Hindawi
Journal of Advanced Transportation
Volume 2019, Article ID 6383097, 18 pages
https://doi.org/10.1155/2019/6383097

Research Article

Travel Behavior Analysis Using 2016 Qingdao's Household Traffic Surveys and Baidu Electric Map API Data

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Received 18 December 2018; Accepted 24 February 2019; Published 11 March 2019

Academic Editor: Jose E. Naranjo

Household traffic surveys are widely used in travel behavior analysis, especially in travel time and distance analysis. Unfortunately, any one kind of household traffic surveys has its own problems. Even all household traffic survey data is accurate, it is difficult to get the trip routes information. To our delight, electric map API (e.g., Google Maps, Apple Maps, Baidu Maps, and Auto Navi Maps) could provide the trip route and time information, which remedies the traditional traffic survey's defect. Thus, we can take advantage of the two kinds of data and integrate them into travel behavior analysis. In order to test the validity of the Baidu electric map API data, a field study on 300 taxi OD pairs is carried out. According to statistical analysis, the average matching rate of total OD pairs is 90.74%, which reflects high accuracy of electric map API data. Based on the fused data of household traffic survey and electric map API, travel behavior on trip time and distance is analyzed. Results show that most purposes' trip distances distributions are concentrated, which are no more than 10 kilometers. It is worth noting that students have the shortest travel distance and company business's travel distance distribution is dispersed, which has the longest travel distance. Compared to travel distance, the standard deviations of all purposes' travel time are greater than the travel distance. Car users have longer travel distance than bus travelers, and their average travel distance is 8.58km.

1. Introduction

It is axiomatic that a model can never be better than the data from which it is estimated [1]. Household traffic surveys are mainly used in transport planning and urban planning. In early days, household traffic surveys are customarily conducted by telephone, face-to-face interviewing, having become expensive and dangerous to accomplish in most urban areas of the continent [2]. Outside North America, face-to-face interviews are still done, although costs are high and there are threats to the safety of interviewers. Computer-assisted telephone (CATI) survey is the main method presently in some countries, especially in North America. However, the overall response rate is low. In order to overcome the shortfall in trips of CATI [3, 4], some countries, such as the US and Switzerland, try to have a household traffic surveys using GPS location devices [5–9] . However, it also faces some problems. For example, (1) high expense: GPS devices are fairly expensive, with passive devices, capable of storing many days' worth of data, costing on the order of US$750 each; (2) signal loss: serious degradation of the signal often happens in various circumstances, including tunnels, urban canyons, and heavy tree canopies, and in certain types of vehicles.

The past 20 years has seen a tremendous increase in internet use and computer-mediated communication. Researches of online populations have led to an increase in the use of online surveys [10–13]. On one hand, it has some advantages including access to individuals in distant locations, the ability to reach difficult to contact participants, and the convenience of having automated data collection, which reduces researcher time and effort [14]. On the other hand, the disadvantages, such as uncertainty over the validity of the data and sampling issues, and concerns surrounding the design, implementation, and evaluation of an online survey are also obvious [14].

In order to cast off the deficiency of one kind traffic survey method, several traffic survey methods are used to reap the accurate traffic data in Qingdao's third traffic survey (2016). They include online-survey, face-to-face interviewing, public transport survey, traffic flow survey, exit-entry survey, and other surveys (see Section 2).

Travel behavior study often needs huge traffic data which would include traffic survey data (such as household survey data) and some other data (such as mobile phone data, and GPS data) which is related to travel behavior that is also required. A number of studies analyze the details of travel behavior using household traffic survey data [15–27]. Revealing general characteristics of travel behavior, the researchers also use the household traffic survey data to achieve a variety of particular research purposes [28–36].

Some researchers have done some travel behavior analysis using the fusion data or multisource traffic data, such as the smart card data [37–44] ; location-based services data (Global Positioning System (GPS) devices [45–48]). With respect to mobile phone systems, we can see Steenbruggen, Borzacchiello, Nijkamp, and Scholten, 2013 for a review.

Considering the disadvantages of household traffic survey data, we analyzed the travel behavior with different purposes and travel modes (car and bus) by combining household traffic survey data in 2016 and Baidu electric map API data in this paper. The accuracy of Baidu electric map API data is also validated by the actual taxi OD pair survey. This paper is organized as follows. The detail of Qingdao's 2016 traffic survey is described in Section 2, and the Baidu electric map API data in our research are presented in Section 3. In Section 4, the results of trip time and distance with different purposes and modes are shown and analyzed in detail. Finally, we discuss our work in Section 5.

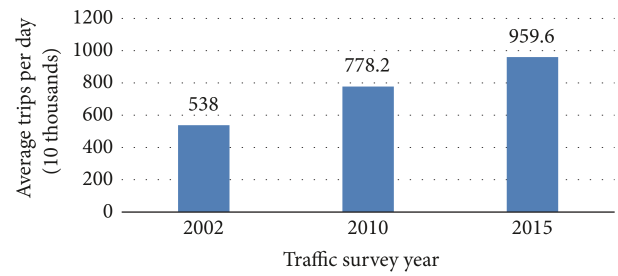


Figure 1: Average trips per day in the 3 traffic surveys of Qingdao.

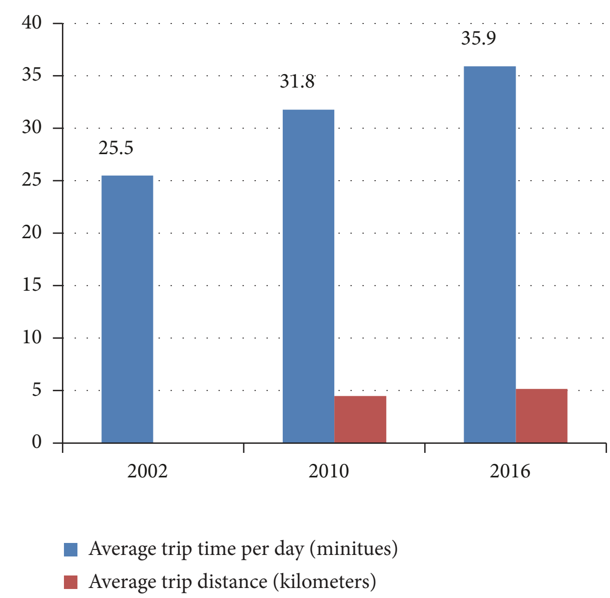


Figure 2: Average trip time and distance per day in the 3 traffic surveys of Qingdao.

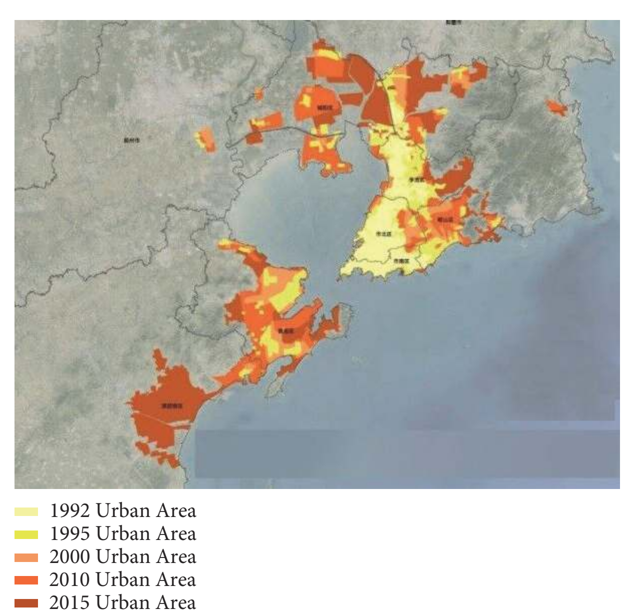


Figure 3: Urban area change of Qingdao from 1992 to 2015.

2. Household Traffic Survey Data in Qingdao

2.1. Necessity of the Third Traffic Survey. Qingdao had two household traffic surveys in 2002 and 2010, respectively. The first survey in 2002 found out the basic rule of the residents' travel at that time and had an important effect on traffic network analysis. In order to adapt the city's rapid development and the needs of subway construction, the government had the second traffic survey in 2010, which plays an important foundation supporting role in the design of subway lines 1, 2, 3, 4, and 8. After that, great changes have taken places in recent years in Qingdao city's population quantity, structure, function, area, population structure, occupational structure of residents, trip structure, and the car ownership and the original survey data cannot support the resident trip analysis now. In view of this, the government had the third traffic survey in 2016. Figures 1 and 2 give the average trips, average trip time, and average distance from 1992 to 2015 and Figure 3 shows the urban area expansion from 1992 to 2015.

2.2. Traffic Survey Design

(1) Preliminary Preparation for the Third Traffic Survey. In order to improve the enthusiasm for participation and ensure the smooth implementation of the trip survey, the sense

Table 1: Traffic survey content.

6 categories	16 classification	Survey time	Scope and source of investigation
Mobile phone data	Mobile phone data	Aug-Oct,2015	All citizens in Qingdao
Household survey	online-survey	20th/Apl-21st,2016	38740 families in Qingdao
	Face-to-face	23th/Apl,2016	2500 questionnaires
Public transport survey	Rail traffic survey	18th/Apl-26th/Apl,2016	10 stations of M3
	Bus survey	14th/Sep-20th/Sep,2015	Bus card data of 334 lines, one week's GPS data of 5387 buses
	Taxi survey	10th/Apl-16th/Apl,2015	All taxis in Qingdao
Traffic flow survey	Check line survey	10th/Apl-16th/Apl,2016	70 roads of 5 check lines
	Important intersections	10th/Apl-16th/Apl,2016	293 intersections
	Speed survey	14th/Sep-20th/Sep,2015	One week's GPS data of buses
Exit-Entry survey	Traffic volume survey of external passenger hub	Dec,2015	Airport, Railway stations and Coach stations
	Volume survey of highways	Sep,2015	All highways of Qingdao
	Volume survey of expressway entrances	Sep,2015	Expressway entrances in Qingdao
Other surveys	Land use status	Sep-Dec,2015	Urban and Rural Planning Bureau
	Population-employment	Sep-Dec,2015	Statistical Bureau
	Hotel distribution	Sep-Dec,2015	Tourism Bureau
	Car ownership distribution	Sep-Dec,2015	Traffic Police detachment

of this household traffic survey and the method of filling in questionnaires of resident trip survey are propagated by television news, newspaper, broadcasting, bus TV, Metro TV, and so on. Some Wechat public accounts, such as Qingdao Daily, Qingdao News, and New Life of Qingdao Metro, are also used to push the sense of this household traffic survey and the online-survey questionnaires.

(2) Traffic Survey Design. The third survey is classified into 6 categories and 16 classifications, which includes household survey, public transport survey, traffic flow survey, exit-entry survey, mobile phone data, and other surveys. The specific survey content is listed in Table 1 and the main survey point is shown in Figure 4. As shown in Table 1, this survey combines mobile phone data, traffic detection data, online-survey data, face-to-face interviewing data, IC card data, and GPS data. Resident trip survey mainly adopted online-survey questionnaire and household survey questionnaire. Public transport survey includes subway survey, bus car data, GPS data, and taxi data. Traffic flow survey and exit and entry survey mainly used the traffic surveillance system and traffic flow monitoring system.

As shown in Table 2, every row is a trip (OD). Family 3 has 3 members, i.e., 8, 9, and 10. Family 4 has 2 members, i.e., 11 and 12.

3. Electric Map API Data

Although traditional traffic survey could reap some data we need, most traffic survey, especially the online-survey and face-to-face interviewing only acquire the OD information, trip mode, and trip time. It is difficult to get the trip routes information. At the same time, the trip time is usually inaccurate. What is exciting is that electric map API (e.g., Google Maps, Apple Maps, Baidu Maps, Auto Navi Maps and so on) could provide the trip route and time information, which remedies the traditional traffic survey's defect. In this paper, we try to use Baidu Maps to find the routes.

Baidu Map supplies Web API v2.0 service for developers. People could obtain the route planning service by the style of HTTP/HTTPS. Table 3 shows the data sample from Baidu Maps Web API v2.0.

As shown in Table 3, for one OD, it recommends 5 routes. For bus travelers, it includes the route length, travel time, initial walk time, initial walk time, travel distance by bus, travel time by bus, arrival walk distance, and arrival walk time and so on.

In fact, we do not know the data validity of the Baidu Maps Web API v2.0. For this, we take taxi as the test object and have a taxi follow investigation. The accuracy of the Baidu Maps Web API v2.0 is checked by comparing the recommended data and actual taxi investigate data.

Table 4 gives the style of taxi following questionnaire. As shown in Table 4, taxi following questionnaire includes OD pairs, departure time, arrival time, the passing intersections, and the road and traffic conditions.

Here, we randomly chose 300 OD pairs in Qingdao city from the total taxi survey ODs. Figure 5 shows the recommendation routes of the 300 OD pairs generated by Baidu Maps Web API v2.0.

3.1. Accuracy Analysis on Recommended Routes Generated by Baidu Maps Web API v2.0. The coincidence factor of intersections is used to verify the accuracy of Web API.

Table 2: Online-survey samples.

OD Number	Family ID	Personal ID	Origin			Destination			Purpose	Trip mode						
			Longitude	Latitude	Departure time	Longitude	Latitude	Arrival time		Bus	Car	Taxi	Walk	Subway	Bike	Commuting Bus
12	3	8	120.4378	36.1007	7:30	120.4144	36.1314	7:55	Work	No	Yes	No	No	No	No	No
13	3	8	120.4144	36.0857	17:30	120.3796	36.0875	17:45	Shopping or F&B	No	Yes	No	No	No	No	No
14	3	8	120.3796	36.0875	18:15	120.4378	36.1007	18:30	Home	No	Yes	No	No	No	No	No
15	3	9	120.4378	36.1007	7:20	120.4377	36.1008	7:25	School	No	No	No	Yes	No	No	No
16	3	9	120.4377	36.1008	16:00	120.4378	36.1007	16:05	Home	No	No	No	Yes	No	No	No
14	3	10	120.4378	36.1007	7:30	120.4335	36.1225	7:50	Work	Yes	No	No	No	No	No	No
15	3	10	120.4335	36.1225	17:00	120.4378	36.1007	17:40	Home	Yes	No	No	No	No	No	No
16	4	11	120.3988	36.0813	7:10	120.4118	36.1207	8:10	Work	Yes	No	No	No	No	No	No
17	4	11	120.4118	36.1207	18:00	120.3988	36.0813	19:10	Home	Yes	No	No	No	No	No	No
18	4	12	120.3988	36.0813	7:10	120.3976	36. 1027	7:56	Work	No	No	No	No	Yes	No	No
19	4	12	120.3976	36.1027	20:00	120.3988	36.0813	20:40	Home	No	No	No	No	Yes	No	No

Table 3: Data sample of Baidu Maps Web API v2.0.

OD Number	Recommended Travel Routes	Length (m)	Travel time(s)	Initial Walk Distance (m)	Initial walk time (s)	Travel distance by bus	Travel time by bus	Arrival walk distance (m)	Arrival walk time (s)
8	1	10685	3286	164	131	10202	2300	319	255
8	2	10580	3782	383	306	229	183	255	204
8	3	12363	4193	386	308	10890	2415	1087	869
8	4	11989	4145	179	143	10447	2311	1363	1090
8	5	11183	4127	143	114	363	290	323	258

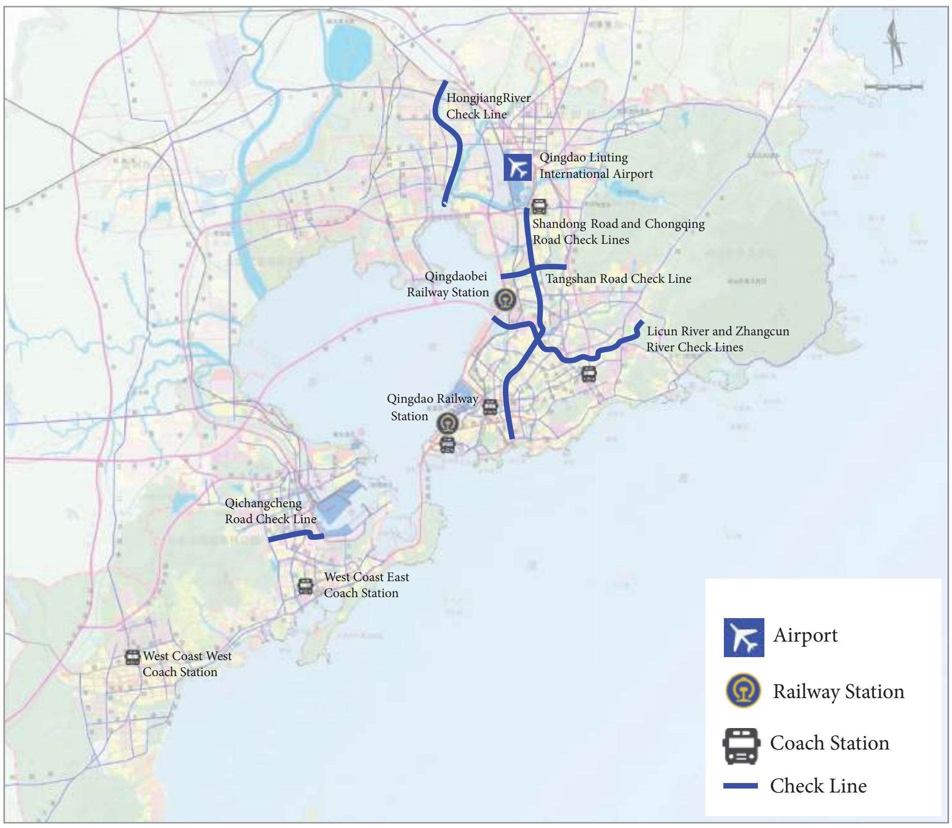


Figure 4: The main traffic survey point.

Specifically, the ith OD pair's matching rate can be written as follows:

$$\omega_i = \frac{N_{is}}{N_{id}}, \quad i = 1, 2, 3, \ldots, n; \; n \in Z^+ \tag{1}$$

In (1), ω_i is the ith OD pair's matching rate. When ω_i is bigger, the accuracy of the Web API data will be higher. N_{is} is the coincidence number of intersections between the Web API's recommendation route and actual taxi survey route of the ith OD pair. N_{id} is the number of intersections of actual taxi survey route of the ith OD pair. n is the number of OD pairs. Accordingly, the average matching rate of total OD pairs can be written as follows:

$$\omega = \frac{\sum_{i=1}^{n} \left(N_{is}/N_{id}\right)}{n}, \quad n \in Z^+ \tag{2}$$

where n is the total number of survey OD pairs.

According to statistical analysis, the average matching rate of total OD pairs is 90.74%. It is a high ratio which reflects high accuracy of Web API v2.0. However, in statistics, not all OD pairs' matching rates are high. Here we chose three kinds of OD to analyze the matching rates. Table 5 gives the three kinds of OD pairs.

As shown in Table 5, between OD pair MIXC and Shiyan community, taxi survey route and Baidu's recommended route have the same passing intersections. The ratio of intersections overlap is 100%, which reflects the Baidu API's high accuracy. However, the OD pair Taidong and

Table 4: Taxi following questionnaire.

Taxi following questionnaire									
			Weather:—	Date: —		Investigator: —			
OD Number	Departure time	Origin	Passing intersections 1	2	...	Destination	Arrival time	Travel time cost(m)	Road and traffic conditions
1	8:00	Railway Station	Taian Road-Feixian Road	Feixian Road-Feixian branch Road	...	Polar Ocean World	8:52	52	Congestion
2	9:30	MIXC	Hongkong Road-Shandong Road	Shandong Road-Minjiang Road	...	Shiyan community	10:02	32	Accident
3	13:30	Taidong	Taidong 6th Road-Weihai Road	Chenkou Road-Weihai Road	...	Jinguihuayuan community	13:53	23	Normal
4	14:23	Wanda Plaza	Xuzhou Road-Longcheng Road	Xuzhou Road-Dunhua Road	...	Fuan community	14:48	25	Normal
5	16:20	No.59 middle school	Yanan 3th Road-Huayan Road	Yanan 3th Road-Xiuzhan 3th Road	...	Liantong Building	16:28	8	Normal
6	17:00	Tianjiahuayuan community	Xintian Road-Hetian Road	Xintan Road-Ningxia Road	...	No.44 middle school	17:18	18	Congestion
7	18:00	No.83, Jiangxi Road	Jiangxi Road-Panyanghu Road	Jiangxi Road-Nanjing Road	...	No.162, Jiaoning Road	18:11	11	Congestion
8	20:20	No.1517, Wutaishan Road	Wutaishan Road-Tuanjie Road	Tuanjie Road-Jialingjiang west Road	...	Tianjiameiju community	19:00	40	Normal

Table 5: Matching rate of three kinds of OD pairs.

	Same	Recommendation	Survey	Recommendation	Survey
Origin	MIXC	Taidong		Wanda Plaza	
Destination	Shiyan community	Jinguihuayuan community		Fuan community	
Intersections	Hongkong Road-Shandong Road	Taidong 6th Road-Weihai Road	Taidong 6th Road-Weihai Road	Yanji Road-Xuzhou Road	Xuzhou Road-Longcheng Road
	Shandong Road-Minjiang Road	Chenkou Road-Weihai Road	Chenkou Road-Weihai Road	Yanji Road-Lianyungang Road	Xuzhou Road-Dunhua Road
	Shandong Road-Jiangxi Road	Changchun Road-Weihai Road	Changchun Road-Weihai Road	Yanji Road-Nanjing Road	Dunhua Road-Lianyungang Road
	Shandong Road-Jiaoning Road	Hankou Road-Weihai Road	Hankou Road-Weihai Road	Yanji Road-Wuxing Road	Liangyungang Road-Haizhou Road
	Shandong Road-Yanji Road	Shandong Road-Hangan Road	Hankou Road-Hexing Road	Yanji Road-Shaoxing Road	Lianyungang Road-Hangan Road
	Shandong Road-Anshan Road	Anshan Road- Harbin Road	Dunhua Road-Zhenjiang Road	Yanji Road-Qingtian Road	Fuzhoubei Road-Dunhua Road
	Shandong Road-Fushun Road	-	Xiwu Road-Zhenjiang Road	Qingting Road-Dunhua Road	Dunhua Road-Yongji Road
	Hailun Road-Anda Road	-	Shandong Road-Hangan Road	Dunhua Road-Yongji Road	-
	-	-	Anshan Road- Harbin Road	-	-
Matching Rate	100%	66.7%		14.3%	

Figure 5: Recommendation routes of the 300 OD pairs.

Jinguihuayuan community has the different results. There are three different intersections. The matching rate is 66.7%. The reason is explicable. We found that it was in evening peak, and the traffic congestion made the driver changing the route. Surprisingly, the survey route and recommendation route are totally non-overlapping between OD pair Wanda Plaza and Fuan community. The matching rate is only 14.3%. According to the investigation on Yanji Road, it is in construction repair during the survey day. Therefore, the taxi driver changed the trip route.

In a word, although the matching rates of intersections between some OD pairs are low, they are imaginable. Some unforeseen circumstances, such as the bad weather, accident, and congestion, would make drivers change their route which deviates from recommended routes.

Undoubtedly, according to the statistics on the 300 OD pairs, OD pairs' matching rates are high (90.74%). Therefore, it is highly accurate and credible.

3.2. Accuracy Analysis on Recommended Trip Time Generated by Baidu Maps Web API v2.0. In order to further verify the validity of Baidu map Web API data, we also compare the travelling time. Here, two kinds of data are used to verify the accuracy of recommended trip time generated by Baidu Maps Web API v2.0. One is the 300 taxi OD survey data. As shown in Table 4, the trip time is also recorded. Here the ratio between the recommendation trip time and actual taxi survey time is used to verify the accuracy of the Baidu electric map API data. Specifically, the ith OD pair's time matching rate can be written as follows:

$$\theta_i = \frac{\min(T_{id}, T_{is})}{\max(T_{id}, T_{is})}, \quad i = 1, 2, 3, \ldots, n; \; n \in Z^{+} \tag{3}$$

where T_{is} is the Baidu electric map API recommendation trip time of the ith OD pair. T_{id} denotes the actual taxi survey trip time of the ith OD pair. The average time ratio of total OD pairs can be calculated as follows:

$$\theta = \frac{\sum_{i=1}^{n} (\min(T_{id}, T_{is}) / \max(T_{id}, T_{is}))}{n}, \quad n \in Z^{+} \tag{4}$$

According to statistical analysis, the average ratio of total OD pairs is 78.16%, which is lower than the average route matching rate of total OD pairs (90.74%). Unlike trip route, trip time has higher randomness, even the same route, the same time of different days, or the same route, different time with the same day. Therefore, we think the ratio (78.16%) is high enough that could reflect the high accuracy of Baidu electric map API data.

4. Data Fusion and Traveler Behavior Analysis in Time and Space

4.1. Data Fusion, Processing, and Curve Fitting. Trip survey could obtain the accurate OD pairs, trip mode, travel purpose and so on. However, it cannot reap the travel route information and the travel time is inaccurate. Consider that Web API could provide route planning service and its high accuracy. This paper tries to take advantage of the two kinds of data and integrate them together and then have some traffic behavior analysis based on the integrated data. Table 6 gives a sample of the integrated data. Table 6 includes the OD pairs, the length of the route between one OD, the origin coordinate, the destination coordinate, the passing intersections, trip purpose, trip mode, walk distance, and walk time.

Matplotlib is used to have a python drawing. Specifically, Pylab and pyplot are the main processing tools. Hist function in pyplot is used to have interval setting and sample statistics of corresponding intervals. Here, data is set 150 intervals by considering the numerical span and frequency statistics. According to every interval's median value (independent variable) and the statistics (dependent variable), the least-square method is used to curve fitting. The mean and standard deviation of the travel time and distance are analyzed by Pandas in Python.

4.2. Travel Behavior Analysis with Different Purposes. This section discussed the travel behavior with 6 purposes (i.e., work, home, school, taking children to school, shopping, and company business) from the angle of trip distance and time.

Figure 6 shows trip distance distribution with 6 purposes. As shown in Figure 6, all curves with different trip purposes show normal distribution approximately. Most purposes' trip distances distributions are concentrated, which are no more than 10 kilometers. It is relevant to the urban size, residence distribution, company distribution, and school distribution. Figure 7 shows the distribution of schools, residential communities, companies, supermarkets, and shopping arcades of Qingdao city. From Figure 7, we can see that, unlike western developed countries, Qingdao's schools, residential communities, companies, supermarkets, and shopping arcades are concentrated in the urban area, which reflects Chinese most cities' characteristics of non-separation of work and residence. It is worth noting that students have the

Table 6: Sample of the integrated data.

OD Number	Length (m)	Travel time (s)	Origin		Passed intersections	Destination		Purpose	Walking distance(m)	Walking time (s)	Trip mode
			Longitude	Latitude		Longitude	Latitude				
12	6319	2368	120.4378	36.1007	...	120.4144	36.1314	Work	1036	600	Bus
13	9634	3046	120.4378	36.0178	...	120.3796	36.0875	Shopping or F&B	759	450	Bus
14	14142	3531	120.3796	36.0875	...	120.4378	36.1007	Home	129	80	Car
15	6115	2356	120.4378	36.1007	...	120.4378	36.1008	Home	926	560	bus
16	3164	1261	120.4377	36.0813	...	120.4118	36.1207	Work	826	600	bus
17	1841	600	120.4118	36.1207	...	120.3988	36.0813	Home	527	506	bus
18	2436	760	120.3988	36.0813	...	120.3976	36. 1027	Work	679	620	bus
19	4326	1642	120.3976	36.1027	...	120.3988	36.0813	Home	260	206	car

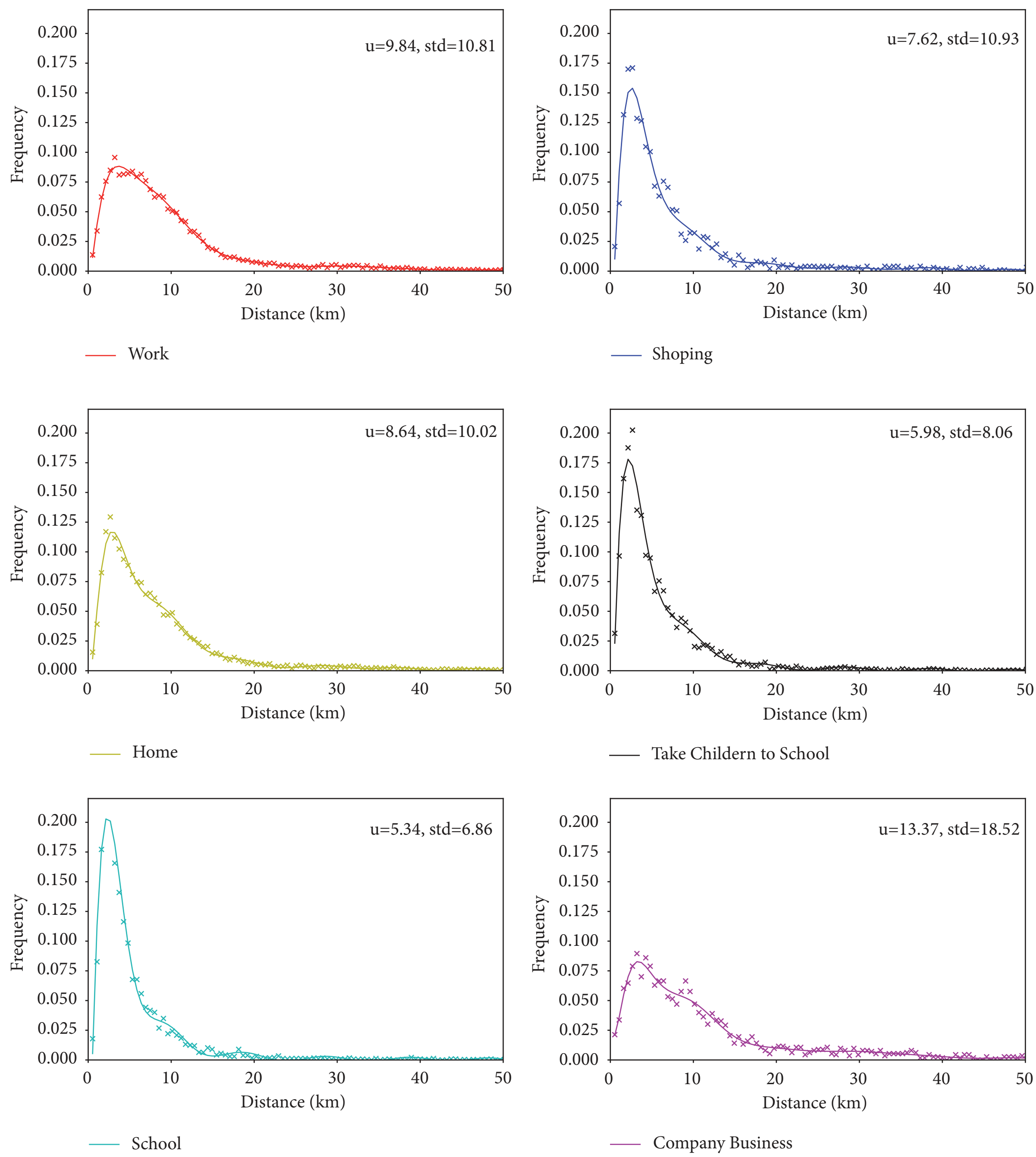
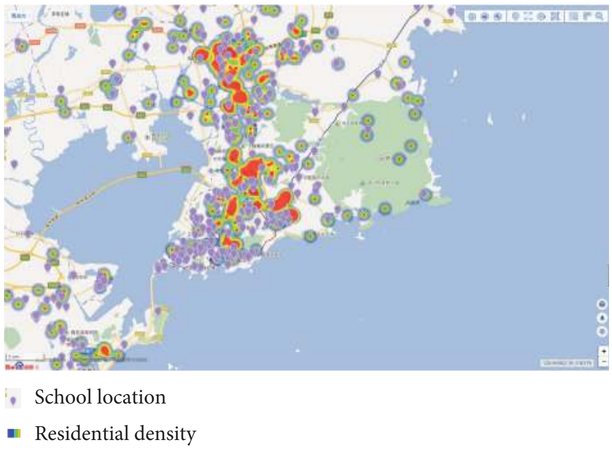


Figure 6: Trip distance distribution with 6 travel purposes.

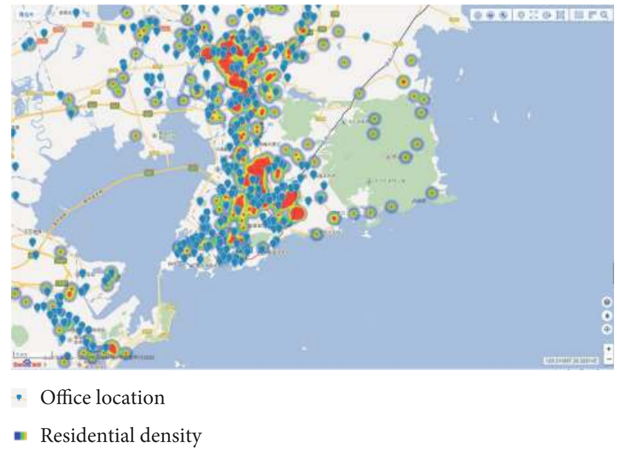
shortest travel distance. The average travel distance is 5.34 kilometers. Similarly, taking children to school is the second shortest travel distance. Their average travel distance is 5.98 kilometers. It may have three reasons: (1) most families preferring to choose nearby schools if their children go to school alone; (2) the Qingdao's education policy (such as the nearby enrollment policy); (3) the number of schools being large.

For company business, its travel distance distribution is dispersed, and it has the longest travel distance (13.37 kilometers) which may be related to the randomness of company business.

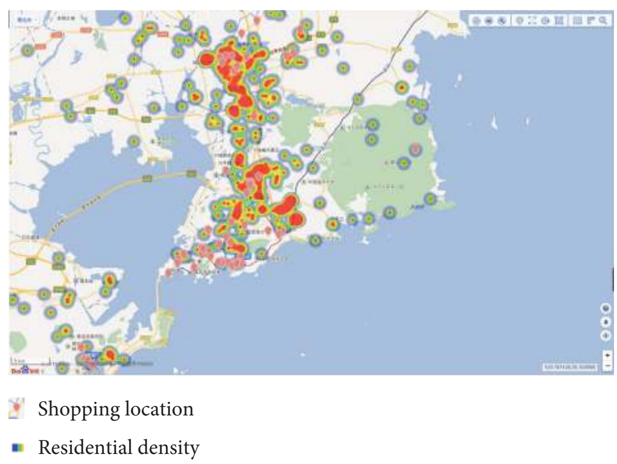
As shown in Figure 8, the same with travel distance distribution, the average travel time of going to school and taking children to school is minimum. They are 22.54 minutes and 19.44 minutes. Because some parents drive children to school, its average travelling time is less than children going to school themselves. However, not all travelling time is directly proportional to travel distance. Taking company business and work as an example, although company business has



(a) The distribution of schools



(b) The distribution of offices



(c) The distribution of shopping arcades

Figure 7: Distributions of residential communities, schools, offices, and shopping centers in Qingdao.

the longest travel distance, work has the longest travel time instead of company business. Compared to travel distance, the standard deviations of all purposes' travel time are bigger than the travel distance. This may be decided by the randomness of travel time. Unlike travel route, travel time is easier influenced by road and traffic conditions, such as signal control, traffic congestion, weather, accident, and driving habits. Another interesting thing is that most trip purposes have two peaks when the travel time is approximately 10 minutes and 30 minutes.

4.3. *Travel Distance and Time Analysis with Different Modes*

4.3.1. Travel Distance Analysis with Bus and Car. Figures 9, 10, and 11 show the travel distance distribution by bus and car with different purposes. For bus travelers, all purposes' travel distance peaks are less than 5km and the average travel distance is 7.66km. Compared to work, going home and company business, going to school, taking children to school, and shopping's travel distance distribution are more centralized. Their average travel distance is about 6.4km. The company business still has the longest average travel distance, 9.51km. Compared to bus travelers, car users have longer travel distance; their average travel distance is 8.58km. Work, going home, shopping, and company business travel by car have longer travel distance than bus. The most respective example is company business travel, 13.65km, 5 kilometers more than bus travel, which is determined by the high convenience and comfort of car service.

Interestingly, for purposes of going to school and taking children to school, car travelers will take shorter distance than bus travelers. The average travel distance of going to school by car is only 4.82km and taking children to school is 5.93km. Correspondingly, the average travel distance of going to school and taking children to school is 6.08km and 6.18km, respectively. Actually it is comprehensible. Car could achieve door-to-door service but not bus. Bus traveler should go to bus station first and then travel by bus. Some bus lines are even not the optimal route from home to school. However, for car traveler, they would choose the optimal route generally.

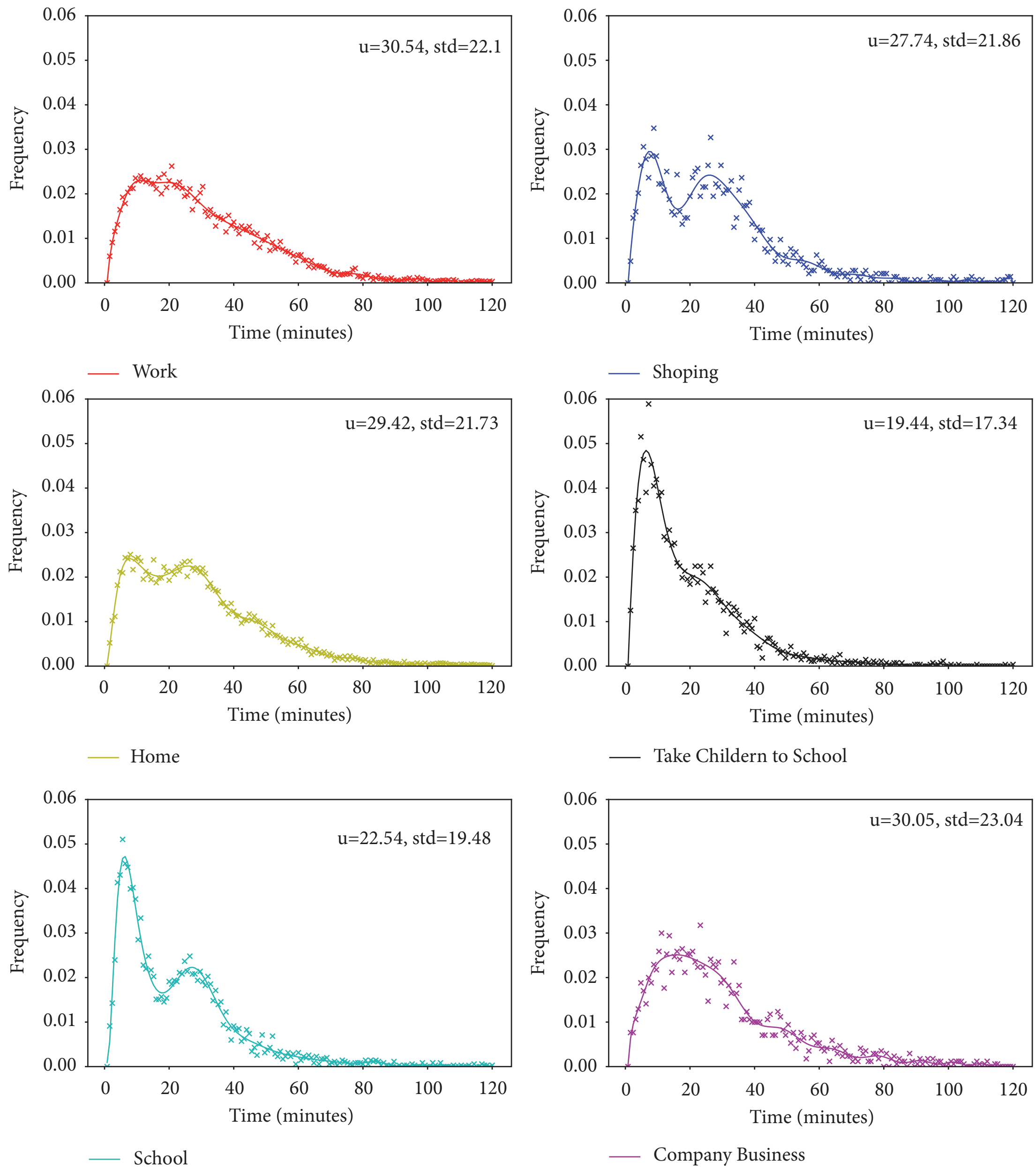


Figure 8: Trip time distribution with 6 travel purposes.

In addition, bus travelers also must go to school from bus station. Thus, compared to car users, bus travelers would take more travel distance.

4.3.2. Travel Time Analysis with Bus and Car. Figures 12, 13, and 14 present car and bus travel time distribution with different purposes. Unlike travel distance distribution, travel time distribution has a great difference between car and bus. Bus travelers would spend more time than car travelers when finish their travel. Taking work as the example, compared to car users, bus traveler spends more than 28 minutes on average. On one hand, it is determined by the characteristic of bus. Bus travelers take extra walking time (go to station and go to work place), station waiting time, bus stop time, and even transfer time. On the other hand, it also reflects the low efficiency of bus system, such as the low departure frequency, unreasonable bus line and station setting, no bus lanes, and so on. The big difference between car and bus in travel time would induce more car travel demand which increases traffic congestion.

Therefore, in order to alleviate the congestion, the traffic manager should improve the bus service to suppress the high increasing of the car demand. As shown in Figure 13, most bus travelers' travel durations are between the intervals of 20 and 60 minutes. Most car travelers' travel durations are between the intervals 2 and 40 minutes.

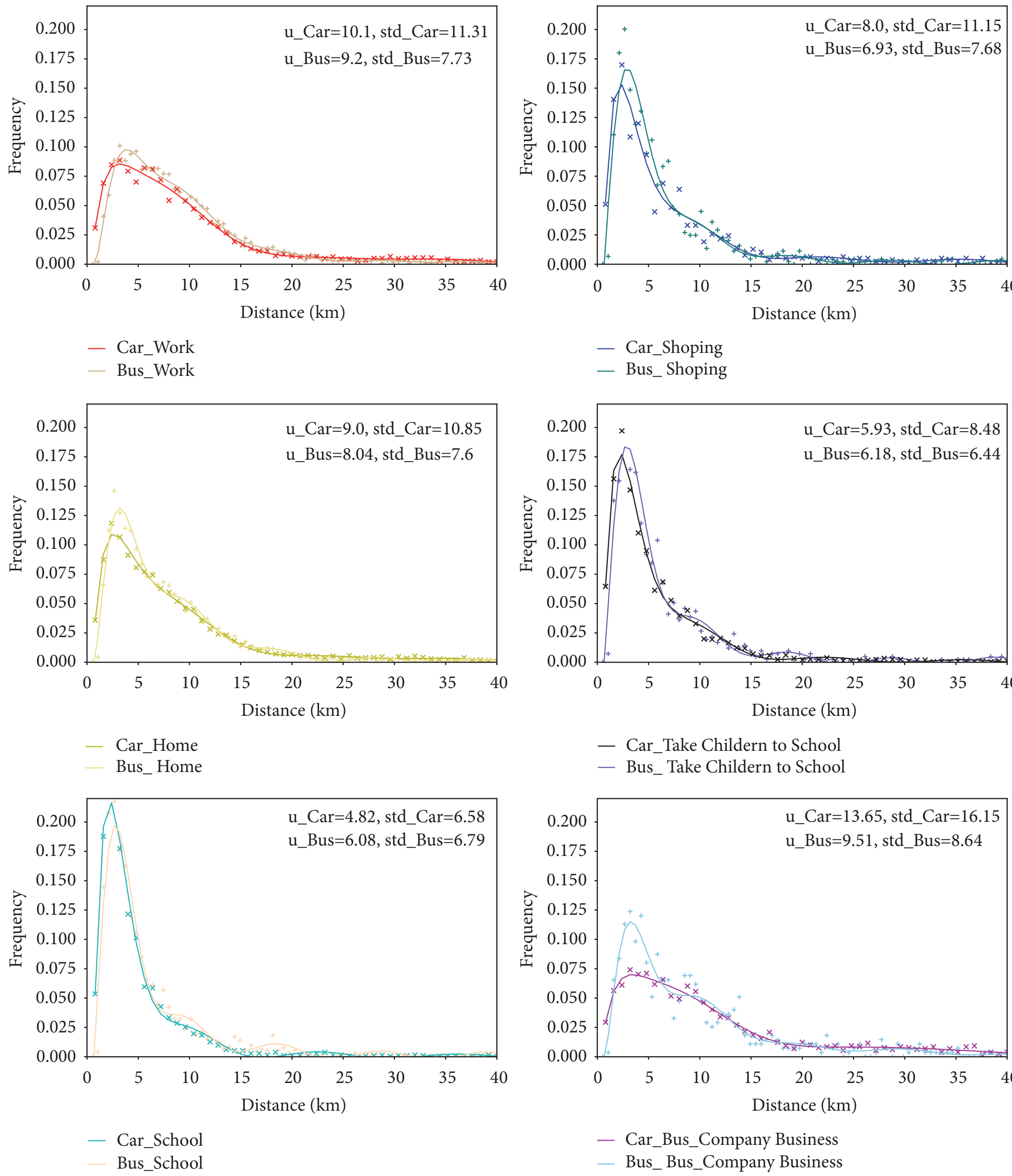


FIGURE 9: Car and bus travel distance distribution with different purposes.

5. Discussion

This paper tries to integrate resident trip survey data and electric map API data together. In order to verify the accuracy of electric map API data, we take taxi as the test object and have a taxi follow investigation. Accuracy of recommended routes and travel time is analyzed. According to statistical analysis, the average matching rate of total OD pairs is 90.74%, which reflects high accuracy of electric map API data. In statistics, not all OD pairs' matching rates are high. Some unforeseen circumstances, such as the bad weather, accident, and congestion, would make drivers change their route which deviates from recommended routes. According to statistical analysis, the average ratio of total OD pairs is 78.16%, which is lower than the average route matching rate of total OD pairs (90.74%). Unlike trip route, trip time has higher randomness, even the same route, or the same time of different days, or the same route, different time with the same day. Therefore, we

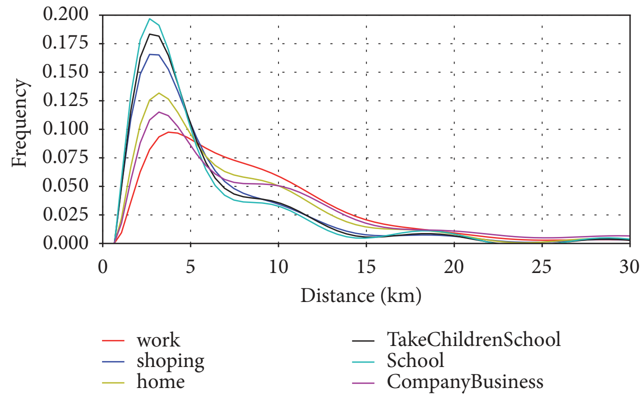


Figure 10: Comparison of travel distance with different purpose by bus.

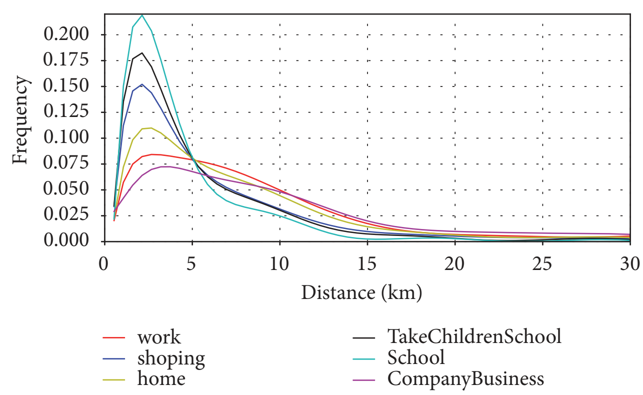


Figure 11: Comparison of travel distance with different purpose by car.

think the ratio (78.16%) is high enough that could reflect the high accuracy of electric map API data.

Based on the fusion data, travel behavior with different purposes and modes is analyzed. We found that most purposes' trip distances distributions are concentrated, which are no more than 10 kilometers. It is relevant to the urban size, residence distribution, company distribution, and school distribution. Unlike western developed countries, Qingdao's schools, residential communities, companies, supermarkets, and shopping arcades are concentrated in the urban area, which reflects Chinese most cities' characteristics of non-separation of work and residence. It is worth noting that students have the shortest travel distance. The average travel distance is 5.34 kilometers. Company business's travel distance distribution is dispersed, and it has the longest travel distance (13.37 kilometers) which may be related to the randomness of company business. Compared to travel distance, the standard deviations of all purposes' travel time are greater than the travel distance. This may be decided by the randomness of travel time. Unlike travel route, travel time is easier influenced by road and traffic conditions, such as signal control, traffic congestion, weather, accident, driving habits, and so on.

For bus travelers, all purposes' travel distance peaks are less than 5km and the average travel distance is 7.66km. Compared to work, going home and company business, going to school, taking children to school, and shopping's travel distance distribution are more centralized. Car users have longer travel distance than bus travelers, and their average travel distance is 8.58km. Work, going home, shopping, and company business travel by car have longer travel distance than bus. The most respective example is company business travel, 13.65km, 5 kilometers more than bus travel, which is determined by the high convenience and comfort of car service. What is surprising is that, for purposes of going to school and taking children to school, car travelers will take shorter distance than bus travelers.

Unlike travel distance distribution, travel time distribution has a great difference between car and bus. Bus travelers would spend more time than car travelers when finish their travel. The big difference between car and bus in travel time would induce more car travel demand which increases traffic

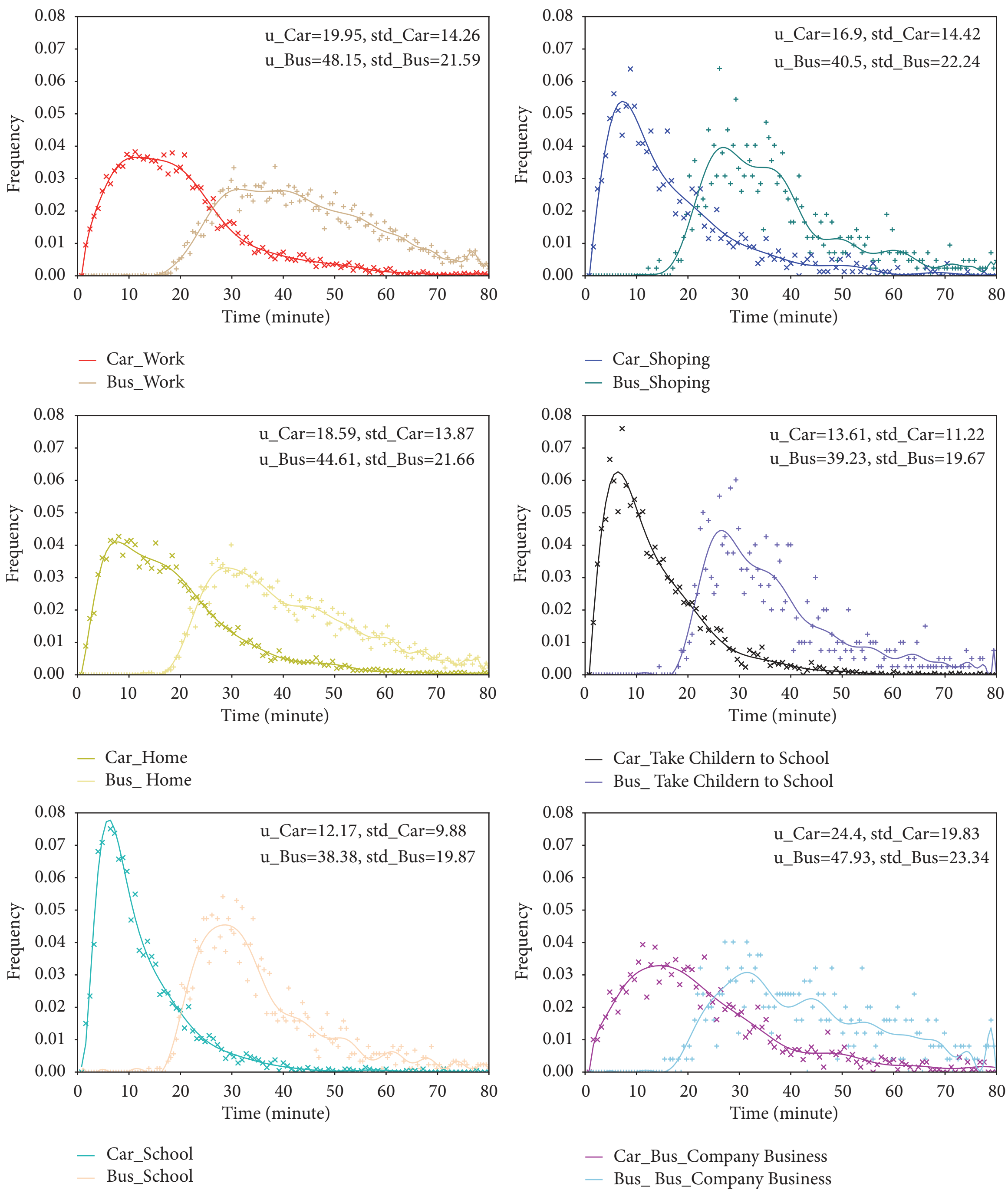


Figure 12: Car and bus travel time distribution with different purposes.

congestion. Therefore, in order to alleviate the congestion, the traffic manager should improve the bus service to suppress the high increasing of the car demand.

Data Availability

The survey data are put into the file of Supplementary Materials. The route information of Baidu recommend is available online at https://map.baidu.com/.

Disclosure

The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

Conflicts of Interest

The authors declare no conflicts of interest.

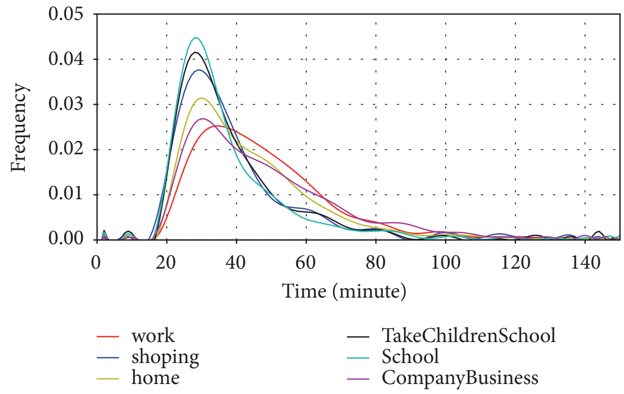


Figure 13: Comparison of bus travel time with different purposes.

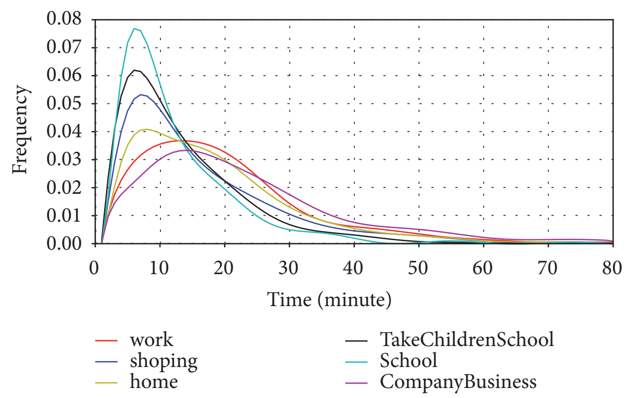


Figure 14: Comparison of car travel time with different purposes.

Acknowledgments

This paper is partly supported by the NSFC (71801144, 71371111, 71322102, and 71701189) and the China National Funds for Distinguished Young Scientists (71525002).

Supplementary Materials

Attachment 1 is the field survey data and Baidu recommend routes of 300 taxi OD pairs. Attachment 2 is the OD pairs information with bus. Attachment 3 is the OD pairs information with car. *(Supplementary Materials)*

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