban area. Therefore, the commute with both residence and employment in the urban area is called within commute, the one with residence in the urban area while employment in the suburban area is defined as reverse commute, the one with residence in suburban area while employment in urban area is defined as inward commute, and the one with both residence and employment in suburban area is called lateral commute. In Guangzhou, the private vehicle increases rapidly. The private passenger vehicle number in Guangzhou was from 150,197 in 2001 to 664,083 in 2007, and private passenger vehicle ownership per hundred households arrived to 27.9, much higher than both the national and provincial average level (Guangzhou Statistical Bureau, 2008).

This paper adopted questionnaire method to acquire the private car travel data. All participants in the survey were car owners. It covered all ten districts of Guangzhou municipality. Each district was taken as an independent stratum, and every stratum was surveyed randomly by the procedure of "all street communities→sa-

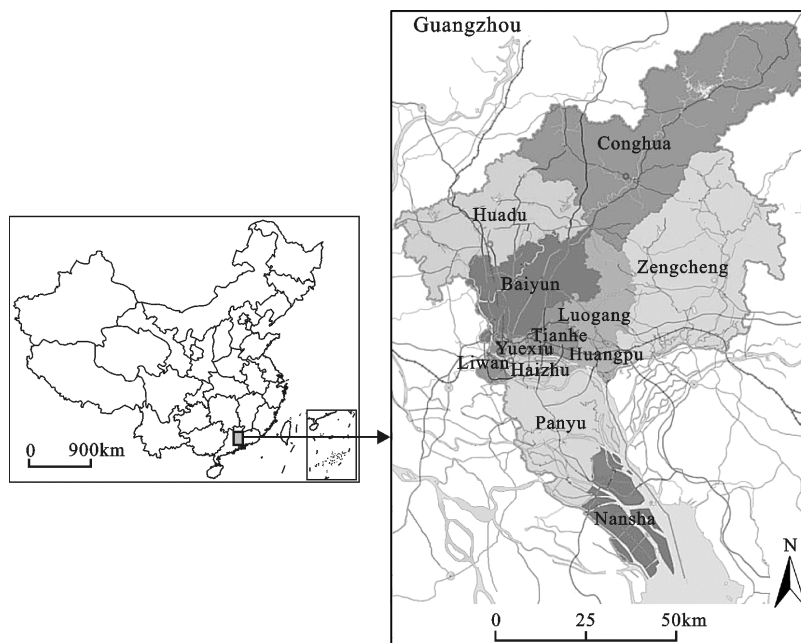


Fig. 1 Location sketch of Guangzhou

mple street community→sample neighborhood committee→sample household→personal”. To ensure the equal-probability in sample choosing from the overall samples, we adopt the multi-stage systematic random sampling method. That is to say, the sub-clusters including the sample units systematically make up the next-stage sampling frame. Therefore, the sample units of each systematical sampling frame can be equally chosen.

In this survey, we mainly acquire information including socio-economic characteristics of car inhabitants, car travel characteristics (including weekly trip frequency, daily trip time, monthly trip expenditure, annual average mileage, trip mode, trip purpose, commute time and commute distance, etc.), and car owners' satisfaction degree on the inhabited environment and public traffic service. In all, 515 questionnaires were collected and the sampling size in each district was decided according to its resident population. Among all the questionnaires, 480 were available with the effective rate of 93.2%.

We find that the car owners have several attributes as follows: 1) The gender is mainly male with a proportion of 66.5%, and the age is mostly 20–35 years old accounting for 56.5% of the total sampling population. 2) Most of the car owners have high education attainment and 82.1% of them have attained undergraduate or specialized college degree. 3) They have mainly middle-level household income with family monthly income per person being 3,000–6,000 yuan (RMB), which account for 50.4% of the total surveyed households. And 4) their family sizes are often small and 54.3% of the families are three-member nuclear family. These people are representative of the overall characteristics of private car travelers in Guangzhou because the individuals surveyed cover a wide range of ages, education attainment and social classes.

3 Private Car Travel Characteristics

3.1 Trip purpose

The multi-purpose travel activities represented a significant change of urban travel behavior in recent years. Generally speaking, the primary purpose of private car travel in Guangzhou is traditional commute and business affairs, and the second one is shopping, education and entertainment (Table 1). That is to say, in residents' everyday living, private cars satisfy their routine needs

for commute and business, and flexible needs for shopping and entertainment. The survey also reflected the spatial differences of private car travel purpose in Guangzhou. Flexible trip proportion shows the percentage of shopping, education, sociality and other purposes in districts. Higher flexible trip proportion occurs in urban areas such as Yuexiu, Tianhe, Haizhu and Liwan districts as well as surrounding areas including Baiyun and Huangpu districts (Fig. 2). The flexible trip demand is probably promoted by diverse land use in urban core area and superior infrastructure for shopping and entertainment in those districts.

Table 1 Sequence of private car trip purposes

Trip purpose	Sequence			Expectation value	Sequence by expectation value
	First	Second	Third		
Commute	297	38	3	970	1
Education	27	14	5	114	7
Business	88	138	23	563	2
Shopping	32	140	105	481	3
Entertainment	16	70	97	285	4
Sociality	7	45	111	222	5
Other purposes	13	12	88	151	6

Note: Expectation value=sample size×weight (weight=3 when ranked first, weight=2 when ranked second, weight=1 when ranked third)

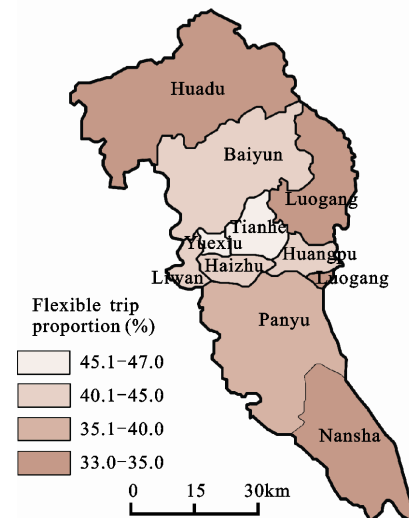


Fig. 2 Flexible trip proportion of car travel in all districts of Guangzhou in 2005

3.2 Trip intensity

Private car travelers in Guangzhou made 8.31 trips per week on average. The amount of private cars in Guang-

zhou had reached 528,000 by the end of 2006, and the total trips of private car travel in Guangzhou got to 4,387,700 times/week. And the peripheral area of the city has a higher trip frequency than urban core area (Fig. 3).

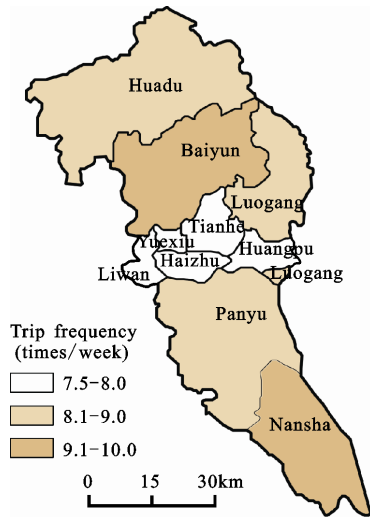


Fig. 3 Trip frequency of car travel in all districts of Guangzhou in 2005

Most private car travelers, about 66.7% of the total sampling number, traveled less than an hour every day on average. However, there are still 20.2% of the car

travelers spending more than 80 minutes in traveling. As for commute time, it was below 30 minutes for most private car travelers, the number of whom takes up 75.63% of the total sampling number. The percentage of commuters in the total samples tended to decrease as the commute time increases.

For about 70.9% of the private car travelers, their annual average mileage was below 8,000km, while 18.1% was above 10,000km. Moreover, there is a significant positive correlation between the annual average mileage and daily car travel time. And the peripheral districts such as Panyu, Huadu and Nansha shared a relative high annual average mileage, all above 7,000km, however the core areas such as Huangpu and Luogang had much lower ones, with 5,167km and 5,231km.

The private car travel duration, commute distance and commute time were not high in Liwan and Yuexiu of Guangzhou and their surrounding area (Table 2). The travelers there had a less dependence and usage level of private car. It probably attributes to the diverse function distribution in this region and neighboring area including residence housing, industry, and business service, which means that higher employment density occurs in this region, and the travelers there can be more easily employed nearby and use car for commute less.

Table 2 Car commute time and commute distance of all districts in Guangzhou

	Liwan	Yuexiu	Haizhu	Tianhe	Baiyun	Huangpu	Panyu	Huadu	Nansha	Luogang
Commute time (min)	20.86	18.49	20.31	22.50	20.57	20.19	25.28	23.45	24.07	24.62
Commute distance (km)	6.29	5.49	5.93	6.13	5.15	6.19	7.89	6.84	7.93	6.58

3.3 Trip time distribution

Commute is a significant trip purpose of private car and its time distribution can mostly represent the overall trip time distribution. Figure 4 shows car trip time distribution, which reflects two significant peaks occurring in the morning and afternoon, and one trough in the mid-day. This is due to the effect of planned economy, which leads to the rigid timetable and similar long lunch time in most employment. Some surveyed individuals even spent lunch time in going back home and taking a rest. From the angle of time allocation, the peak time occurs at about 8:00 in the morning, and 13:00 and 18:00 in the afternoon, taking up 12.1%, 3.3% and 12.9% of the total commute amount respectively, and the trough occurs at 11:00, besides 0:00–6:00 and 22:00–24:00 with a commute proportion of only 0.3%.

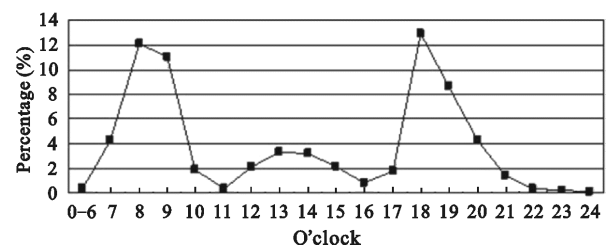


Fig. 4 Trip time distribution of car travel in Guangzhou

3.4 Trip spatial distribution

The private car commute categories differed greatly among districts of Guangzhou. As Table 3 shown, above 80% of the commute in urban area belonged to within commute with a high proportion in Yuexiu and Tianhe, while the commute in the suburban area was dominant by lateral commute with a percentage closing to the

proportion of reverse commute. The private car commute in Guangzhou was mainly commute with the destination in the urban area (including within commute and inward commute) accounting for 66.1% of total commute. And within commute, with residence and employment locations in the same area, was dominant. It may attribute to that most of employment concentrated in urban area which led to high employment density in this region. However, the reverse commute and lateral commute were increasing as the urban sprawl and suburbanization occur. The proportion of lateral commute was about 29.3%, more than that of inward commute. Still the reverse commute shared a little proportion in the total commute of all districts in Guangzhou.

Table 3 Structure of car commute spatial categories in Guangzhou

District	Commute spatial category (%)			
	Within commute	Lateral commute	Inward commute	Reverse commute
Liwan	88.0	0	12.0	0
Yuxiu	96.4	0	3.6	0
Haizhu	87.3	0	12.7	0
Tianhe	93.4	0	6.6	0
Baiyun	0	27.5	0	72.5
Huangpu	0	30.0	0	70.0
Panyu	0	46.4	0	53.6
Huadu	0	46.7	0	53.3
Nansha	0	34.6	0	65.4
Luogang	0	47.4	0	52.6

4 Factors Influencing Private Car Travel

The influence on private car travel is related to many aspects, and this article focuses on two main factors including private car travelers' attributes and urban attributes.

4.1 Private car travelers' attributes

Private car travelers' attributes can be classified into two

categories: personal attributes and household attributes. Personal attributes include gender, age, education attainment, occupation, driving experience and car type. While household attributes include per capita monthly household income, household structure and household car ownership. Meanwhile, private car travel can be evaluated by six indexes: weekly trip frequency, daily trip time, monthly trip expenditure, annual trip mileage, commute distance and commute time. The former four indexes reflect the car usage level of travelers and the latter two can show the commute characteristics of private car.

By the correlation analysis, we find that the age, occupation, car type and household car ownership weakly correlate with car usage characteristics, but contrarily, gender, education attainment, driving experience, and per capita monthly household income have significant impacts on car usage level (Table 4). To be more specific, the male are more dependent on car travel. And weekly trip frequency, daily trip time, monthly trip expenditure increase as the travelers' driving experience, education attainment and household income improve. On the other hand, comparing with the car usage characteristics, the commute characteristics are less affected by the travelers' attributes. Still, a significant correlation exists between the age, driving experience, per capita monthly household income and commute distance, which means the commute distance gets longer as those influencing factors improve, furthermore resulting in more widely employment location choices. Additionally, a weak correlation exists between the car type, household car ownership and commute distance.

4.2 Urban attributes

This paper chooses three aspects that greatly influence the private car travel to analyze: land-use pattern, public traffic facility and spatial attributes of residential enviro-

Table 4 Correlation between private car travelers' attributes and private car travel characteristics

	Weekly trip frequency	Daily trip time	Monthly trip expenditure	Annual trip mileage	Commute distance	Commute time
Gender	-0.096*	-0.135**	-0.119**	-0.140**	-0.034	0.009
Age	0.032	0.092*	0.101*	0.151**	0.126**	0.087
Education attainment	0.213**	0.233**	0.171**	0.174**	0.038	0.011
Occupation	-0.035	-0.105*	-0.141**	0.006	-0.063	0.016
Driving experience	0.261**	0.232**	0.257**	0.382**	0.204**	0.035
Car type	0.120*	0.116*	0.124*	0.006	-0.028	-0.101*
Per capita monthly household income	0.156**	0.152**	0.255**	0.226**	0.105*	0.040
Household structure	-0.017	-0.055	-0.020	-0.023	0.033	0.068
Household car ownership	0.091*	0.072	0.116*	0.046	-0.037	-0.134*

Notes: **Significant level of correlation coefficient is below 0.01, * significant level of correlation coefficient is below 0.05

environment.

4.2.1 Land-use pattern

To discuss the influence of land-use pattern on the private car travel, we adopt the Shannon diversity index (H), a term of landscape ecology, to make a quantitative analysis on the land use pattern in all districts of Guangzhou. Compared with car travel characteristics such as commute time, commute distance, flexible trip proportion, private car travel proportion and main commute

spatial type proportion, the correlativity is obvious (Table 5). The private car travel proportion is the percentage of residents who use car as dominant trip mode in the total number of car owners. The main commute spatial type proportion means the commute spatial type accounts for the largest proportion, and it is the proportion of within commute in urban area while in the suburban area it means the proportion of lateral commute.

Table 6 indicates that the urban land-use pattern has

Table 5 Comparison of car travel characteristics and land-use spatial pattern indices in all districts of Guangzhou

	Liwan	Yuexiu	Haizhu	Tianhe	Baiyun	Huangpu	Panyu	Huadu	Nansha	Luogang
Commute time (min)	20.8	18.4	20.3	22.5	20.5	20.1	25.2	23.4	24.0	24.6
Commute distance (km)	6.29	5.49	5.93	6.13	5.15	6.19	7.89	6.84	7.93	6.58
Flexible trip proportion (%)	39.9	45.5	41.9	46.7	43.7	41.3	38.8	34.2	34.5	33.7
Private car travel proportion (%)	34.9	34.4	35.5	36	43.0	36.6	41.2	39.0	46.5	40.6
Main commute spatial type proportion (%)	88.0	96.4	87.3	93.4	72.5	70.0	53.6	43.3	65.4	52.6
Shannon diversity index	1.85	1.82	1.48	2.044	1.38	0.87	0.91	0.49	0.54	0.47

Notes: Shannon diversity index $H = -\sum_{k=1}^n P_k \ln(P_k)$, where P_k refers to the ratio of land area which belongs to the category k to the total land area, and n refers to the land category number. For a certain n , when the proportion of each category of land is the same, that is, when $P_k = 1/n$, H will get its maximum, and $H_{\max} = \ln(n)$.

Table 6 Correlativity between private car travel characteristics and land diversity index

	Commute distance	Commute time	Flexible trip proportion	Private car travel proportion	Main commute spatial type proportion
Correlation coefficient	-0.612*	-0.642*	0.875**	-0.661*	0.922**

Notes: **Significance of correlation coefficient is below 0.01, * significance of correlation coefficient is below 0.05

importance on the commute distance, commute time, trip purpose, and private car usage level as well as commute spatial type. On one hand, car commute distance, commute time and private car trip proportion have significant negative correlations with the land diversity index. In another word, as the diversity of landscape intensifies, more employment opportunities will be provided in a smaller area, so that the commute time and commute distance are shortened, as a result the private car trip proportion in all travel modes decreases. On the other hand, the flexible trip proportion and main commute spatial type proportion have positive correlations with the diversity index, which means that the more diverse the land use is, the higher ratio the flexible trip will be. And the diverse urban land uses may also lead to the concentration of commuting space in the same district and the proportion of both within commute in the urban area and lateral commute in the suburban area will rise.

4.2.2 Public traffic facility

The residents' satisfaction to the public traffic facility is significantly correlated with the annual trip mileage and weekly trip frequency of private car but little related to the daily trip time and monthly trip expenditure of private car. And weekly trip frequency has a negative correlation with the rapidity and punctuality of public transportation, because the discontent about the public transportation will push the residents to use car more frequently (Table 7). As a result, improving rapidity and punctuality of public transportation is essential for appealing to more public traffic users.

The annual trip mileage of private car is also negative correlated with the public transportation service. In another word, with the improvement of public transportation service, the travelers' dependence on car as well as the annual trip mileage of private car will decrease. However, the economic efficiency is not a main factor to determine the private car travel. Also, in the same city, the construction of public transportation exerts an important effect on the car usage. When the residents satisfy with the road density, public transportation density and transportation network distribution, they will be more inclined to choose public transportation that is quick and convenient, thus the usage of the private car will probably decrease.

Table 7 Correlativity between transportation facility service and car usage level in Guangzhou

	Weekly trip frequency	Daily trip time	Monthly trip expenditure	Annual trip mileage
Safety	-0.011	-0.087	-0.008	-0.145**
Comfort	-0.022	-0.020	0.004	-0.165**
Rapidity	-0.126*	0.038	0.068	-0.170**
Convenience	-0.062	0.070	-0.028	-0.218**
Punctuality	-0.113*	-0.003	0.046	-0.243**
Economy	0.014	-0.084	-0.005	-0.079
Road width	-0.018	-0.019	-0.039	-0.152**
Transportation network distribution	-0.085	-0.051	0.027	-0.178**
Public bus line	-0.039	-0.059	-0.010	-0.187**

Notes: **Significance of correlation coefficient is below 0.01; * significance of correlation coefficient is below 0.05

4.2.3 Spatial attributes of residential environment

Taking the indexes including housing type, housing completion time and the residents' satisfaction degree to the housing and environment, we evaluate the spatial attributes of residential environment, thus analyze the correlativity between those indexes and private car travel (Table 8).

There are significant positive correlations between the housing type and weekly trip frequency, daily trip time, and monthly trip expenditure as well as annual trip mileage of private car. In another word, the larger house one family possesses, the more frequently they are likely to use car. While, the housing completion time is weakly positive correlated with weekly trip frequency

Table 8 Correlativity between private car travel and spatial attributes of residential environment

		Weekly trip frequency	Daily trip time	Monthly trip expenditure	Annual trip mileage
Housing type		0.092*	0.120**	0.167**	0.118**
Housing completion time		0.176**	0.092*	-0.017	-0.047
Satisfaction	Parking lot in the neighborhood	-0.067	0.049	0.024	-0.162**
	Outer road of neighborhood without traffic jam	-0.034	-0.070	0.095*	-0.125**
	Adaptability of the neighborhood road for pedestrian	-0.000	0.139*	0.145*	-0.013
	Convenience of using public service facility	-0.035	0.011	0.073	-0.095*
	Convenience of taking bus	-0.091*	0.030	0.050	-0.038

Notes: **Significant level of correlation coefficient is below 0.01; * significant level of correlation coefficient is below 0.05

and daily trip time, indicating that the longer the housing is completed, the higher the trip frequency will generally be.

The influence of residents' satisfaction degree to the housing and surrounding environment on private car travel can be shown in five angles as follows. First, rational distribution of parking lot in the neighborhood can increase the use efficiency of parking lot and decrease the annual trip mileage of private car. Second, the outer road of neighborhood without traffic jam can partially increase monthly trip expenditure while decrease the annual trip mileage, though the influence is not strong. Third, the adaptability of neighborhood road for pedestrian is weakly positive correlated with the daily trip time and monthly trip expenditure of private car. It indicates that rational pedestrian road system does not lead to low car usage rate, instead increases the trip time and expenditure. Fourth, the convenience of taking bus, which means intense connection of the community road and bus station, can improve the public transportation facility and service level, thus make the public transportation be an alternative to car travel. Lastly, the conven-

ience of using public service facility has a negative correlation with annual trip mileage and weekly trip frequency. It reveals that when the community owns enough public service facilities which can meet the need of residents' daily living, they will use the nearby facility and the need to use the car decreases.

5 Conclusions

From the perspective of travelers' behavior, the paper analyzed the private car travel characteristics and influencing factors in Chinese cities taking the case study of Guangzhou, mainly based on the questionnaire survey.

As the study certificated, private car travel has some rules in the angles of trip purpose, trip intensity, trip time distribution and trip spatial distribution. Trip purposes are mainly commute and business affairs, and then some flexible travel needs. Trip intensities are concentrated in a certain extent, which is less than an hour per day and below 8,000km of annual mileage. In addition, the trip time distribution has two significant peaks in the morning and afternoon, and one trough in the midday.

And trip spatial distribution is mainly within commute and inward commute, both with commute directing to urban area, meanwhile the reverse commute and lateral commute is increasing. Furthermore, both trip purposes and trip intensities have differentiation in different urban areas, for instance, the proportion of flexible needs in urban core area is higher and the dependence of private car is lower there, comparing with the peripheral area.

From the micro angle, travelers' socio-economic attributes are the main factors triggering private car travel. And the gender, education attainment, age, driving experience and per capita household monthly income exert significant effects on private car usage level of travelers. In detail, male travelers with high driving experience, high education degree and high income level are inclined to use private car more than other travelers. Contrarily, travelers' attributes have less effects on commute time and commute distance. However, the age growing older, driving experience and per capita household monthly income increasing would still promote the increase of commuting distance.

From the macro angle, urban attributes also make a great influence on private car travel, mainly from three aspects: land-use pattern, public traffic facility and spatial attributes of residential environment. Firstly, diverse urban land uses can shorten the commute distance and commute time of private car travelers, at the same time decrease the usage level of private car, and furthermore enhance the proportion of flexible trips such as shopping and entertainment. Secondly, travelers' dissatisfaction on rapidity and punctuality of public transportation would probably lead to more private car trips, while the improvement of public transportation service may result in less annual mileage of private car. Lastly, rational distribution of parking lot in the neighborhood, convenience of taking bus and using public service facility can in some degree restrict the usage of private car.

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