A STUDY OF BICYCLIST ACCIDENTS IN CHANGSHA OF CHINA AND HANNOVER OF GERMANY

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ABSTRACT

Bicyclists represent a population with high risk of traffic injuries since they are unprotected in vehicle collisions. A study was conducted with an in-depth analysis of bicyclist accidents in China and Germany. The analysis is to identify the hazard of bicyclists in Changsha and to propose the way to reduce the number of these accidents and also severity of injuries. The analysis was carried out in terms of the causes of injury, injury severity and distribution and also type of vehicle involved, accident type, road environment, time distribution etc. The accident cases that occurred from 2001 to 2006 were collected from IVAC database in Changsha, China and GIDAS database in Hannover, Germany. Based on specified sampling criteria, 1,013 bicyclist cases and 1806 cases were selected from the two databases, respectively. Statistical analyses and comparative analyses were carried out with the sampling data. The results show that there were similarities and differences regarding bicyclist accidents between Changsha and Hannover, especially for the frequency and age distribution of the fatalities and also the road environment where accidents occurred. The results from this study suggested that there is a great potential for reduction of the accidents and fatalities by safety countermeasures, such as usage of helmet and improvement of road environment in countries like China.

Keywords: bicyclist accidents, statistical analysis, circular distribution analysis

1 INTRODUCTION

The bicyclist accidents are considered to be an important issue regarding urban traffic safety in China. At present it is estimated that in China more than 500 million [1] bicycles are used. China is a country with the largest number of bicycles over the world. Bicycle is one of the most popular tools for travel in urban areas. The report [2] states that more than 30% of residents travel by bicycle - not other transportation modes. Bicyclists represent a population at high risk injuries since they are unprotected in collisions with vehicles.

It is reported [3] that in China during 2006, about 0.38 million traffic accidents with all together 520,000 casualties (fatalities and injuries), of these were 43,781 (8.4 %) bicyclists, and in this group 8471 (19.3%) were killed.

In comparison in Germany during year 2006, about 2.2 million traffic accidents were registered with altogether 427,000 casualties (fatalities and injuries). Of these 77,054 (18 %) were bicyclists, however only 486 (0.6 %) were killed [4].

These differences are so significant that we decided to make a comparative study to better understand the factors influencing this situation.

2 METHOD AND MATERIALS

2.1 Accident data collection

The bicyclist accident cases from the IVAC database from Changsha and GIDAS database from Germany were collected based on the following criteria: (1) the accident occurred during the period from 2001 to 2006, and (2) the bicyclist accidents occurred in the urban area.

2.1.1 Accident data from police sector in Changsha

Changsha is the capital city of the Hunan province located in the middle of China, with a population of 2.06 million (6,133,000 including residents in suburb) and 452,809 registered vehicles in 2006 [5].

An ad-hoc working team has been organized in Hunan University in co-operation with traffic authority sectors and hospital in Changsha. In-depth traffic accident investigations are carried out and all information is saved in database (IVAC). The accident data is collected from the traffic authority sectors and hospital in Changsha.

In the current study an analysis on police documentations of bicyclist accidents from 2001 to

2006 was carried out, and the 1013 cases were selected for a statistical study. The information about location and type of an accident, vehicle involved in accident, as well as road environment etc. was considered. In the study we used the three levels of victim's injuries: minor, serious or fatal.

2.1.2 GIDAS accident data from Hannover Medical University

In the district of Hannover a representative sampling of accidents was carried out by Accident Research Unit at Medical University of Hanover in cooperation with the FAT (Automotive Industry Research Association) and BASt (Federal Road Research Institute) since the year 1990. In the area of Hannover nearly 1000 accidents with injured person are collected annually [6]. These accident cases were documented in the database GIDAS (German In-Depth Investigation Accident Study). The 1806 bicyclist accident cases were selected from GIDAS database from the accident occurred between 2001 and 2006.

2.2 Statistical analysis of bicyclist accidents

A statistical study with aim to compare bicyclist accident events was conducted by using the selected cases. A general statistical analysis was carried out using the cases in terms of type and number of vehicle involved in accident, accident time, accident type, injury distributions and injury severity and also age, gender of victim, etc.

2.2.1 The circular distribution analysis method

The time occurrence of bicyclist accidents within a day and night was analyzed using circular distribution method[7] where a cyclical scale of 0-360^0 was used. We investigated this distribution and desired to determine if there was some predominant direction (peak time — the time of the day when we can observe maximum number of accidents; and rush hours — time period with heavy bicycle traffic) of time distribution. In circular distribution the mean angle $\bar{\alpha}$ represents the predominant direction. After the mean angle $\bar{\alpha}$ being converted to the time it means the peak time of accidents within a day. The rush hour ranges from ($\bar{\alpha}$ - S) to ($\bar{\alpha}$ + S).

As circular data of accident time were recorded in a frequency table, the following computations are needed for the coordinates (x, y) of the sample mean angle:

$$x = \frac{\sum f_i \cos\alpha_i}{\sum f_i}, \qquad y = \frac{\sum f_i \sin\alpha_i}{\sum f_i}$$

and, then get $r = \sqrt{(x^2 + y^2)}$ (1)

where α_i is the midpoint of the recorded measurement's interval, f_i is the frequency of occurrence of the data within the interval, r is the length of the mean vector.

The value of $\bar{\alpha}$ is determined as the angle fulfilling the following equations:

$$\cos\bar{\alpha} = \frac{x}{r}, \qquad \sin\bar{\alpha} = \frac{y}{r} \qquad (2)$$

Circular standard deviation (S) will be:

$$S = \frac{180}{\pi}\sqrt{-2\ln r} \qquad (3)$$

In our study the r is a measure of concentration of accident over the time. This value varies inversely with the amount of dispersion in the accident data. It has no unit and it may vary from 0 when there is so much dispersion that a mean angle can not be described to 1.0 when all the data are concentrated at same direction. A measure of dispersion can be expressed as: 1- r. Lack of dispersion will be if: 1- r = 0, and maximum of dispersion if: 1- r = 1.0.

The significance of the mean angle was tested by the Rayleigh test. Our hypothesis H_0 is:

H_0: The accident time distribution in a day is uniformly distributed around the circle.

Rayleigh's Z is utilized for testing the H_0:

$$Z = nr^2,\ n = \sum f_i \qquad (4)$$

If $Z > Z_{0.05}$ ($Z_{0.05}$ can be found in the statistical table), H_0 is rejected, we may conclude that there is a peak time within a day, and if $Z < Z_{0.05}$, we may conclude that accident time distribution with in a day to be uniform around the circle.

Furthermore, to determine if there was difference between peak times of two cities a test was made by Watson-William method, it was calculated as follows:

$$t = \sqrt{\frac{K(N-2)(R1+R2-R)}{N-R1-R2}};$$

$$R1 = n_1 r_1;\ R2 = n_2 r_2;\ R = Nr \qquad (5)$$

where: r_1 and r_2 are the length of the mean vectors of data (from circular distributions analysis) from Changsha and Hannover respectively.

R is the length of the mean vector of data but from the united samples from Changsha and Hannover.

$n1$, $n2$ and N are frequencies of these samples.

K is a correction factor.

We were testing the hypothesis:

H_0: The peak times of bicyclist accidents in Changsha and Hannover are equal.

If $t < t_{0.05}$, H_0 is accepted and we may conclude that the peak times within a day in Changsha and Hannover are significantly same.

3 RESULTS AND ANALYSIS

The results from comparative statistical analysis based on the selected bicyclist accident cases are presented for the frequency of bicyclist accidents, injuries, and injury severities.

Table 1 Distribution of vehicle type in bicyclist accidents

Vehicle	Changsha, China		Hannover, Germany	
	N	%	N	%
Truck	122	12.0	95	5.3
Bus	104	10.3	27	1.5
Passenger car	593	58.5	1157	64.1
Motorcycle	161	15.9	20	1.1
Bicycle	-	-	223	12.4
Pedestrian	11	1.1	59	3.3
None	1	0.1	223	12.4
Others	21	2.1	2	0.1
Total	1013	100	1806	100

3.1 Analysis of involvement of vehicles

The distribution of vehicle types in bicyclist accidents in Changsha and Hannover is presented in Table 1. In Changsha the passenger cars were involved in 58.5% of the bicyclist accidents, motorcycles and trucks in about 15.9% and 12.0% of these accidents, respectively. In Hannover the passenger cars accounted for 64% of reported bicyclist accidents, which indicated the passenger cars are involved more frequently in bicyclist accidents than in Changsha.

3.2 Injury severity

Among all casualties in Changsha, 5% bicyclists were killed, 5.4% bicyclists were serious injured, 85.6 % were slightly injured, and 4% had no injuries (Table 2). In Hannover, the relative frequency of the bicyclist fatalities (0.8%) is much lower than that in Changsha. The relative frequency of the slightly injured bicyclists is on the same level both in Changsha and Hannover.

Table 2 Proportions of bicyclist injury severity

Severities	Changsha, China		Hannover, Germany	
	N	%	N	%
Fatalities	51	5.0	15	0.8
Seriously injured	55	5.4	318	17.6
Slightly injured	867	85.6	1345	74.5
No injuries	40	4.0	128	7.1
Total	1013	100	1806	100

3.3 Age and gender

The distributions of relative involvement in bicyclist accidents by the age and gender are similar in both Changsha and Hannover. In both towns, male had a higher rate of involvement in accidents for example in Changsha: male 60%, and female 30%, unknown 10%; in Hannover: male 57%, and female 43%. Regarding the age, bicyclists ranged from 36-40 years old have a high frequency of involvement compared with other age groups.

Table 3 Age vs. Injury severity

Age	Changsha, China (%)				Hannover, Germany (%)			
	Fatalities	Seriously injured	Slightly injured	No injuries	Fatalities	Seriously injured	Slightly injured	No injuries
0-5	-	-	0.6	-	-	1.3	1.1	3.9
6-10	-	-	0.1	-	-	3.5	3.3	3.1
11-15	3.9	5.5	6.1	10	-	10.7	8.3	12.5
16-20	-	7.3	9.8	20	6.7	4.7	8.0	10.9
21-25	-	3.6	7.2	7.5	-	3.8	7.7	7.8
26-30	9.8	5.5	7.5	7.5	-	4.1	8.0	7.0
31-35	5.9	7.3	7.6	7.5	13.3	7.2	6.8	8.6
36-40	15.7	23.6	10.7	15	6.7	8.2	9.7	7.0
41-45	11.8	5.5	7.8	5	6.7	6.3	7.9	9.4
46-50	13.7	7.3	11.2	7.5	-	5.0	6.8	1.6
51-55	5.9	5.5	7.2	2.5	6.7	5.7	4.8	4.7
56-60	7.8	12.7	4.3	-	6.7	5.7	5.7	3.9
61-65	9.8	5.5	3.1	2.5	6.7	9.1	6.1	0.8
66-70	7.8	3.6	3.5	-	13.3	6.6	5.0	3.1
71-75	2.0	5.5	1.2	2.5	20.0	8.2	4.3	1.6
76-80	2.0	-	0.5	-	6.7	5.3	3.2	3.1
81-85	-	-	0.2	-	6.7	3.8	1.1	-
86-90	-	-	-	-	-	0.6	0.3	-
Unknown	3.9	1.8	11.5	-	-	0.3	1.6	-
Total	100	100	100	100	100	100	100	100

3.4 Age and injury severity

Table 3 shows the distribution of injury severity by different age groups. The frequency of fatalities by the age in Changsha is different from the situation in Hannover. It indicates that in Changsha 41.2% of fatalities were bicyclists 36-50 years old and 21.6% of fatalities were these above 60 years old. In Hannover 53.3% of fatalities were bicyclists above 60 years old.

3.5 Circular distribution analysis with 24-hour accident time

Accident data were divided into 24 (15 degree) bins (Table 4). The mean angles of two samples (212.07 degree in Changsha and 211.02 degree in Hannover) were found. Rayleigh's test indicated that the distribution was not uniform (in Changsha: $p<0.05$, $r = 0.2447$; in Hannover: $p<0.05$, $r = 0.4997$). The results indicated that the most frequently bicyclist accident time of a day was 14:08, the period of rush hour was 7:44 - 20:33 ($\bar{\alpha} \pm S$) in Changsha. In comparison in Hannover the most frequently time was 14:04 and the rush hour ranged 9:34 - 18:34 (Table 5).

Using the Watson-William test method the value of t was calculated according to the Equation (5). We obtained $t = 0.28$ that is lower than $t_{0.05} = 1.96$. That means the most frequently bicyclist accident time in Changsha and Hannover are same.

Table 4 The 24 hours circular distribution analysis

Time	Changsha, China				Hannover, Germany			
	f	α	$f\sin\alpha$	$f\cos\alpha$	f	α	$f\sin\alpha$	$f\cos\alpha$
00:00-00:59	27	7.5	3.5	26.8	16	7.5	2.1	15.9
01:00-01:59	18	22.5	6.9	16.6	3	22.5	1.1	2.8
02:00-02:59	7	37.5	4.3	5.6	2	37.5	1.2	1.6
03:00-03:59	3	52.5	2.4	1.8	3	52.5	2.4	1.8
04:00-04:59	6	67.5	5.5	2.3	3	67.5	2.8	1.1
05:00-05:59	10	82.5	9.9	1.3	7	82.5	6.9	0.9
06:00-06:59	48	97.5	47.6	-6.3	33	97.5	32.7	-4.3
07:00-07:59	94	112.5	86.8	-36.0	111	112.5	102.6	-42.5
08:00-08:59	60	127.5	47.6	-36.5	93	127.5	73.8	-56.6
09:00-09:59	44	142.5	26.8	-34.9	105	142.5	63.9	-83.3
10:00-10:59	54	157.5	20.7	-49.9	127	157.5	48.6	-117.3
11:00-11:59	57	172.5	7.4	-56.5	124	172.5	16.2	-122.9
12:00-12:59	46	187.5	-6.0	-45.6	142	187.5	-18.5	-140.8
13:00-13:59	56	202.5	-21.4	-51.7	121	202.5	-46.3	-111.8
14:00-14:59	57	217.5	-34.7	-45.2	134	217.5	-81.6	-106.3
15:00-15:59	41	232.5	-32.5	-25.0	154	232.5	-122.2	-93.7
16:00-16:59	53	247.5	-49.0	-20.3	133	247.5	-122.9	-50.9
17:00-17:59	62	262.5	-61.5	-8.1	146	262.5	-144.8	-19.1
18:00-18:59	65	277.5	-64.4	8.5	139	277.5	-137.8	18.1
19:00-19:59	43	292.5	-39.7	16.5	73	292.5	-67.4	27.9
20:00-20:59	53	307.5	-42.0	32.3	54	307.5	-42.8	32.9
21:00-21:59	60	322.5	-36.5	47.6	39	322.5	-23.7	30.9
22:00-22:59	27	337.5	-10.3	24.9	22	337.5	-8.4	20.3
23:00-23:59	22	352.5	-2.9	21.8	22	352.5	-2.9	21.8
$\sum$	1013		-131.6	-210.0	1806		-465.0	-773.4

Table 5 Results of 24 hour circular distribution analyses

	Changsha, China	Hannover, Germany
x	-0.2073	-0.4283
y	-0.1299	-0.2575
r	0.2447	0.4997
$\bar{\alpha}$	212.07	211.02
S	96.14	67.49
Rayleigh's Z	60.64	450.97
$\bar{\alpha} \pm S$	7:44÷20:33	9:34÷18:34

3.6 Road line type

Comparing the accident ratio on intersections, bicyclist accidents took place more frequently in Hannover (56%) than in Changsha (13.2%) where the most common place of accident was straight road (81.4%). We can say that for this accident place the situation in Changsha is opposite to that in Hannover.

Table 6 The distribution of bicyclist accidents vs. road line type

Road line type	Changsha, China		Hannover, Germany	
	N	%	N	%
Straight	825	81.4	545	30.2
Slope	39	3.8	40	2.2
Intersection	134	13.2	1011	56.0
Others	15	1.5	210	11.6
Total	1013	100	1806	100

3.7 Type of bicyclist accidents

The type of bicyclist accidents is shown Table 7. It can be found that the most common types of bicyclist accidents were lateral impact and front impact, in both Changsha and Hannover city area. However the frontal impact is 50% more common in Hannover than in Changsha.

Table 7 Type of bicyclist accidents

Accident type	Changsha, China		Hannover, Germany	
	N	%	N	%
Lateral impact	527	52.0	871	48.2
Front impact	213	21.0	629	34.8
Rear Impact	60	5.9	75	4.2
Scratching	133	13.1	-	-
Fall	-	-	103	5.7
Roll over	1	0.1	45	2.5
Others	79	7.8	83	4.6
Unknown	1013	100	1806	100

3.8 Distribution of injuries by body regions

Table 8 shows that the lower extremities, head and upper extremities were found to be the most frequently injured. The total 345 bicyclist cases which were used in the Table 8 were all registered in police data in Changsha, while bicyclist accidents cases with no registered injury regions were ignored. In these police data only one main injured body part was registered for each case, but in Hannover data there are multiple injuries registered regarding the bicyclist casualties. So Changsha data can only be appropriate in the preliminary comparative analyses.

Table 8 Distribution of body regions

	Changsha, China (N=345)	Hannover, Germany (N=1806)
	RF *, %	RF, %
Head	31.3	37.5
Neck	0.3	4.6
Thorax & Back	2.3	22.0
Up limbs	12.8	42.1
Waist & Abdomen	2.0	5.3
Pelvis	-	12.5
Low limbs	51.3	54.1

* RF=the number of bicyclists injured a certain part / total of casualties N

Table 9 shows that the frequency of fatalities and injuries in urban bicyclist accidents by main body parts including the head, the lower extremities and the upper extremities. It indicates that the head is most common part of the bicyclist body when injuries are classified as serious or fatal. In Changsha, 25.9% of bicyclists suffered fatal head injury. In Hannover, only 1% of these were fatal. In Changsha some limbs injuries also leaded the bicyclist's dead. The possible reason is that the criteria of injury severity used by Chinese policeman are rude.

Table 9 Distribution of injuries by head, low limbs and up limbs for bicyclist accidents

	Changsha, China (N=345) (%)				Hannover, Germany (N=1806) (%)				
	Slightly injured	Seriously injured	Fatalities	Total	Slightly injured	Seriously injured	Fatalities	No injuries	Total
Head	53.7	20.4	25.9	100	76.1	18.4	1.0	4.4	100
Up limbs	86.4	9.1	4.5	100	91.5	7.0	-	1.6	100
Low limbs	89.8	9.6	0.6	100	88.8	9.8	-	1.3	100

4 DISCUSSION

The present study is based upon an analysis of 1013 bicyclist accidents in urban area of Changsha in China and 1806 cases in the area of Hannover in Germany. The evaluation method is described in methodology section and the available accident data were analyzed. The quality of data is acceptable in this preliminary study. The presented methodology of comparison of different in-depth accident studies could be used for evaluation of the injury risk and injury outcome in different countries. Such methodology can be used for further studies with new accident data in the area of special research issues.

4.1 Involvement of vehicle

Table 1 shows that passenger cars are most frequently involved in bicyclist accidents in both Changsha and Hannover. For this reason the safety

design of passenger cars considering bicyclists is vital for reducing the injury risk of bicyclists. It is also found that in Changsha compared to Hannover motorcycles, trucks and buses are more frequently involved in bicycle accidents. In addition we have to say that there are differences also in vehicle types. Most motorcycles registered in police data in Changsha are three-wheel light motorcycles when in Hannover are heavy motorcycles. Due to the difference of involved vehicles between countries, the priority of safety countermeasures should be given considering the frequency of involved vehicles.

4.2 Bicyclist injuries

The bicyclist accident is a common problem in both motorized countries and motorizing countries, which occur frequently in city area. The all results of the analysis of the two different areas of China and Germany show major resources for further countermeasures on car safety developments.

It was found that both in Changsha and Hannover the male bicyclist had a higher rate of accidents than the female one. It can be explained by the fact that male had more opportunities to work or travel by bicycle. We also found that bicyclists ranged from 36-40 years old have a higher percentage compared with other age groups. It is directly related to the fact that they are exposed to traffic more frequently when working and taking part in social activities.

The injury severity and risk to die in accident for bicyclists in Hannover can be seen as much lower as in Changsha. One possible reason of this high relative frequency is related to the layout of urban traffic network [8]. The design of road traffic system in most of cities in China doesn't consider bicyclists as road users. Consequently bicyclists are more frequently exposed to a mixed traffic situation including motor vehicles. Therefore the risk of bicyclist fatalities is high. The other reason is due to that the bicyclists travel in Changsha without using any helmets. The protection effect of helmets in bicycle accident is known since 1980's. For example, a conclusion was made by Kroon et al. [9] that bicycle helmets, even simple ones, could be recommended for cyclists of all categories as they protect against head injuries, at least against head injuries of minor severity. Another report [10] stated that the risks of serious head injuries had reduced by 85% with wearing helmets in vehicle-bicyclist accidents.

As it was shown in Table 3, frequency distribution of fatalities by the age in Changsha is quite different from that in Hannover. The possible reason for this situation is that bicycles are used differently in these two countries. In China, bicycles is one of the most popular means for living and work and are often chosen by middle aged people. In Germany, bikes are usually used by young and the elderly for pleasure, trip and besides commuting purpose.

The findings of the distribution of bicyclist injuries were compared in our study between the results from both cities. As a common tendency, the head, lower extremities and upper limbs have been found to be the most frequently injured body regions. This confirmed the findings from several studies performed already at 80's and 90's in European countries [11, 12].

4.3 Accident time

Initial approaches using a linear scale were not fruitful. For this reason 24-hour time distribution of accidents was analyzed by circular distribution method. The most frequently bicyclist accident time of a day was proved to be existed by Rayleigh's Z test and the rush hours of bicyclist accidents in Changsha and Hannover were tested to be identical by Watson-William method. Whereas the period of heavy traffic in a day in Changsha is longer than that in Hannover: 7:44-20:33 versus 9:34-18:34.

4.4 Accident type & road line type

Lateral impact is the most frequent type of bicyclist accident. According to results from the study we can see that most accident cases in Hannover occurred at intersection. However in Changsha the main accident places is straight road. These results indicate that it is a potential to improve the bicyclists safety in both cities.

4.5 Limitations

It is has to be noticed that the limitations existed in the study. The data sources partly reflect the real situations of bicyclists in traffic accidents in Changsha and Hannover and not in the whole country. Compared to this the data of GIDAS are comprehensive and give information on every issue of accident and injury details.

Another problem existed with the police records in Changsha: they provided data on the injury severity that seldom included exact details of the locations and severity of the injuries. Therefore it make difficult to compare them with the injuries coded according to the AIS. This problem can be solved by further in-depth studies using detailed accident data collected from hospital and police sectors, as well as on-site and retrospective investigations.

5 CONCLUSIONS

Bicyclists represent a group of vulnerable road users with high risk of injuries, therefore a priority

should be given to this road user group in research of safe urban transportation.

There are some similarities regarding bicycle accidents in developed country (Hannover, Germany) and developing one (Changsha, China). Male bicyclist shows a higher involvement rate in vehicle-to-bicycle accidents than female one. Passenger cars are most frequently involved in bicyclist accidents. The most bicyclist cases occurred at the same time of a day. The study confirmed that head, lower extremity and upper limbs injuries are dominant. The head injuries are the main cause for the high frequency of bicyclist fatalities especially in Changsha.

There are also some differences between the two cities,. It was found that in Changsha the frequency of bicyclist fatalities is much higher, more often young bicyclists are involved in fatal accidents and the time period of rush hour is longer, besides accident place in Changsha is opposite to that in Hannover.

There are different possibilities to reduce the number and the risk of bicyclist fatalities in Changsha. One of the possible solutions is to make the use of helmets popular because it has good protection effect.

The further in-depth study is needed to develop efficient counter-measures for improvement of bicyclist safety.

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REFERENCE

[1] Qiao WG. (2005). Study of the Accident Modalities and the Protective Methods about Motorcycle, Bicycle, Pedestrian Collisions. Thesis for the Degree of Doctor. Wuhan University of Technology. (in Chinese)

[2] Li S. (2007). A Study on Head-Brain Protections of Cyclists in Vehicle-Bicycle Collisions. Thesis for the Degree of Master. Hunan University. (in Chinese)

[3] Traffic Administration (2006). Statistics of Road Traffic Accidents in P.R. of China. Ministry of Public Security. (in Chinese)

[4] Statistical Bureau (2006). Statistical Data from Germany, Wiesbaden.

[5] Kong CY, Yang JK, Li L, Li WQ, Zhao Z, Otte D. (2006). In-Depth Investigation of Vehicle Traffic Injuries in Changsha of China, International Conference on Expert Symposium on Accident Research (ESAR), Hannover, Germany. pp.38-46.

[6] Otte D, Krettek C, Brunner H, Zwipp H. (2003). Scientific Approach and Methodology of a New In-Depth-Investigation Study in Germany so called GIDAS, Proceedings of the 18th ESV Conference, Nagoya, Japan, Paper No. 03-161.

[7] Jin PH. (2003). Methods of Statistics in Medicine. Fudan University. ISBN: 730903653. Issue.2. pp.211-217. (in Chinese).

[8] Liu Q. (2006). Effective Urban Roads System in Germany. Urban Planning International. (in Chinese).

[9] Kroon PO, Bunketorp O, and Romanus B. (1986). The Protective Effect of Bicycle Helmets - A Study of Paired Samples in a Computer – Based Accident Material in Gothenburg, Sweden. International Conference on the Biomechanics of Impact (IRCOBI). pp249.

[10] Fatality Facts: Bicycles. Insurance Institute for Highway Safety, 1999. Web sitS: http://www.highwaysafety.org/safety_facts/fatality_facts/bikes.htm.

[11] Otte D. (1980). A review of different kinematic forms in two-wheel-accidents-their influence on effectiveness of protective measures. Society of Automotive Engineers, Inc., 24th Stapp Car Crash Conference, Troy, Michigan, USA. pp.575.

[12] Otte D. (1989). Injury mechanism and crash kinematic of cyclists in accidents-An analysis of real accidents. Society of Automotive Engineers, Inc., 33rd Stapp Car Crash Conference, Washington, DC, USA. pp. 3-5.