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Characteristics and risk of violation behavior of non-motorists at signalized intersections

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Abstract: Aiming at prevalent violations of non-motorists at urban intersections in China, this paper intends to clarify the characteristics and risks of non-motorist violations at signalized intersections through questionnaires and video recordings, which may serve as a basis for non-motorized vehicle management. It can help improve the traffic order and enhance the degree of safety at signalized intersections. To obtain the perception information, a questionaire survey on the Internet was conducted and 972 valid questionnaires were returned. It is found that academic degree contributes little to non-motorist violations, while electrical bicyclists have a relatively higher frequency of violations compared with bicyclists. The video data of 18 228 non-motorist behaviors indicate that the violation rate of all non-motorists is 26.5%; the number of conflicts reaches 1 938, among which violation conflicts account for 66.8%. The study shows that the violation rates and the violation behavior at three types of surveyed intersections are markedly different. It is also concluded that the conflict rates and the violation rates are positively correlated. Furthermore, signal violation, traveling in the wrong direction, and overspeeding to cross the intersection are the most dangerous among traffic violation behaviors.

Key words: traffic violation behavior; traffic safety; non-motorist; signal intersection

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Compared with developed countries, China differentiates itself regarding mixed traffic of motorized vehicles, non-motorized vehicles and pedestrians. The non-motorized vehicles which mainly include bicycles and electrical bicycles are set as the research object of this paper.

Widely known as the kingdom of bicycles, China ranks the first in terms of production capacity, bicycle quantity and the usage of bicycles. In recent years, electrical bicycles among the public have become increasingly popular. However, electrical bicycles lead to one of the major problems in the traffic system. According to the statistics of the annual report for traffic accidents from the Traffic Administration of the Ministry of Public Security, the traffic accidents caused by non-motorist violation behaviors reached 8 912, which led to the death of 1 405 people and the injury of 9 475 people in the year of 2009.

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As the nodal points of the urban road network, intersections collect various traffic flows from different directions. Non-motorized vehicles, motorized vehicles and pedestrians easily collide with each other, thus resulting in traffic jams and accidents.

Therefore, in recent years, a number of scholars have devoted themselves to the researches on non-motorized vehicle behavior and contributing factors at intersections. Elliott et al.[2] developed a questionnaire that measured the behavior of motorcyclists. Liu[3] mainly investigated the aggregation behavior of bicyclists at intersections. Su et al.[4] mainly studied about the conflicting patterns when crossing urban intersections. Huang and Wu[5] focused on the group-riding behavior of cyclists. Jou and Wang[6] did an investigation of four types of moving violations among Taiwan motorcyclists including speeding, running red lights, right turn on red violations, and drunk driving. Harkey et al.[7] constructed the countermeasure module to find appropriate engineering, education, and enforcement treatments. Carter et al.[8] concluded that indicative variables in the bicycle safety models included various combinations. In China, Shi[9] found that violations of traffic law have become universal behavior; different groups only differentiate themselves in violation modes. Through roadside investigation, Zhao[10] found that signal violation, crossing a motorway illegally and traveling in the wrong direction are most likely to lead to accidents for non-motorized vehicles.

Therefore, this paper aims to highlight violation behavior characteristics of non-motorists at intersections, and disclose its universality as well as the risk of non-motorist violation behavior, which may serve as a basis for non-motorized vehicle management and traffic order maintenance at intersections.

1 Research Methodology

1.1 Questionnaire

The survey was conducted on the Internet in January 2010. 1 162 questionnaires in total were withdrawn, including 972 valid questionnaires, with a valid recovery rate of 83.2%. Bicycle questionnaires and electrical bicycle questionnaires withdrawn are respectively 647 and 515, leaving 556 and 416 valid questionnaires, respectively. The questionnaire is anonymous.

The questionnaire includes the demographic items of the respondents, such as age, gender and academic degree. Tab. 1 gives the statistics of the individual information of the respondents.

Four kinds of violation behaviors at signalized intersections are listed in the questionnaire: running on the motorway (abbreviated as occupying), traveling in the wrong di-

rection (abbreviated as reverse traveling), disobeying traffic signals (abbreviated as signal violation) and traveling too fast around the corner (abbreviated as fast turning)[11].

Tab. 1 Statistics of respondent information

Demographic items		Bicycle	Electrical bicycle
Age	<18	50	0
	18 to 30	204	206
	31 to 40	145	133
	41 to 50	108	56
	>50	49	21
Gender	Male	357	216
	Female	199	200
Academic degree	Middle school or below	39	11
	Technical secondary school or high school	62	40
	College or university	389	293
	Master or above	66	72

Respondents are required to impart the frequency of occurrence of the above-named behaviors. The form of Likert's 5-point scale "often, sometimes, average, seldom, never" with 1-5 points for different degrees is used. Higher points indicate a lower frequency of violation behaviors.

Survey data is analyzed by SPSS 17.0 and correlation between violations and demographics is explored. Four detailed violation behaviors and average value difference are analyzed with ANOVA for individuals of different ages, genders, and academic status, in order to know the influence of these demographics on non-motorists.

1.2 Video recording survey

How do non-motorists behave at signalized intersections of different types? In order to obtain the answer, first, the intersections which have different phase settings, sizes and traffic volumes are chosen. Meanwhile, the intersections need to have a higher degree of mixed traffic without special interference characteristics and without supervision by traffic police. Through the field investigation of a number of intersections, three standard intersections are finally determined and designed as three types (see Tab. 1). Xuefu Road-Chengxian Street intersection is adjacent to Southeast University with a light traffic volume, and Chengxian Street is for mixed traffic of motorized vehicles and non-motorized vehicles. Jiefang South Road-Liuting Street intersection has a medium traffic volume with left-turning phase. Hongwu Road-Huaihai Road intersection is located at the commercial center of Nanjing city, surrounded by a plurality of large-scale shopping malls, and it has a heavy traffic volume and a high pedestrian volume. Tab. 2 shows other information of the three intersections.

Tab. 2 Intersection video recording

Intersection type	Intersection	Area size	Signal phase	Signal cycle length/s	Lane number of intersecting roads	Survey time span/h
A	Xuefu Road-Chengxian Street	Small	2	42	2-2	4
B	Jiefang South Road-Liuting Street	Medium	4	138	4-3	4
C	Hongwu Road-Huaihai Road	Big	6	126	4-4	4

Good recording places which have a whole and clear visual field of the intersections are important to ensure the quality of data collection. The recording should be arranged in fine weather to ensure the normal psychology and traffic behavior of non-motorists. Due to the particularity of evening traffic hours on Friday, video recording selects 17:30 to 18:30 from Monday to Thursday and comprises a total of 12 h.

Through preliminary investigation, it is found that major violations of non-motorists at intersections include overspeeding to cross the intersection, signal violation, occupying motorway, traveling in the wrong direction, and parking outside the stop line. Among these behaviors, "overspeeding to cross the intersection" contains the condition of arriving at the end of the green light and accelerating to cross the intersection at that time.

After observation of 12 h of videos, the following data are finally obtained: motorized vehicles, bicycle and electrical bicycle volumes, various violation behavior data of non-motorists, number of total conflicts, number of conflicts caused by each violation behavior of non-motorists. The video data of 18 228 non-motorist behaviors and 4 711 violation cases of non-motorized vehicles have been acquired. The number of conflicts with respect to non-motorists (abbreviated as conflicts) reaches 1 938, among which violation conflicts account for 66.8%.

In the processing of the video data, statistical methods and SPSS software are applied in the analysis of the relevant data of non-motorist violations in order to identify the relationships between violations and traffic volume. Then, the Spearman rank correlation coefficient is applied in order to test the relationships between the violation rate and the conflict rate, and the relationships between the correlation factors are fitted. To ensure a unitary criterion of conflict judgment, data statistics participants are provided with unified training and testing and the number of data statisticians is reduced as far as possible. ANOVA is also applied to test the characteristic value and the risk degree of major violation behaviors at three types of intersections.

2 Results

2.1 Analysis on violation of bicyclists of different demographics

2.1.1 Age differences

Most bicycle users are centered in the group with the age of 18 to 30. Tab. 3 shows different violation behaviors of bicycle users of different ages.

Through variance analysis it can be found that there are marked differences between "traveling in the wrong direction" and "traveling too fast around the corner" in terms of age. Judging from the average value, it is obvious that bicyclists of different ages vary remarkably in violating traffic laws (when $\alpha = 0.025$, $F(4, 642) \approx 2.85$, namely $F > 2.85$ as well as $p < 0.05$). Bicyclists with the age of above 40 are less likely to violate traffic laws.

2.1.2 Gender differences

Through variance analysis as shown in Tab. 4, it can be

Tab. 3 Analysis on violation of bicyclists of different ages

Violation	Age					F	p
	<18	18 to 30	31 to 40	41 to 50	>50		
Occupying	3.50	2.89	2.96	3.21	3.57	1.892	0.110
Reverse traveling	3.00	3.15	2.98	3.78	3.70	3.972	0.003
Signal violation	3.50	3.59	3.55	3.86	4.11	1.422	0.228
Fast turning	3.50	3.59	3.68	4.33	4.25	4.621	0.001
Average	3.38	3.31	3.29	3.8	3.91	4.004	0.007

concluded that bicyclists of different genders show marked differences in violation behavior (when $\alpha = 0.025$, $F(1, 642) \approx 5.05$, namely $F > 5.05$ as well as $p < 0.05$). The males are more likely to make violation behaviors than the females.

Tab. 4 Analysis on violation of bicyclists of different genders

Violation	Gender		F	p
	Male	Female		
Occupying	2.85	3.18	7.811	0.005
Reverse traveling	3.10	3.29	2.636	0.105
Signal violation	3.51	3.82	8.132	0.005
Fast turning	3.58	3.88	7.846	0.005
Average	3.26	3.54	18.849	0

2.1.3 Academic degree differences

From Tab. 5 it can be seen that there are not marked differences in all the values of violation behaviors among bicyclists of different academic degrees, since all the values satisfy $F < 3.15$ or $p > 0.05$ (when $\alpha = 0.025$, $F(3, 642) \approx 3.15$). Therefore, there is little difference in violation behavior among bicyclists of different education levels.

Tab. 5 Analysis on violation of bicyclists of different academic degrees

Violation	Academic degree				F	p
	Middle school or below	Technical secondary school or high school	College or university	Master or above		
Occupying	3.20	3.04	2.96	2.96	0.175	0.913
Reverse traveling	3.20	3.24	3.18	3.08	0.159	0.924
Signal violation	3.65	3.61	3.61	3.62	0.003	1.000
Fast turning	4.10	3.70	3.70	3.61	0.486	0.692
Average	3.54	3.4	3.36	3.32	0.728	0.536

2.2 Analysis on violation of electrical bicyclists of different demographics

2.2.1 Age differences

Electrical bicycle users questioned are 18 to 55 years old and most users are centered in the group with the age of 26 to 40. Tab. 6 shows different violation behaviors of electrical bicycle users of different ages.

Through variance analysis it can be found that all the values of violation behaviors of electrical bicyclists of different ages satisfy $F > 2.50$ as well as $p < 0.05$ (when $\alpha = 0.025$, $F(5, 509) \approx 2.50$). Namely, there is little difference in violation behavior among electrical bicyclists of different ages. Among all age levels, electrical bicyclists with the age of above 50 are the least likely to violate traffic laws.

Tab. 6 Analysis on violation of electrical bicyclists of different ages

Violation	Age				F	p
	18 to 30	31 to 40	41 to 50	>50		
Occupying	2.55	2.56	2.41	3.00	1.300	0.263
Reverse traveling	2.84	2.98	3.00	3.00	1.787	0.114
Signal violation	3.12	3.14	3.18	3.36	0.595	0.704
Fast turning	3.08	3.26	3.06	3.55	1.504	0.187
Average	2.89	2.98	2.91	3.23	1.859	0.087

2.2.2 Gender differences

Through variance analysis as shown in Tab. 7, the conclusion can be drawn that there are marked differences in violation behavior among electrical bicyclists of different genders (when $\alpha = 0.025$, $F(1, 509) \approx 5.08$, namely $F > 5.08$ as well as $p < 0.05$); a few differences exist in "traveling in the wrong direction". According to the average values, the males are more likely to make violation behaviors than the females.

Tab. 7 Analysis on violation of electrical bicyclists of different genders

Violation	Gender		F	p
	Male	Female		
Occupying	2.38	2.74	13.153	0
Reverse traveling	2.87	2.83	0.190	0.663
Signal violation	3.04	3.24	5.120	0.036
Fast turning	3.04	3.25	5.659	0.018
Average	2.83	3.015	12.163	0.001

2.2.3 Academic degree differences

From Tab. 8 it can be seen that there are not marked differences in violation behavior among electrical bicyclists of different academic degrees, and all the values satisfy $F < 3.18$ or $p > 0.05$ (when $\alpha = 0.025$, $F(3, 509) \approx 3.18$). According to the average value, electrical bicyclists with the academic degree of middle school or below are most likely to violate traffic laws.

2.3 Statistics of violation behavior and violation rate

Through analyzing the video documents, the non-motorized vehicle volumes and violation numbers are presented in Tab. 9. It can be seen that among the three types of intersections, the A-type intersection has the least traffic volume; non-motorized vehicles account for the largest proportion with approximately 55% and also has the highest violation rate. The traffic flow at the B-type intersection has the heaviest traffic volume. The non-motorized vehicle proportion at the B-type intersections is the smallest, about 25%, and the non-motorist violating rate is less than that at the A-type intersections. The C-type intersection has a traffic volume between the flow values of A-type and B-type; non-motorized vehicles account for approximately 40% and has the lowest violation rate.

Tab. 8 Analysis on violation of electrical bicyclists of different academic degrees

Violation	Academic degree				*F*	*p*
	Middle school or below	Technical secondary school or high school	College or university	Master or above		
Occupying	1. 90	2. 43	2. 54	2. 56	1. 530	0. 206
Reverse traveling	2. 60	3. 02	2. 85	2. 86	0. 877	0. 453
Signal violation	2. 40	3. 09	3. 15	2. 88	3. 018	0. 030
Fast turning	3. 00	3. 17	3. 11	3. 16	0. 154	0. 927
Average	2. 48	2. 93	2. 91	2. 87	0. 954	0. 415

Tab. 9 Intersection traffic volume and statistics of non-motorist violation

Intersection type	Motorized vehicle volume/ (veh · h^{-1})	Non-motorized vehicle volume/ (veh · h^{-1})	Total vehicle volume/ (veh · h^{-1})	Proportion of non-motorized vehicle	Proportion of electrical bicycle in non-motorized vehicles	Violation number/ (times · h^{-1})	Violation rate
A	756	1 059	1 815	0. 583	0. 31	549	0. 518
	783	930	1 713	0. 543	0. 32	417	0. 448
	819	1 035	1 854	0. 558	0. 40	438	0. 423
	828	1 173	2 001	0. 586	0. 43	480	0. 409
Average	797	1 049	1 846	0. 568	0. 37	471	0. 449
B	4 069	1 616	5 685	0. 284	0. 36	509	0. 315
	3 762	1 255	5 017	0. 250	0. 36	446	0. 355
	3 738	1 716	5 454	0. 315	0. 43	558	0. 325
	4 306	1 466	5 772	0. 254	0. 28	406	0. 265
Average	3 969	1 513	5 482	0. 276	0. 36	480	0. 316
C	2 982	1 888	4 870	0. 388	0. 39	296	0. 157
	2 764	1 880	4 644	0. 405	0. 34	219	0. 116
	2 812	2 094	4 906	0. 427	0. 32	240	0. 115
	2 904	2 116	4 960	0. 427	0. 35	268	0. 127
Average	2 866	1 995	4 845	0. 412	0. 35	256	0. 129

2. 4 Analysis of contributing factors to violation rate

The video data is analyzed with units of 10 min, which contains 24 groups of data for each intersection. Tab. 10 gives the analysis on differences among the violation rates of non-motorists at the three types of intersections, which is caused by several factors such as different signal designs, physical conditions, and area sizes at different types of intersections.

Tab. 10 Variance analysis on violation rate of various intersections

Intersection type	Mean value of violation rate	Std. deviation	*F*	*p*
A	0. 449	0. 069		
B	0. 316	0. 037	71. 579	0
C	0. 129	0. 034		

The relationships among factors which correlate with the violation rates are fitted for each intersection, and the data outside confidence intervals are deleted. From Tab. 11, it can be found that the violation rate is negatively correlated with the motorized vehicle volume and the total motorized vehicle volume. Furthermore, the correlation between the violation rate and the intersection type is significant.

Tab. 11 Analysis on contributing factors of violation rate

Spearman's rho		Other main factors			
		Motorized vehicle volume	Total vehicle volume	Proportion of non-motorized vehicles	Proportion of electrical bicycles in non-motorized vehicles
Violation rate	Correlation coefficient	−0. 557 *	−0. 424 *	0. 235	0. 676
	Sig. (2-tailed)	0. 017	0. 029	0. 654	0. 140

Note: * represents that the correlation is significant at the 0. 05 level (2-tailed).

It can be concluded that, in general, traffic volumes have little influence on violation behaviors among the different types of intersections, while motorized vehicle volumes and vehicle volumes are the objective factors contributing to the violation behaviors at each intersection. For each intersection, the smaller the motorized vehicle volume is, the higher the violation rate of the non-motorized vehicles will be.

2. 5 Analysis of risk of non-motorist violations

As it is impossible to obtain the data of accidents occurring at intersections annually, this paper makes an effort by way of rules of conflict to analyze the risk of non-motorist violation behavior.

In this study, the violation conflict number is defined as the number of the conflicts between the non-motorized vehicles and other road users, caused by non-motorist violation behaviors, while the total conflict number refers to the number of the non-motorized vehicle conflicts, regardless of the reasons.

Tab. 12 shows that the A-type intersection has the most violation conflicts and total conflicts. The proportions of violation conflicts of three types of intersections are all above 50%, among which violation conflicts account for 80% at the C-type intersection.

As shown in Tab. 13, the violation conflict rate and the total conflict rate at intersections are positively correlated with the violation rate. In this paper, the violation conflict rate is defined as the ratio between the number of the non-motorized vehicle violation conflicts and the total number of the non-motorized vehicles, while the total conflict rate refers to the ratio between the number of the non-motorized vehicle conflicts and the total number of the non-motorized vehicles.

Tab. 12 Description of conflicts at various intersections

Parameter	Intersection type	Mean value of conflicts/ (times · (10min)$^{-1}$)	Std. deviation
Violation conflict number	A	22.833	3.061
	B	15.250	4.393
	C	15.833	3.189
Total conflict number	A	33.667	3.983
	B	27.418	3.988
	C	19.667	3.724
Proportion of violation conflict	A	0.679	0.063
	B	0.547	0.099
	C	0.804	0.058

Tab. 13 Correlation analysis of conflict and violation rate

Spearman's rho		Violation conflict rate	Total conflict rate
Violation rate	Correlation coefficient	0.713**	0.512*
	Sig. (2-tailed)	0.003	0.011

Note: * represents correlation is significant at the 0.05 level; ** represents correlation is significant at the 0.01 level.

As far as the two contributing factors mentioned above are concerned, the relationships among factors which correlate with the violation rate are fitted, and the data outside confidence interval are deleted. The relationships between violation conflict rates and violation rates, and the relationships between total conflict rates and violation rates are shown in Fig. 1.

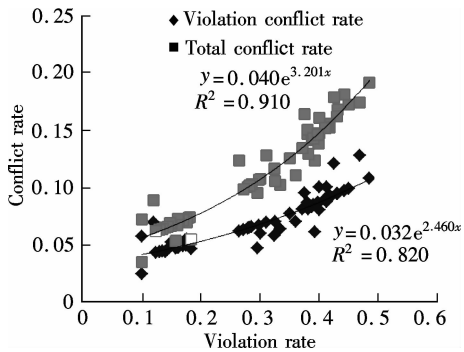

Fig. 1 Relationships between conflict rates and violation rates

Based on the statistical data of traffic conflicts caused by various violation behaviors, numbers of various violation behaviors and conflicts caused by various violation behaviors at different types of intersections are obtained and shown in Tab. 14, and the proportions of various violation behaviors and conflicts caused by violation behaviors are analyzed.

Tab. 14 Numbers of various violation behaviors and conflicts times/(10min)

Intersection type	Overspeeding to cross the intersection		Signal violation		Occupying motorway		Traveling in the wrong direction		Parking outside the stop line		Non-violation conflicts
	V	*C*	*V*	*C*	*V*	*C*	*V*	*C*	*V*	*C*	
A	10.3	1.8	48.7	15.2	5.5	2.7	3.2	1.5	11.0	1.7	10.8
B	3.9	0.8	33.8	10.7	15.6	0.6	18.7	1.5	7.6	1.7	12.2
C	7.3	3.7	14.5	6.3	5.8	1.7	5.0	2.8	10.0	1.3	3.8

Note: *V* represents violation number, and *C* represents conflicts caused.

Fig. 2 demonstrates the violation proportion and the conflict proportion at three types of intersections. Signal violation is the leading contributing factor to accidents at the three intersections. Non-violation conflict refers to the conflict caused by vehicles which comply with traffic law; non-violation conflict is also a major contributing factor to the accidents. However, it can be reduced by reasonable signal design and intersection channelization. From Fig. 2(b) it can be seen that the non-violation conflict proportion at the B-type intersection is the highest among the three types of intersections.

In order to analyze the risk of non-motorist violation behavior at signalized intersections, this paper defines the conflict number minus the violation number caused by some violation behavior as the risk degree.

From Tab. 15 it can be seen that "occupying motorway" and "traveling in the wrong direction" are dangerous violation behaviors with similar risk degrees higher than 0.5 for the A-type intersection. However, risk degree of "signal violation" is far higher than that of other behaviors for the B-type intersection. "Overspeeding to cross the intersection" and "signal violation", particularly "traveling in the wrong direction" are dangerous violation behaviors for the C-type intersection. Generally speaking, "signal violation", "traveling in the wrong direction" and "overspeeding to cross the intersection" are the most likely to expose travelers to risk.

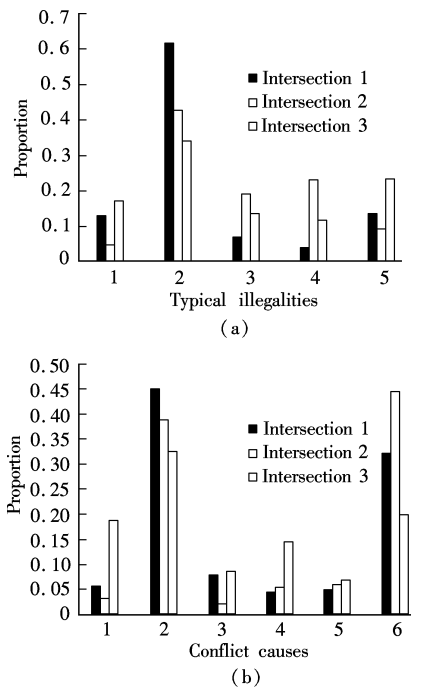

Fig. 2 Proportions of major violation behavior and conflict caused. (a) Proportion of typical violation behaviors; (b) Proportion of conflicts

Tab. 15 Description of risk degrees of major violation behaviors

Serial number of behavior	Violation behavior	Intersection type	Mean risk degree
1	Overspeeding to cross the intersection	A	0.175
		B	0.205
		C	0.507
		Total	0.296
2	Signal violation	A	0.312
		B	0.317
		C	0.434
		Total	0.354
3	Occupying motorway	A	0.491
		B	0.038
		C	0.293
		Total	0.274
4	Traveling in the wrong direction	A	0.469
		B	0.080
		C	0.560
		Total	0.370
5	Parking outside the stop line	A	0.155
		B	0.224
		C	0.130
		Total	0.169

3 Discussions

3.1 Universality of non-motorists' violation in China

Through the analysis above it can be seen that academic degree does not contribute to differences in non-motorist violation behaviors; non-motorists of different genders show marked differences in violation behavior. The males are more likely to make violation behaviors than the females. Electrical bicyclists of middle school or below academic degree are most likely to disobey traffic laws. It is shown that violation has become a universal phenomenon in China.

On the other hand, it can be easily found that electrical bicyclists commit violations more frequently compared with bicyclists, since electrical bicycles are relatively faster, more flexible and more difficult to control compared with bicycles.

3.2 Contributing factors to violation rate of non-motorists at intersections

The video data of 18 228 non-motorists' behaviors and 4 711 violation cases of non-motorized vehicles have been acquired, which indicate that the violation rate of all non-motorists is 26.5%. Through ANOVA analysis it can be found that the violation rates of the three types of surveyed intersections are markedly different. The A-type intersection is the smallest intersection among the three, which is two-phase and has the smallest motorized vehicle volume but the highest violation rate; non-motorists behave rather randomly at the intersection. The C-type intersection is the largest intersection among the three, which boasts of a complicated and reasonable phasing system as well as a relatively heavier motorized vehicle volume; as a result, it has the lowest violation rate of non-motorists. Through correlation analysis it can be found that the violation rate is negatively correlated with the motorized vehicle volume and the total motorized vehicle volume. For each intersection, the smaller the motorized vehicle volume is, the higher the violation rate of the non-motorized vehicles is. On the other hand, the smaller the total vehicle volume is, the higher the violation rate of the non-motorized vehicles is, too.

3.3 Characteristics of non-motorists' violation at different types of intersections

Through processing of video recording and analysis of non-motorist violation behaviors at three types of intersections, it can be concluded as follows.

The A-type intersection has the slightest motorized vehicle volume and "signal violation" is rather conspicuous; non-motorists often make light of the consequences of violation behavior; some non-motorists stop beyond the line, thus disturbing the right-turning motorized vehicles at the same entrance driveway.

As the B-type intersection has unreasonable settings of the left-turning phase, some non-motorists are likely to commit "signal violation". From the video of the Jiefang South Road-Liuting Street intersection it can be seen that the east-west bicycle lane is installed with shelters, and as a result, violation behaviors such as parking outside the line have been significantly reduced.

The C-type intersection boasts of a reasonable signal phasing system and a heavy motorized vehicle volume, which gives great psychological pressure to non-motorists for the violation behavior, thus causing a relatively lower rate of violation behavior such as "signal violation" compared with the other two intersections.

3.4 Risk of non-motorist violation behavior

Tab. 12 shows that the violation conflict proportions of the three types of intersections are above 0.5, among which the violation conflict proportion of the C-type intersection reaches 0.8. It is thus clear that non-motorist violation behavior is a major contributing factor to accidents at intersections.

The violation conflict rate and the total conflict rate at intersections are positively correlated with the violation rate, which indicates that the higher the violation rate, the higher the conflict rate at intersections. The A-type intersection has the most violation conflicts and total conflicts.

Tab. 15 shows that on the whole, "signal violation", "traveling in the wrong direction" and "overspeeding to cross the intersection" are the most dangerous violation behaviors; specifically speaking, "signal violation" at the B-type intersection is exposed to the highest degree of risk; all kinds of violation behaviors demonstrate relatively higher degrees of risk at the C-type intersection, among which the risk degrees of "overspeeding to cross the intersection" and "traveling in the wrong direction" are higher than those of the other two intersections.

4 Conclusions

1) Demographics such as academic degree contribute little to non-motorist violation behavior and violation has become a universal phenomenon. Compared with bicyclists, electrical bicyclists have a higher frequency of violation.

2) For each intersection, the violation rate is negatively correlated with the motorized vehicle volume and the total

number of vehicles. Non-motorists commit violations frequently at small-scale intersections and often behave randomly.

3) Non-motorist violations are the major factors contributing to accidents at intersections. The conflict rate at intersections is positively correlated with the violation rate; namely, the higher the violation rate, the higher the conflict rate at intersections.

4) At intersections, "signal violation", "traveling in the wrong direction" and "overspeeding to cross the intersection" are the most dangerous among traffic violation behaviors. All violation behaviors demonstrate relatively higher degrees of risk at large-scale intersections.

5) The reasons why non-motorist violations at intersections is universal are integrated. Therefore, it is significant to construct perfect transportation projects, carry out studies on traffic systems, and strengthen the management of high-degree violation and traffic law enforcement with an aim to restoring a favorable traffic order.

More intersections will be surveyed and conducted for further research, in order to reveal the quantity relationships among violation behaviors, intersection areas, canalization and signal timing.

References

[1] Ministry of Public Security Traffic Administration. *Road and traffic accident statistics reports of the People's Republic of China* [M]. Beijing: Ministry of Public Security Traffic Administration, 2009. (in Chinese)

[2] Elliott M A, Baughan C J, Sexton B F. Errors and violations in relation to motorcyclists' crash risk [J]. *Accident Analysis and Prevention*, 2007, **39**(3): 491 - 499.

[3] Liu J M. Study on the behavior characteristics of bicycles at signal intersections [D]. Beijing: School of Traffic and Transportation of Beijing Jiaotong University, 2005. (in Chinese)

[4] Su Y L, Yao D Y, Zhang Y, et al. Road user's behavior analyses of urban intersections [C]//*IEEE Intelligent Transportation Systems Conference*. Seattle, WA, USA, 2007: 784 - 789.

[5] Huang L, Wu J P. A study on cyclist behavior at signalized intersections [J]. *IEEE Transactions on Intelligent Transportation Systems*, 2004, **5**(4): 293 - 299.

[6] Jou R C, Wang P L. The intention and willingness to pay moving violation citations among Taiwan motorcyclists [J]. *Accident Analysis and Prevention*, to appear.

[7] Harkey D L, Mekemson J, Chen M, et al. *Pedestrian and bicycle crash analysis tool* (*PBCAT*): *user's manual* [M]. US Federal Highway Administration, 1999.

[8] Carter D L, Hunter W W, Zegeer C V, et al. *Pedestrian and bicyclist intersection safety indices* [M]. US Department of Transportation Federal Highway Administration, 2007.

[9] Shi Q H. Research on the current traffic violation behavior — experience & research on the traffic violation behavior of the habitants of Nanjing city, Jiangsu province [J]. *Theory Horizon*, 2009 (2): 77 - 80. (in Chinese)

[10] Zhao X J. On the violation behavior of non-motors and pedestrians at signal intersections [D]. Beijing: School of Traffic and Transportation of Beijing Jiaotong University, 2006. (in Chinese)

[11] Wang Z H. Research on the safety evaluation system of urban intersections [D]. Beijing: College of Architecture and Civil Engineering of Beijing University of Technology, 2008. (in Chinese)

信号交叉口非机动车违法行为特征及其危险性

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摘要:针对我国城市道路信号交叉口非机动车广泛存在的违法行为,通过问卷调查与视频采集处理,揭示非机动车在交叉口的违法行为特征及其对信号交叉口安全的影响,以作为非机动车管理的依据,改善信号交叉口秩序混乱、安全系数低的状况. 通过网络调查得到 972 份有效问卷,发现学历对非机动车违法影响较小;相对于自行车,电动自行车骑行者的违法行为发生频率更高. 视频调查获取了 18 228 个非机动车样本,其违法率为 26.5%,发生冲突 1 938 次,其中违法冲突占 66.8%. 研究发现:3 类被调查的交叉口违法率与违法行为具有显著差异,交叉口冲突率与违法率显著正相关,其中非机动车闯红灯、逆行、绿灯快结束抢行 3 种交通违法行为的危险度最高.

关键词:交通违法行为;交通安全;非机动车;信号交叉口

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