Analysis of Bicycle Accidents and Recommended Countermeasures in Beijing, China

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In Beijing, China, bicycle traffic constitutes more than 50 percent of passenger transportation and more than 30 percent of traffic accident fatalities. Nearly 70 percent of the traffic accidents were related to bicycles. The rate of fatalities for bicyclists 60 and older is five times greater than the average. Farmers have the greatest number of bicycle incidents. The peak hour for bicycle accidents is usually 7:00 to 8:00 a.m., depending on the bicycle and motorized vehicle traffic flows. Monday is the peak day for bicycle accidents. It was also found that more bicycle accidents happened in July, which is Beijing's tourism season. Generally speaking, roads and streets with higher speed limits, such as arterials and rural highways, have higher rates of bicycle accident fatalities. Bicycle accidents can be attributed to many causes, including road and environmental conditions, traffic safety measures, operations of motorized vehicles, and bicyclists' habits and skills. The most pressing factor contributing to bicycle accidents is the inadequate and insufficient facilities provided for bicyclists. To reduce the annual toll of bicyclist injuries and fatalities, a number of countermeasures, such as improvement of road and environmental conditions, education in traffic laws, training in cycling, and use of helmet, are recommended.

Beijing, the capital of China, has been the locality of many dynasties. It is famous not only for being the political and cultural center of China, but also for having many historic sites. Every year, many tourists from other parts of China and abroad visit Beijing. Statistical data show that there are more than 1.2 million daily visitors and temporary workers in Beijing. The city of Beijing has an area of 16 800 km² with more than 10 million residents. Its nearly 8 million registered bicycles make it the city with highest bicycle ownership in China (1). There are also more than 700,000 motor vehicles registered, and at the end of 1992, the length of highways and streets in Beijing totaled 11 400 km.

Because of reform policy, the economy of China has been rapidly growing at a two-digit annual rate during the last decade and a half. Great changes have taken place in Beijing. From 1980 to 1992, the ownership of bicycles and automobiles in Beijing increased two and three times, respectively (Figure 1) (2). According to a 1986 origin-destination survey, bicycles constitute 54 percent of urban passenger transportation, a trend that has grown in recent years (3). In 1992 about 60 percent of all passenger trips were made by bicycle. Bicy-

cles will continue to be one of the major modes of private transportation in Beijing in the coming decades (4).

With the growth in bicycle traffic, conflicts between bicycle and automobile traffic also increase. As shown in Figure 2, traffic accidents, fatalities, and injuries in Beijing have increased between 1980 and 1992. The highest annual toll for road fatalities was 756, in 1985. But even though the number of motorized vehicles has doubled and the number of bicycles has increased by 1.3 times, the death toll has decreased steadily during the past half decade. Nevertheless, traffic accidents are still a serious problem. The death rates per 10,000 vehicles for China and Beijing are 56 and 9.7, respectively, compared with less than 3.0 for most motorized countries. The big discrepancy is due to the mixed traffic in Beijing, in which about 60 percent of passenger trips are made by bicycle (1). Bicyclists are major participators in traffic accidents. An analysis of accident data recorded from 1981 to 1990 reveals that accidents related to bicycles account for more than 70 percent of the total (5). Table 1 reveals the principal parties in road accident rates. Bicycles are responsible for 38.7 percent of the traffic fatalities. Obviously, bicycle traffic is a significant contributor to road accidents. Therefore, an analysis of bicycle accidents to determine countermeasures against accidents is warranted.

This paper attempts to characterize bicycle accidents in Beijing and study their trends on the basis of Beijing road accident records between 1980 and 1992; analyze the causes of bicycle accidents in terms of human factors, road and environmental conditions, urban transportation operations, and traffic characteristics; and propose effective countermeasures for reducing bicycle accidents.

DATA COLLECTION

Questionnaire surveys were conducted to collect data. Detailed statistical data for bicycle accidents in Beijing are not available on a routine basis because there is no well-developed accident reporting system. In this study, data on bicycle accidents from 1980 to 1992 were obtained from the traffic management police department. Other data were obtained from the Beijing Statistics Report.

The traffic management police department in Beijing is the unit authorized to enforce traffic laws, manage traffic flow, and respond to traffic accidents. It is also responsible for having traffic accidents recorded and input into a data base. The research conducted in this paper is based on the traffic accident statistic data recorded during recent years. The authors realize that more data are needed for performing a comprehensive analysis of bicycle accidents. Therefore, the conclusions derived hereafter are considered preliminary. Further data analysis will be needed for verification.

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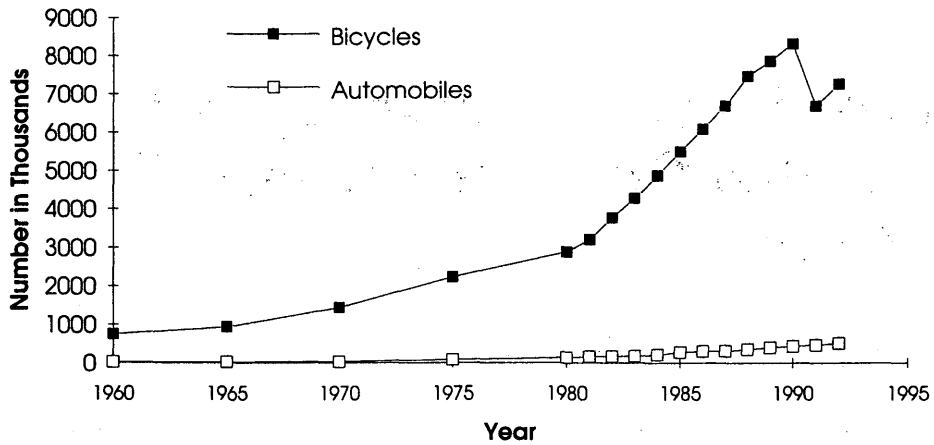
FIGURE 1   Ownership of bicycles and automobiles in Beijing.

ANALYSIS OF BICYCLE ACCIDENT CHARACTERISTICS

Many factors, such as bicycle usage, automobile operations, bicycle safety facilities, road environments, bicyclist skill, traffic management, and weather, contribute to the number of bicycle accidents. Other major factors closely related to bicycle accidents are considered in the following analysis.

Rate of Bicyclists in Accident Fatalities

Figure 3 shows the rates of bicyclists in accident fatalities in a yearly time series. The highest rate is 43.3 percent, in 1981; the lowest is 25.5 percent, in 1989; and the average is 31.4 percent. It was also found that the accident rate is related closely to automobile operating speed. In 1989 automobile operating speeds were about 25 km/hr lower than those in 1992 or 1982. Therefore, more attention should be given to managing the high-speed roads.

In recent years, the rate of traffic accidents displayed an increasing trend. One reason for this may be the traffic "chaos" during the construction of transportation facilities. Obviously, it is beneficial and life-saving to find and implement effective countermeasures.

Time Distribution

Hourly Distribution

The hourly distribution of bicycle accidents is shown in Figure 4. It is easy to see that a distinguishable peak is located between 7:00 and 8:00 a.m., when bicycle flows are the heaviest. In other words, the peak period for accidents coincides with the peak period for traffic. It may be concluded that roads with insufficient capacities cannot adequately accommodate both bicycles and motor vehicles during rush hours and the mix of different modes with different operating speeds leads to more automobile-bicycle accidents.
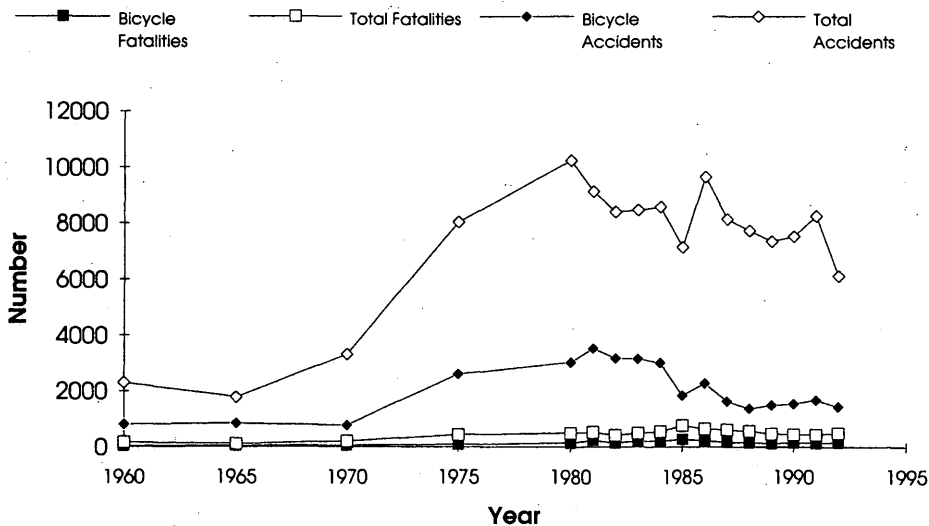

FIGURE 2   Statistics of traffic accidents in Beijing.

TABLE 1 Percentages of Traffic Accidents by First Participator, 1981–1990

	First Participator		
Type	Automobile	Bicycle	Pedestrian
Number of Accidents (%)	63.5	27.9	8.6
Number of Injuries (%)	41.6	45.7	12.7
Number of Fatalities (%)	45.7	38.7	15.6

Day and Night Distribution

Day and night distributions of bicycle accidents, injuries, and fatalities are presented in Table 2. Most accidents in Beijing occur during the day, but those that happen at night are more severe. Statistics reveal that each daytime accident results in 0.93 injury and 0.15

death, whereas each nightime accident results in 0.97 injury and 0.24 death. In explanation, most roads in Beijing are poorly illuminated at night, contributing to poor visibility, and automobiles can operate at a faster speed during the night because there is less road congestion. Furthermore, a significant portion of commuters in Beijing work in the suburbs of the city and return in the late afternoon. Considering that approximately 85 percent of the average daily traffic occurs in the daytime (*6*), the rate of nightime bicycle accidents is high.

Daily Distribution

The daily distribution of bicycle accidents in Beijing is shown in Figure 5. It should be noted that the normal working days in Beijing before May 1, 1995, were Monday through Saturday. It can be seen that Monday has the highest percentage of fatalities, whereas Sunday has the lowest percentage of accidents. It is obvious that bicy-
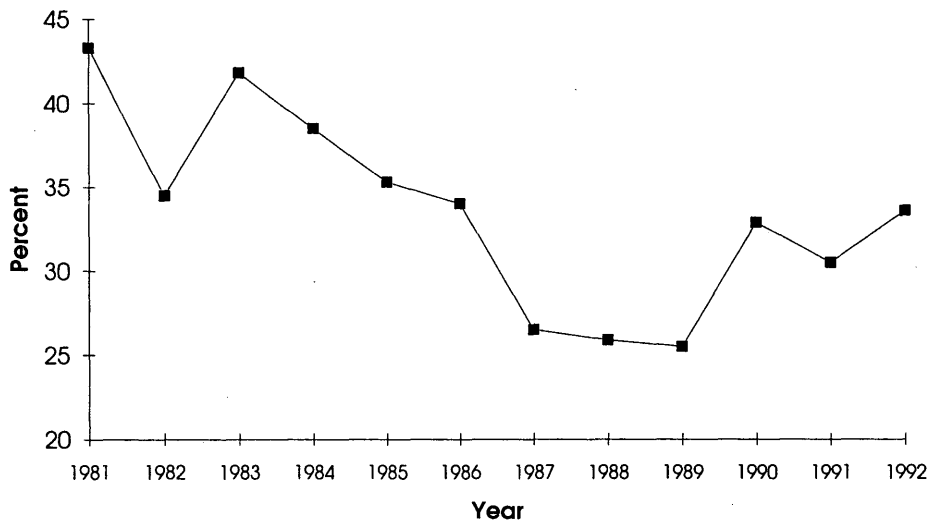

FIGURE 3 Percentage of bicyclists in accident fatalities in Beijing.
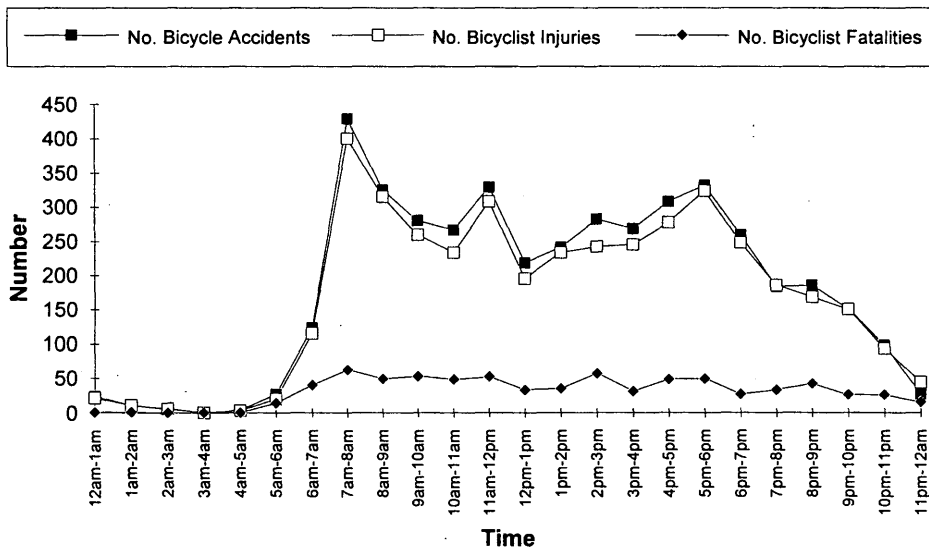

FIGURE 4 Hourly distribution of bicycle accidents in Beijing.

TABLE 2 Day and Night Distribution of Bicycle
Accidents, Injuries, and Fatalities in Beijing

Type	Day	Night
Accidents (%)	80.8	19.2
Injuries (%)	79.2	20.8
Fatalities (%)	73.3	26.7
Ratio of Injuries to Accidents	0.93	0.97
Ratio of Fatalities to Accidents	0.15	0.24

cle accidents are closely related to the volume of bicycles on the road.

Monthly Distribution

Figure 6 shows the monthly distributions of bicycle accidents, injuries, and fatalities in Beijing. The highest rate of accidents and injuries occurred in July. Since it is very hot in July in Beijing, drivers are easily exhausted and bicyclists ride faster. In addition, more trips are made this month because July is the tourism season for Beijing.

Rider Characteristics by Age

Table 3 gives the frequency distributions of bicycle accidents by age group. The most critical age group is those persons 60 years and older. The percentage of fatalities for this group is higher than that for the general population. The age group between 17 and 59 as a whole has a lower bicycle accident rate than that of the general population. It is clear that more attention should be paid to elderly bicyclists in traffic safety.

Rider Characteristics by Gender

In Beijing the ratio of men to women is approximately 1 to 1 (7). However, men have about twice as many bicycle traffic accidents as women (66.2 versus 33.8 percent). This discrepancy may be

explained by the riding characteristics of women, who generally ride more carefully and at lower speeds than men. Another factor may be that many men over 60 still ride bicycles, but few women of that age do. The rate of bicycle accidents involving men over 60 is about 25.7 percent (8).

Occupation Characteristics

Figure 7 shows the distribution of bicycle accidents among different occupations. The data in this figure are obtained by averaging the data from 1989 to 1991. Farmers have the highest rate, 38.2 percent, of bicyclist fatalities; they are followed by blue-collar workers. The leading causes for farmer bicyclist fatalities are as follows:

- Farmers have the poorest knowledge of traffic laws and little concept of obeying the laws.
- Many farmers ride bicycles that are in poor repair, such as those having unstable braking systems.
- Medical help is often delayed because of a lack of communication equipment and the longer distance necessary for transportation.
- Automobiles operate at higher speeds in rural areas, increasing the chances for serious damage.

Location Distribution

Table 4 reveals the numbers of bicycle accidents, injuries, and fatalities by urban and rural areas. Although bicycle accidents occurring in urban areas are as much as 2.34 times of those in rural areas, the fatality share in the rural areas is larger than that of the urban areas. However, the ratio of injury to bicycle ownership is comparable. Therefore, it can be safely assumed that accidents in rural areas are more severe than those in urban areas. A logical explanation for this may be that automobiles operate at higher speeds in rural areas. Another reason may be that a rural bicyclist has a poorer knowledge of
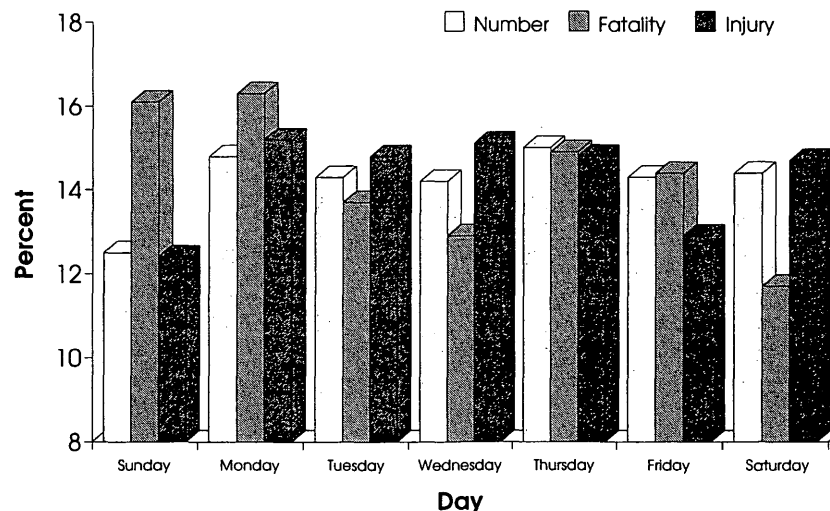

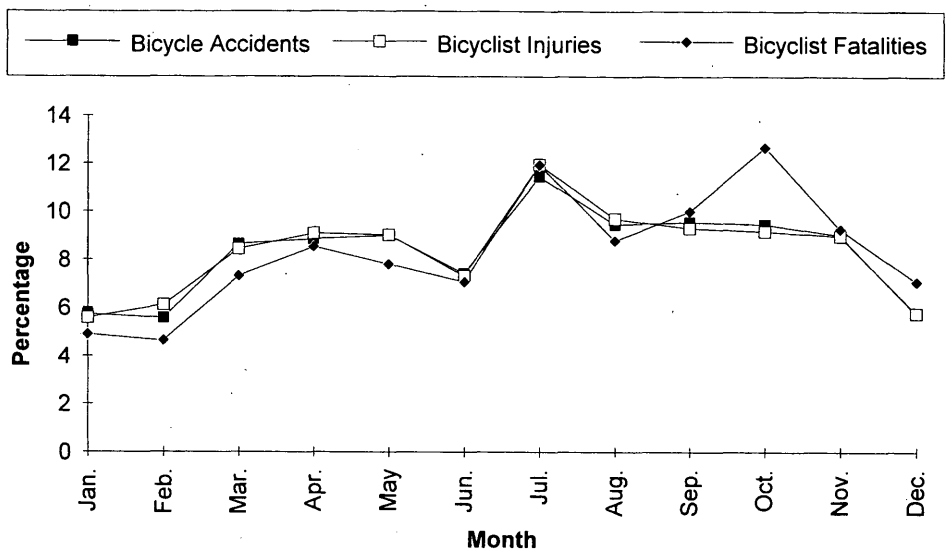**FIGURE 5 Daily distribution of bicycle accidents in Beijing.**

FIGURE 6   Monthly distribution of bicycle accidents in Beijing.

TABLE 3   Age Distribution in Cyclist Fatalities in Beijing, 1981–1992 (8)

	Age				
	<7	7-16	17-35	36-59	60 & over
Population (%)	8.47	10.54	35.01	34.68	11.30
Trips (%)	N/A	9.25	47.96	34.70	5.13
Fatalities (%)	N/A	8.82	34.08	31.40	25.70

traffic laws and a lesser sense of traffic danger than an urban bicyclist.

Road and Site Distribution

Studies of the sites where bicycle accidents occur are important for identifying specific roadway characteristics that cause problems for

bicyclists and the situations in which the roadway could avert future accidents. Figure 8 reveals that 80 percent of all bicycle accidents in Beijing occur on arterials and subarterials. These accidents may be attributed to the higher operating speeds on these roadways than on other roadways. Moreover, there are many more entrances and exits along these roadways, which increases the likelihood for collision. According to statistics, 54 percent of the accidents occurred at intersections. Only about a quarter of intersections in Beijing are
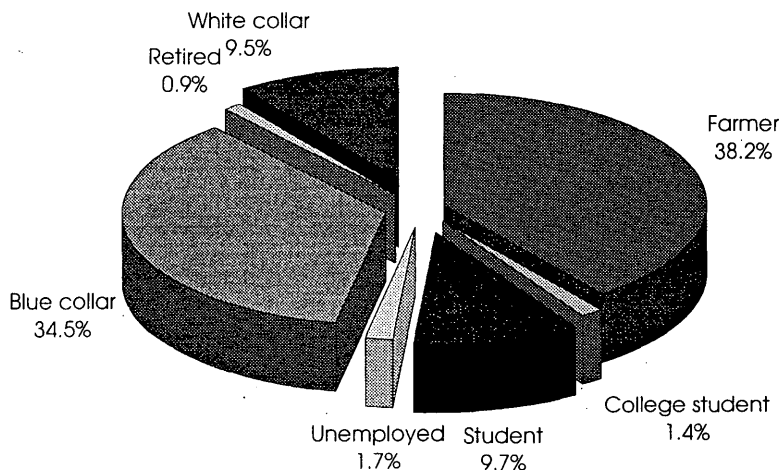

FIGURE 7   Occupation distribution in bicyclist fatalities in Beijing.

TABLE 4 Bicycle Ownership and Accidents in Urban and Rural Areas

	Area	
	Urban	Rural
Population (%)	58.0 (61.4)[a]	42.0 (38.6)[a]
Bicycle Ownership (%)	67.6	32.3
Accidents (%)	70.1	29.9
Injuries (%)	68.2	31.8
Fatalities (%)	48.0	52.0

[a]Including temporary residents

signalized, and many of the roads with signalized intersections are inadequate to meet traffic demand during the peak hours.

FACTORS RESULTING IN BICYCLE ACCIDENTS

Many factors may contribute to the high rate of bicycle incidents. These include motorcycles, other bicycles, environmental and road conditions, and inadequate traffic management. Often, an accident is the result of a combination of these factors. To accurately identify the causes of accidents in Beijing from 1981 to 1990, factors directly responsible for traffic accidents are categorized in Figure 9 (*9*). It was found that bicycles are responsible for 37.3 percent of traffic accidents.

Bicyclists

The leading cause of bicycle accidents is bicyclists themselves. It is not unusual to see bicyclists displaying unlawful riding characteristics. Riders commonly pay no attention to the traffic regulations at intersections. This is a serious problem in that bicyclists ignore not only traffic lights but also the directions made by police officers. It is thought that only automobile drivers need to follow traffic regulations.

Studies show that more than 80 percent of bicycle accidents are caused by bicyclists. The most dangerous behavior is that bicyclists do not yield to motorized vehicles, as indicated in Table 5. The second cause is sudden turning (mainly, turning left), which accounts for 26.3 percent of bicycle accidents. The acci-

dents resulting from not yielding to other traffic, suddenly turning, and riding on a highway make up 69.4 percent of the bicycle accidents.

Mixed Traffic

One of the major characteristics of urban traffic in Beijing is the mix of bicycles and motor vehicles. Mixed traffic exists on about 70 percent of the roads and at more than 85 percent of intersections. According to the survey (*10*), the average volume of bicycle traffic at intersections within the second-beltway expressway is 16,000 bicycles per hour. The volume between the second- and third-beltway expressways is 12,000 bicycles per hour. Inside the first beltway, more than 90 percent of intersections formed by primary and secondary streets have a flow of over 10,000 bicycles in the peak hour. Moreover, 14 percent of the intersections have a flow of more than 20,000 bicycles per hour. The mixing of these two transportation modes with totally different operating speeds results in a low traffic capacity and a high accident rate.

Additionally, the ratio of bicycle flows during the peak hour to lowest flows in the daytime decreased from 3.0 in 1986 to 1.7 in 1991. In other words, as daily bicycle trips increase, so does the chance for collisions between bicycles and automobiles. From the survey, 45 percent of the collisions between bicycles and motorized vehicles lead to fatalities. Separating bicycles from motorized vehicles may be a key to reducing bicycle accidents and improving bicycle safety.

Bicycle Lanes

The growth in bicycle ownership outpaces that in bicycle lanes. In Beijing, many roads do not have sufficient capacities for bicycle traffic. That forces bicycles to ride in vehicle lanes and cause bicycle-automobile traffic accidents easily. Table 6 gives the required widths for bicycle traffic on some roads inside the third beltway (*10*). Along arterial roads, there are many exits and entrances with insufficient sight distances. These locations are the places where collisions easily happen between bicycles and automobile vehicles.

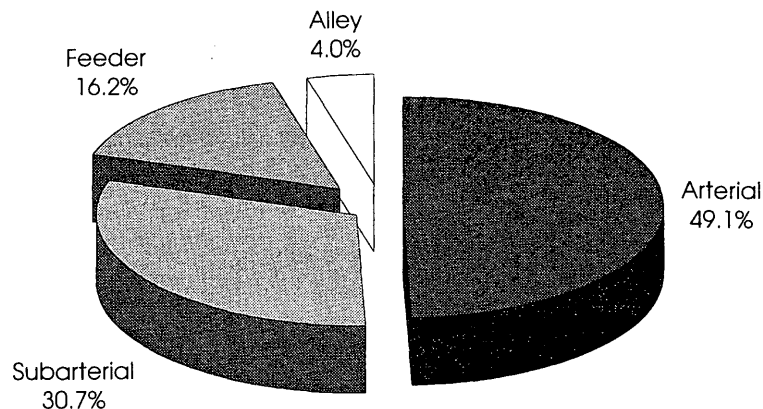Three typical bicycle lanes are used on the roads and streets of Beijing:

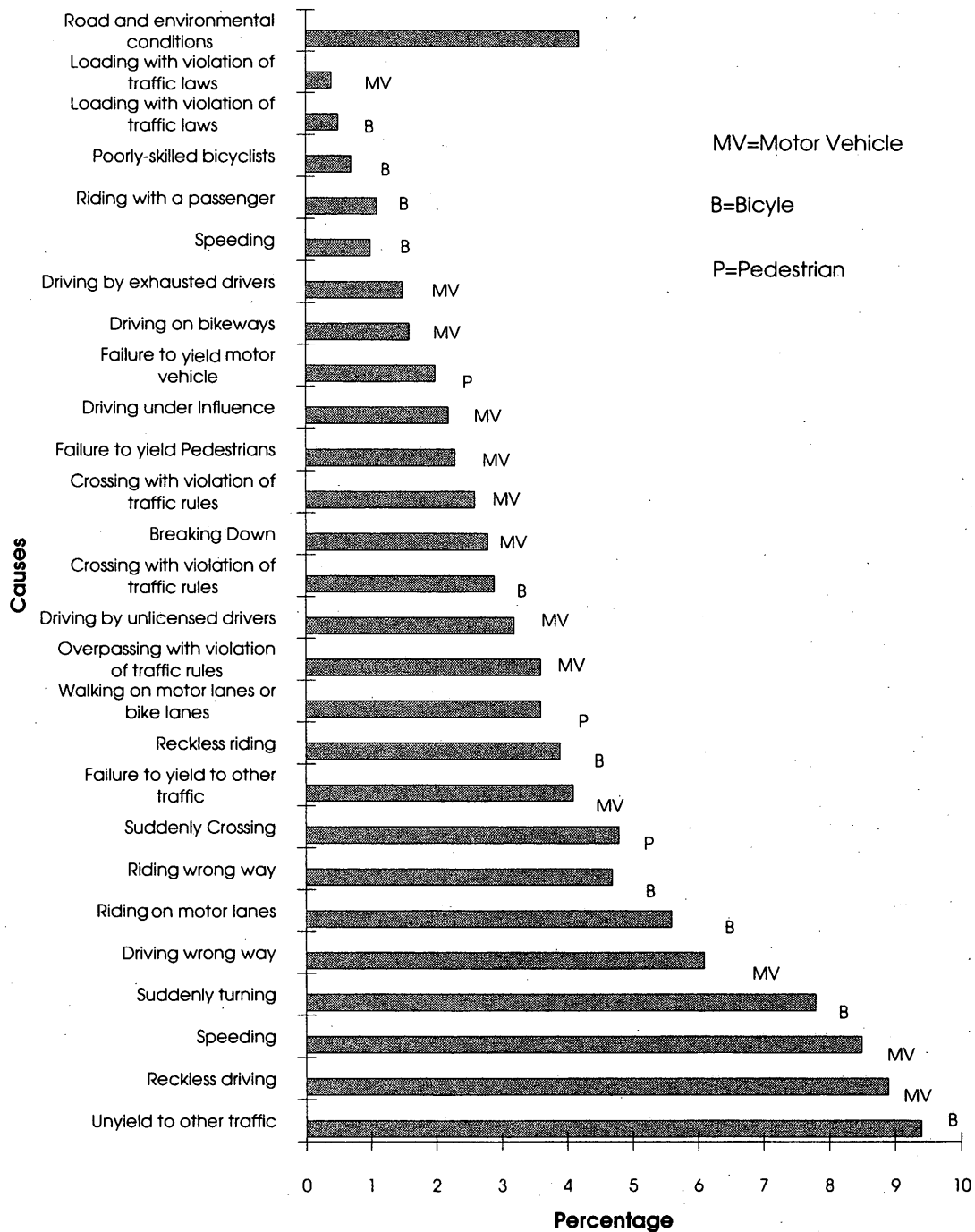**FIGURE 8 Road distribution in bicyclist fatalities in Beijing.**

FIGURE 9   Percentages of traffic accidents in Beijing by cause.

• Type A: *exclusive bicycle lanes* are mostly located on one or both sides of automobile lanes with grass median or Jersey separators. These roads are called "three-slab roads" by Chinese transportation engineers.

• Type B: *independent bicycle lanes* are located on one or both sides of automobile lanes with traffic barriers or a grass median.

• Type C: *dependent bicycle lanes* are located on both sides of automobile lanes without physical or marking separation, but some may be separated by pavement markings.

Although the Type A and B lanes are considered safer for bicyclists, only 28.7 percent of the roads have these lanes. It is noteworthy to mention that such roads carry more than 60 percent of passenger transportation.

Management

Increased education and enforcement would contribute to safety improvement in many dangerous situations.

TABLE 5 Causes of Bicyclist Fatalities in Beijing

Causes	Percentage
Unyielding to other traffic	27.0
Suddenly turning	26.3
Riding on motorway	16.1
Crossing more than four lanes	8.5
Riding on the wrong way	7.7
Reckless riding	5.3
Riding with a passenger	1.9
Poor riding skills	1.2
Riding under influence	0.9
Others	2.3

- It is very common in Beijing to see automobiles parked on bicycle lanes, severely blocking the bicyclists' sight distances and forcing them to ride on the roadway.
- A number of bicyclists ignore or disobey the traffic regulations because of poor knowledge of traffic laws.
- No inspections of bicycles are mandated to guarantee that bicycles are operated in a good state of repair.
- No bicyclists wear helmets. When an accident happens, the heads of cyclists will be easily injured.

COUNTERMEASURES

Policy

The bicycle plays a key role in passenger transportation in Beijing, accounting for more than 54 percent of passenger trips. Because of the ideal geographic and weather conditions in Beijing, the bicycle is the favorite mode of residents. Moreover, bicycle transportation will continue to be one of the major modes for private passenger transportation in Beijing in the coming decade (*11*).

Increasing numbers of bicycles and motor vehicles will add to the problems of effectively managing urban transportation in Beijing. To improve passenger transportation and reduce bicycle accidents, public transportation systems, which would reduce the need for private bicycles, should be incorporated in the transportation plans for the city. Bicycles can then be used only for short-distance trips,

(within 30 min or 6 km) or as a substitute for walking. The general objective is to establish an efficient, comfortable, and safe urban transportation system.

Bicycle Road Systems

In an effort to reduce vehicular collisions and decrease bicycle accidents, it is strongly recommended that bicycle traffic be segregated from motorized vehicle traffic by raising rails, Jersey barriers, and separating strips. In other words, to ensure that bicycles have their own rights of way, the following countermeasures are recommended for road environments:

- Reshape the roads of Type C cross sections into roads of Types A or B,
- Use physical barriers to separate bicycles from automobiles,
- Widen bicycle lanes to increase their capacity,
- Build a three-level cloverleaf interchange for bicycles,
- Carefully design entrances and exits,
- Warrant enough sight distances in design,
- Set up obstacles at bicycle entrances to prevent automobiles from entering,
- Set up obstacles at motor vehicle entrances to prevent bicycles from entering,
- Add bicycle lanes in some business areas, and
- Manage well the bicycle and motor vehicle flows at intersections (*12*).

Education

Educational programs about traffic laws should be offered at the preschool and elementary school levels. The education can be conducted with the help of pictorial books and videotapes, with emphasis on traffic regulations. Education is very important in improving bicycle safety. Drivers, elementary students, and senior citizens should be given special attention. In addition to general knowledge of bicycle safety, bicyclists should be familiar with traffic psychology and accident characteristics. The psychological and physical characteristics of aged people should be stressed for senior citizens.

TABLE 6 Existing and Required Bicycle Lanes on Roads and Streets in Beijing

Roads/Streets	Bicycle Flow (bicycles/hr)	Required Lanes[a] (meters)	Existing lanes (meters)	Short (meters)
North Dongshi	10,813	11.4	6.5	-4.9
North Xishi	5,596	6.1	4.5	-1.6
Xuanwumennei	11,797	12.3	9.5	-2.8
East Dianmen	6,903	7.5	5.5	-2.0
South Lishilu	4,627	5.2	5.0	-0.2
Congwenmenwai	14,437	15.0	8.5	-7.0
South Xinhua	10,430	11.0	8.0	-3.0
West Zhusiko	9,552	10.1	7.5	-2.6
Xuanwumenwai	10,634	11.2	8.5	-2.7
Guanganmennei	14,825	15.4	7.0	-8.4

[a]Required lanes (meter) = (Flow+500)/1,000

Training of Cycling and Wearing Helmets

The primary cause of bicycle accidents in Beijing is lack of safety training in riding. For example, bicyclists who are new to riding should be required to attend a bicycle safety training program. In addition, according to the research reports from other cities, about 90 percent of bicyclist fatalities are caused by head injuries (*13*). Therefore, it should be recommended that bicyclists wear helmets when riding.

Special Countermeasures for Elderly Cyclists

The following countermeasures against bicycle accidents are recommended for elderly cyclists:

- Reeducate elderly bicyclists about traffic regulations,
- Organize elderly bicyclists to watch videotapes with special emphasis on their needs for bicycle safety, and
- Require a regular physical examination, with recommendations to discontinue bicycling if one's health is found to be poor.

CONCLUSIONS AND RECOMMENDATIONS

On the basis of the study, conclusions and recommendations follow:

1. Bicycle transportation plays an important role in the passenger transportation system in Beijing. Bicycle fatalities accounted for 38.7 percent of Beijing's road fatalities. Therefore, more attention should be paid to improving the safety of bicycle transportation.

2. Bicycle accidents are related closely to the volume of bicycles and motor vehicles on the roadway. The peak hour for bicycle accidents is from 7:00 to 8:00 a.m.

3. Bicycle accidents occurring at night usually result in injuries more severe than do those in the daytime.

4. There is a correlation between the number of bicycle accidents and the operating speeds of motor vehicles higher rates of accidents happen on arterial and subarterial roads.

5. Elderly cyclists have a fatality rate 4.76 times higher than average. Students have a fatality rate 1.3 times the average level.

6. In an occupational distribution, farmers have the highest rate of bicycle accidents.

7. The most pressing causes of bicycle accidents are inadequate bicycle facilities and large numbers of bicyclists who ignore the traffic law, especially when no police are on duty.

8. The best way to improve the safety of bicycle transportation is to separate bicycles from automobiles with strips or barriers and allow bicycles to have their exclusive rights of way.

9. Wearing a helmet when cycling is strongly recommended.

10. Certificates of recognition should be awarded to elementary and high school students who have completed bicycle safety training.

ACKNOWLEDGMENTS

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