**Citation:** ZHAO Linna, JIA Xingwu, DAI Shuai, GONG Jianguo, ZHI Ye. Characteristics of Urban Road Traffic Safety in China [J], Urban Transport of China, 2018 (03): 9–14, 20.

# Characteristics of Urban Road Traffic Safety in China

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**Abstract:** Being in a period of rapid urban development intertwined with fast motorization in China, the country experiences different level of safety between urban roadways and non-urban highways. Focusing on the characteristics of urban traffic safety, this paper summarizes the characteristics of urban road traffic safety at different time periods based on the accident data and traffic citations from 2007 to 2016, which takes into account the crash temporal and spatial characteristic. By analyzing the causes of these accidents' characteristics, the paper discusses the relationship between road safety and roadway design, travel modes, and travel behaviors. Finally, the paper proposes improving traffic safety techniques aiming at high accident risk factors and event such as timing, intersection, resurging non-motor traffic accident, the rising electric-bike accident, high frequency of truck accidents at night, high fatal and injury pedestrian accidents, and increasing accident risk for elderly. **DOI:** 10.13813/j.cn11-5141/u.2018.0302-en

**Keywords:** traffic safety; urban roadway; temporal and spatial characteristic; electric-bikes; pedestrian

## 0 Introduction

In 2016, the death toll for urban road traffic accidents in China was close to 20, 000, and the number of the injured was close to 100, 000, resulting in a direct economic loss of 400 million yuan [1]. Compared with on highways, the average speed and the severity level of traffic accidents on urban roads is relatively low. As a result, the traffic safety of urban roads has not been given much attention for a long time. However, urban road traffic accidents are frequent, and their impacts on the order and road efficiency of urban traffic cannot be ignored. As of the end of 2016, the urban road mileage in China accounted for 7.5% of the total road mileage nationwide [2]. However, the number of urban road traffic accidents accounted for 45.8% of the total number of road traffic accidents in China, and the number of casualties accounted for 38.8% [1]. The number of traffic accidents per 100 kilometers of urban roads was four times that of freeways and ten times that of highways.

China is in a period of rapid urban development intertwined with fast motorization. Cities are the integration centers of regional economy, culture and information. In cities, the traffic is intensive and diverse, the traffic environment is complex and changeable, and the traffic conflicts are highly concentrated. They show new characteristics in many aspects, such as the spatial and temporal distribution of urban road traffic accidents, the traffic control of electric-bikes and freight trucks, and safety risks of travelers. Urban road traffic safety is far more complicated than thought.

## 1 Spatial and temporal distribution characteristics of urban road traffic accidents

### 1) Accidents are concentrated around rush hours

According to the 24-hour distribution of urban road traffic accidents from 2007 to 2016 (see Fig. 1), urban roads had an accident prone period in the morning and in the evening respectively. In the morning, the accident prone period was 7:00–8:00. After 5:00, the number of traffic accidents began to rise rapidly, and reached the peak between 7:00 and 8:00. In the evening, the accident prone period was 18:00–19:00. The number of traffic accidents increased gradually from 17:00, reaching the peak between 18:00 and 19:00. In terms of the trend, the temporal distribution of traffic accidents in the morning became more concentrated, and the proportion of traffic accidents between 7:00 and 8:00 was increasing year by year, which increased from 4.7% in 2007 to 5.9% in 2016. The temporal distribution of traffic accidents in the evening showed a trend to shift its peak forward, moving from 20:00–21:00 in 2007 to 18:00–19:00 in 2016.

**Received:** 2018-03-01
**Supported by:** National Natural Science Foundation of China (41601434); National Key Research and Development Project of China (2017YFF0207504); Central Financial Fund Project (11104100000001516061801 01)
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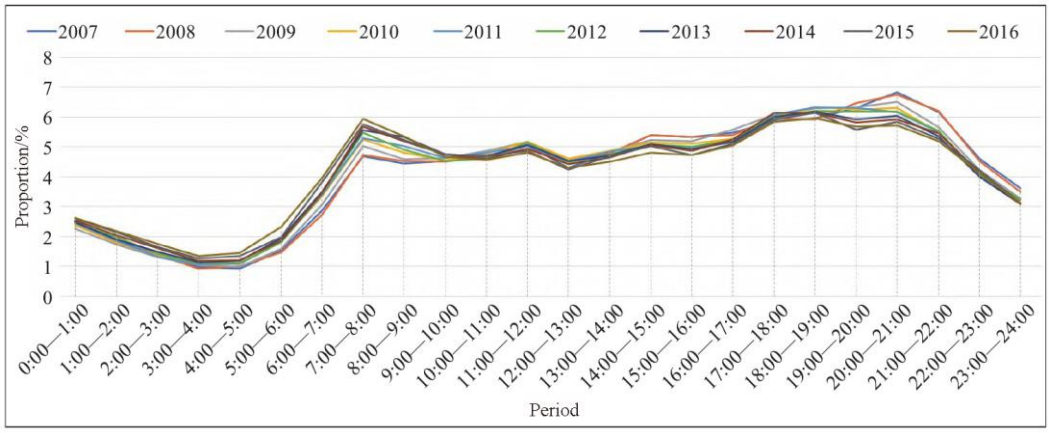


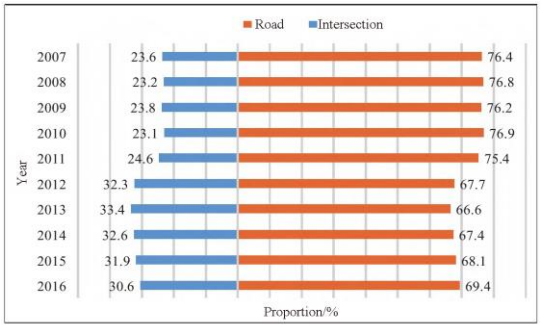

**Fig. 1** 24-hour distribution of urban road traffic accidents over the recent decade

Source: the data of general traffic accidents on urban roads from 2007 to 2016 from the Traffic Management Bureau of the Ministry of Public Security.

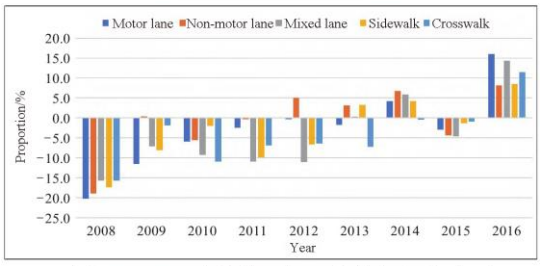
The accident prone period for urban roads is getting closer to the peak period of road traffic, which increases the uncertainty in the operations of urban road network during the morning and evening peaks. While the urban road network is operating under the pressure of daily traffic overload, it also needs to face traffic bottlenecks and even aggravates traffic jams caused by accidents, which makes the urban network more vulnerable. It is worth noting that, unlike on highways, minor traffic accidents on urban roads cannot be ignored. In 2016, 8.34 million minor traffic accidents occurred in China, and they accounted for 97.5% of the total road traffic accidents, of which 63% of minor traffic accidents occurred on urban roads [1]. Especially during rush hours, minor traffic accidents such as rear-end collisions and side impact collisions occur frequently. Although these minor traffic accidents do not involve personal injuries, they occupy a large amount of road resources and cause traffic jams, resulting in a decline in the overall operational efficiency of urban traffic.

### 2) Traffic accidents at intersections and in non-motor lanes show an obvious rebound trend

In terms of road composition (roadway segments and intersections), the proportion of traffic accidents at intersections is small, but the rebound trend is obvious. Seventy percent of urban road traffic accidents occur on roadway segments, and the rest occur at intersections. From 2007 to 2016, while traffic accidents on roadway segments declined year by year, traffic accidents at intersections rebounded markedly. From 2007 to 2010, traffic accidents at intersections showed a rapid downward trend, with an average annual decline of 12.5%. However, they showed an upward trend with an average annual growth rate of 6% from 2011 to 2016, and their proportion among total urban traffic accidents kept increasing, from 23.6% in 2007 to 30.6% in 2016 (see Fig. 2a). In terms of roadway cross sections, the rebound trend of traffic accidents in non-motor lanes is prominent (see Fig. 2b). In particular, the number of traffic accidents in non-motor lanes increased with fluctuation from 2012 to 2016, and the average annual growth rate was 3.3%. As a comparison, they only increased by 3% over the five years from 2007 to 2011. Over the same period between 2012 and 2016, the number of traffic accidents in motor vehicle lanes, mixed-flow lanes with motor and non-motor vehicles, crosswalks and sidewalks showed a marked downward trend except for the rebound in 2014 and 2016. As a comparison, they decreased between 2007 and 2011 by 13%, 25.9%, 16.9%, and 25% respectively.




a Proportion of traffic accidents at intersections and on roads




b Year-over-year growth of traffic accidents on the distribution of road sections

**Fig. 2** Distribution and growth of urban road accidents from 2007 to 2016

Source: the data of general traffic accidents on urban roads from 2007 to 2016 from the Traffic Management Bureau of the Ministry of Public Security.

The vulnerability of urban road network is often embodied in the key intersections. As the traffic volume is

increasing, the intertwined conflicts of various types of vehicles from all directions are becoming more and more complicated. In addition, the development of hardware facilities such as channelization and signal control is not suitable, which becomes a more serious problem, and traffic safety risks at intersections increase further. At the same time, it is necessary to pay attention to the fact that the passage space and traffic environment of non-motor lanes are deteriorating. As the travel demand of bike sharing is increasing, traffic safety issues in non-motor lanes are re-emerging, including inadequate lane width, discontinuous right of way, and serious conflicts between motor vehicles and non-motor vehicles, which results in a lack of security for cyclists. In addition, the problem of non-motor vehicle violations needs to be emphasized. From 2007 to 2016, the number of traffic accidents caused by the violation of non-motor vehicles doubled, with an average annual increase of 7.1%. The proportion of accidents caused by the violation of non-motor vehicles rose from 4.8% in 2008 to 10.4% in 2017.

## 2 Traffic safety of electric-bikes and trucks

### 2.1 Electric-bikes have the highest traffic safety risks

More than 30 million new electric-bikes were added to the roadway network each year from 2007 to 2016 [3], and the average annual increase in autos was 15 million during the same period. With the rapid growth, electric-bike had become one of the main travel modes for urban residents in China. In particular, the proportion of electric-bike travels in small- and medium-sized cities was as high as 10% to 30% [4], which was generally higher than the proportion of bike travels. In the meantime, the traffic safety risks of electric-bikes accumulated rapidly. From 2007 to 2016, along with the rapid increase in electric-bikes, the number of traffic accidents caused by electric-bikes on urban roads increased by 9.9% per year. The annual growth rate of electric-bike traffic casualties was 10.5%, which was much higher than that of other travel modes (see Fig. 3). In 2007, traffic accidents caused by electric-bike violations accounted for 2%–3% of traffic accidents on urban roads, and they led to 4%–6% casualties. By 2016, these numbers had risen to 7%–8% and 16%–18%, respectively. Compared with bikes, electric-bikes travel faster, but their vehicle stability and braking performance are poor, and the traffic accident consequences are more serious. Between 2007 and 2016, traffic accidents caused by electric-bikes were 3.8 times higher than that by bikes, and the number of casualties was 4.1 times higher.

The traffic safety risk of electric-bikes is mainly reflected

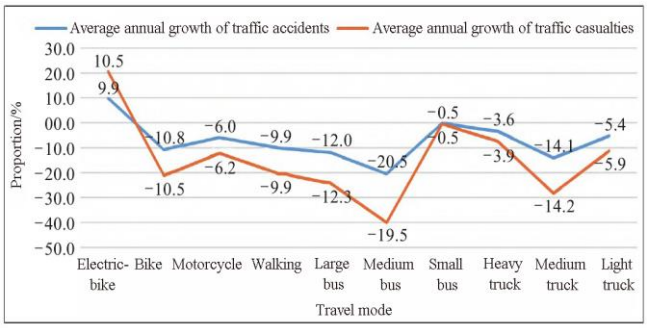



**Fig. 3** Annual average growth of traffic fatalities and injuries on urban road accidents by travel modes from 2007 to 2016

Source: the data of general traffic accidents on urban roads from 2007 to 2016 from the Traffic Management Bureau of the Ministry of Public Security.

in two aspects: the excessive use of over-standard electric-bikes and the serious traffic violation by electric-bike cyclists. According to the *Technical Specifications for Safety of Electric-bikes (GB/T 17761-2018)*, the maximum speed for electric-bikes is 25 km $h^{-1}$, and the mass standard for an electric-bike is 55 kg [5]. Statistics show that 60% to 70% of electric-bikes on the market are over-standard [6]. The speeds of some electric-bikes are even close to motor vehicles, but their safety performance is far below. There is a big difference in the characteristics of electric-bikes and bikes, but they share the same right of way, which leads to many safety problems. At the same time, the hazard level of electric-bike traffic violations is high, and more than 60% of traffic accidents of electric-bikes are caused by violating traffic signals, illegal driving in motorized lanes, driving against the traffic, drunk driving, speeding, and so on. In 2017, the number of traffic accidents caused by electric-bike traffic violations was 7 times that of bikes, and the number of traffic casualties was 7.7 times higher. If the manufacture and use of electric-bikes are not regulated comprehensively and the traffic management is not strengthened, the safety risks of electric-bikes will accumulate further in the future, which will become an important restriction factor affecting urban traffic safety.

### 2.2 The safety issue of truck driving at night should not be ignored

In order to alleviate traffic jam and protect the urban environment, many cities in China impose traffic control measures on trucks. Within a certain range of urban central areas, trucks are banned from passing through for a certain period of time. The truck traffic is very common at night on urban roads, especially from 22:00 to 6:00 with many traffic violations and traffic accidents. In 2016, the proportion of urban truck accidents at night (22:00–6:00) reached 19.6%, and the proportion of casualties reached 20%. What is worth noting is the impact of truck traffic on pedestrian safety on urban roads. More than a fifth of urban truck traffic accidents in 2016 were in the form of scratching pedestrians and

crushing pedestrians. Due to the large size, heavy weight, and long body of trucks, visual blind spots appear when trucks make a turn or a U-turn at intersections, which is easy to conflict with pedestrians and cause accidents [7]. Especially at night, traffic violations such as illegal driving on the road, violating traffic signals, speeding, driving against the traffic, illegal driving in the wrong lane, and drunk driving are more prominent. In 2016, the proportion of nighttime truck accidents caused by the above mentioned traffic violations exceeded 20% (see Fig. 4).

Trucks play an irreplaceable role in urban development because of their functions such as urban logistics, distribution and freight transportation. Truck safety has always been a difficult problem in urban road traffic management. From 2007 to 2016, on average, 14% of urban road traffic accidents were caused by trucks, and they accounted for 14% of casualties. With the promotion and implementation of urban traffic control measures, more and more trucks choose to pass through a city at night, which is prone to illegal driving, speeding, and drunk driving. The safety hazards are prominent, while the management and traffic law enforcement at night is relatively weak, so it is urgent to pay attention to this issue and strengthen the management.

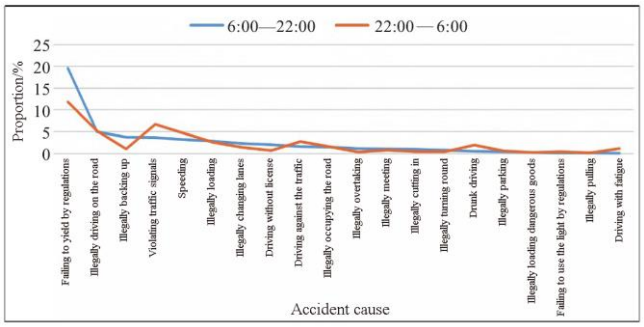



**Fig. 4** Distribution of truck accident contributing factors on urban roads in 2016

Source: the data of general traffic accidents on urban roads from 2007 to 2016 from the Traffic Management Bureau of the Ministry of Public Security.

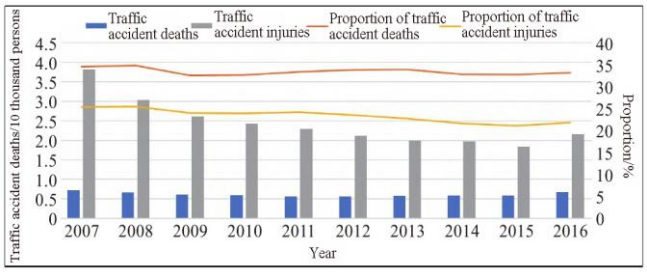



**Fig. 5** Pedestrians fatalities and injuries on urban roads from 2007 to 2016

Source: the data of general traffic accidents on urban roads from 2007 to 2016 from the Traffic Management Bureau of the Ministry of Public Security.

## 3 Travel safety of vulnerable groups

### 3.1 The number of casualties in pedestrian accidents remains high

The initial and final part of any travel is on foot, so walking safety is closely related to each traveler. Between 2007 and 2016, the number of pedestrian casualties in China accounted for more than 30% of the total number of urban traffic accident casualties, and every year tens of thousands of pedestrians were injured or even died as a result of traffic accidents (see Fig. 5). The period between 19:00 and 21:00 is the most dangerous period for pedestrians, and the proportion of pedestrian casualties in this period increased year by year, from 17.2% in 2007 to 19.5% in 2016. The most dangerous road section for pedestrians is a road section without isolation facilities or protected right of way: 60% of pedestrian deaths occurred on road sections without any isolation facilities, and 70% occurred in motor lanes. However, less than 6% of pedestrian accidents occurred on sidewalks, crosswalks, and other roads with exclusive road rights for pedestrians. The most dangerous traffic violation affecting pedestrian safety is the failure for motor vehicles to yield to pedestrians, which results in more than 20% of pedestrian casualties each year.

"People can feel the temperature of a city only when they can stroll on the street". As a result, walking is regarded as an important symbol of the quality of a city. Pedestrian safety is the basic requirement of urban life, and strengthening the protection of pedestrian safety is necessary for people-oriented urban traffic. However, there is a gap between the current situation of walking environment and the needs of urban development. The phenomena of "crossing the street in the Chinese way" and "walking in a violent way at night" have made the safety of urban walking a focus of public opinion and a social hot spot for a while. As for the main factors affecting walking safety, they include unreasonable planning and design of walking space, unreasonable setting of pedestrian crossing facilities, unreasonable pedestrian traffic organization and weak safety awareness of traffic participants [8].

### 3.2 The traffic accident risk in elderly population is rising rapidly

As China formally becomes an aging society, there are still many mismatches between the development of urban road traffic safety and the travel needs of the elderly, and the risk of traffic accidents among the elderly population is rising rapidly. By calculating the traffic accident risk coefficient (the proportion of the number of traffic accidents involved in a specific age group to the proportion of the population of the specific age group in the total urban population), it was found that the group aged 30 to 39 in a city had the highest risk of traffic accidents. The next was the group aged 20 to 29 and the group aged 40 to 49. The traffic accident risk coefficients for all three age groups were

above 1. In terms of the trend between 2007 and 2016 (see Fig. 6), the risk of traffic accidents among people over 50 years old has increased significantly. In particular, the traffic accident risk of the group aged 60 to 64 showed the fastest and the biggest increase, followed by the group aged 50 to 59, and the growth of risk coefficient in people aged over 65 had slowed down.

Strengthening the travel safety of the elderly not only helps reduce the number of injuries in urban road traffic accidents, but also reflects the humanistic concern of urban traffic management. The traffic environment perception, traffic event judgment and emergency risk avoidance ability of the elderly have deteriorated, and they need longer response and evaluation time [9–11]. As for the traffic management for the elderly, special attention should be paid to the safety of riding motorcycles and electric-bikes. In 2016, the proportions of casualties in motorcycle and electric-bike accidents were about 25% and 20% respectively in the group over 60 years old, which were the top two travel modes that cause injuries and casualties in traffic accidents. In addition, more attention should be paid to the protection of elderly pedestrians. The consideration of the elderly's needs should be strengthened when setting up transportation facilities.

## 4 Countermeasures and suggestions for improving urban road traffic safety

### 4.1 Improve the efficiency of traffic law enforcement and promote the refinement of traffic organization

Based on the temporal distribution characteristics of urban road traffic accidents, traffic police should improve the efficiency of law enforcement and traffic accident handling, and strengthen the operational reliability of road network. Especially in the peak period from 7:00 to 8:00 and 18:00 to19:00, it is necessary to increase the density and intensity of road patrol and strengthen the application of information technology in law enforcement and supervision. "Police Cube", "Law Enforcement Footprint" and other traffic police service information systems should be used to track and evaluate the effectiveness of traffic guidance in real time, which can promote the initiative and efficiency of traffic police. On the other hand, the *Regulations on the Procedures for Handling Road Traffic Accidents* should be followed to standardize the contents and workflow of law enforcement and shorten the response time for accident rescue. Especially for minor accidents, accident scenes should be cleared in time after completing the evidence collection to minimize the impact of accidents and the occurrence of secondary accidents.

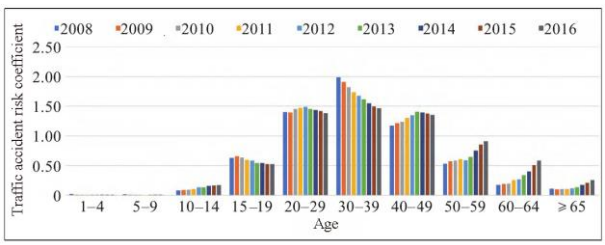



**Fig. 6** Distribution of traffic accident risks by age group

Source: the data of general traffic accidents on urban roads from 2007 to 2016 from the Traffic Management Bureau of the Ministry of Public Security.

Based on the spatial distribution characteristics of urban road traffic accidents, refined traffic organization and traffic law enforcement management should be promoted to improve the traffic safety at intersections and in non-motor lanes. At intersections, it is proposed to standardize lane markings such as lane lines, crosswalk lines, and diversion lines for optimization of lane functions, improve signal phase, phase sequence and timing parameters for coordination and optimization of space-time resources, and separate mixed traffic flow by applying color paving, clearing obstacles of sight distance, and adding diversion islands. In terms of traffic management, it is proposed to strengthen the innovation and application of technologies in law enforcement, such as face recognition of violators, and recognition and prediction of traffic events. It is also proposed to intensify the investigation and punishment of traffic violations such as failing to yield by regulations at intersections, violating traffic lights, and traveling in wrong lanes. For non-motor lanes, it should set up isolation facilities such as fences on urban trunk roads and green median strips, promote the standardization of signs and markings, enhance the visibility of non-motor lanes, and ensure the continuity of riding space. At the same time, to ensure the order of non-motor lanes, it is proposed to strengthen the management of on-street parking, and intensify the investigation and punishment of traffic violations of non-motor vehicles, such as traveling against the traffic, illegal driving in motor lanes, and violating traffic signals.

### 4.2 Strengthen the management of key vehicles and create a good travel environment

It is proposed to promote the integration of the source control of electric-bikes and the treatment of road surfaces, and regulate the use of electric-bikes to ensure safe riding. It is proposed to fully grasp the opportunity of the revision and implementation of the *Technical Specification for Electric-bike*, urge manufacture and sales enterprises to fulfill their responsibility for traffic safety management, clarify the basic positioning of electric-bikes as a type of non-motor vehicles, and prevent the over-standard electric-bikes from flocking the road. At the same time, it is necessary to promote the enforcement of responsibility for traffic accidents of electric-bikes, especially the civil, administrative and even criminal liabilities that should be borne by manufacture and sales enterprises. In January 2018, some local

courts in Zhejiang and Jiangsu sentenced the manufacture enterprises to pay for the loss in traffic accidents involving over-standard electric-bikes, which promoted the source management through the rule of law [12]. In addition, the protection of electric-bike road rights should be promoted by coordinating planning, municipal and other departments. Exclusive passage space and special signal phase for electric-bikes should be provided in small- and medium-sized cities when road conditions allow, the control of electric-bike traffic violations should be emphasized, and the law enforcement on the road surface should be strengthened to control the traffic order of electric-bikes.

The traffic management of trucks driving at night should be strengthened, and the illegal behavior of trucks should be strictly controlled. It is proposed to innovate the police service mode at night, ensure enough nighttime road patrol, promote the integration of the electronic police and the road surface inspection, focus on strengthening the inspection and control of trucks, improve the efficiency of traffic police in responding to and handling traffic accidents at night, and intensify the investigation and punishment of traffic violations. At the same time, it is proposed to promote the establishment of dynamic monitoring mechanism for trucks by urban freight enterprises, promote the inclusion of truck drivers and trucks into the key urban management watch list, and realize automatic alarm and real-time supervision of truck speeding, fatigue driving and illegal driving through the road video surveillance system or the enterprise dynamic monitoring system.

### 4.3 Pay attention to the travel safety of vulnerable groups, and guide safe travel

In order to improve the walk environment of a city, the pedestrian safety should be ensured from various aspects such as engineering, law enforcement, and education. 1) It should promote the standard setting of pedestrian facilities by complying with existing road design specifications. The width of sidewalks and crosswalks and the density of pedestrian crossing facilities should be ensured. The pedestrian priority on right of way should be protected by adding pedestrian safety islands, raising crosswalks, and highlighting curbs, etc. The pedestrian priority on signal should be ensured by reasonably setting the green time and cycle length, adding a special phase for right-turn lanes and setting up pedestrian signals. 2) It should continue to promote the “courtesy at zebra crossing” action by public security traffic control departments, promote the installation of video surveillance system before pedestrian crossing facilities, and strengthen the application of automatic forensics of traffic violations, especially at night (19:00–21:00) to enhance the safety of pedestrians. 3) It should promote pedestrian traffic safety extensively, develop pedestrian safety education content for each age group, and strengthen awareness of traffic regulations, safety common sense, and risk identification, etc.

It is proposed to actively advocate non-motor and green travel for the elderly, coordinate public transportation management departments and enterprises to improve public transportation facilities for meeting the elderly people’s travel needs, and send travel information messages directly to the elderly for improving the level of urban transportation equity. At the same time, it should strengthen the education and training of older drivers, design the training material and courses specific for them, and strengthen the education on traffic emergency handling and accidents prevention through traffic situation experience and safe driving practice. In addition, the barrier-free design and error tolerance design should be promoted for transportation facilities, such as promoting curb ramps, building pedestrian safety islands to reduce crossing distance, and strengthen the visibility of signage and markings.

## 5 Conclusions

The ideal state of urban road traffic safety is to make each travel mode in its own right of way without interfering with each other through effective traffic management measures. However, mixed flow is a typical characteristic of urban traffic in China. With the rapid shift of traffic structure to individual motorization, the traffic volume on urban roads increases sharply, and the conflicts between motor and non-motor vehicles, and between cars and pedestrians will exist for a long time. At the same time, the new characteristics of urban road traffic safety are more prominent. For example, the spatial and temporal distribution of traffic accidents are more concentrated; the hidden hazards of electric-bikes and freight trucks are more prominent; the development of walking traffic safety is lagging; and traffic safety risks among the elderly increase rapidly.

As China’s social development enters a new era, the connotation of urban residents’ travel demand has greatly expanded, which puts forward higher expectations and requirements for urban road traffic safety. By the end of 2017, 53 cities across the country have more than 1 million vehicles, 24 cities have more than 2 million, and 7 cities have more than 3 million. By 2020, 70 cities are expected to have more than one million vehicles. However, the civilization of urban traffic safety is far from being formed. The proportion of traffic accidents caused by human error is 80%–90% per year [9], in which more than 30% are caused by traffic violations such as failing to yield, driving without a license, drunk driving, and violating traffic signals. Urban traffic safety should be developed with the development of traffic mitigation and traffic civilization, and the management of urban road traffic safety still has a long way to go.

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