The Analysis of Taxi Operation Features in Chinese Large Cities Based on Floating Cars

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***Abstract*—As one of basic trip modes for urban residents, taxi plays a role that cannot be neglected in the urban traffic system, but there are a few studies on taxi at home and abroad and the analysis of taxi operation features is insufficient and lacks fundamental and quantitive technical indices, rules and data. With GPS data of 16,000 taxis in Wuhan and 66,000 taxis in Beijing and through horizontal comparison of the data of Wuhan and Beijing, Shanghai, Guangzhou and Shenzhen, the profound analysis is conducted for taxi operation features, like the passenger capacity, the occupied road resources, the temporal and spatial distributions of taxi, and the emphasis is placed on four aspects, namely the taxi operation features, the relation between taxi and road traffic, the features of taxi users and the relation between taxi and other traffic modes. From the accessibility and comparability of data collection of the floating car system, the quantitive data indices and analysis conclusion are first proposed. This study provides references for the functional orientation of taxi in urban traffic, the formulation of macro-policies for urban traffic development, the scientific coordination and planning of layout and operational organization of various urban traffic facilities.**

***Index Terms*—taxi, operation features, the role of taxi in urban traffic**

I. Introduction

At present, the traffic development in Chinese cities, especially super cities, faces the increasing difficulty and challenge along with the alternation and mutual acceleration of urbanization and mechanization. In the course of seeking solutions, people turn eyes and attach importance to subway, conventional bus and the management and control of purchasing and driving privates' cars, while the comprehensive and systematic analysis and studies of taxis are lacking. Currently, close attention should be paid to at least two trends. On one hand, large-scale construction and development and network operation of urban rail transportation lead to an improvement of trip comfort and speed and shunt the taxi passenger source to a certain extent, and this also benefits from the subway passenger flows. On the other hand, the urban road system faces the severe test of huge stock and explosive increase of motor vehicles, and the deterioration of road operation conditions and the intensified congestion bring about adverse effects for taxi operation and service quality. Though the related departments have taken countermeasures positively, the phenomenon and problem of "difficult taxi-take" haven't changed fundamentally. Timely understanding and comprehensive mastery of the taxi operation features and development rules through scientific researches, especially dynamic information technological means, as well as the clarification the role of taxi in the urban traffic system are of great significance in formulating macro-policies for urban traffic development, coordinating and planning the layout and operational organization of various urban traffic facilities.

There are certain researches on the taxi stop feature, path selection and total volume control ([1]) at home and abroad. Along with the popularization of GPS, there is richer quantitive data support for the analysis of taxi operation features ([2]-[7]). However, the current analysis on taxi operation features based on the floating car system is focused on the operation management, but the role of taxi in urban traffic system, the effects of taxi on urban road traffic and the supporting effects of taxi for urban passenger transportation lack extensive and profound systematic analysis. Existing research findings are applicable to certain cities and the data analogy analysis among the large- and medium-sized cities of different features are lacking so that it is difficult to derive the universality and peculiarity of taxi operations.

From the perspective of urban planning, this paper, with the taxi and floating car information and the taximeter data as the carrier, analyzes and extracts the

Manuscript received July 1, 2017; revised November 21, 2017.

doi: 10.18178/jtle.5.2.60-67

taxi operation indices and the passenger transportation indices and makes a comparison among taxi, rail transportation, conventional public and car transportation based on the taxi operation data in domestic cities like Wuhan, Beijing and Shenzhen and proposes the optimization suggestions for the taxi operation management.

In this paper, the second part mainly introduces the research method employed in this paper, the third part summarizes the taxi operation features and the fourth part reaches a conclusion and puts forwards the optimization suggestions.

II. Methods

A. Conventional Research Methods

At present, there are many analysis methods for taxi operation, for example the statistical bulletin data analysis method and the sampling survey. However, the statistical bulletin has relatively long circle and its data investigation columns are fixed and cannot be added in accordance with the specific circumstances. The sampling survey is difficult to reflect the group characteristics because of limited samples and it has relatively high requirements for question and form design. Furthermore, the sampling survey is largely affected by the will of taxi drivers, so it lacks the objectivity and fails to reflect the continuous features of taxi operation as well as the changes of taxi operation features at different traffic congestion degrees because of incomplete samples.

B. The Research Method Employed in This Study

In this study, the floating car analysis method is employed to derive the data of taxi operation features. The floating car analysis method takes advantage of GPS information platform on taxis. The project of the location and direction of taxis uploaded by GPS every once in a while to the GIS map can be widely applied to the calculation of taxi speed and the evaluation of traffic congestion. Meanwhile, GPS on taxi is connected to taximeter and the real-time geological location and state (carrying passenger and empty) of taxis under the operation state can be derived through the combination of GPS and taximeter. There is the investigation of taxi passenger carrying rate as supplement. As a result, the taxi operation features in urban cities can be mastered comprehensively. The floating car analysis method is capable of calculating and storing the location and state information of the taxi under the operation state for a long time continuously and automatically and takes massive data as basis and avoids enormous manpower consumption, limited samples and the subjective factors of both parties in the traditional investigation and analysis, thus providing a new possibility for comprehensive, objective and accurate analysis and mastery of taxi operation features.

Due to urban land use, population size, trip modes, social and economic development level, the total number of taxis as well as the diversified infrastructures like rail transportation and conventional bus, the taxi operations have similarities and differences. Towards this end, the comparative analysis method is employed, and a comparison is made between Wuhan and Beijing and a horizontal data comparison is made among taxi, bus and private cars.

C. Data Selection

In this study, two cities, i.e. Wuhan and Beijing, are chosen and currently there are 760,000 operational taxis in total whose location and state information are uploaded every 40 seconds. The floating car systems in these two cities were established in 2010 and 2005 respectively and run maturely and stably. To reflect the changes of taxi operation features, 2012, 2013 and 2014 are selected as the feature years to analyze the yearly variation features; the 12 months of the second half of 2013 and the first half of 2014 are selected as the feature months to analyze the monthly variation features; several working days in May, 2014 are selected to analyze the daily variation features. The feature days shall be ordinary working days and the taxi samples sent back by GPS shall account for over 70% of the total number in the feature days so as to avoid nonconforming data quality and reflect taxi features comprehensively.

Furthermore, the operation data of bus and car in Wuhan are chosen, in which the bus data are derived from real-time GPS data of 6,500 buses and about 4,500,000 person-times of IC card swiping every day and the car data come from Wuhan traffic forecasting model.

III. Analysis of Taxi Operation Features

In this study, the taxi operation features are analyzed from four aspects: firstly, the taxi operation features, and a set of widely-used taxi operation evaluation indices shall be established; secondly, the relation between taxi and road traffic and the differences between peak and non-peak hours shall be analyzed; thirdly, the analysis of the features of taxi users is beneficial to taxi planning management; fourthly, the relation between taxi and other transportation means shall be analyzed and the position of taxi in the urban traffic system shall be clarified.

A. Analysis of Taxi Operation Indices

Zhou Jingyi [8] proposed the basic evaluation index system for taxi operation level, which consisted of 14 detailed evaluation indices like the average vehicle category, the average number category, the average day category, the average month category, the category of total service level and so on. Considering that not all taxis in large cities can extract the above-mentioned detailed indices and the comparative analysis is difficult, this paper proposes several indices that is convenient to comparative analysis and can directly reflect the taxi operation efficiency, including the operation time, the operation mileage, the passenger carrying times and the mileage utilization rate.

The operation time can reflect the duration of service provided by taxi and indicate the reliability of taxi service from the perspective of time; the operation

mileage can reflect the spatial service scope of taxi and indicate the reliability of taxi service from the perspective of space; the passenger carrying times can reflect the frequency of taxi service and indicate the effective of taxi service from the perspective of passenger; the mileage utilization rate can reflect the taxi operation efficiency and indicate the usefulness of taxi service from the angle of resources occupation.

1) Operation time

The shift system is employed for taxi operation in Wuhan and the average daily taxi operation times in three consecutive years from 2012 to 2014 are 16 hours, 15.7 hours and 15.3 hours respectively, with an annual decrease rate of 2% (Data in May, 2014 of Wuhan is shown in Table I). The daily taxi operation time in Shenzhen [9] is about 19 hours. The daily taxi operation time in Beijing is about 11.9 hours, in which the daily taxi operation time is about 8.8 hours for one shift and about 13.97 hours for double shifts (the data in April, 2014, the numbers of taxi samples are 26,131 for one shift and 24,756 for double shifts, detailed number in Fig. 1). The data comparison of several cities shows that the taxi operation time is closely related to the living habits of urban residents. In China's large cities, the urban residents in the south have relatively longer daily activity time and accordingly the average taxi operation time is longer, while the taxi operation time is short in the north because the urban residents in the north have relatively shorter activity time.

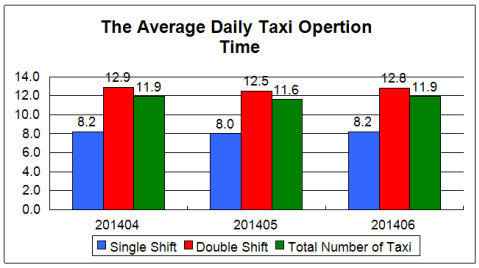

Figure 1. The taxi operation time in Beijing

The index corresponding to the operation time is the passenger carrying time, which indirectly reflects the time utilization efficiency of taxi, as is shown in the table below. The data show that the taxi operation time at peak hours is far higher than that at non-peak hours. At the same time, the time utilization efficiency of taxi at peak hours is also apparently higher than that at non-peak hours and about 1.07 folds of that at non-peak hours. This also indirectly reflects the cause for the difficulty of taxi-take at peak hours.

TABLE I. THE ANALYSIS OF TAXI OPERATION TIME AND PASSENGER CARRYING TIME IN WUHAN (THE DATA IN MAY, 2014)

Item	Four Peak Hours	Non-peak Hours	The Whole Day
The Taxi Operation Time (hour per taxi)	3.11	11.97	15.07
The Passenger Carrying Time (hour per taxi)	1.88	6.73	8.60
The Time Utilization Rate (The Passenger Carrying Time/The Taxi Operation Time)	60.4%	56.2%	57.1%

2) Operation mileage

The daily operation mileage of taxi is mainly subject to the effects of the operation time and speed of taxi as well as the traffic congestion degree. The investigation shows that the daily taxi operation mileage in Wuhan decreases annually along with the intensified traffic congestion. For example, the daily taxi operation mileages in 2012, 2013 and 2014 are 385.3 km per taxi, 375.5 km per taxi and 346.2 km per taxi, with annual decrease rates of 2.5% and 7.8% respectively (Detail data is shown in Table II). At the same time, the traffic congestion index of Wuhan in 2013 rises by 22.7% compared with that in 2012 and the traffic indices from February to December in 2014 go up by over 35% compared with those in 2013. The relations between the average vehicle speed on roads and the average operation mileage per taxi in Wuhan from 2012 to 2014 are as follows:

TABLE II. THE AVERAGE VEHICLE SPEED ON ROADS AND THE AVERAGE DRIVING MILEAGE PER TAXI IN WUHAN IN THREE YEARS

	May, 2012	May, 2013	May, 2014
The Driving Mileage (km)	385.3	375.5	346.2
The Decrease Rate	—	2.5%	7.8%
The Average Vehicle Speed on Roads (km/h)	24.2	24.0	22.7
The Decrease Rate	—	0.8%	5.4%

The daily operation mileage per taxi is largely affected by short-term factors like the adjustment of taxi fare. According to the analysis, the daily operation mileage per taxi on the working days was 287.9 km and decreased by 5.6km compared with that before taxi fare adjustment (293.5km) over one year since The Suggestions Concerning the Enhancement of Taxi Management and the Improvement of Taxi Operation Service Level by Beijing People's Government was put into effect in June, 2013. There are differences in the daily operation mileages per taxi in the quarters as indicated in Fig. 2.

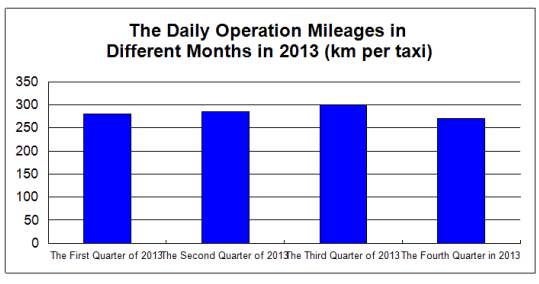

Figure 2. The analysis of quarterly variations of monthly and daily taxi operation mileages in Beijing

3) The passenger carrying times

The daily average passenger carrying times of taxi reflects the role and position of taxi in urban passenger transportation. The daily average passenger carrying times of taxis in Beijing and Wuhan in recent years show that the functions of taxis are weakened against the background of substantial growth of cars and rapid construction of rail transportation.

At present, Wuhan is in the stage of rapid construction of rail transportation, the newly-added subway mileage in the central downtown area reaches 20km each year and the daily taxi passenger carrying times decrease largely. The daily taxi passenger carrying times was 45 in 2011 but decreases to 34 in 2014 in Wuhan (Detail data is shown in Table III). The shunt has achieved prominent effects. Of course, the subway construction has exerted certain effects on the road traffic operation. In Beijing, the rail transportation network has basically formed and the newly-added rail transportation lines are concentrated in the outskirts and staggered with the taxi operation space and scope, so the taxi passenger carrying times are relatively stable. The taxi passenger carrying times in Beijing in 2013 basically equals to that in 2014.

TABLE III. THE VARIATIONS OF DAILY PASSENGER CARRYING TIMES OF TAXIS IN WUHAN AND BEIJING IN RECENT YEARS

	May, 2012	May, 2013	May, 2014
The Average Passenger Carrying Times Per Taxi in Wuhan	42.2	37.9	34.2
The Decrease Rate	—	10.2%	9.8%
The Average Passenger Carrying Times Per Taxi in Beijing	24.0	22.9	22.6
The Decrease Rate	—	4.6%	1.4%

Remarks: (1) The taxi preservation has not changed significantly in the above-mentioned years; (2) The taxi data in Beijing in June, 2013 were affected by the elevation of taxi fare.

4) Mileage utilization rate

The unoccupied taxi ratio reflects the operation state of empty taxis. The larger the unoccupied taxi ratio is, the smaller the effective utilization rate of taxi is. The index corresponding to the unoccupied taxi ratio is the mileage utilization rate.

The data show that the effective utilization rate of taxi is largely related to the taxi fare. For example, the mileage utilization rates of taxis in Wuhan in three consecutive years from 2012 to 2014 are 60.2%, 65.1% and 60.2% respectively. The mileage utilization rates of taxis in 2013 is obviously higher than those in 2012 and 2014 and the main cause is the bunker adjustment surcharge. The bunker adjustment surcharges were 2 Yuan in May, 2012 and May, 2014 but decreased to 1.5 Yuan on May 1, 2013 in Wuhan. The decrease of bunker adjustment surcharge causes the mileage utilization rate of taxi to rise by about 8%.

The adjustment of taxi fare usually has short-term effects on the mileage utilization rate of taxi. The data of Beijing show that the daily average mileage utilization rate per taxi dropped from 66.1% to 63.5% after the price adjustment in June, 2013 and went up to 65.3% in the second quarter of 2014 which was equivalent to that before the adjustment of taxi fare.

B. The Relation between Taxi and Road Traffic

1) Taxi Speed

The taxi speed is subject to the overall operation speeds on roads as well as the states of taxi (empty or carrying passengers). The data of Wuhan and Beijing show that the taxi speed is large when the taxi is empty but small when the taxi carries passenger (Detail data in Wuhan is shown in Table IV). However, at peak hours, the taxi speed has limited differences and similar fluctuation range with the speeds of social vehicles [10], [11].

TABLE IV. THE ANALYSIS OF DRIVING SPEEDS OF EMPTY TAXIS AND TAXIS CARRYING PASSENGERS IN WUHAN (THE DATA IN MAY, 2014)

Type	Four Peak Hours	Non-peak Hours	The Whole Day
The Driving Speed of Empty Taxi (km/h)	20.8	23.7	23.2
The Driving Speed of Taxi Carrying Passengers (km/h)	20.6	24.2	23.4
The Driving Speed of Taxi Carrying Passengers /The Driving Speed of Empty Taxi	99.1%	102.2%	101.3%

Along with the intensified traffic congestion, the taxi speed decreases annually, in particular, the proportion of passenger transportation of taxi at peak hours is larger than that at non-peak hours (in comparison with other transportation modes) and the taxi serves for less people due to the effects of traffic congestion. In Wuhan in 2014, the speed of taxi carrying passengers at peak hours is 19.8km/h and the person-times served by taxi at peak hours account for 5% of those by motor vehicles; the speed of taxi carrying passengers at non-peak hours is 24.0km/h and the person-times served by taxi at peak hours account for 8% of those by motor vehicles.

2) The relation between taxi speed and driving mileage

Along with the intensified traffic congestion in urban cities, the vehicle speeds on roads decrease gradually. The decrease of taxi speed directly affects the taxi operation mileage and they exhibit the 1:1 correspondence. The average taxi speed in Wuhan decreases from 24km/h in 2012 to 22km/h in 2014, with a decrease rate of 8.3%, while the taxi operation mileage declines from 385km/pcu in 2012 to 346km/pcu in 2014, with a decrease rate of 10.1%.

3) The relation of peak and non-peak hours

Due to the traffic congestion at peak hours, the taxi speed at peak hours drops slightly compared with that that at non-peak hours and the operation mileage and passenger carrying effects at peak hours are slightly lower than those at non-peak hours (Detail data is shown in Table V). During four peak hours in Wuhan, the passenger carrying time of taxis accounts for 21.8% of that in the whole day, but the passenger carrying mileage accounts for 19.2% of that in the whole day and the speed of taxi carrying passenger is 87.8% of the daily average speed. The speed exerts large effects on taxi operation.

TABLE V. THE COMPARISON OF TAXI DATA AT PEAK HOURS AND THOSE AT NON-PEAK HOURS IN WUHAN

Type	Four Peak Hours	Non-peak Hours	The Whole Day	The Proportion of the Indices at Peaks Hours in Those of the Whole Day
The Operation Time (h/taxi)	3.11	11.97	15.07	20.6%
The Passenger Carrying Time (h/vehicle)	1.88	6.73	8.60	21.8%
The Driving Mileage (km/taxi)	64.17	287.28	351.45	18.3%
The Passenger Carrying Mileage (km/taxi)	38.63	163.08	201.71	19.2%
The Driving Speed of Empty Taxi (km/h)	20.8	23.7	23.2	89.7%
The Driving Speed of Taxi Carrying Passengers (km/h)	20.6	24.2	23.4	87.8%

C. The Analysis of Taxi Users

1) The average trip distance

The average trip distance is largely related to the city scale. The central downtown area of Wuhan (within the Third Ring Road, including Yangze River and East Lake) reaches 650km^2 and the average trip distance of taxi passengers per time is 6.7km and within 10km for 51% of taxi passengers. The central downtown area of Beijing (within the Fifth Ring Road) occupies 750km^2 and the average trip distance of taxi passengers per time is 8.6km.

As the built-up area of cities expands constantly and the multi-center structure of central downtown areas has formed gradually, the activity radius of residents is enlarged gradually and the trip distance of residents by taking taxi becomes increasingly large as well. Nowadays, Wuhan is till in the stage of constant expansion and the trip distance of taxi rises slightly. The average trip distances by taxi in 2012, 2013 and 2014 are 5.8km/time, 6.3km/time and 6.6km/time respectively, with annual increase rates of 8% and 4% respectively. However, Beijing has undergone relatively mature development, the average trip distance by taxi is relatively stable.

The service objects of taxi have certain differences from the bus and car users. In Wuhan, the average trip distance of passengers by bus per time is 7.2km and 7% higher than that by taxi, while the average trip distance of passenger by car per time is 9.1km and 35% higher than that by taxi. Therefore, it can be seen from the average trip distances by taxi, bus and car that the trips of medium and short distances are mostly undertaken by taxi.

2) Features of trip time

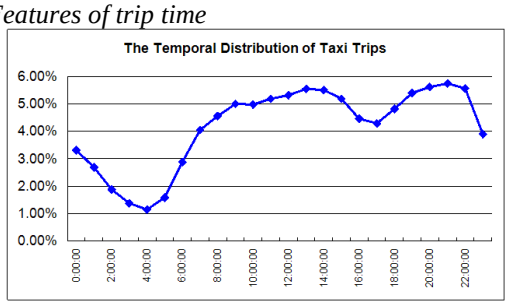

Figure 3. The temporal distribution of passenger flows of taxi in Wuhan in 2014

Remarks: The shift change of taxis is from 16:30 to 17:30 in Wuhan.

Unlike bus and car passenger flows which have obvious morning and evening peak hours, the overall distribution of passenger capacity is uniform throughout 7:00~22:00 except for 24:00~07:00 and the shift change time. According to the data of Wuhan and Shenzhen [12], in the cities where the average taxi operation time exceeds 12 hours, the taxi passenger flows have peak hours at 20:00-22:00 (Detail data is shown in Fig. 3) and account for a higher proportion than that at daytime because the bus operation has ended and the flexible advantages of taxi as ancillary transportation means become prominent.

3) Number of passengers per taxi

The number of passengers per taxi and the trip objectives of taxi users have a close relation. For example, the passengers with the trip objectives of work are single and the passengers who send children to school or pick children after school are usually double. The car mainly undertakes commuting and business trips at peak hours and family leisure and shopping at weekends. Therefore, the number of passengers per car at working days and weekends are different. However, the taxi users are diversified and taxi has undertaken the trips of different objectives, like commuting at peak hours, business, life and entertainment at non-peak hours so that the number of passengers per taxi has slight fluctuation.

The investigation data of Wuhan [13] show that the number of passengers per taxi at working days and weekends has little differences and they are 1.35 and 1.31 respectively, but the number of passengers per car at working days and weekends are 1.30 and 1.46.

Taxi features the advantages of high accessibility, convenience, higher speed, greater comfort and longer service time, so it is a very good ancillary transportation means for public traffic. The differences of taxi users determine that the trip time and locations of taxi passengers can be arranged in advance through call, appointment and taxi-taking software so as to better match the demands and serve the taxi users.

D. The Relation between Taxi and Other Transportation Modes

1) Passenger flow and proportion

Taxi, as one of the passenger transportation modes, undertakes and shunts a part of passengers but the passenger proportion is low. In particular, the passenger flows undertaken by taxi are relatively limited at peak hours because of the traffic congestion.

The data show that the passenger flow of taxi in the whole day in Wuhan in 2014 is about 730,000 person-times/day and accounts for 7% of total passenger

flow ([14], by motor vehicles, similarly hereinafter); the passenger flow of taxi in the whole day in Beijing in 2014 is about 1,990,000 person-time/day and accounts for 7.7% of the total passenger flow ([15]); the passenger flow of taxi in the whole day in Guangzhou in 2014 is about 2,110,000 person-time/day and accounts for 9.8% of the total passenger flow ([16]); the passenger flow of taxi in the whole day in Shenzhen in 2014 is about 1,110,000 person-time/day and accounts for 6.3% of the total passenger flow ([17]). Detail data is shown in Table VI.

TABLE VI. THE COMPARISON OF TAXI OPERATION DATA IN SEVERAL LARGE CITIES

Type	Population of Permanent Residents (10,000 persons)	The Total Number of Taxis (10,000)	The Daily Average Passenger Flow (10,000 persons/time)	The Average Passenger Flow Per Taxi (person-time/day)	The Number of Taxi Ownership Per 10,000 People
Beijing	2069.3	6.66	199	29.9	32.2
Shanghai	2380	5.07	293.7	57.9	21.3
Guangzhou	1283.9	1.9936	199.395	100.0	15.5
Shenzhen	1055	1.53	111	72.5	14.5
Wuhan	1012	1.66	97.9	59.1	16.4

It can be seen from the comparison of data of Wuhan and Beijing, Shanghai, Guangzhou and Shenzhen that the number of taxi ownership per 10,000 persons is highly negatively correlated to the average passenger flow per taxi. The higher the number of taxi ownership per 10,000 persons is, the lower the average passenger flow per taxi is. In addition, in spite of great differences in taxi scale in different cities, the proportions of passenger flow undertaken by taxi in the total passenger flow undertaken by motor vehicles are basically consistent in five cities except Guangzhou, which are about 6%-8%, and have no significant differences.

The proportion of passenger flow served by taxi at peak hours in the total passenger flow at peak hours in Wuhan is 5% and lower than the proportion in the whole day. Bus undertakes the maximum passenger flow (including bus only, the rail transportation not taken into consideration, similarly hereinafter) which account for over 50% of the total passenger flow and is higher of the total passenger flow at peak hours. Car undertakes 40%~50% of total passenger flow which is lower of the total passenger flow at peak hours. Detail data is shown in Table VII.

TABLE VII. THE PASSENGERS CARRIED BY MOTOR VEHICLES IN THE WHOLE DAY IN WUHAN

	Taxi	Bus	Car	Total
Peak Hours (10,000 person-times)	13	147	109	269
Proportion	5%	55%	41%	
The Whole Day (10,000 person-times)	73	505	419	997
Proportion	7%	51%	42%	

2) The road resources occupied by taxi

Since the preservations of taxi, bus and car are different in the cities, their daily operation mileages are quite different. However, the proportions of the operation mileages of different vehicles in the total mileages show certain convergence. The statistical data of Wuhan show that the proportion of the operation mileages by taxi, bus and car at peak hours is 10:10:80 and the proportion of the operation mileages by taxi, bus and car in the whole day is 15:10:75. Detail data is shown in Table VIII.

TABLE VIII. THE OPERATION MILEAGE OF MOTOR VEHICLES AT PEAK HOURS AND IN THE WHOLE DAY IN WUHAN

	Taxi	Bus	Car	Total
Peak Hours (10,000km per taxi)	106	83	736	925
Proportion	11%	9%	80%	
The Whole Day (10,000km per taxi)	580	285	2655	3520
Proportion	16%	8%	75%	

3) Operation Efficiency

To judge the operation efficiencies of the above-mentioned three motor vehicles, the index of "person-time / km" is adopted in this paper, which reflects the passenger transportation scale of different vehicles per kilometer.

In terms of the operation efficiency, the operation efficiency of bus is the maximum and far exceeds those of car and taxi, the car operation efficiency ranks the second and the taxi has the minimum operation efficiency.

The data of Wuhan shows that the bus has the maximum operation efficiency and averagely carries 17,700 persons per kilometer, followed by car whose operation efficiency is 8.5% of that of bus and taxi whose operation efficiency is the minimum, 6.8% of the operation efficiency of bus and about 80% of the operation efficiency of car. Detail data is shown in Table IX.

TABLE IX. THE COMPARISON OF OPERATION EFFICIENCIES OF DIFFERENT MOTOR VEHICLES IN WUHAN (10,000 PERSON-TIME/KM)

	Taxi	Bus	Car
Peak Hours	0.12	1.77	0.15
The Whole Day	0.13	1.77	0.16

It can be found through the data above that taxi has the lowest operation efficiency, that is, the road utilization amount by taxi is far larger than that by bus but the passenger flow served by taxi is far lower than those by bus and car, so taxi cannot be deemed as the major transportation tool in urban cities. Nevertheless, it cannot

be denied that taxi has unique user groups and thus this uniqueness of taxi should be taken into consideration in urban traffic planning, construction and management.

IV. Conclusion

There are certain analyses on the evaluation of taxi operation in the international arena and traditional methods like statistical bulletin data analysis and sampling survey are employed in the researches on taxi stop characteristics, route selection and total volume control, etc. However, these methods have the disadvantages like the relatively long investigation cycle, incomplete data samples, and the difficulty to reflect the characteristics of continuous taxi operation, and the analyses are not thorough due to limited data. The installation of GPS devices on taxis lays a good foundation for real-time, dynamic and long-term analyses of taxi operation characteristics. Domestic and foreign researches on the analyses of taxi operation characteristics and the scale deduction are focused on the operation management and a few research findings are adaptable to certain cities, while the comparative data analyses among large and intermediate cities of different features are lacking and the researches on the functions of taxis in urban traffic system, the effects of taxis on urban roads and traffic as well as the supporting role of taxis for urban passenger transportation are weak.

In this paper, the taxi traffic operation indices proposed by Zhou Jingyi [8] are simplified and employed for parallel comparison of multiple cities. Based on the construction of traffic information system in Wuhan [10] and the construction report of floating car in Beijing [11], profound analyses on the passenger flow of taxis, the road resources occupied by taxis and the temporal and spatial distribution of taxis are conducted with GPS data of 16,000 taxis in Wuhan and 66,000 taxis in Beijing and through horizontal comparison among Shanghai, Guangzhou, Shenzhen and other domestic cities. The emphasis is placed on four aspects, namely the operation indices of taxis, the relation between taxi operation and road traffic, the characters of taxi passengers as well as the relation between taxi and other modes of transportation. From the availability and comparability of data collection by the floating car system, the quantitive data indices and analysis conclusions are first proposed. This study provides references for the functional orientation of taxi in urban traffic, the formulation of macro-policies for urban traffic development, the scientific coordination and planning of the distribution and operation of different urban traffic facilities.

In this paper, the following conclusions and enlightenments are derived through researches and analyses. (1) The taxi operation time exhibits regional features and there is an increasing trend of taxi operation time from the north to the south. The minimum taxi operation time is 11.9 hours in Beijing and the maximum taxi operation time is 19 hours in Shenzhen. The taxi operation time is 15.3 hours in Wuhan but it decreases annually. (2) The daily taxi operation mileage is subject to the influences of taxi operation time and urban road congestion degree. In the short term, the taxi fare and the bunker adjustment surcharge are influential factors. Along with the intensified congestion of urban roads, the daily taxi operation mileage and the passenger carrying times both decline. (3) As the urban construction expands constantly, the travel distance of taxi rises slightly. However, compared with other modes of transportation, the average travel distance of taxi is mainly medium. (4) The number of taxi ownership per 10,000 people is in highly negative correlation to the average passenger capacity of taxi. The larger the number of taxi ownership per 10,000 people is, the lower the average passenger capacity of taxi is. In addition, in spite of the relatively larger differences in taxi size among different cities, the taxi passenger capacity account for about 6-8% of the total passenger capacity of motor vehicles and there is no significant differences. (5) The study indirectly reveals the universal problem, i.e. it is difficult to take a taxi in peak hours. Though the measures of off-peak shift changes are taken in many cities, the taxi operation time in 4 peak hours is 3.11 hours and accounts for 77.6% due to the mealtime and other reasons. Moreover, the operation and passenger carrying time of taxi at peak hours accounts of 21.8% of the all-day operation and passenger carrying time, while the passenger carrying mileage accounts for only 19.2% of the all-day passenger carrying mileage. (6) In three transportation modes of bus, taxi and car, the number of passengers carried by taxi per kilometer is 6.8% of that by bus in Wuhan. The taxi circulation efficiency is minimum. To be specific, the road utilization amount of taxi exceeds that of bus, but the passenger flow of taxi is far lower than those of bus and car. The taxi operation exerts important influences on urban traffic and it is necessary to carry out the quantum control for taxi.

In the analysis of taxi operation, the emphasis is placed on the relation among the taxis, the users, the road traffic and other means of transportation, while the correlation among the spatial distribution features of taxi, the urban land utilization, the urban population structure and features (including permanent residents and floating population) and the traffic distribution scale of external hub stations as well as the verification of taxi transportation predication model, the reasonable calculation of taxi utilization scale, the better match between taxis and passenger demands on the basis of GPS operation paths and the influences of taxi-taking software on taxi operation are not involved in this paper and the researchers can be conducted towards the above-mentioned directions in the future.

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