A STUDY ON TRAFFIC CHARACTERISTICS AT SIGNALIZED INTERSECTIONS IN BEIJING AND TOKYO

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1 INTRODUCTION

Intersections play a important role in the road network, where traffic flows in different directions converge. Because of their influence each other, disturbance of pedestrians and bicycle to vehicles, and the lost of green time for beginning and clearance and so on , the capacity of intersections is much lower than that of their approach links. Thus, the intersections usually are the bottleneck of the network, the popular and immediate source of the traffic jam and traffic accidents.

It is especially true in China. Recent years, population in cities, vehicle ownership and traffic volume in links increase dramatically due to the continuous high speed growth of economy, which cause traffic congestion of different level in most cities. Under this circumstance, velocity of vehicles drops largely and in some cities, the velocity in peak hour is even lower than 10 km/h. All of these already influence the normal performance of urban function, hamper the continuous and steady growth of economy and affect residents' daily lives. Unfortunately, even though great efforts are made, the situation of traffic congestion become worse and worse. It is also same for the developed country, the most traffic congestion happen at intersection in Tokyo. First two main reasons causing the traffic congestion in Tokyo are as follows: there is not a exclusive lane for right turn, right turn vehicle obscure the following vehicle and capacity of the intersection is not enough.

Thus, it is significant to study the traffic flow characteristics at signalized intersections in the developed country and the developing country, because capacity of the intersection can be improved according to their Characteristics. Study on traffic flow characteristics at signalized intersections is one of most effective and immediate measure to enhance the capacity of road networks and relieve the congestion in cities. In this study, the traffic flow characteristics of the typical signalized intersections located at Beijing and Tokyo are observed and analyzed. Then, saturation flow rates and delays of the intersections in both cities are compared and the factors affected to the saturation flow rates are discussed. Finally, some countermeasures for enhancing the capacities of the intersection are proposed including channelization of the traffic flow in the intersection, drawing the traffic marking and line in the intersection, strengthen traffic safety education, improving traffic control method, regulation of pedestrians and bicycle flows at the signalized intersection and improving the safety facility and capacity at the signalized intersections and so on.

2 INVESTIGATION METHOD AND CALCULATATION OF SATURATION TRAFFIC FLOW AT THE SIGNALIZED INTERSECTIONS

2.1 Manual Investigation Method

Only stopwatch and record lists are required in this investigation method. After counting the vehicles passing by the intersection per unit time during the green time, the saturation traffic flow at the signalized intersections can be calculated.

The method used was proposed by TRRL in England. Usually, it is suitable to include only 2~3 vehicles within one counting unit time. For the sake of convenience, we take 5 seconds as investigation interval.

The saturation traffic flow of the intersections is calculated according to the following method. Fig 1 shows the distribution pattern of vehicles passing by the intersection during the green time. Each column represents the average number of vehicles in the interval (veh / 5 sec). The pattern is just like this: due to the starting delay, the average of vehicles in the initial interval is less than that in the following ones (starting lost), then vehicles proceed at a certain flow density. In the end of the green time, the average of vehicles is also lower (clearance lost).

The saturation traffic flow is the average number of vehicles passing by in the effective green time, that is, the green time excluding the starting and clearance lost (shown as dot line in Fig. 1). Starting lost (*Ls)* can be gotten by:

$$Ls = t - ns/s \quad (1)$$

where, t --- survey interval (5 sec).
  ns --- the average number of vehicles passing by in the initial interval t.
  s --- the saturation traffic flow.

The formula for clearance lost (Lc) is just similar with the above,

$$Lc = tc - nc/s \quad (2)$$

where, tc --- interval of clearance
  nc --- the average of vehicles passing by in the clearance interval tc

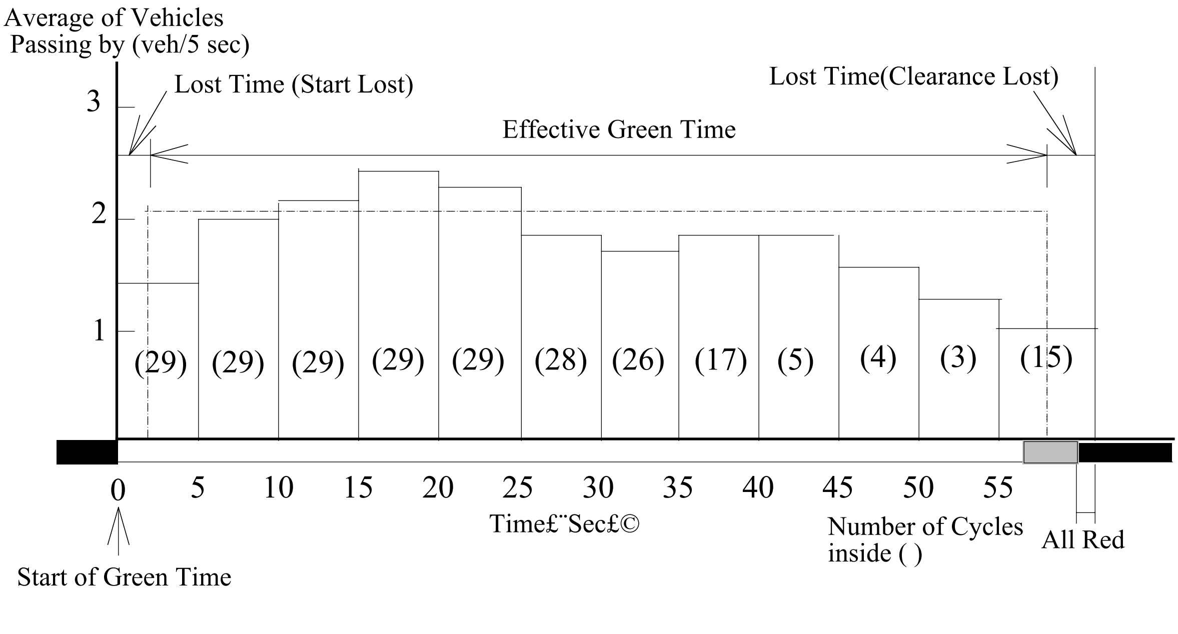

Fig 1 the distribution pattern of vehicles passing by the intersection during the green time

2.2 Camera Method

Investigation using camera has the advantage of repeating the traffic phenomena of the investigated traffic flow. During the investigation, the photography of the traffic flow is taken , and the beginning time of green time, amber time and red time are recorded. At same time, the time of the last vehicle in the line passing by the stopping line is markup.

Using the above formula or average headway time method, we can deal with the datum obtained by camera investigation. The average headway time method can be described as follows: first, the average headway time under saturation conditions is calculated, then the saturation traffic flow is calculated by (3), in which the equivalence unit of large truck E_T is calculated by (4). Finally the basic saturation traffic flow can be obtained by (5).

$$SFR_P = \frac{1}{\sum h/n} \times 3600 \quad (3)$$

$$E_T = (CT + TC)/CC - 1 \quad (4)$$

$$SFR_B = SFR_P \times \{(1 - TMR) + E_T \times TMR\} \quad (5)$$

where SFR_p is possible saturation flow rate, SFR_B is basic saturation flow rate, CT is the average headway time of heavy truck following car, TC is the average headway time of car following heavy truck , CC is the average headway time of car following car and TMR is mixture rate of heavy truck.

3 GENERAL DESCRIPTION OF SITE INVESTIGATION

In order to make the comparative study on traffic characteristic of intersections, analyze the major factors affecting the saturation traffic flow of intersection , and improve the capacity of intersections, the site investigation on saturation traffic flow and delay of intersections is carried out in Beijing and Tokyo. Typical intersections where the road and traffic conditions are suitable to study the saturation flow rate and delay are choose, that is, the investigated intersections have different geometry condition, different location in the road network, large traffic flow and heavy congestion. Finally, we choose the following intersections: Baishiqiao, Xidan, Xinjiekou, Yuetanbeiqiao, Guanyuanqiao, Sitongqiao, Beitaipingqiao and Jishuitanqiao in Beijing, Gotanda, Fufuzaka and Nishioka in Tokyo. Delay on intersections was surveyed by license plate method.

4 COMPARATIVE ANALYSIS ON INVESTIGATION RESULT

4.1 Saturation Flow Rate

In this comparative analysis, we emphasis on the saturation traffic flow and the major factors impacting it. Table 1 shows the saturation flow rate of the investigated intersections in Tokyo by the average headway time method, accumulate calculation method and TRRL method separately. Table 2 and table 3 show the investigation results of Xidan, Jishuitan and Baishiqiao intersection in urban area of Beijing.

It is clear from Table 1, 2, 3 that whatever method is used to computer, the saturation flow rate of the intersections in Beijing is lower than that in Tokyo. The calculated value of the saturation flow rate in Beijing is among 989 ~ 1477 Veh / one hour green time, while that in Tokyo is among 1163 ~ 1899 Veh / one hour green time. There is big difference between them. That is, the saturation flow rate in Tokyo is about 1.3 ~ 2.0 times than that in Beijing. Moreover, the average headway times at the investigated four intersections in Tokyo are 1.95, 2.22, 2.27 and 2.35. Contrary, the minimum average headway time at the investigated intersections in Beijing is 2.57, and maximum average headway time is 3.64. In the Baishiqiao intersection, most of average headway times are beyond 3 seconds in both AM and PM.

Table 1 The saturation flow Rate of intersections in Tokyo

	Nishigodanta 1 Chome (Veh / h_g £©	Fufuzaka £¨outer ring£© (Veh / h_g £©	Fufuzaka £¨inner ring£© (Veh / h_g £©	Nishioka machi (Veh / h_g £©
Average Headway Time	1.95 sec	2.27 sec	2.35 sec	2.22 sec
Possible SFR	1843	1325	1535	1619
Basic SFR	1901	1749	1795	
Accumulate Method	Y=0.53X-1.99	Y=0.42X-4.78	Y=0.46X-2.65	Y=0.45X-0.92
Possible SFR	1899	1516	1649	1614
Basic SFR	1961	2003	1930	1614
TRRL	2.52Veh/5 sec	1.62 Veh/5 sec	2.06Veh/5 sec	2.30 Veh/5 sec
Possible SFR	1811	1163	1485	1656
BasicSFR	1870	1537	1738	1656

Notes: h_g --- one hour green time

Table 2 The saturation traffic flow of Baishiqiao in Beijing

		North°˙South		South°˙North	
		Lane 1	Lane 2	Lane 1	Lane 2
AM	TRRL	1.51Veh/5 sec	1.55 Veh/5 sec	1.62 Veh/5 sec	1.39 Veh/5 sec
	Possible SFR	1084	1125	1164	1000
	Basic SFR	1106	1148	1208	1031
PM	TRRL	1.71Veh/5 sec	1.81 Veh/5 sec	1.41Veh/5 sec	1.66Veh/5 sec
	Possible SFR	1229	1301	1031	1197
	Basic SFR	1247	1317	1043	1225

Table 3 The saturation traffic flow of Xidan, Jishuitan and Baishiqiao in Beijing

Intersections	Direction of Traffic	Lane	Samples of Cycles	Samples of Vehicles	Average of Vehicles	Saturation Traffic Flow
Xidan	W— E	1	250	487	1.95	1403
Xidan	W— E	2	252	487	1.93	1391
Xidan	W— E	3	173	355	2.05	1477
Jishuitan	N— S	1	270	467	1.73	1245
Jshuuitan	N— S	2	290	510	1.76	1266

Baishiqiao	N— S	1	153	229	1.50	1078
Baishiqiao	N— S	2	99	136	1.37	989

Table 4 is the average delay of the investigated intersections in Beijing, and Table 5 is the traffic volume and V/C ratio of partial intersection in Beijing, in which V is the traffic volume of the approach at the intersection and C is the capacity of the approach.

Table 4 The delay of the approach at some intersections in Beijing

Intersections	Direction of Traffic	Delay of Intersections (sec)	Intersections	Direction of Traffic	Delay of Intersections (sec)
Sitongqiao	E°˙W	134.8	Yuetanbeiqiao	E°˙W	29.2
Sitongqiao	W°˙E	178.3	Yuetanbeiqiao	W°˙E	27.2
Sitongqiao	S°˙N	19.2	Yuetanbeiqiao	S°˙N	38.7
Sitongqiao	N°˙S	208.8	Yuetanbeiqiao	N°˙S	43.7
Beitaipingqiao	E°˙W	130.4	Guanyuanqiao	E°˙W	35.8
Beitaipingqiao	W°˙E	55.6	Guanyuanqiao	W°˙E	59.2
Beitaipingqiao	S°˙N	110.2	Guanyuanqiao	S°˙N	111.6
Beitaipingqiao	N°˙S	97.4	Guanyuanqiao	N°˙S	137.6
Xidan	N°˙S	129.5	Xinjiekou	S°˙N	36.1
Xidan	W°˙E	79.1	Xinjiekou	N°˙S	50.6
Jishuitan	N°˙S	113.8	Baishiqiao	N°˙S	125.9
Jishuitan	W°˙E	92.2			

Table 5 The traffic volume and V/C ratio by lane in some intersection in Beijing

Intersections	Traffic Index	East			West			South			North			_
		Left	Straight	Right	Left	Straight	Right	Left	Straight	Right	Left	Straight	Right	
Guanyuan	v	259	477	281	917	365	552	676	125	400	290	93	659	0.96
	c	530	1115	838	918	740	838	810	150	336	587	189	830	
	v/c	0.49	0.43	0.34	1.00	0.49	0.66	0.83	0.83	1.16	0.49	0.49	0.79	
Beitaiping	v	336	300	436	356	426	788	410	435	197	321	505	630	0.80
	c	449	572	754	514	503	995	630	489	179	537	1106	728	
	v/c	0.75	0.52	0.58	0.69	0.85	0.79	0.65	0.89	1.10	0.60	0.46	0.87	
Sitongqiao	v	315	344	398	626	235	108	89	868	528	469	533	362	1.04
	c	436	484	744	788	237	108	159	1663	735	394	448	305	
	v/c	0.72	0.71	0.54	0.79	0.99	1.00	0.56	0.55	0.72	1.19	1.19	1.19	
Jishuitan	v	347	48	465	414	111	149	62	651	217	407	435	599	0.90
	c	497	69	887	627	210	282	117	1175	359	474	951	621	
	v/c	0.70	0.70	0.52	0.66	0.53	0.53	0.53	0.55	0.60	0.86	0.46	0.96	
Yuetanbei	v	39	83	124	441	149	343	346	563	91	224	386	363	0.76
	c	845	180	569	575	192	847	381	726	122	254	410	335	
	v/c	0.46	0.46	0.46	0.77	0.78	0.40	0.91	0.77	0.75	0.88	0.94	1.08	

From the tables, it is known that the traffic volumes of the investigated intersection in Beijing are not so large besides particular one, and are far from the capacity of the intersection. However, the delays in most investigated intersections are larger. The minimum delay is 27.2 second and maximum delay is 208.8 second. Among 23 approaches investigated intersections, the delays of the 13 approaches are lager than 60 seconds. According to the traffic service level standard of the signalized intersection made by America, the traffic service level of the intersections belongs to F when the delay is larger than 60 seconds. Therefore, it can be concluded that the service level of the investigated intersections in Beijing is very pure.

Based on the investigation results and above analysis, it is concluded that the saturation flow rate of the intersection in Beijing are much lower than that in Tokyo, and it is significant to improve the intersection including the physical countermeasures and traffic management countermeasures. The factors to bring about the lower saturation flow rate of the intersection in Beijing can be considered as follows:

- Disturbance by non-automobiles

There are 1.03 million vehicles and 7.36 million bicycles in Beijing and the split ratio is: bicycle 50.28%, transit 27.71%, walker 13.79%, car owned by companies 4.38% and others 5.0%. That is, large amount of bicycles coexist with vehicles on the road links in Beijing. Because there is no physical separator between the vehicle lane and bicycle lane in most links of urban road, during the peak hour, bicycles frequently invade the vehicle lane , which make vehicles suffer the lateral disturbance.

- Disturbance by walkers

Dramatically increase of vehicle ownership is just the case of recent years. There is 132 thousand vehicles in 1980 in Beijing, but up to 1.03 million in 1996, 8 times than it. Many peoples can not keep pace with this developing tendency and still lack of transportation safety concept, which cause many trip makers disobeying traffic rule, for instance some walkers cross the road regardless of the red light , thus delay the vehicles.

- Quality of vehicles

Old and broken vehicles occupy high proportion in the vehicles of China. Because of non-strict vehicle checking system and lower quality of automobile, such kind of vehicles coexist with the good quality vehicles on the same road and delay them. This is one reason to lead to low saturation flow rate.

- Not enough channelization

As above, vehicles are disturbed by non-automobiles and walkers, The reason to which is lack of enough channelization. In China, there are many roads without physical separator. Furthermore, the indication marking and channelization making are not enough. All of these also contribute to the low saturation traffic capacity.

- Driving psychology

Because many peoples can not stick to traffic rules, the drivers are so tense when driving because the possibility of any person occurs suddenly even it is green time at the signalized intersections. Drivers have to decelerate their speeds when going through the intersection in China. Thus, the speed can not be up to that in same traffic and road conditions in Japan.

- Traffic behavior characteristic

Comparing with that in Tokyo, there is much more clearance time at the intersections in Beijing. At some intersections, although traffic of a certain direction is permitted and reach the center of the intersection, they can not pass through but have to wait the rest traffic of the other direction to cross. Still comparing with that in Tokyo, there is less starting delay in Beijing, and many vehicles start before the green light turns on. Less starting delay and more clearance time cause vehicles can not cross the intersections promptly. Such traffic behavior characteristic make traffic condition at the intersection chaotic, then form a transportation bottleneck.

- The signal phases

The signal phases used in Beijing are all 2-phase system. The right-of-way of all vehicle flow, Bicycles and pedestrians are given by one phase. Therefore, conflicts among cars, bicycles and pedestrians occurred everywhere in an intersection. On the other hand, many bicycles and pedestrians wait to their right-of-ways in an intersection. This situation causes the speed reduction of cars which are given a right-of-ways at green signal.

5 SUGGESTION AND CONCLUSION OF ENHANCING CAPACITY OF INTERSECTIONS IN BEIJING

Through the comparative analysis on saturation traffic flow of intersections between Beijing and Tokyo, we can find out the reason to low saturation traffic flow in Beijing , which can be reduced to six : disturbance by non-automobiles, by walkers, quality of vehicles, not enough channelization, driving psychology and traffic behavior characteristic. In the light of these, we can adopt the following countourmeasures to enhance the capacity of intersections.

- Supplement the channelization facility

Use physical separators as much as possible to channelize the vehicles and non-automobiles, walkers, thus eliminate the disturbance to vehicles by non-automobiles and walkers.

- Perfect the guidance markings at the intersections

Perfect the guidance markings and the channelization markings, and the vehicles will cross the intersections smoothly and effectively. As the results, the average headway time will be shorten, because drivers can go through the intersections according to the markings without thinking.

- Strengthen the education on traffic rules and traffic safety consciousness

Enhancing the population_ traffic safety consciousness and the travelers' traffic rules concept to create a good traffic circumstance are critical in order to realize the modern and efficient transportation management. Otherwise, all modern transportation management facilities can not work. As we know, such kind of education will take a long and wide-ranging procedure, it should be done from different ways, from children and from now.

- Improve the quality of vehicles

The quality of vehicles can be improved by two ways: the first is that from the view of vehicle making producers, making the strict performance criterion, strength the quality control to improve the quality of new vehicles; the second is that from the view of existing vehicles, perfecting the vehicle checking system to ensure these vehicles satisfying the basic performance requirements.

- Provide the special phase to bicycles and pedestrians